# ESTIMATING THE LABOUR DEMAND FOR HOUSING CONSTRUCTION

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Housing in the UK accounts for one-third of all new build construction making it the single largest sector in the industry. Houses and flats make up 95% of all residential construction. The question this research aims to address is whether it is possible, given the value, duration and type of a project, to determine the amount of labour for each trade required. To address this, labour co-efficients for nine trades were calculated as the amount of man-years expended per million pounds worth of work. Bills of quantities were analysed for two projects to calculate the co-efficients. One project was traditional construction; the other was timber-framed. In total 80 bills were used representing different types of houses (eg detached, terraced etc). By applying the labour required for each item in the bill, derived from standard estimating price books, it was possible to calculate the labour required in each trade. The total for each trade could then be summed, along with the associated price, to determine the total labour requirement per unit value. The results demonstrated that the variability in the labour co-efficients between houses of the same type is greater than between houses of different types. Using the insight obtained from this finding two sets of labour co-efficients have been produced by this research. One of these addresses traditional construction, the second timber framed buildings. These co-efficients can be used to provide a high-level estimate of the total labour in each trade required for a housing construction project given its value.

Keywords: bills of quantities, housing, labour co-efficients, productivity.

## INTRODUCTION

ConstructionSkills wishes to develop a labour forecasting tool for construction projects to inform the demands for training in its National Skills Academies for Construction. The Academies will focus on project-based training centres and there is therefore a need to forecast the demand for labour of all kinds of trades, on a project-by-project basis. To do this it is necessary to determine labour coefficients which determine the total labour demand per unit cost of a project.

The research presented in this paper develops a measure of productivity in terms of number of man hours per unit cost. A great deal of work has been carried out to improve productivity by measuring the inputs and the outputs (Noor 1992; Horner and Talhouni 1995; Horner and Duff 2001). However the purpose of the research in this paper is very different in measuring productivity in terms of outputs. The aim of this

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research is to determine the training needs on a regional, project-by-project basis, and therefore requires a measure of labour demand in terms of outputs - that output being cost. This is not a metric of productivity which has previously received any attention in the literature.

New domestic building accounts for over one third of all new-build construction work in the UK in 2007 making it the largest single sector and a substantial contributor to the UK economy (Office for National Statistics 2008).

Glenigan collect extensive details on every new planning application and decision from all 456 Local Authorities across the UK and identify design and build, refurbishment and pre-planning projects from a range of industry sources. The Glenigan database contains a breakdown of projects undertaken in the UK (www.glenigan.com). It was used to define the largest element in the domestic sector. In total there are 45,409 projects in the Glenigan database. Of these, 23,661 are housing projects which together account for 32.5% of the total value of projects. This suggests that at least as far as housing is concerned, the database is representative of the UK situation, where housing accounts for 30% of all new build (Office for National Statistics 2008). The results of further analysis of the 23,661 housing projects in the database are shown in Table 1.

*Table 1 Values of Housing Projects in Glenigan Database*

| | Value (£m) | % |
|---|---|---|
| Houses | 72327 | 42.66 |
| Apartments, Flats | 62525 | 36.88 |
| Residential Outlines | 25763 | 15.20 |
| Student Accommodation | 2061 | 1.22 |
| Sheltered Housing | 1742 | 1.03 |
| Key Worker Accommodation | 1663 | 0.98 |
| Nursing Homes | 1417 | 0.84 |
| Luxury Housing | 642 | 0.38 |
| Elderly Persons Homes | 528 | 0.31 |
| Homes and Hostels | 413 | 0.24 |
| Bungalows and Chalets | 346 | 0.20 |
| Bungalows | 67 | 0.04 |
| Hospices | 48 | 0.03 |
| Total | 169542 | 100.00 |

Analysis of the data suggests houses, flats/apartments and residential outlines account for 95% of all residential construction. The study is initially limited to houses and flats, and the calculation of labour coefficients for these types of projects. This encompasses the largest element of the biggest single sector. However, whilst housing is the prime focus, the principles should be capable of extension to other types of projects of all sizes.

