SCHOOL OF ENGINEERING | WEEK 5

Engineering Project Management

Cost Estimation: Part 2

Estimating methods, from ballpark figures to tender bids



Photo by Tierra Mallorca on Unsplash

Today: five methods, then the bid

1

Recap and overview

Why early estimates are rough, and the five methods side by side

2

Broad methods

Global, factorial and labour-hours estimating

3

Detailed methods

Unit-rate and operational estimating, the basis of tenders

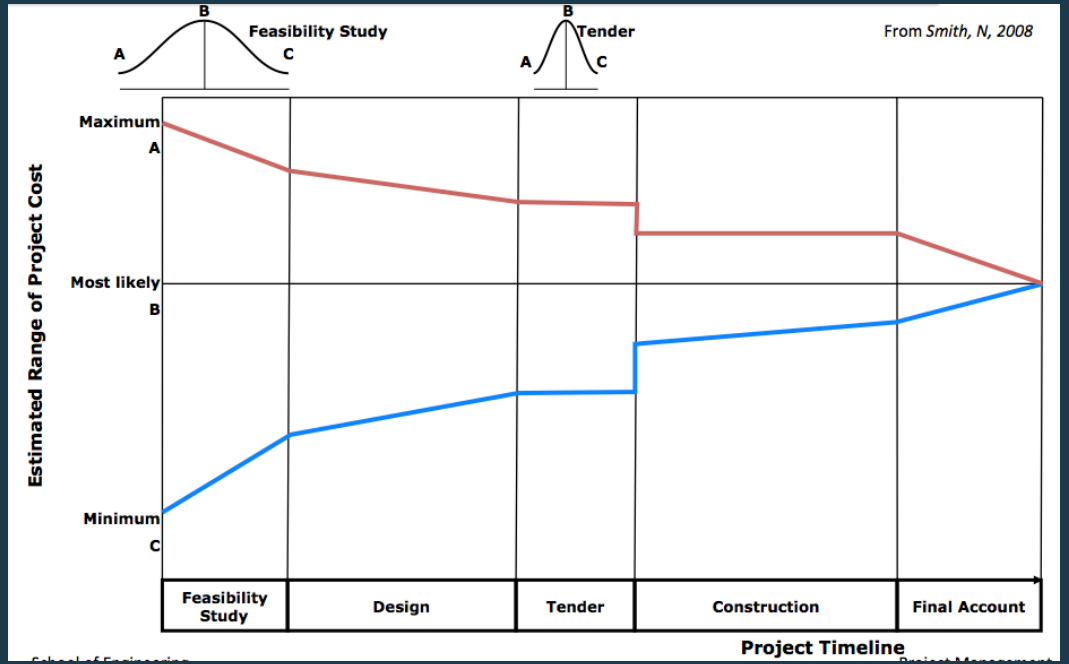
4

From estimate to bid

The estimators' report, uplift and accuracy

Recap: early estimates are broad

- At early stages, accuracy will be low
- An exact figure is not required
- Scope and design details are not yet known
- So 'broad' techniques must be used
- Remember the Holyrood example



Five methods, from broad to detailed

Data are gathered first; an estimating method then converts them into the estimate.

