Agile Construction Initiative

Benchmark Method

Building on CESMM

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Benchmark method

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Introduction

The Agile Construction Initiative (ACI) is a response to the report by Sir Michael Latham into the UK construction industry[1]. The report highlighted the need to reduce the cost of construction in the UK by 30% by the year 2000. In order to achieve this ambitious target the industry must change. As Roger Milliken observed: "Insanity is doing the same thing the same way and expecting a different result"[2]. The question is what changes are required? One way to answer this question is through the process of benchmarking.

Benchmarking has become a management buzzword in the 1990s. Every company and many academic institutions are declaring that they are carrying out benchmarking. Many are carrying out quite different activities, so it is useful to define what ACI means by benchmarking. The following definition was developed by the International Benchmarking Clearinghouse (IBC) and represents the view of ACI.

> "Benchmarking is a systematic and continuous measurement process; a process of continuously measuring and comparing an organisation's business processes against business process leaders anywhere in the world to gain information which will help the organisation take action to improve its performance."

There are a number of key elements to pick out of the definition.

A continuous process. The business process leaders are not static, they will be leaders because they are constantly innovating and improving. The purpose of benchmarking is to promote action. The measurement must therefore be continuous to track improvements and to set targets for UK performance exceeding the level that the business leaders will achieve *in the future*.

A systematic measurement process. Benchmarking follows the simple philosophy that if you want to control or improve something you must first measure it.

An organisation's business processes. Business processes are combinations of people, equipment, materials and methods organised in a way that produce desired outputs[3]. To be effective benchmarking must concentrate on business processes that have a direct effect on customer satisfaction and therefore the bottom line.

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[1] Latham, Sir Michael (1994) *Constructing the Team*, London: HMSO

[2] Roger Milliken, CEO of Milliken Company in his address to the National Quality Forum, following his company's receipt of the Malcolm Baldridge National Quality Award, quoted in Watson, G (1993) *Strategic Benchmarking*, New York: John Wiley and Sons

[3] Harrington, H J (1991) *Business Process Improvement: The Breakthrough Strategy for Total Quality, Productivity, and Competitiveness,* New York: McGraw-Hill

Business process leaders. It is important to learn from the best. Other programmes have shown that the performance of business process leaders is significantly better than average[4].

Anywhere in the world. The world of business is global. UK civil engineering industry is already under threat from overseas competition. It must therefore look for the business process leaders worldwide and not just in the UK or Europe.

Take action to improve. The benchmarking process itself must start to shed light on the mechanisms that give rise to the outstanding performance. The organisations must then adapt these superior processes to their own unique conditions.

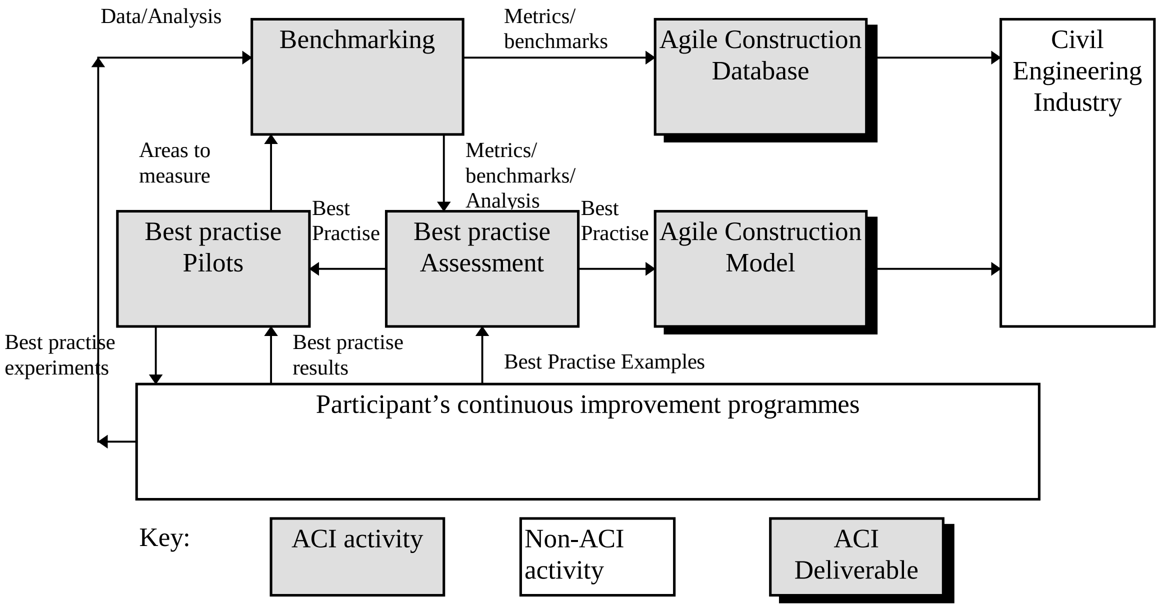
The remainder of this report will discuss the methodology that ACI has developed for benchmarking the UK civil engineering industry and the wider programme of work that will promote actions to improve the sector.