## DATA ANALYSIS

Bills of Quantities for 29 conventionally constructed houses, six separate garages and the associated substructures (including detached houses with and without garages, semi-detached, terraced and bungalows) and bills of quantities for 21 houses and 30 flats (all timber-framed) were obtained. These bill of quantities listed all of the items associated with the projects and provided a reasonable sample of different house and flat types. All of the bills had been priced by a quantity surveyor prior to our receipt of them. The bills were obtained from two different organisations.

Standard estimating books list a rate for the number of hours required to carry out listed activities. For this research the labour content of each bill was determined principally by using information provided in the BCIS Wessex Estimating Price Book, 13th Edition 2008 (BCIS 2008). Where items were not listed in Wessex information on the cost was obtained from alternative estimating books or from the manufacturers of particular equipment or materials.

In calculating the total labour requirement for housing projects preliminary and enabling works were excluded from the analysis. It is entirely possible to determine the labour requirement associated with these two items, but they are site specific. By omitting them from the analysis it is possible to ensure that the co-efficients which are calculated are applicable across a wide range of different projects.

## ANALYSIS OF BILLS OF QUANTITIES

The total labour requirement for each of the bill of quantities was calculated across nine trades Labourers (LA), Bricklayers (BL), Joiners (JO), Roofers (RO), Electricians (EL), Plumbers (PL), Plasterers (Plas), Painters (PA), Tilers (TI). Plant operatives were included in labourers. There were some additional smaller trades (eg metalworkers) in certain bills. The labour for these trades was recorded separately. The labour requirement was calculated by assigning the labour hours for each trade to each item in the bill and summing this across the full bill.

### Houses

The bills of quantities for the conventional housing projects were separated into a bill for each of 29 different types of houses. These included detached, semi-detached and terraced dwellings of two and three bedrooms. Some of the dwellings had integrated garages. There were additionally six types of garages where the garage was not integrated. The garage bills were each a separate bill. The sub-structure bill was also separate from the superstructures of the houses and the garages.

The total labour requirement for each of the 29 types of houses is given in Table 2, along with the cost of that house type. This is broken down by each of the nine trades. The same information is given in Table 3 for the garage and sub-structure bills.

It was not clear from the bills whether all of the dwellings included a garage, except in the integrated garage cases where it was included in the house bill. The sub structure bill is associated with all of the houses and garages. To account for the labour hours in these seven bills the hours for the garages and sub-structure for each trade were distributed among all the houses in proportion to their cost. The total labour hours for each dwelling type were calculated by summing the basic hours for the dwelling and the additional requirement for the garages and sub-structure. Where there was an integrated garage the cost of a garage was not distributed across the bill for that house type.