1	2	3	4	5
Global	Factorial	Labour-hours	Unit rate	Operational

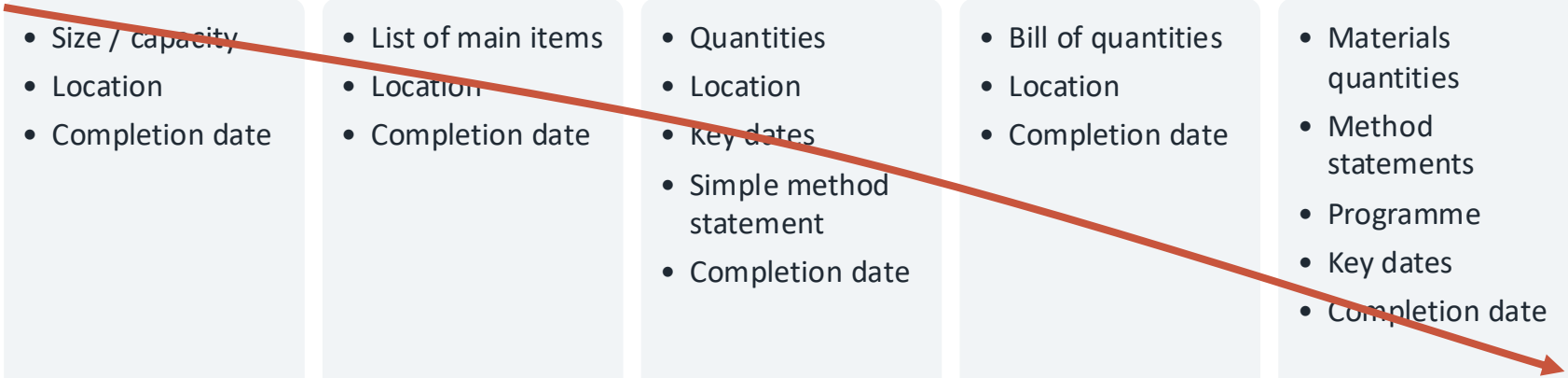
Broad: used at project conception — **Detailed: ideal for tenders**

Increasing accuracy

After Smith, N. (2008)

What data does each method need? 1. Project data

Global / approximate	Factorial	Labour-hours	Unit rate	Operational
• Size / capacity • Location • Completion date	• List of main items • Location • Completion date	• Quantities • Location • Key dates • Simple method statement • Completion date	• Bill of quantities • Location • Completion date	• Materials quantities • Method statements • Programme • Key dates • Completion date



From Smith, N. (2008).

Data needs grow with each method, and so does accuracy.

What data does each method need? 2. Cost data

Global / approximate	Factorial	Labour-hours	Unit rate	Operational
• Overall costs of similar projects • Inflation indices • Inflation forecasts	• Factorial estimating system • Quotes for main plant items • Inflation forecasts	• Hourly rates • Productivities • Overheads • Materials costs • Hourly rate forecasts • Material costs forecasts • Plant data	• Historical unit rates for similar work items • Preliminaries • Inflation indices • Inflation forecasts	• Labour rates and productivities • Plant costs and productivities • Materials costs • Overhead costs • Materials costs forecasts • Plant capital and operating cost forecasts

From Smith, N. (2008).

Data needs grow with each method, and so does accuracy.

Mini case: Grand Designs



Channel 4 shows real projects with the same themes as this course:

The client
Usually a couple

The project manager
Often the client, to save money

The designer
May or may not help manage the project

Time, cost and quality
Constantly in tension, often very visibly

Watch: Grand Designs clips





While watching
Where do time, cost and quality pull against each other?

Clip 1: learningonscreen.ac.uk/ondemand/index.php/clip/17723

Clip 2: learningonscreen.ac.uk/ondemand/index.php/clip/17724

Clip 3: learningonscreen.ac.uk/ondemand/index.php/clip/17725

PART 2

Broad methods

Global, factorial and labour-hours estimating

Method 1: Global estimating

Also known as

- **Order of magnitude**
- **Approximate**
- **Rule of thumb**
- **Ballpark**

Relies on an archive of costs from similar projects, related to overall capacity or size.

Cost of new project

= historical cost/capacity rate × new project capacity

Global estimating: typical rates

Cost per megawatt: power stations

Cost per tonne of output: process plants



Cost per bed: hospitals

Cost per linear metre: highways and railways



Cost per m^2 or m^3: buildings

Cost per flight capacity: airports



Gives a broad idea at feasibility stage, and shows what capacity an available budget buys. But there are many dangers…

Global problem 1: what are we measuring?

What is the cost?

Does it include final account sums, design and engineering fees, finance costs, land?

This was a problem with the early Holyrood estimates.

What is the capacity?

