# Measuring material wastage on construction sites: a case study of local authority highway projects

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## ABSTRACT

The construction industry in the UK is vast. It is one of the largest sectors of the economy with an output of over £100 billion, representing approximately 8% of the country's GDP. The enormous amount of resources the industry consumes and produces coupled with the large number of construction companies in the market place has resulted in a growing awareness of the environmental impact of the construction industry. Construction produces more than 100 million tonnes of waste a year, representing more than 50% of the total waste production of the country. Of this waste, more than 60 million tonnes goes straight to landfill, three times more than all the domestic waste produced by the UK's twenty one million homes. Increasing pressure on landfill sites coupled with the growing awareness of the environmental impact of the industry has made the minimisation of construction waste absolutely essential. The research project outlined in this paper attempts to measure material wastage occurring on selected Local Authority highway construction sites. To achieve this, a review will be undertaken to determine the main areas of interest in sustainable construction, construction waste production, and waste minimisation. Primary data will be collected in the form of measurements taken of theoretical and actual quantities of construction materials used during the course of selected highway projects. The results will be used to compare actual on-site material quantities against theoretical material quantities. The difference in these quantities will then be calculated, giving the amount of wastage occurring on site. The findings from this paper are drawn from both the secondary and the primary data analysis and statistical testing. The research concludes by suggesting a waste minimisation strategy for use on highway construction sites to try and reduce, re-use, and recycle the amount of construction waste local authority highway projects generate.

Keywords: Construction site, local authority highway, waste minimisation, environmental impact and sustainability.

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## INTRODUCTION

There is now an overwhelming body of scientific evidence showing that environmental issues are serious and urgent issues in our world. Over the last few years, some interesting research on this subject has begun to emerge (Barret et al., 1999; Zsidisin and Siferd, 2001; Shayoh et al., 2002; Horvath, 2004; Ding, 2005; Fergusson and Langford, 2006; Kibert, 2007 and Ball et al., 2009). In construction, contemporary arguments suggest that the built environment is responsible for half of all CO2 emissions, half of water consumption, one third of landfill waste and one quarter of raw materials used in the UK (BERR, 2008). In recent years, one of the key drivers in promoting environmental issues within construction has been sustainable development and, in particular, sustainable construction (Chaharbaghi and Willis, 1999; Khalfan, 2002; Gupta & Chandiwala, 2007). One of the fundamental themes of sustainable construction is material usage and wastage (Ferguson et al., 1995; Faniran and Caban, 1998; Yahya and Boussabaine, 2006 and Srivastava, 2007).

Material waste is becoming a serious environmental problem in many large cities around the world. In the UK, the construction industry generates lots of waste which has a significant impact on the environment (i.e. demand for landfill and the depletion of natural resources) (Ferguson et al, 1995). Each year, poor design and site management leads to approx 13% of all solid materials delivered to sites, some 10 million tonnes, going unused. This makes the construction industry the largest generator of controlled waste going to landfill (NCE, 2007; WRAP, 2007). Waste production on construction sites is often down to inadequate storage and protection, poor or multiple handling, poor site control, over-ordering of materials, bad stock control, lack of training, and damage to materials during delivery (DETR, 2000; WRAP, 2007). Increased pressure on landfill sites, accompanied by rising prices, strict controls and taxation, and a growing understanding of the environmental issues surrounding waste disposal has made the minimisation of construction waste an absolute necessity (Ferguson et al, 1995). Reviews by Egan (Egan Report, 1998, 2002) suggested that 30% of construction is rework and at least 10% of materials are wasted. But he believed that there is plenty of scope for improving efficiency and quality simply by taking waste out of construction. The amount of waste construction generates continues to be a major problem for the industry and in many countries.