*Table 2 Total labour and cost for each house type*

| House | Total Man-Years | | | | | | | | | Cost (£) |
|---|---|---|---|---|---|---|---|---|---|---|
| Type | LA | BL | JO | RO | EL | PL | Plas | PA | TI | |
| 1 | 39 | 286 | 241 | 29 | 73 | 82 | 287 | 117 | 26 | 33406 |
| 2 | 39 | 333 | 244 | 31 | 73 | 84 | 298 | 117 | 26 | 37294 |
| 3 | 39 | 455 | 313 | 50 | 73 | 105 | 427 | 163 | 42 | 48670 |
| 4 | 39 | 297 | 269 | 33 | 73 | 85 | 299 | 118 | 26 | 35275 |
| 5 | 52 | 501 | 350 | 23 | 64 | 97 | 293 | 168 | 34 | 39159 |
| 6 | 59 | 496 | 371 | 19 | 73 | 95 | 316 | 184 | 34 | 39146 |
| 7 | 52 | 461 | 343 | 20 | 64 | 96 | 303 | 186 | 31 | 38438 |
| 8 | 52 | 336 | 294 | 18 | 64 | 94 | 269 | 116 | 19 | 31025 |
| 9 | 52 | 301 | 295 | 15 | 93 | 88 | 282 | 160 | 31 | 32411 |
| 10 | 52 | 410 | 300 | 14 | 93 | 91 | 259 | 160 | 31 | 33307 |
| 11 | 52 | 509 | 306 | 20 | 93 | 89 | 238 | 160 | 31 | 35581 |
| 12 | 59 | 626 | 361 | 31 | 73 | 108 | 372 | 155 | 34 | 50774 |
| 13 | 68 | 704 | 434 | 55 | 102 | 102 | 397 | 188 | 42 | 51028 |
| 14 | 60 | 455 | 364 | 28 | 73 | 113 | 421 | 185 | 33 | 45214 |
| 15 | 60 | 471 | 352 | 23 | 73 | 124 | 423 | 185 | 33 | 43660 |
| 16 | 59 | 577 | 400 | 24 | 73 | 115 | 379 | 183 | 29 | 48759 |
| 17 | 59 | 663 | 394 | 24 | 73 | 116 | 366 | 183 | 35 | 49970 |
| 18 | 61 | 451 | 358 | 20 | 64 | 95 | 308 | 143 | 25 | 38915 |
| 19 | 61 | 563 | 358 | 22 | 64 | 98 | 289 | 143 | 25 | 41153 |
| 20 | 61 | 497 | 338 | 20 | 93 | 93 | 316 | 204 | 25 | 38185 |
| 21 | 61 | 602 | 342 | 21 | 93 | 95 | 296 | 204 | 25 | 39509 |
| 22 | 52 | 489 | 351 | 19 | 64 | 100 | 333 | 169 | 20 | 36874 |
| 23 | 52 | 600 | 350 | 21 | 64 | 101 | 315 | 169 | 20 | 38912 |
| 24 | 61 | 464 | 329 | 16 | 93 | 94 | 293 | 185 | 36 | 35166 |
| 25 | 61 | 537 | 333 | 18 | 93 | 94 | 270 | 185 | 36 | 37534 |
| 26 | 68 | 546 | 394 | 29 | 102 | 104 | 455 | 168 | 49 | 48855 |
| 27 | 68 | 641 | 397 | 31 | 102 | 105 | 485 | 168 | 49 | 53692 |
| 28 | 68 | 653 | 450 | 19 | 102 | 95 | 512 | 306 | 34 | 54152 |
| 29 | 68 | 795 | 462 | 21 | 102 | 96 | 480 | 307 | 34 | 57661 |

## Normalising the bills of quantities

Using these total hours and the cost including the sub-structure and garages, the labour coefficients were calculated in man-hours per million pounds (Man-hours/£m) for each trade for the dwellings. This was based on a working year of 1856 hours (BCIS 2008). The labour coefficient for each trade for each house is given in Table 4. These coefficients include the labour from the garage and substructure bills distributed across the 29 houses.

*Table 3 Total labour and cost for garages and substructure*

| Bill | Man Hours | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | LA | BL | JO | RO | EL | PL | Plas | PA | TI | Cost (£) |
| Garage 1 | 17 | 81 | 50 | 7 | 26 | 4 | 0 | 1 | 0 | 5171 |
| Garage 2 | 21 | 72 | 54 | 9 | 26 | 4 | 25 | 2 | 0 | 6621 |
| Garage 3 | 17 | 69 | 46 | 6 | 26 | 4 | 0 | 1 | 0 | 4654 |
| Garage 4 | 16 | 85 | 50 | 7 | 36 | 3 | 0 | 1 | 0 | 4751 |
| Garage 5 | 16 | 109 | 57 | 8 | 36 | 4 | 0 | 1 | 0 | 5642 |
| Garage 6 | 16 | 62 | 43 | 6 | 36 | 2 | 0 | 1 | 0 | 3908 |
| Substructure | 20759 | 12010 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 775067 |

The weighted mean of these values was calculated for each trade, along with standard deviation (SD). The weighted mean was used to take account of the different prices of the dwellings and is calculated as shown in Equation 1. Where x is the labour coefficient; w is the cost of each bill and n is the number of bills. The co-efficient of variation (Cv - ratio of standard deviation to the mean) was determined to provide an estimate of the relative dispersions. The ratio is shown in Equation 2. These values are provided in the last three rows of Table 4.