How does linear capacity allow for interchanges?

How is associated infrastructure allowed for (access roads, power supplies)?

Is area measured internally, or including walls?

Global problem 2: like with like?

Different ground conditions

Different sites: e.g. flat terrain vs mountainous, with different logistical issues

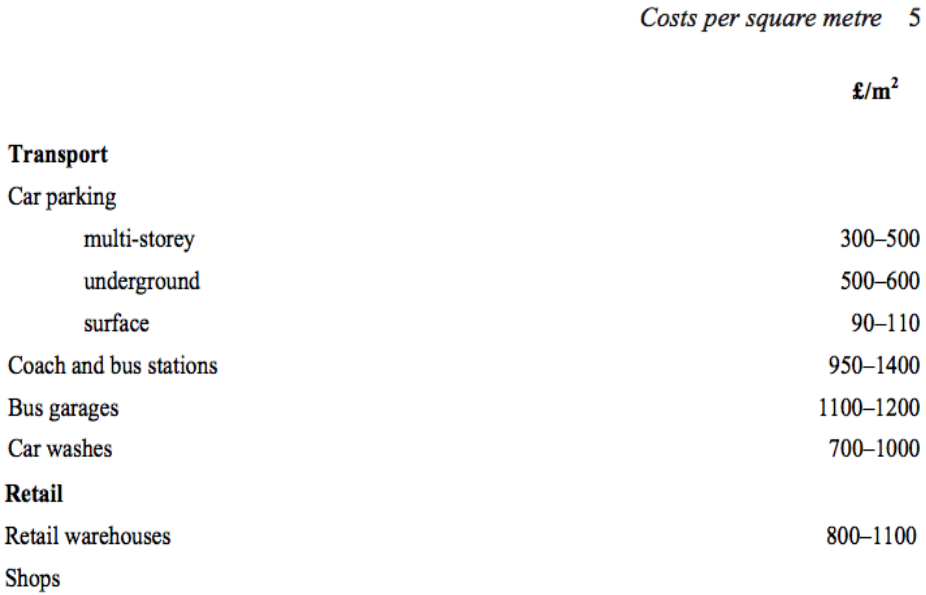
Different quality standards: motorway vs minor road

Brownfield (contaminated?) vs greenfield

Item prices from old contractors' estimates may not reflect true cost

Example: Spon's approximate estimating

- Spon's gives rates for many facility types, based on area
- Area is measured between external walls, with no deduction for internal walls, columns, stairs or lift wells



Costs per square metre 5

	£/m²
Transport	
Car parking	
multi-storey	300–500
underground	500–600
surface	90–110
Coach and bus stations	950–1400
Bus garages	1100–1200
Car washes	700–1000
Retail	
Retail warehouses	800–1100
Shops	

Spon's First Stage Estimating Handbook, 3rd ed. Available online via DiscoverEd.

Method 2: Factorial estimating

- A central fixed plant item can be priced accurately in advance from suppliers (process or power plants)
- Ancillary work (pipework, foundations, instrumentation) is usually a factor of the main plant cost
- Also known as Lang factors
- (see paper on Learn from 2014* that updates the theory)

* - see: Suggested Articles for Further Reading

Main plant item
Quoted by the supplier

×

Factor
From the estimators' experience

=

Installed plant cost

Factorial: reliability and judgement

What the estimate depends on

- Factors built from the department's experience
- Factors shift as the design or plant specification changes
- Reliable plant prices: estimators may make their own judgement

Use with judgement

- Never apply blindly to every area
- Check ancillary items are realistic
- Current supplier costs mean little inflation adjustment
- Not reliable for civil engineering, where materials predominate