[4] Womack, J, Jones, D, Roos, D (1990) *The Machine that Changed the World*, New York: Rawson Associates.

What are ACI going to Benchmark?

The logical flow of ideas and data

The model below describes the logical flow of ideas and data within ACI.



• Figure 1 The logical flow of ideas and data

Benchmarking

It will consist of data collection, collation, validation and analysis. The main outputs will metrics, benchmarks and analysis. A secondary output will be debriefing of individual participants.

The main deliverable will be the Agile Construction Database, containing the key metrics and benchmarks.

Best practice assessment

Best practice assessment will attempt to identify the characteristics of an superior performing civil engineering project. The sources of information will be:

1. Benchmarking
2. Literature surveys
3. Best practice pilots
4. Other continuous improvement work being carried out by participants

5. Other related projects outside of ACI.

The best practice assessment will be documented in the Agile Construction Model.

Best practice pilots

Best practice pilots may be ACI activities, participants activities or may be carried out under different projects and programmes. A best practice pilot will draw on the following:

1. Existing programmes within ACI's participants.

2. Best practice that emerges from analysis of the metrics and benchmarks.

3. Best practice that already exists in other industries that may be transferable to civil engineering.

The main outputs will be proven best practice in civil engineering.

The main best practice deliverable will be the Agile Construction Model, this will be analogous to the Lean Enterprise Model[5] being developed by the Lean Aircraft Initiative at MIT.

The detailed results of the best practice experiments will be confidential. The Agile Construction Model will contain only guidelines and techniques.

Best practice pilots have been planned in the areas of management accounting and total life cycle costing. Other pilots may be proposed as ACI progresses.

Some fundamental beliefs about benchmarking

It is important to get a few concepts and definitions clear before going on to describe the approach to benchmarking in more detail.

1. What does ACI mean by a *metric*?

2. What does ACI mean by a *benchmark*?

3. What does ACI mean by *best practice*?

4. What is the appropriate division of responsibility between partners?

What does ACI mean by a metric*?*

1. A *metric* a quantitative measure.

[5] The Lean Enterprise Model is described by Stanley W. Kandebo in an article in Aviation Week and Space Technology, June 3 1996, pp 79-82. It represents the main output of the Lean Aircraft Initiative, a research programme at Massachusetts Institute of Technology (MIT). The programme is being sponsored by the US Air Force and involves all the major manufacturers of U.S. military aircraft.

2. A *metric* is clearly defined, along with the method that will be used to measure it.

3. ACI expects to look for *metrics* on processes that are in main value chain rather than those in support activities.

What does ACI mean by a benchmark*?*

1. A *benchmark* is the best or highest measure achieved by any company on a given *metric*.

2. A *benchmark* represents a level of performance on a particular *metric* that all companies can aspire to or exceed.

What does ACI mean by best practice*?*

1. *Best practice* is a method of working that analysis shows is likely to lead to a company achieving performance that approaches the *benchmark* on one or more of the *metrics*.

What is the appropriate division of responsibility?

The work carried out with ACI will divide into three types:

1. Benchmarking

2. Best practice development

3. Best practice implementation.

Benchmarking

The University of Bath will act as a neutral “honest broker”. The University of Bath will store and collate data and present it to the participants in ACI in a way that hides the origin of the data. This will allow many organisation to participate in and benefit from the exercise without giving away commercially sensitive information to their competitors.