What is clear is that the UK construction industry aims to contribute to waste reduction or elimination by adopting new policies and practices, which have a more positive impact on economic, social and environment systems. Improvements are sought in all stages of the construction process, such as land use, replenishment of natural resources, transport networks, construction processes, embodied energy of building whilst in use, social interaction and economic benefits for the whole supply chain. The research project outlined in this paper attempts to measure material wastage occurring on selected Local Authority highway construction sites. To achieve this, a review will be undertaken to conceptualise material waste in construction. Primary data will be collected in the form of measurements taken of theoretical and actual quantities of construction materials used during the course of selected highway projects. The results will be used to compare actual on-site material quantities against theoretical material quantities. The difference in these quantities will then be calculated, giving the amount of wastage occurring on site. The findings from this paper are drawn from both the secondary and the primary data analysis and statistical testing. The research concludes by suggesting a waste minimisation strategy for use on highway construction sites to try and reduce, re-use, and recycle the amount of construction waste local authority highway projects generate.

## CONCEPT OF MATERIAL WASTE IN CONSTRUCTION

The issue of material waste is not a new concept. Previous studies suggest that construction is a major contributor to the generation of waste all over the world (Craven et al., 1994; Kartam et al., 2004; Begum et al., 2006; Tam et al., 2007 and Jaillon et al., 2009). However, the figures appear not to be consistent from country to country, but what is clear is that the waste in construction is substantial compared to other industries. Over 2 billion tonnes of waste are generated in the European Union every year, approximately half of which is produced by the construction industry (Ferguson et al, 1995) and globally data shows that approximately 40% of waste generated originates from the construction industry (Nitivattananon and Borongan, 2007).

BERR (2007) highlights that in the UK alone, construction produces more than 100 million tonnes of waste a year, representing more than 50% of the total waste production of the country (see Figure 1). Of this waste, more than 60 million tonnes goes straight to landfill, three times more than all the domestic waste produced by the UK's twenty one million homes. This makes the construction industry the largest generator of controlled waste going to landfill (NCE, 2007).

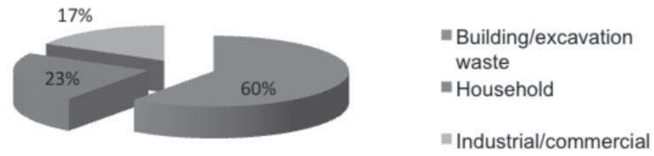


*Figure 1: Typical composition of waste production in UK (adapted from DTI, 2006).*

When considering construction material waste, it is important to define what is meant by the term "material waste". Kwan et al (2001) argues that construction waste can be divided into two main categories; waste generated due to design and specification, and waste generated by construction activities. However, studies have shown that the most significant sources of construction waste are generated during the construction phase (usually stemming from: inadequate storage, protection, and site control; poor or multiple handling; poor quality material; inaccurate or over ordering of materials or leftover; inefficient use of materials; bad stock control; lack of training; damage to materials during deliveries; damage generated by poor co-ordination with other trades; and theft and vandalism). However, in classifying waste, Formoso et al (1999) argued that there can be unavoidable waste (or natural waste), in which the investment necessary to its reduction is higher than the economy produced; and avoidable waste, when the cost of waste is significantly higher than the cost to prevent it.

The research described here will measure the actual levels of material waste occurring on selected highway construction sites and compare the measured waste with theoretical material waste quantities that have been determined before the projects commenced. The research will conclude by suggesting how material waste can be minimised on highway construction sites for the benefit of the local authority.

## METHODOLOGY

### Procedure for data gathering and analysis

The aim of this research is to determine actual levels of material wastage occurring on selected highway construction sites. This wastage quantity will then be compared against the 5% material wastage allowance included within the tendering and estimating process. To achieve this aim, a deductive approach will be undertaken to test the hypothesis that actual material usage on site is greater than theoretical material usage + 5% wastage allowance. This can be expressed by the following hypothesis:

$H_1$: *Actual material usage on site > Theoretical material usage + 5% wastage allowance*

### Case Study

Measurements will be taken of the difference between theoretical and actual quantities of construction materials used during the course of selected highway maintenance schemes completed over the last five financial years, 2003/04 to 2007/08 by a local authority. The data will be taken from twenty schemes and will consider the following parameters:

- New construction methods, improved construction technology, new health & safety legislation, and environmental concerns all have a bearing on how construction activities take place on site. This in turn has a bearing on material usage and wastage.
- The geographical area of the scheme and locality of materials suppliers can also have a bearing on the quantity of material ordered. The further the scheme from the works depot or material supplier, the more likely additional material quantities will be ordered to avoid another visit to the supplier or depot.
- The size and financial value of the scheme will also have an impact on material usage. The bigger the scheme, the more materials used, the greater the possibility of material wastage.
- Choosing the schemes using a range of different site managers and quantity surveyors will also ensure that data collected is accurate. Each individual site manager may carry out construction activities slightly differently, resulting in different material usage. Also, as the primary data is taken from agreed final accounts, there is a possibility that the quantity surveyor has missed some works carried out on site. This will result in actual materials being used on site that have not been included within the theoretical quantities.
  - By choosing maintenance schemes consisting of the same or similar works and activities, the authors hope to determine any significant trends in actual and theoretical material usage between schemes.

Selecting the primary data from construction schemes selected within the above parameters will ensure data collected is fair and correct, and will allow accurate conclusions to be drawn.

The actual material measurements will be taken from a range of highway maintenance contracts to ensure the data collected is representative of the varied types of maintenance schemes the department undertakes. Measurements will be taken of materials used in new carriageway and footpath construction, drainage, and kerbing works. This will help to establish and quantify the amount of material wastage occurring on site, and assist in comparing this material wastage quantity against theoretical quantities. The results will be used to calculate the difference between actual on-site material quantities against theoretical material quantities to establish the amount of wastage occurring. This wastage figure will then be converted to a percentage and compared against the 5% allowance within the tendering and estimating process.

To obtain the actual material quantities, weekly site diaries for each scheme will be used. These site diaries include details of labour, plant, and materials used to undertake construction works for that particular week. To establish the theoretical material quantities used, 'Microrate' (ROCC, 1997) bill of quantities software will be utilised. This software programme allows the input of quantities of construction items e.g. square metres of carriageway and footpaths, linear metres of kerbs etc into a bill of quantities. These quantities are taken from the final valuation of each scheme, agreed between the client and quantity surveyor. Microrate then breaks down these bill items into a detailed report showing the quantities of different construction materials theoretically used on site.

## RESULTS

### Statistical data analysis

From experience and pilot study conducted, the materials used to measure differences in actual waste from the theoretical are as follows: concrete (cubic metres), tarmac (tonnes), sand (tonnes), and cement (25kg bags). The authors believe that these particular materials can generate the most wastage on site because of their widespread use and inclusion within most highway maintenance construction activities. The results will be used to compare actual on-site material quantities against theoretical material quantities to establish the amount of wastage occurring, with graphs produced showing actual and theoretical material quantities used on all schemes across the four material types. Detailed charts showing all the schemes and comparison of the actual and theoretical material quantities are depicted in Figures 2, 3, 4, & 5).