Example: factorial estimating

PROCESS-PLANT COST RATIO FROM INDIVIDUAL EQUIPMENT*

Equipment	Factor†
Blender	2.0
Blowers and fans (including motor)	2.5
Centrifuges (process)	2.0
Compressors:	
Centrifugals, motor-driven (less motor)	2.0
Steam turbine (including turbine)	2.0
Reciprocating, steam and gas	2.3
Motor-driven (less motor)	2.3
Ejectors (vacuum units)	2.5
Furnaces (package units)	2.0
Heat exchangers	4.8
Instruments	4.1
Motors, electric	8.5
Pumps:	
Centrifugal, motor-driven (less motor)	7.0
Steam turbine (including turbine)	6.5
Positive displacement (less motor)	5.0
Reactors—factor as approximate equivalent type of equipment	
Refrigeration (package unit)	2.5
Tanks:	
Process	4.1
Storage	3.5
Fabricated and field-erected (50,000 + gal)	2.0
Towers (columns)	4.0

*From W. F. Wroth, "Factors in Cost Estimation," *Chem. Eng.*, vol. 67, October, 1960, p. 204; and F. C. Jelen (ed.), *Cost and Optimization Engineering*, McGraw-Hill Book Company, New York, 1970, p. 317.

†Multiply purchase cost by factor to obtain installed cost, including cost of site development, buildings, electrical installations, carpentry, painting, contractor's fee and rentals, foundations, structures, piping, installation, engineering, overhead, and supervision.

Item	Cost/£	Factor	Plant cost/£
Blowers and fans	15,000	2.5	37,500
Compressors	70,000	2.3	161,000
Furnaces	100,000	2.0	200,000
Heat exchangers	95,000	4.8	456,000
Instruments	70,000	4.1	287,000
Motors	55,000	8.5	467,500
Pumps	32,000	7.0	224,000
Tanks	145,000	2.4	348,000
Towers	250,000	4.0	1,000,000
Total	**832,000**		**£3,181,000**

Factors: Barrie & Paulson (1992), Professional Construction Management, 3rd ed. Based on US projects.

Method 3: Labour-hours estimating

- One of the earliest techniques (Smith calls it ‘man-hours estimating’)
- Needs some idea of how the work will happen, like operational estimating
- Suits labour-intensive work: fabrication, mechanical and electrical installation



Labour-hours: productivity outputs

Best based on historical data. Without it, Spon's or similar can be used. E.g.

Description		unit	rate
Loading loose materials by hand:			
	bricks	tonne/hr	1.7
	kerbs	tonne/hr	1.1
Laying & jointing clay pipes in trenches up to 1.5m deep:			
	150mm pipes	m/hr	7
	300mm pipes	m/hr	4
Placing ready mixed concrete:			
	reinforced up to 500mm thick	m3/hr/gang	6.25
	blinding concrete 150mm thick	m3/hr/gang	5.5
Fixing reinforcing steel:			
	straight bars (13-19mm) to beams and slabs	tonne/hr	0.06
	bent bars (13-19mm) to beams and slabs	tonne/hr	0.03

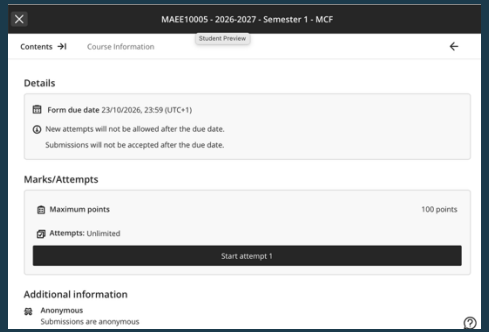
Labour-hours: all-in rates

- General operative: general labour, dumper drivers, banksmen
- Skilled 4: For intermediate skilled workers and operators.
- Skilled 3: For intermediate skilled workers and operators.
- Skilled 2: For highly competent operators with significant responsibilities.
- Skilled 1: The highest specialized tier below full craft level.
- Craft operative: (e.g. joiners, steelfixers)

£	Craft	Cat 1	Cat 2	Cat 3	Cat 4	General
Total weekly earnings	617.37	587.73	566.28	529.62	500.76	491.40
Weekly employer's costs	185.21	176.32	169.88	158.89	150.23	147.42
Total weekly cost	802.58	764.05	736.16	688.51	650.99	638.82
Cost per hour	**20.58**	**19.59**	**18.88**	**17.65**	**16.69**	**16.38**

August 2025 version of Working Rule Agreement. Based on 39 hours per week.

