



**Network Cost Drivers  
A “Bottom Up” Approach**

**A Report on Behalf of Wales & West Utilities**

**by John Spiller**

**Director of Consultancy**

**JOHN SPILLER ASSOCIATES**



**25 April 2007**

# Index

---


<b>SUBJECT</b>	<b>PAGE</b>
<b>Introduction</b>	<b>3</b>
<b>Executive Summary</b>	<b>4</b>
<b>Geography and Topography</b>	<b>6</b>
<b>Form Factor</b>	<b>8</b>
<b>Customer Density</b>	<b>10</b>
<b>Studies – customer density</b>	<b>13</b>
<b>Studies – customer density &amp; form factor</b>	<b>14</b>
<b>Effects on the business</b>	<b>15</b>
<b>Area spread, shape and customer density – Indirect penalty costs</b>	<b>16</b>
<b>Area spread, shape and customer density – Direct penalty costs</b>	<b>19</b>
<b>Extended network length and configuration - Statistics</b>	<b>21</b>
<b>Extended network length and configuration – Direct penalty costs</b>	<b>24</b>
<b>Summary of Penalty Costs</b>	<b>28</b>
<b>Capex and Repex</b>	<b>29</b>
<b>Other Utilities</b>	<b>30</b>
<b>Appendix A, Examples of study calculations</b>	<b>32</b>

# Introduction

---

Wales and West Utilities (WWU) has a network which is unique among the UK GDNs by virtue of the following:

- The territory is physically very large and includes an area circumscribed by a circle of radius 500km. It is not well supported by motorways and travel times from the central HQ are much longer than those prevailing in other GDN networks.
- The geography is split into two separate areas relatively isolated from each other by the river Severn estuary. Each of these areas, particularly the South West, is an irregular shape making it difficult and expensive to support.
- Much of WWU's area is sparsely populated but, unlike Scotland for example, penetration of gas usage is relatively high. As a result the customer pattern to be serviced is widespread but with a very low average customer density.
- WWU has the second highest total length of mains per customer of all GDNs and nearly twice the length of LTS network per customer.
- The territory has a much longer coastline than any other GDN, with no part of the network being more than 90 kms from the sea. This, combined with prevailing weather patterns means that corrosion is a much more potent force to WWU than to any other network



As a result WWU incurs costs ( both direct and indirect) which are not suffered by any other UK GDN, and which would be avoided if WWU's size and shape were similar to, say, that of West Midlands.

This report explains how and to what extent these "penalty costs" arise.

## Executive Summary

---

- 1 The Lecq report recognized that the WWU service area and network was unusually large and suggested that a bottom up approach be carried out to quantify these effects. This report does that.
- 2 There are four main features of the WWU service area which impact adversely on operating costs i.e. described as “penalty” costs:
  - (a) the wide spread geography, irregular shape and form.
  - (b) low customer density.
  - (c) the extended network length.
  - (d) the proximity to the coastline.
- 3 To meet the emergency service 1 hour response standard, it is necessary to provide outbased depots, staffed and stocked with materials, vehicles etc. and the necessary front line support. The penalty costs associated with this are £671k for Indirect costs and £1,642k for Direct costs.
- 4 WWU has about 11% more mains per customer than the average GDN and about 58% more Pressure Reduction Stations (PRSs) than the average GDN. These extended network effects incur penalty costs of £2,905k for additional repairs and maintenance.

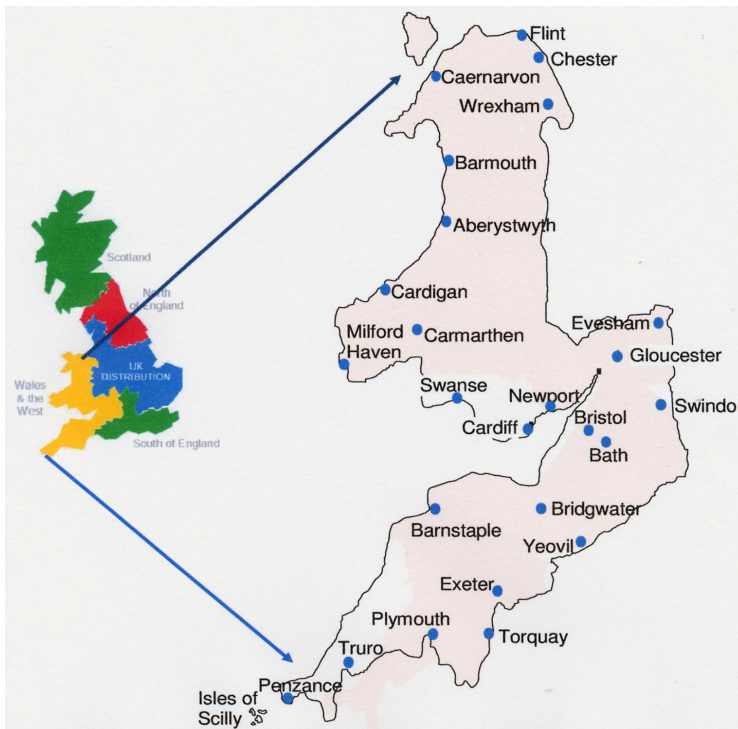
## Executive Summary

---

- 5 The proximity to the coastline results in WWU using a painting frequency programme for gas holders of 9 years and this incurs a penalty cost of £72k.
- 6 The overall effect is to produce a total penalty cost of about £5.29m together with additional stock levels being held in outbased depots to the value of £0.21m.
- 7 A similar cost impact occurs with Capex and Repex. Contractor's rates in North Wales are typically in the range 19 to 30% more than for South Wales and in Devon and Cornwall the contractor's rates are typically between 8 and 13% higher than in South Wales.
- 8 An independent check of electricity distribution use of system charges shows that the Wales and West service area is between 47 and 71% more expensive to operate than the lowest cost area of the South East.
- 9 An independent check of water charges shows that the Wales and West service area is between 35 and 38% more expensive to operate than the lowest cost area of Southern water.
- 10 There is therefore an overwhelming case for a "Local GDN Effect" allowance to be made for WWU in the price control based on the factors outlined in this report which equate to £5.29m.
- 11 Despite these penalties, in 06/07 WWU has the second lowest operating cost per km of main and the third lowest operating cost per customer of all GDNs.