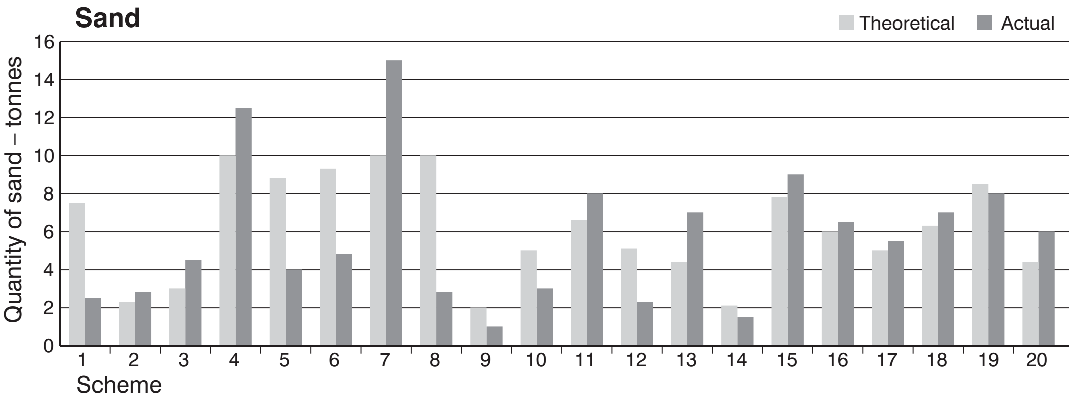


*Figure 2: Theoretical and actual quantities of sand waste*

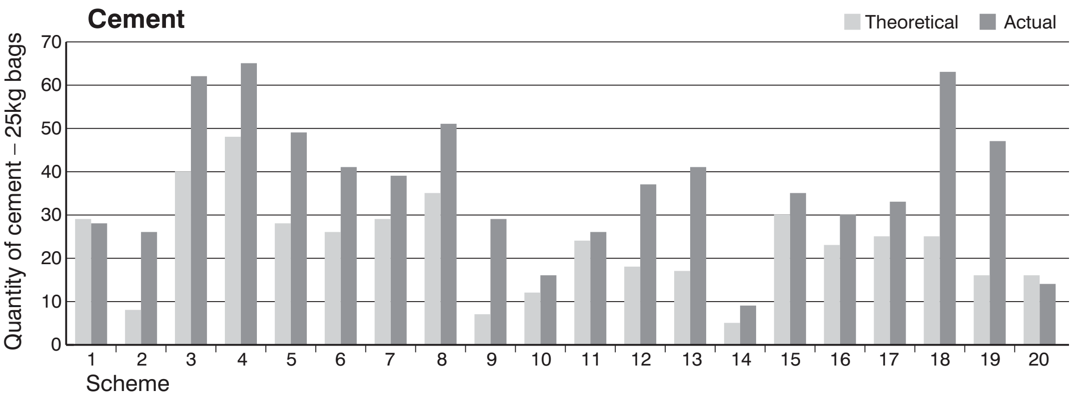


*Figure 3: Theoretical and actual quantities of cement waste*

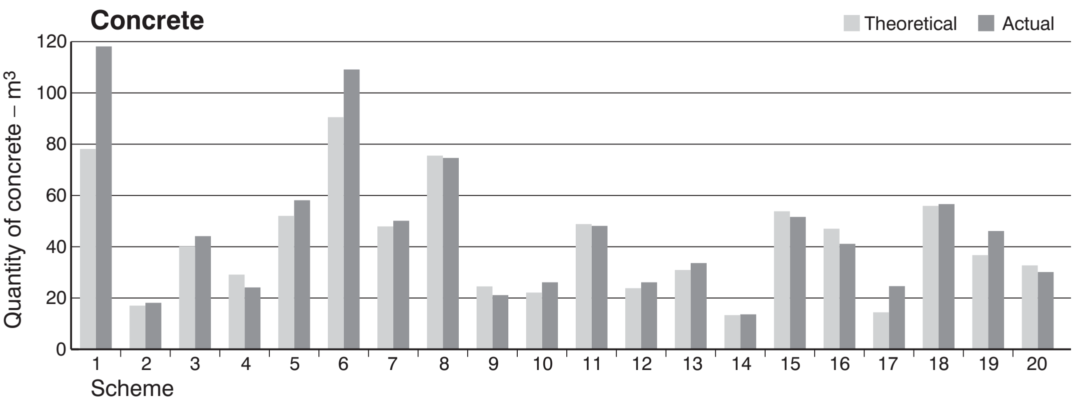


*Figure 4: Theoretical and actual quantities of concrete waste*

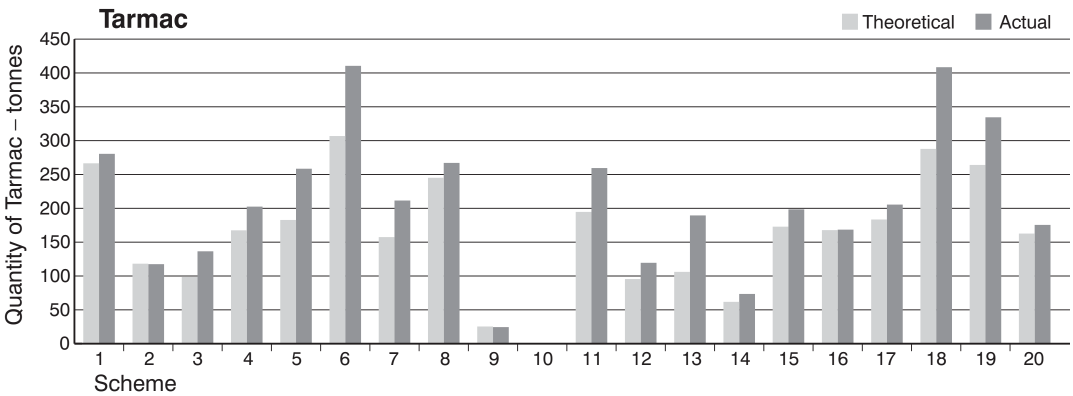


*Figure 5: Theoretical and actual quantities of tarmac waste*

As can be seen from the above figures, the actual quantities used on site for sand, cement, and tarmac differ greatly to the theoretical material quantities produced from the agreed final accounts, both above and below the theoretical quantities. The graph for concrete shows actual material usage corresponding quite closely to the theoretical quantities.

To illustrate this point further, an additional summary table was produced showing the actual material quantities used on site as a percentage, both +/-, compared against the theoretical quantity. Positive percentages show materials used above theoretical values and negative percentages shows materials used below. This table can then be used to make comparisons with the 5% material wastage. The results are in table 1.

Concrete produced some interesting results. The standard deviation of the results was 0.20 and, on average, an extra 10.9% of concrete was used on site. This figure is the closest to the 5% material wastage allowance. Six schemes all used less concrete than the theoretical quantity, three schemes used within the 5% wastage allowance, four schemes used within 5% – 10%, and the remaining seven schemes used over 10%.

Sand produced some varied and surprising results. On average, 5.7% less sand was used on site. Of the twenty schemes analysed, just under half (nine) used less sand on site than the theoretical value, only three were close to the 5% wastage allowance, and the remaining eight used between 16.1% – 57.7% more sand on site. However, it is the difference in values that is surprising. One scheme used 