Pause
please complete Mid-Course Feedback



PART 3

Detailed methods

Estimating for tenders: unit-rate and operational

Why must a tender estimate be accurate?

- Tenders are the most common reason to estimate (see Topic 4: Contract Management)
- The broad methods are not generally suitable
- Unit-rate and operational estimating can be very detailed
- Disadvantage: they need a lot of cost data

Estimate too high
The chance of winning the work is reduced

Estimate too low
You may win it, but costs may not be covered, so a loss is more likely

Method 4: Unit-rate estimating

Global
A rate applied to a project's overall capacity, e.g. cost per length of motorway

Unit rate
An estimate built up from rates applied to individual items (types of work)

It therefore needs some means to list all the individual items of work

This is known as a Bill of Quantities.

Units and rates

Labour + plant + materials	**= rate per unit**	**× quantity**	**= item cost**

- A rate (cost) is estimated for each unit of an item
- Example: ‘install data cabling’ has the unit metre (m), and the rate is the cost of one metre
- The rate includes all resources: labour, plant (equipment) and materials

Example: a completed Bill of Quantities

-56-

A123 Fulton to Exwood Trunk Road

Item	Description	Unit	Quantity	Rate		Amount	
1.2.2.1	Removal of topsoil less than 100mm deep	m^2	20,000	0	30	6,000	00
1.2.2.2	Removal of topsoil greater than 100mm deep and less than 300mm deep	m^2	45,000	0	70	31,500	00
1.2.2.3	Removal of topsoil greater than 300mm deep	m^2	15,000	1	15	17,250	00
1.2.3.1	Excavation of unacceptable material	m^3	207,500	1	05	311,250	00
1.2.3.2	Excavation of acceptable material	m^3	508,900	0	95	483,455	00
1.2.3.4	Disposal of unacceptable material	m^3	207,500	2	50	477,250	00
1.2.3.5	Deposition of acceptable material in embankments	m^3	508,900	1	90	966,910	00
1.2.3.6	Compaction of acceptable material in embankments	m^3	508,900	0	20	101,780	00
					Carried forward to summary	**2,395,395**	**00**

The finished bill

Each item has a quantity, a rate and an amount. The rates are what the estimator builds up.

Where do the rates come from?

Historical rates from similar projects

Price books such as Spon's

The estimator's personal manual

Built up from labour, plant and materials at current rates

To build up a rate you need
The cost of each resource, and its output (productivity)

Unit-rate worked example (1 of 2)

Item	Description	Unit	Qty	Rate	Amount
G526.0	Fix high yield steel bars BS 4449 Grade 460/425, 20 mm, 15 m	tonnes	6.350	£??	£??

Resource	Output/productivity	Cost
Rebar (cut, bent, delivered)	1.1 t/t (wastage)	£397.93 per tonne
Steelfixer	0.054 tonnes/hr	£10.12 per hour
20 t mobile crane (off-loading)	5 tonnes/hr	£26.89 per hour

Outputs come from company or personal data, amended to suit site conditions. Materials have an output rate too: wastage.

Unit-rate worked example (2 of 2)

Resource	Calculation	Cost per tonne
Rebar	1.1 × 397.93	£437.72
Steelfixer	10.12 ÷ 0.054	£187.40
Crane	26.89 ÷ 5	£5.38
Total item rate	**437.72 + 187.40 + 5.38**	**£630.50**

Item amount = 630.50 × 6.35 = £4,003.68

Item	Description	Unit	Qty	Rate	Amount
G526.0	Fix high yield steel bars 20 mm	tonnes	6.350	£630.50	£4,003.68

Unit-rate: the hidden problems

117.6 hrs
steelfixing for 6.35 tonnes

12 days
for one steelfixer, or 4 days for three

1¼ hrs
of crane time. Then what?