Best practice development

There will be a number of sources of best practice development activities:

1. Existing programmes within ACI’s participants.

2. Best practice that emerges from analysis of the metrics and benchmarks.

3. Best practice that already exists in other industries that may be transferable to civil engineering.

A best practice development activity can only be included in the ACI work plan if the lessons learned are made public. The exact details of the work done and the participants involved can be hidden, but the best practice itself must be public domain.

Best practice implementation.

Best practice implementation is a matter for the participants. Best practice pilots can be included in the ACI work plan with the same proviso as above, i.e. that the best practice that emerges be put into the public domain.

The Development of the ACI Benchmark Method

ACI has developed a method for benchmarking civil engineering projects based on the principles outlined in the previous section. The elements of the method are as follows:

1. Define a standard civil engineering product in terms of the elements defined by the CESMM[6].

2. Add additional guidance where required to obtain uniformity.

3. Decide on the basis for comparison with respect to non-productive times (i.e. sickness, weather, holidays).

4. Add measurements associated with materials wastage, capital employed, and other overheads, such as number of site staff, storage space for materials etc.

5. Define additional metrics for the non-production activities.

The standard civil engineering product

The problem that we must solve was well summed up by John Krafcik and James Womack of MIT:

> 'The problem in comparing assembly plants is one of "apples to apples" to insure that the activities being compared and the products being produced are comparable.'

In addition to standard activities, they decided that a standard product was required. Finally the amount of work done by employees was standardised by leaving out non-productive hours such as lunch, coffee-breaks and clean-up time.

> ACI will develop a limited number of standard civil engineering product each being made up of activities that are common to the majority of projects of that type and which contribute most to overall cost of the project.

[6] CESMM. The Civil Engineering Standard Method of Measurement developed by the Institution of Civil Engineers. The current version is version 3. This version has made strenuous efforts to match the product classification in CESMM, which is used in creating bills of quantity, with the actual construction activities that are carried out on site. The makes it an axcellent basis for identifying the activities that should be benchmarked.

• Recommendation 1 Standard civil engineering products

There may have to be a number of standard products for different sectors; roads, rail, tunnels etc. Within each sector decisions will have to be taken about what constitutes standard activities and what is non-standard. As an example, a road standard product may have the following standard and non-standard activities:

	Standard	Non-Standard
Structures:		
	• Formwork	• Excavation
	• Steel fixing	• Backfilling
	• Concrete pouring	• Concrete batching
	• Concrete finishing	• Hauling of concrete from batcher
Roadworks		
	• Prepare ground	• Communications
	• Lay sub-base	• Install lighting
	• Roadbase	• Signage
	• Surfacing	• Hauling of aggregates
	• Install drainage	• Traffic Management
	• Kerbs and channels	
	• Install safety barriers	
	• Road markings	
Earthworks		
	• Excavation	• Haulage
	• Deposition of fill	• Management of tips
	• Compacting	
	• Trimming	
	• Landscaping	

• Table 1 Standard and non-standard activities

Haulage is being excluded on the grounds that the effort required is a function of distance to tips and not a function of the construction process itself. It is expected that the effectiveness of the haulage operation will be reflected in the metrics obtained for the earthworks and roadworks activities so that this important aspect of civil engineering will not be lost.

Communications are being excluded as they are likely to vary greatly and a simple way to produce a size factor will be difficult to find.

Management of tips is being excluded on the grounds that size comparisons will be difficult and that this is a specialist activity beyond the scope of the current exercise.

There may be problems with structures, some projects may be dominated by bridges based on precast concrete or steel beams, whilst others will be poured in situ. This may cause problems.

The metrics

The basic *Measures of Construction Productivity* will need to be defined. The following have been identified at present:

1. The effort in productive unit[7] hours required to build the standard product.

2. The utilisation of major plant items will be measured. This will be a weighted average of the utilisation of individual items of plant. The utilisation will be the productivity divided by the rated productivity of the piece of plant.

3. The material wastage factor. This will be a weighted average of material purchased divided by the material sold for the standard civil engineering product.