72.4% less sand than the theoretical quantity whereas another used an additional 57.7%. This gives a value range of +/- 128.1% and a standard deviation of 0.42. It can only be assumed that there is an element of mis-recording of sand within the analysed schemes to explain such a large range and standard deviation.

As can be seen from the above data, there are significant differences between the theoretical and actual quantities of sand, cement, concrete, and tarmac used within the twenty schemes analysed. Therefore, the hypothesis that actual material usage on site > theoretical material usage + 5% wastage allowance can be implied in the case of cement, tarmac, and concrete.

| YEAR | Scheme | Additional Material % used on site | | | |
|---|---|---|---|---|---|
| | | Sand (Tonnes) | Cement (25kg Bags) | Concrete (m3) | Tarmac (Tonnes) |
| 2007/08 | **Scheme 1** | -66.7% | -2.0% | 51.3% | 5.3% |
| | **Scheme 2** | 21.7% | 222.6% | 6.3% | -0.6% |
| | **Scheme 3** | 50.0% | 55.0% | 10.0% | 38.8% |
| | **Scheme 4** | 25.0% | 35.4% | 17.2% | 21.0% |
| 2006/07 | **Scheme 5** | -54.4% | 74.2% | 11.8% | 41.5% |
| | **Scheme 6** | -48.8% | 55.0% | 20.6% | 33.8% |
| | **Scheme 7** | 50.5% | 34.3% | 4.6% | 34.4% |
| | **Scheme 8** | -72.4% | 46.0% | -1.2% | 9.0% |
| 2005/06 | **Scheme 9** | -48.7% | 319.1% | -13.9% | -3.5% |
| | **Scheme 10** | -40.0% | 33.3% | 18.2% | 0.0% |
| | **Scheme 11** | 21.6% | 7.1% | -1.4% | 33.4% |
| | **Scheme 12** | -54.7% | 108.8% | 9.9% | 25.3% |
| 2004/05 | **Scheme 13** | 57.7% | 135.1% | 8.9% | 79.0% |
| | **Scheme 14** | -29.9% | 66.4% | 2.6% | 19.0% |
| | **Scheme 15** | 16.1% | 14.9% | -4.1% | 14.9% |
| | **Scheme 16** | 8.7% | 30.4% | -12.6% | 0.4% |
| 2003/04 | **Scheme 17** | 10.0% | 32.0% | 71.1% | 12.0% |
| | **Scheme 18** | 10.8% | 150.4% | 1.3% | 42.0% |
| | **Scheme 19** | -5.3% | 189.1% | 25.7% | 26.7% |
| | **Scheme 20** | 35.1% | -13.2% | -7.9% | 7.9% |
| | **Mean** | -5.7% | 79.7% | 10.9% | 22.0% |
| | **Standard Deviation** | 0.42 | 0.85 | 0.20 | 0.20 |