- What if only 2 steelfixers are available, or the programme allows 2 weeks?
- Resource movement around the site, and concurrent items (bent bars, other diameters) slowing output
- Plant idleness is not allowed for: can the crane move on, or does it wait?
- Materials are assumed off-loaded when and where needed

Unit-rate: limitations in summary

Ignores the programme
No account of the sequence of work

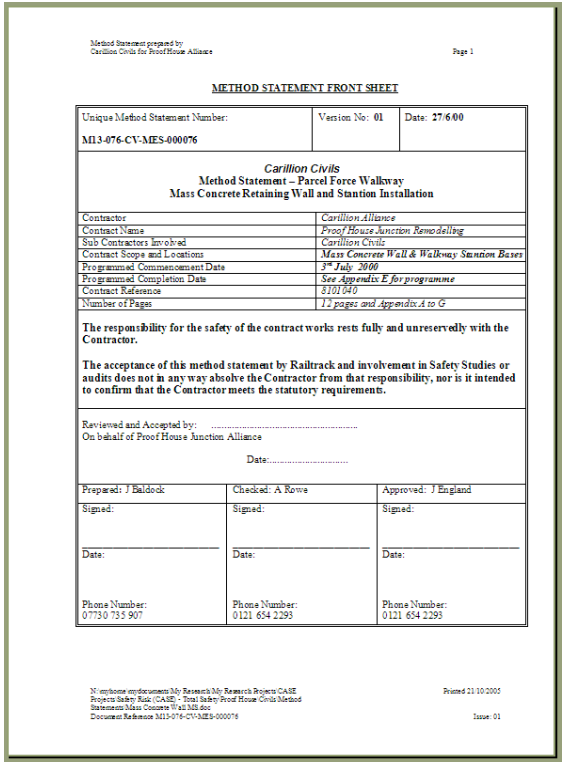
Assumes resources are always available
All of them, all of the time

False confidence
Precise rates (to 2 dp) can hide uncertainty

History may mislead
Past work may differ in nature, conditions and duration

Method 5: Operational estimating

- The most fundamental type: built from the operations and activities in the construction programme
- Needs a programme and at least outline method statements, i.e. how the work will be done
- Allows a very detailed estimate with real advantages



Method Statement prepared by
Carillion Civils for Proof House Alliance

Page 1

METHOD STATEMENT FRONT SHEET

Unique Method Statement Number:	Version No: 01	Date: 27/6/00
M13-076-CV-MES-000076		

Carillion Civils
Method Statement – Parcel Force Walkway
Mass Concrete Retaining Wall and Stantion Installation

Contractor	*Carillion Alliance*
Contract Name	*Proof House Junction Remodelling*
Sub Contractors Involved	*Carillion Civils*
Contract Scope and Locations	*Mass Concrete Wall & Walkway Stantion Bases*
Programmed Commencement Date	*3rd July 2000*
Programmed Completion Date	*See Appendix E for programme*
Contract Reference	*8101040*
Number of Pages	*12 pages and Appendix A to G*

The responsibility for the safety of the contract works rests fully and unreservedly with the Contractor.

The acceptance of this method statement by Railtrack and involvement in Safety Studies or audits does not in any way absolve the Contractor from that responsibility, nor is it intended to confirm that the Contractor meets the statutory requirements.

Reviewed and Accepted by: .....
On behalf of Proof House Junction Alliance

Date:.....