4. The quality index. This is defined as the costs incurred by the contractor at the acceptance date divided by the costs incurred by the contractor at one year after the acceptance date.

5. The delivery index. This is defined as the time from the start of the contract to the originally agreed completion date divided by the time from the start of the contract to the actual acceptance date.

> ACI will develop Measures of Construction Productivity to help rank performance on civil engineering projects.

Recommendation 2 Measures of Construction Productivity

If necessary further guidance will be developed on the product to ensure that the metrics obtained give a fair comparison of the participants.

ACI will decide on the basis for comparison with respect to non-productive times (i.e. sickness, weather, holidays). The treatment of weather conditions is of particular importance due to the effect of weather on productivity. This will gain additional importance when looking at participants from different countries.

In addition to the productivity measures a number of other *Indicators of Construction Practice* will be developed associated with materials wastage, capital employed, and other overheads, such as number of site staff, storage space for materials etc. These “indicators of manufacturing practise” proved

[7] The definition of a productive unit will vary according to the type of activity. For labour intensive activities it will be a single labourer, for plant intensive activities it will be a gang including both labour and plant.

invaluable in the IMVP for starting to describe the characteristics of lean production. We are sure that they will prove equally valuable in describing the characteristics of an agile construction company.

> ACI will develop Indicators of Construction Practice to help determine the factors for success for civil engineering projects.

Recommendation 3 Indicators of Construction Practice

By analogy with IMVP these will include:

1. The amount of space occupied by offices and materials storage.
2. The quality of the products assembled, measured in terms of the number of defects reported by the client.
3. The levels of inventories, measure in terms of the average days of supply of non-perishable parts.

Other indicators that are thought to be necessary are:

1. Ratio of productive to non-productive staff
2. Ratio of on-site to off-site staff.
3. Safety and environmental performance
4. Amount of capital equipment in use, the metric needs further definition .

Additional metrics for non-production activities

Construction activities are only one part of the overall construction process. The way that organisations perform on non-production activities will also be of interest to ACI. In order to compare different projects a standard construction process model will be defined including these non-construction activities. A set of metrics will then be developed for these activities.

> A standard construction process model will be developed to allow performance on non-production activities to be compared.

• Recommendation 4 A standard process model

The measurement of production effort

Two approaches are possible to the measurement of the working time required to construct the standard product; a top down approach and a bottom up approach. The top down approach starts with the total effort on the project under consideration and then factors this figure according to the size of the project relative to the standard product. The bottom up approach starts with the effort per unit of output for each of the activities that makes up the standard product and then multiplies the effort per unit by the total number of units in the standard product. These two options are described in more detail below.

Top down approach

The first possible approach is to start from a measurement of the total effort expended on different projects and then to factor the figures to give a fair comparison.

The approach is shown in the flow chart below.

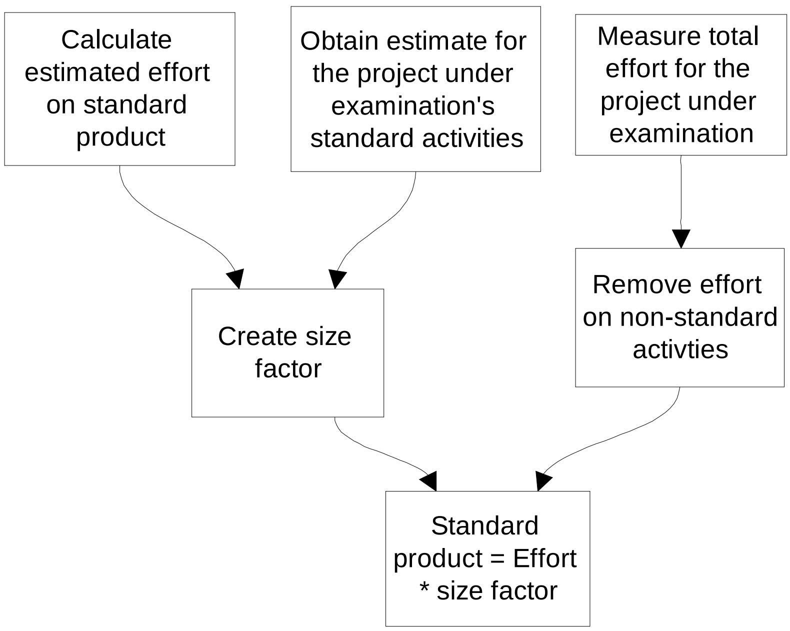


Figure 2 Top down approach

A number of other factors are required on the total effort figure to allow fair comparison:

- Relief time factor - Total hours adjusted for normal work practices in terms of paid breaks for refreshment, washing up, travel to site etc.