*Table 1: Additional material percentages used on site*

### Inferential data analysis

The statistical data analysis obtained has been drawn from only a small sample of the thousands of Highway schemes carried out by the first author's employer. To draw accurate conclusions on the larger population as a whole, inferential testing of the data was carried out in the form of T-Tests.

There are significant differences between the theoretical and actual material quantities obtained from the statistical analysis. The data collected suggests there is a difference, but is it statistically significant? To prove or disprove the above argument, T-Tests were carried out on the total quantities of the four material types used for all schemes spanning the five financial years. The results are summarised in table 2 below:

The T-Test results in table 2 for sand, concrete, and tarmac are not statistically significant. Although actual quantities for these materials vary considerably from theoretical values, they do not differ enough to be considered statistically significant. Therefore the null hypothesis can be accepted and the original hypothesis rejected.

The T-Test result for the total quantity of sand in table 2 can be classed as statistically significant as the result is below the accepted level of $P<0.05$. Therefore, the null hypothesis can be rejected and the original hypothesis accepted.

To further reinforce the results of the T-Tests, the standard error of the sample mean of the four material types was calculated. The standard error is defined by the equation:

$$S_E = \frac{s}{\sqrt{n}}$$

SE being the standard error, s is the sample standard deviation, and n is the sample size. It provides an approximate value for the uncertainty in the sample mean compared to the population mean for a normally distributed data set. The equation implies that in order to reduce the uncertainty in the sample mean, a larger sample size is required (Backhouse, 1967).

After calculating the value of the standard error for sand, the sample mean for the theoretical usage of sand can be written as 6.2 ± 0.6, reflecting the uncertainty in the value of the sample mean. The actual sand usage is 5.7 ± 0.8. As can be seen, the mean theoretical sand use is within the uncertainty ranges of the actual sand use and vice versa and therefore cannot be deemed statistically significant. The same theory applies