$$\bar{x} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \qquad \text{(Equation 1)}$$

$$Cv = \frac{\sigma}{\bar{x}} = \frac{standard\ deviation}{mean} \qquad \text{(Equation 2)}$$

**Flats and mixed use development**

Bills of quantities for a mixed used development of 21 houses and 30 flats were analysed using the same process as for the houses. This project was not conventional construction but was timber framed. The total cost of the project (excluding the preliminaries and enabling works - as for the conventional housing project) was £4,046,688.

A further difference between the two projects was the format of the bills. While the housing project had a separate bill for each house type, the 51 dwellings in the development of mixed-use dwellings was combined into one bill. It was therefore not possible to compare the differences between the different types of flats and house in this project. Finally, this project did not have a mechanical and electrical element included in the bill. Therefore, co-efficients could not be calculated for plumbing and electrical trades. The number of man hours required in each of the trades were calculated as before. Table 5 shows the results.

*Table 4 Man-hours per million pounds*

| House Type | Man-Yrs/£m LA | BL | JO | RO | EL | PL | Plas | PA | TI |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5.93 | 6.11 | 2.43 | 0.29 | 0.76 | 0.80 | 2.78 | 1.13 | 0.25 |
| 2 | 5.89 | 6.24 | 2.21 | 0.28 | 0.69 | 0.73 | 2.59 | 1.01 | 0.23 |
| 3 | 5.81 | 6.37 | 2.18 | 0.34 | 0.54 | 0.70 | 2.84 | 1.09 | 0.28 |
| 4 | 5.91 | 6.07 | 2.56 | 0.32 | 0.72 | 0.78 | 2.74 | 1.08 | 0.24 |
| 5 | 5.98 | 7.48 | 2.98 | 0.20 | 0.59 | 0.80 | 2.42 | 1.38 | 0.28 |
| 6 | 6.03 | 7.44 | 3.16 | 0.17 | 0.66 | 0.79 | 2.61 | 1.52 | 0.28 |
| 7 | 5.99 | 7.22 | 2.98 | 0.19 | 0.60 | 0.81 | 2.55 | 1.56 | 0.26 |
| 8 | 6.09 | 6.85 | 3.16 | 0.20 | 0.73 | 0.98 | 2.81 | 1.21 | 0.19 |
| 9 | 6.07 | 6.35 | 3.04 | 0.17 | 0.99 | 0.89 | 2.81 | 1.59 | 0.31 |
| 10 | 6.05 | 7.32 | 3.00 | 0.15 | 0.96 | 0.89 | 2.52 | 1.55 | 0.30 |
| 11 | 6.02 | 7.96 | 2.88 | 0.19 | 0.90 | 0.81 | 2.17 | 1.45 | 0.28 |
| 12 | 5.92 | 7.33 | 2.40 | 0.21 | 0.52 | 0.70 | 2.37 | 0.99 | 0.22 |
| 13 | 6.06 | 7.79 | 2.80 | 0.35 | 0.65 | 0.65 | 2.56 | 1.21 | 0.27 |
| 14 | 5.98 | 6.59 | 2.70 | 0.21 | 0.58 | 0.82 | 3.01 | 1.32 | 0.24 |
| 15 | 5.99 | 6.83 | 2.70 | 0.18 | 0.60 | 0.92 | 3.13 | 1.37 | 0.24 |
| 16 | 5.94 | 7.17 | 2.75 | 0.17 | 0.54 | 0.77 | 2.52 | 1.21 | 0.19 |
| 17 | 5.93 | 7.63 | 2.64 | 0.17 | 0.53 | 0.76 | 2.37 | 1.18 | 0.23 |
| 18 | 6.05 | 7.09 | 3.06 | 0.18 | 0.59 | 0.80 | 2.56 | 1.19 | 0.20 |
| 19 | 6.03 | 7.77 | 2.91 | 0.19 | 0.56 | 0.77 | 2.28 | 1.13 | 0.19 |
| 20 | 6.06 | 7.55 | 2.96 | 0.18 | 0.85 | 0.80 | 2.68 | 1.73 | 0.21 |
| 21 | 6.05 | 8.26 | 2.90 | 0.19 | 0.82 | 0.78 | 2.42 | 1.67 | 0.20 |
| 22 | 6.00 | 7.63 | 3.17 | 0.18 | 0.62 | 0.88 | 2.92 | 1.48 | 0.17 |
| 23 | 5.98 | 8.32 | 3.00 | 0.19 | 0.59 | 0.85 | 2.62 | 1.40 | 0.16 |
| 24 | 6.11 | 7.60 | 3.12 | 0.16 | 0.91 | 0.87 | 2.70 | 1.70 | 0.33 |
| 25 | 6.07 | 7.96 | 2.96 | 0.17 | 0.86 | 0.82 | 2.33 | 1.59 | 0.31 |
| 26 | 6.08 | 6.93 | 2.65 | 0.19 | 0.68 | 0.70 | 3.06 | 1.13 | 0.33 |
| 27 | 6.04 | 7.18 | 2.43 | 0.19 | 0.62 | 0.64 | 2.97 | 1.03 | 0.30 |
| 28 | 6.04 | 7.22 | 2.74 | 0.11 | 0.62 | 0.58 | 3.11 | 1.86 | 0.21 |
| 29 | 6.01 | 7.78 | 2.64 | 0.12 | 0.58 | 0.54 | 2.74 | 1.75 | 0.19 |
| Mean | 6.00 | 7.26 | 2.77 | 0.20 | 0.67 | 0.77 | 2.67 | 1.36 | 0.24 |
| SD | 0.07 | 0.62 | 0.28 | 0.06 | 0.14 | 0.10 | 0.26 | 0.25 | 0.05 |
| CV | 0.01 | 0.09 | 0.10 | 0.29 | 0.21 | 0.13 | 0.10 | 0.19 | 0.20 |