- Weather factor - The total hours may need adjusting for productive time lost due to weather in order to allow fair international comparison. This may prove difficult.

The main disadvantage of this approach is that the size factor is based on estimated figures. The main advantage is that the collection of information on the amount of effort used will be relatively straightforward.

Bottom up approach

In this approach the performance measurements for each individual component in the standard product are supplied by the project team. The total for the entire standard product built from the bottom up.

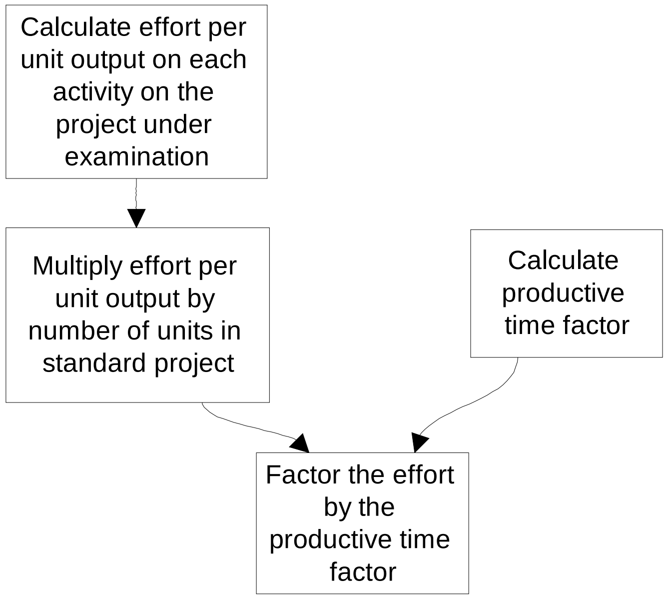


Figure 3 Bottom up approach

The advantage of the bottom up approach is that the size factor is taken care of by the build up of the total effort figure from the individual labour usage figures.

The disadvantage is finding the labour usage for each individual item in the standard product.