| | | **Additional Material Quantities used on site** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Sand (Tonnes) | | Cement (25kg bags) | | Concrete (m3) | | Tarmac (Tonnes) | |
| **Year** | **Scheme** | Theoretical | Actual | Theoretical | Actual | Theoretical | Actual | Theoretical | Actual |
| 2007/08 | **Scheme 1** | 7.5 | 2.5 | 29 | 28 | 78.0 | 118.0 | 266.0 | 280.0 |
| | **Scheme 2** | 2.3 | 2.8 | 8 | 26 | 16.9 | 18.0 | 117.7 | 117.0 |
| | **Scheme 3** | 3.0 | 4.5 | 40 | 62 | 40.0 | 44.0 | 98.0 | 136.0 |
| | **Scheme 4** | 10.0 | 12.5 | 48 | 65 | 29.0 | 34.0 | 167.0 | 202.0 |
| 2006/07 | **Scheme 5** | 8.8 | 4.0 | 28 | 49 | 51.9 | 58.0 | 182.3 | 258.0 |
| | **Scheme 6** | 9.3 | 4.8 | 26 | 41 | 90.4 | 109.0 | 306.3 | 410.0 |
| | **Scheme 7** | 10.0 | 15.0 | 29 | 39 | 47.8 | 50.0 | 157.0 | 211.0 |
| | **Scheme 8** | 10.0 | 2.8 | 35 | 51 | 75.4 | 74.5 | 244.6 | 266.6 |
| 2005/06 | **Scheme 9** | 2.0 | 1.0 | 7 | 29 | 24.4 | 21.0 | 24.9 | 24.0 |
| | **Scheme 10** | 5.0 | 3.0 | 12 | 16 | 22.0 | 26.0 | 0.0 | 0.0 |
| | **Scheme 11** | 6.6 | 8.0 | 24 | 26 | 48.7 | 48.0 | 194.2 | 259.0 |
| | **Scheme 12** | 5.1 | 2.3 | 18 | 37 | 23.7 | 26.0 | 95.0 | 119.0 |
| 2004/05 | **Scheme 13** | 4.4 | 7.0 | 17 | 41 | 30.8 | 33.5 | 105.6 | 189.0 |
| | **Scheme 14** | 2.1 | 1.5 | 5 | 9 | 13.2 | 13.5 | 61.3 | 73.0 |
| | **Scheme 15** | 7.8 | 9.0 | 30 | 35 | 53.7 | 51.5 | 172.4 | 198.0 |
| | **Scheme 16** | 6.0 | 6.5 | 23 | 30 | 46.9 | 41.0 | 167.3 | 168.0 |
| 2003/04 | **Scheme 17** | 5.0 | 5.5 | 25 | 33 | 14.3 | 24.5 | 183.0 | 205.0 |
| | **Scheme 18** | 6.3 | 7.0 | 25 | 63 | 55.8 | 56.5 | 287.3 | 408.0 |
| | **Scheme 19** | 8.5 | 8.0 | 16 | 47 | 36.6 | 46.0 | 263.6 | 334.0 |
| | **Scheme 20** | 4.4 | 6.0 | 16 | 14 | 32.6 | 30.0 | 162.2 | 175.0 |
| | **Mean** | **6.21** | **5.69** | **23** | **37** | **41.61** | **46.15** | **162.79** | **201.63** |
| | **Standard Deviation** | **2.71** | **3.62** | **11.02** | **16** | **21.72** | **27.70** | **84.44** | **109.91** |
| | **T-Test** | **0.61028** | | **0.00246** | | **0.56710** | | **0.21771** | |

*Table 2: T-Test results for total materials used on site*

to concrete, with a mean theoretical material usage of 41 ± 5 and an actual material usage of 46 ± 6, and also to tarmac with a theoretical usage of 162. ± 19 and an actual material usage of 202 ± 25. The standard error provides a further illustration as to why the T-Tests carried out on the above material types do not produce statistically significant results.

However, the opposite can be said of cement. The theoretical cement usage after applying the standard error can be written as 23 ± 3 and actual usage can be written as 37 ± 4. As can be seen, the mean theoretical cement use falls outside the uncertainty range of the actual cement use and vice versa and therefore the results can be deemed statistically significant.

## DISCUSSION

The construction industry is one of the biggest contributors towards environmental and climate change through its construction methods, resource usage, $CO_2$ emissions and carbon footprint, energy and natural resource consumption, and waste production. Enormous quantities and types of waste are generated by the construction industry each year. From previous work in this area, it was identified that construction waste could be divided into two main categories: waste generated due to design and specification, and waste generated by construction activities. Waste production on construction sites is often down to poor storage and protection, poor or multiple handling, inaccurate or over-ordering of materials and damage to materials during deliveries or by poor co-ordination with other trades (DETR, 2000a). Various waste minimisation strategies can be deployed on site. Reduced construction waste means reduced landfill use and lower environmental damage in connection with extracting, transporting and processing the raw materials (WRAP, 2007b).

The waste minimisation principles, reduction, re-use, recycling, and recovery can produce significant savings in terms of time, cost, wasted materials, transport and disposal charges, as well as long-term environmental benefits. However, the problem with waste minimisation is the perception that it will incur additional costs and increase construction times. Waste is often seen as a minor issue and the implementation of proper waste minimisation procedures as requiring too much time, effort, and expense (Kwan et al, 2001). The common view is that reducing the amount of waste generated on site is hindered by tight time and contractual restraints. This means there is often limited manpower available during construction works to minimise waste and manage resources effectively. This is not the case. Effective waste minimisation requires a change in attitude towards waste. A team approach is required, with the client, design team, contractor, and sub-contractor all required to consider waste minimisation throughout the project phases, from outline design to project completion (WRAP, 2007b).