*Table 5 Total labour for mixed use development*

| Trade | Total Man-hours |
|---|---|
| Labourer | 32947 |
| Bricklayer | 13051 |
| Joiner | 42410 |
| Roofer | 2298 |
| Electrician | n/a |
| Plumber | n/a |
| Plasterer | 18982 |
| Painter | 14182 |
| Metalworker | 169 |
| Tiler | 1432 |
| Floorer | 24 |

Using the same process as for the housing project, the labour co-efficients in the number of man years per million pounds were calculated for each trade. These results are presented in the following section.

## THE LABOUR COEFFICIENTS

The labour coefficients for the conventionally constructed houses are shown in Table 6. They represent the weighted averages derived from all 35 bills. The 29 bills were partitioned into different types of houses (eg. semi-detached; with/without integral garage). This showed that the variability in the labour coefficients for houses of the same type is greater than the variability in the labour coefficients between houses of different types, suggesting that there is no point in developing different models for different types of houses, and that a single model for all housing is feasible. The results obtained for the analysis of the 21 houses and 30 flats, which were timber-framed, are given in Table 7. As all the dwellings for the mixed-use project were combined in one bill it was not possible to calculate the mean and deviation as it had been for the houses.

*Table 6: Labour calculated for co-efficients for housing projects*

| Trade | Weighted Mean (Mn-yrs/£m) | Standard Deviation | St Dev/Mean |
|---|---|---|---|
| Labourer | 6.00 | 0.07 | 0.01 |
| Bricklayer | 7.26 | 0.62 | 0.09 |
| Joiner | 2.77 | 0.28 | 0.10 |
| Roofer | 0.20 | 0.06 | 0.29 |
| Electrician | 0.67 | 0.14 | 0.21 |
| Plumber | 0.77 | 0.10 | 0.13 |
| Plasterer | 2.67 | 0.26 | 0.10 |
| Painter | 1.36 | 0.25 | 0.19 |
| Tiler | 0.24 | 0.05 | 0.20 |