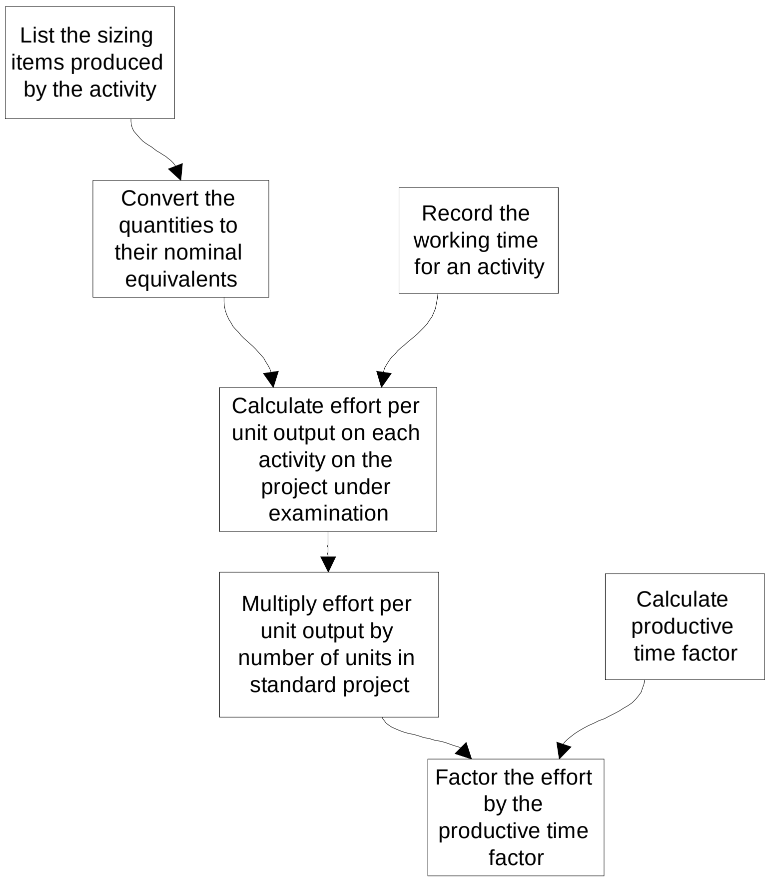
Modified bottom up approach

During the piloting of the benchmark method it became apparent that using CESMM items as the basis of returns had two problems associated with it:

1. Finding CESMM items that were common to all projects was difficult.

2. Projects gather data on production at a more generic level than an individual CESMM item.

The bottom up approach was modified. Sizing items were introduced. The purpose of the sizing items were to allow returns to be provided at a more generic level and then adjusted for the different scope of activities on projects supplying data.



- Figure 4 Modified bottom up approach

Discussion of the approaches to the standard product

The modified bottom up approach has been chosen. This method provides good visibility of the construction process and collects data that the majority of projects will be have available.

In the long run the bottom up approach may form the backbone of a project management system that moves away from project control through monetary measures to project control by setting and monitoring productivity targets.

A summary of the ACI benchmark method

The standard civil engineering project

A typical construction project is selected

ACI wants to compare the performance of civil engineering companies to find out what represents best practice in civil engineering. A typical construction project in a particular sector of civil engineering is chosen as the basis for comparing performance so that all companies can submit comparable data on performance. However any project no matter how representative will contain some activities that are particular to that project.

The non-standard activities are removed from the typical project so that all companies can submit equivalent data. The number of activities remaining runs into the hundreds. This is considered too many for ACI to be able to work with.

Finding the highest value activities

A pareto analysis is carried out on the list of standard activities to find the 20% or so that contribute 80% or so of the overall project value. Experience shows that this ratio holds approximately for all projects. This now gives a shorter list of standard activities on which to collect data.

Eliminate duplication

The list of activities for the standard project will be couched in specific terms related to that project. The companies being compared may not carry out the exact same activities themselves. The activities in the standard project need to be generalised according to the construction processes, resources and productivity rates achieved. This will allow companies to provide returns on activities that they carry out that are equivalent to the standard activities in terms of their construction processes.

The standard project

The final standard project can now be defined in terms of a limited set of activities defined in a way that will allow companies to submit data on their nearest equivalent activities.

Measuring productivity

Productivity should be measured from the perspective of the customer. For each standard activity a productive unit is defined as being the assembly of plant and labour resources required to produce a unit of output of the standard activity. The productivity metric that is chosen is the working time taken by the productive unit as a whole to produce a unit of output for each of the standard activities. This give a measure that is independent of the method of construction used by a particular project.

In order to make fair comparison the method of measuring a unit of output and working time will be defined for each of the standard activities.

However, some activities will be plant intensive and a company using large plant inefficiently may appear to outperform a company using smaller plant more effectively. As a result a second measure will be used. The capability of the plant being used on plant intensive activities will be calculated and then compared with the actual productivity achieved. The two measures taken together will then give a good picture of the performance of the different companies.

Sizing items allow similar activities with a different scope to be compared. For example, the time taken to lay pipes varies according to the size and depth of the pipe. By asking for these data, the quantity of pipe laid can be adjusted take account of this variation. As a result a fair comparison can be made between the performance of two projects laying different sizes of pipe.

Materials wastage

For each of the standard activities a list of key materials will be defined. This will allow comparisons of materials wastage to be made.

Some materials will go through a transformation as a result of the activity. For these materials a conversion factor will need to be defined that give the number of units of output material that should be obtained from processing a unit of input material.

Because quantities of materials cannot be summed directly due to difference in units of measurement, the materials will have to be weighted in order to allow them to be summed.

The materials wastage on an activity will then be the calculated as:

$$MaterialsWaste = \frac{\sum OutputMaterial * weight - \sum InputMaterial * ConversionFactor * weight}{\sum OutputMaterial * weight}$$

Environmental factors

Differences in the performance measures may in part be accounted for by differences in the environment in which the work is being carried out. The effect of these differences needs to be understood to ensure that the inferences drawn from the comparison of metrics are valid.