Prepared: J Baldock	Checked: A Rowe	Approved: J England
Signed:	Signed:	Signed:
Date:	Date:	Date:
Phone Number: 07730 735 907	Phone Number: 0121 654 2293	Phone Number: 0121 654 2293

N:\emhome\mydocuments\My Research\My Research Projects\CASE Projects\Safety Risk (CASE) - Total Safety\Proof House Civils\Method Statements\Mass Concrete Wall MS.doc
Document Reference M13-076-CV-MES-000076

Printed 21/10/2005

Issue: 01

Operational estimating: advantages

Allows for idle time, common in plant-dominated work

Allows for operations with real uncertainty and risk

Shows the basic sources of cost

Lets you test sensitivity to changed assumptions and methods

Lets you investigate reasons for cost variations

Builds a library of operational data over time

Unit-rate vs operational

	Unit rate	Operational
Cost basis	Rate × quantity, from assumed outputs	Resources costed for the time on site
Programme	Ignored	Drives the estimate
Idle plant	Not allowed for	Included
Needs	Bill of quantities, unit rates	Bill of quantities, unit rates, programme and method statements

Operational example: the item and duration

Item	Description	Unit	Qty	Rate	Amount
F523.0	Placing 50N concrete to bases thickness 300-500 mm	m^3	12.71	£??	£??

Note: Material cost not included in this example

8,000 m^3
concrete in the whole bill

210 m^3/week
from records, planners and the programme

38 weeks
total duration

A BoQ is still presented, as it has many advantages for payment (see contract management lectures).

Operational example: plant cost

Plant	No.	£/week	Weeks	Cost
Concrete pump (truck mounted)	1	985.00	38	£37,430.00
Vibrator compactors	6	28.50	38	£6,498.00
Total direct plant cost				**£43,928.00**



Hired and held on site for all 38 weeks, used only for placing concrete.

£5.49 per m³

43,928 ÷ 8,000

Operational example: labour cost

Gang: one concrete finisher (ganger), four general labourers and a plant operator for the pump.

Labour	No.	£/hr	Hrs/week	Weeks	Cost
Concrete finisher (cat 2)	1	7.15	53.25	38	£14,468.03
General labourers (cat 1)	4	6.82	53.25	38	£55,201.08
Plant operator (cat 4)	1	9.16	53.25	38	£18,535.26
Total direct labour cost					**£88,204.37**

£11.03 per m^3

88,204.37 ÷ 8,000

Operational example: the finished rate

5.49 + 11.03 = £16.52 per m³

Item amount = 16.52 × 12.71 = £209.97

Item	Description	Unit	Qty	Rate	Amount
F523.0	Placing 50N concrete to bases 300-500 mm	m³	12.71	£16.52	£209.97

- Insert this rate in every bill item for placing concrete (all 8,000 m³)
- Run separate calculations for different seasons or years

PART 4

From estimate to bid

Estimators’ report, uplift and accuracy

A direct-cost estimate is not a bid

Direct costs
Built up item by item

+

Uplift
Risk, overheads, profit

=

Tender bid

- The sum of direct costs is the cost of delivery, not the bid
- The contractor must still allow for **risk**, **profit** and **overheads**
- Together these extras are called ‘uplift’

The estimators' report

Context

- Project description
- General method statements
- Risks, and unresolved contractual issues
- Design risks: poorly designed areas (the contractor may know more than the designer)
- Major assumptions in direct costs

Commercial picture

- Indication of profitability
- Market and industry conditions (an upswing can push prices above inflation)
- Direct costs by resource, including subcontractors
- The Bill of Quantities with direct costs

Senior management sets the uplift

The report gives management what they need to assess the commercial side. They decide the mark-up, which allows for:

Risk
For areas or the whole project, if losing money is considered intolerable

Overheads
Head office and site costs

Profit
Depends on prevailing market conditions

The uplift is spread across item rates, weighted more heavily in some areas. The priced BoQ is then submitted as the tender bid, as the contract documents prescribe.

Summary: choosing a method

Method	Built from	Best for
Global	Cost per unit of capacity	Feasibility stage
Factorial	Main plant cost × factors	Process and power plants
Labour-hours	Hours × all-in rate	Fabrication, installations
Unit rate	Rate × quantity per BoQ item	Tenders with a BoQ
Operational	Resources over programme time	Tenders with a programme

Key takeaways

Match method to stage
Broad methods early, detailed methods for tenders

Rates need context
Outputs, programme and idle time change the real cost

Direct cost ≠ bid
Risk, overheads and profit are added as uplift