*Table 7: Labour calculated for co-efficients for flat projects*

| Trade | Weighted Mean (Mn-yrs/£m) |
|---|---|
| Labourer | 4.39 |
| Bricklayer | 1.74 |
| Joiner | 5.65 |
| Roofer | 0.31 |
| Electrician* | 0.67 |
| Plumber* | 0.77 |
| Plasterer | 2.53 |
| Painter | 1.89 |
| Tiler | 0.20 |

** Insufficient data was available to derive the co-efficients for the flats for electrical and plumbing trades. The values incorporated in the model are those derived from the conventionally designed houses.*

## Accuracy

The results in Table 6 suggest that the accuracy of the models, expressed as the coefficient of variation (defined as the ratio of the standard deviation to the mean value) for each coefficient varies between 1% and 29%. The larger errors are generally associated with the trades with the smaller labour coefficients. These are associated with the trades in which the fewest operatives are engaged. The authors consider this to be an appropriately accurate measure of the labour co-efficients. It may be possible to improve this with real data.

Since there were not separate bills for the timber framed dwellings (Table 7), the accuracy of the model could not be estimated, but is likely to be of the same order of magnitude as that of the conventionally designed houses.

## Limitations

The labour co-efficients determined from this research are accurate across the conventional and timber framed housing projects. However, there are some limitations associated with the outcomes.

Firstly, as discussed, only the substructure and superstructure are included in the model. No account is taken of preliminaries, enabling works, demolition, preparation or other work. These are considered to be too site specific. Land costs are also excluded from the contract sum when determining the total cost and so should be omitted when applying the labour coefficients.

The labour elements of bill items were generally taken from BCIS Estimating Price books and other sources. They are not based on real data from past projects. Additionally, being based on bills of quantities; they are estimates of what might happen rather than a report of what did happen.

The model is currently populated only for non-timber framed houses and timber framed houses and low-rise flats. The electrical and plumbing coefficients for all project types are currently based on the non-timber framed houses. Insufficient details were available for the timber framed development for these trades. Overall, the coefficients are limited to the following trades: Labourer, Bricklayer, Joiner, Roofer, Electrician, Plumber, Plasterer, Painter and Tiler. Plant operators are included in labourers.

Metalworkers and floorers were also included in the timber framed model but the coefficients for these trades were very small. These coefficients have therefore been omitted from the general list as the small number does not provide a sufficiently accurate coefficient.

## CONCLUSIONS

The approach of measuring productivity in terms of outputs is one which has not previously received much attention in the literature. This research has demonstrated that it is possible to calculate the labour requirement for housing in terms of man-years per million pounds of construction cost.

The data analysis has reviewed bills of quantities for 80 houses and flats along with the associated sub-structure and ancillary buildings. By analysing a large sample of bills it was possible to develop two sets of labour co-efficients. The analysis showed that it was not necessary to develop different coefficients for different types of houses (eg. detached/semi-detached dwellings). It is however, necessary to define different co-efficients for timber and non-timber framed residential construction. The notable differences between the two types are in the joiner and bricklayer trades. This is due to the increased wood element and the reduced masonry element in timber framed and vice versa. One of the limitations of determining the labour demand from bills of quantities is that it is a very time-intensive process. Collecting real data from existing projects would be a more effective means of obtaining data if it were available.

It has been demonstrated that labour coefficients have been calculated with sufficient accuracy. However, there are some notable limitations of the co-efficients. These primarily relate to the fact that the data has been taken from price books and is not real data from projects. Additionally, the estimates of the coefficients are restricted for some trades (electrical, plumbers, metal workers and floorers). Further research is required to define robust coefficients for these trades.

Despite these limitations, the research that has been presented in this paper has calculated coefficients for timber framed and non-timber framed dwellings. These coefficients can be used to determine the total labour demand across nine trades given the value of a project. This is of particular importance in determining the training requirement for major housing projects. There is no reason why a similar approach could not be applied to other sectors within the construction industry (eg. schools, hospitals).

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