For each standard activity the respondents will asked to assess the effect of a small list of external factors on the progress of the activity.

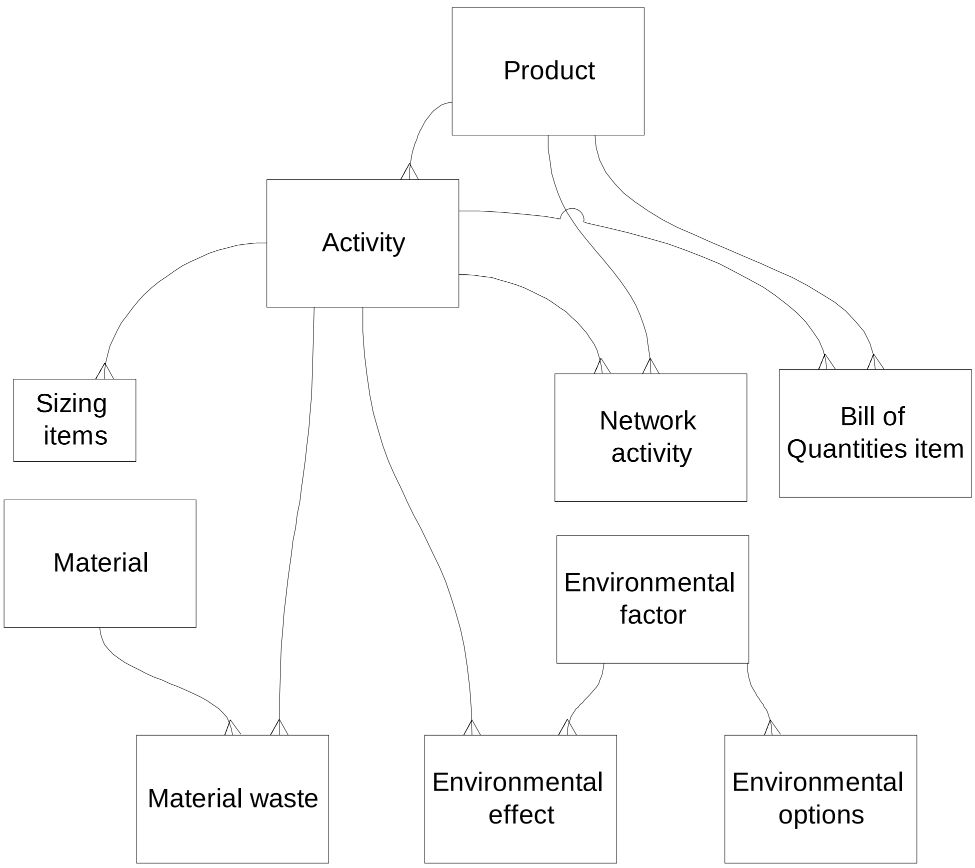
The Agile Construction Database

The methodology described in earlier sections is supported by a database. The database is used for both the development of the standard construction products and the storage and processing of the data returned by companies.

Definition of the standard product

The standard product is captured as a Bill of Quantities and a list of standard activities. Each standard activity has a classification. This classification is added to each Bill of Quantities item. The Bill of Quantities item also has a work breakdown structure identification added to it. This allows the result to be aggregated in two different ways. Finally the standard activities are also included in a precedence network to allow an overall project duration to be estimated from the results.

The tables and their relationships are shown in Figure 5.



• Figure 5 Standard product definition

The results

The database will hold the results of the benchmarking exercise. The companies taking part will submit returns on a number of different projects. For each project they will submit a project level return covering delivery performance, quality and the Indicators of Construction Practice. Then for each standard activity they will submit one or more returns of the level of performance achieved by the project on that activity.

Conclusions

A method has been developed to benchmark civil engineering projects. The method is based on creating a set of standard projects that companies are asked to 'build'. They provide information on their performance on the standard activities that comprise the standard project. This information is then aggregated to give their overall performance for the standard project.

Indicators of practice are collected that can be used to start to determine the factors that lead to superior performance.