The purpose of the research is to measure material usage on selected construction projects to establish how much material wastage is actually occurring on site and to suggest a waste minimisation strategy to help reduce, recycle, recover and re-use the waste materials that are produced. The work carried out during this research measured the actual material usage on site and compared it with the theoretical material usage + 5% wastage allowance. There were significant differences between the theoretical and actual quantities of sand, cement, concrete, and tarmac used within the twenty schemes analysed. On average, sand used 5.7% less material on site, concrete used an additional 10.9%, tarmac used an extra 22.0%, and cement used an additional 79.7%. Therefore, the hypothesis H1: Actual material usage on site > Theoretical material usage + 5% wastage allowance can be implied in the case of cement, tarmac, and concrete. However, the hypothesis cannot be implied in the case of sand, which has used less material on site.

The primary data obtained to test the hypothesis was drawn from only a small number of highway schemes undertaken by the authors' employer. To test the hypothesis and draw accurate conclusions on the larger population as a whole, inferential analysis of the data was carried out. T-Tests were carried out on the total quantities of each material used across all twenty schemes spanning the five financial years. The T-Test results for sand, concrete, and tarmac are not statistically significant. Sand produced a result of 0.61 or 61%; concrete produced a result of 0.567 or 56.7%; and tarmac produced a result of 0.217 or 21.7%. Although actual material quantities for sand, concrete and tarmac vary considerably from theoretical values, the standard deviation does not differ enough to be considered statistically significant, as the results are considerably higher than the accepted value of $P < 0.05$ Therefore the null hypothesis can be accepted and the original hypothesis rejected for these material types. However, the T-Test result for the total quantity of cement can be classed as statistically significant. The result of 0.002 is below the accepted level of $P<0.05$ therefore the null hypothesis can be rejected and the original hypothesis accepted for this material type.

To summarise the analysis of the primary data, the hypothesis that actual material usage on site is greater than theoretical material usage + 5% wastage allowance can be implied in the case of sand, concrete and tarmac used during construction activities within the twenty schemes analysed. The hypothesis cannot be implied in the case of cement. However, as the twenty schemes analysed are only a very small sample taken from the thousands of Highways schemes the Local Authority has carried out over the years, to allow accurate conclusions on the larger population as a whole to be drawn, statistical testing of the data must be carried out. T-Tests were carried out the total quantities of each material used across all twenty schemes spanning the five financial years. The results for sand, concrete, and tarmac were all above the statistical significance value of $P>0.05$ so the original hypothesis has been disproved and the null hypothesis has been accepted. However, in the case of cement, the P value was 0.002, below the accepted P value of 0.05 and statistically significant. Therefore, the original hypothesis for cement can be accepted and the null hypothesis rejected.

There are several factors that could contribute towards additional material wastage occurring on site. The theoretical material quantities obtained from the Microrate reports are based on very precise foundation/excavation/drainage trench dimensions. If there has been any over-digging or soft spots that have occurred on site and backfilled with concrete, this additional material will not be included within the theoretical quantity but will be included within the actual site quantity. There is always the possibility of mis-recording by the site manager when allocating materials to schemes or the quantity surveyor missing some works that have been carried out on site. This could account for the surprisingly low quantities of sand and concrete encountered on some schemes. Sand and cement are classed as 'granular' materials and are very difficult to store and move around site once the bag/container has been opened. It is also possible that rather than mixing 4:1 sand /cement bedding mix for laying kerbs, flags, block-paving etc, operatives on site may have only used cement. This could explain the excessive quantities of cement used and the lower quantity of sand.

Also, additional material quantities may be ordered to try and reduce any part-load or haulage charges for material deliveries, especially concrete and tarmac. When constructing new footpaths and carriageways, a sub-base capping layer is required to receive the tarmac. If this sub-base layer is not to the required thickness or within tolerance, this can affect the tarmac quantity. Even a small difference of 10– 20mm in sub-base thickness, over hundreds of square metres, can result in significant additional quantities of tarmac being used. Finally, if any concrete or tarmac is used in temporary works that are un-measurable or carried out at the contractor's own expense, this will result in excess materials being used on site that are not included within the theoretical quantities.

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