## Geography and Topography

---



There is nowhere in the service area which is more than 90km from the sea.

The strong prevailing winds blow in from the south west bringing in a salty laden atmosphere.

Consequently, above ground plant, such as holders, are more exposed to the salty corrosive atmosphere.

## Geography and Topography (Cont'd)



Taking the centre of a circle as Newport and scribing an arc which touches the network extremities of the South West and North Wales, the circle also takes in:

- Eastbourne
- Cambridge
- Peterborough
- Sheffield
- Manchester
- Liverpool and well to the east of London.

The circle has a diameter of about 500km which demonstrates the unique spread of the WWU network in the UK and puts the travel challenges for WWU in the wider UK context.

No other GDN has this travel distance to cope with.

The area is not well covered by motorways/dual carriageways and travel through Mid-Wales and Devon and Cornwall is slow at the best of times and particularly difficult in the holiday season.

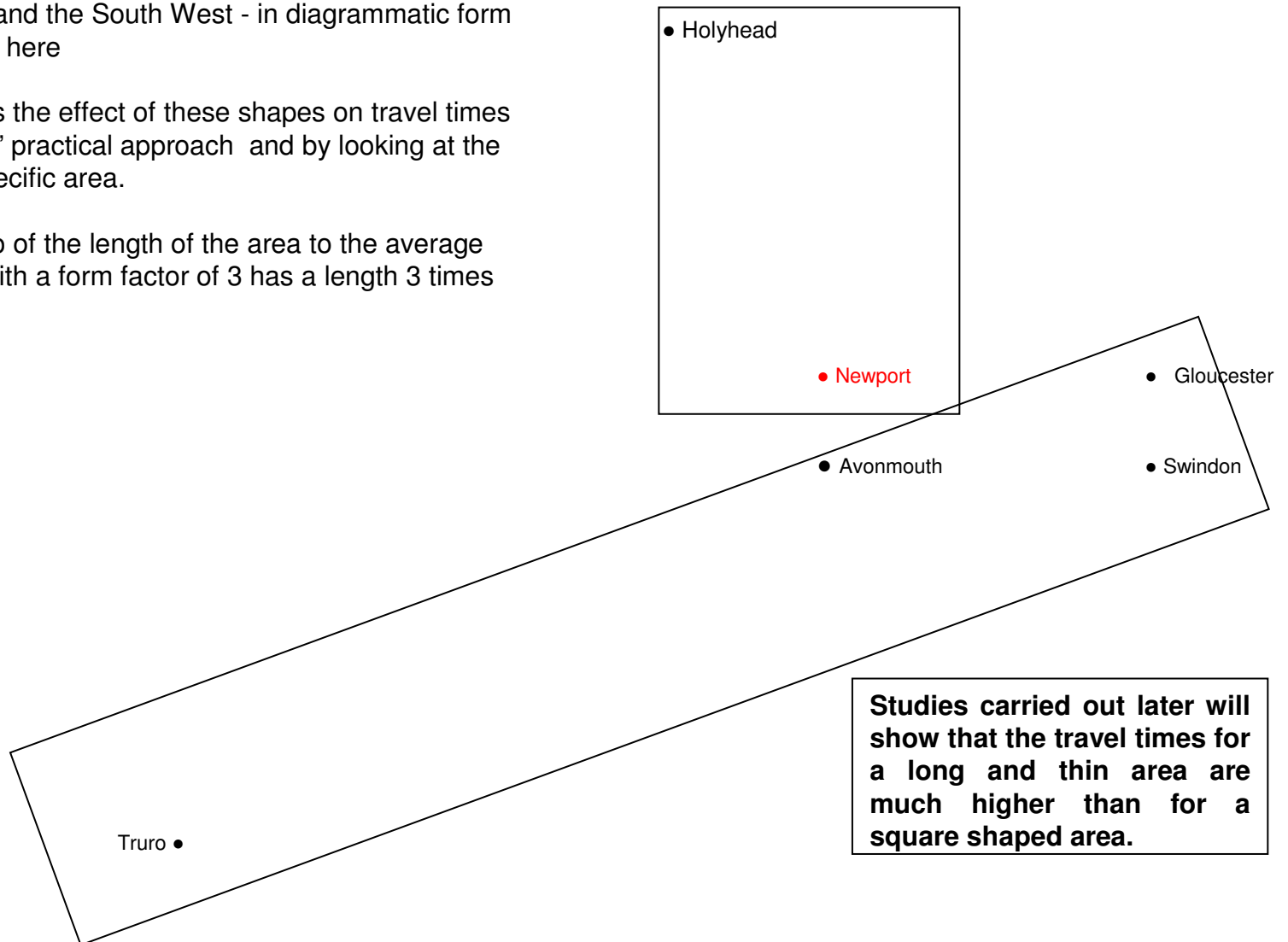
## Form Factor

---

The Severn estuary effectively splits the WWU into two distinct service areas, Wales and the South West - in diagrammatic form they appear as shown here

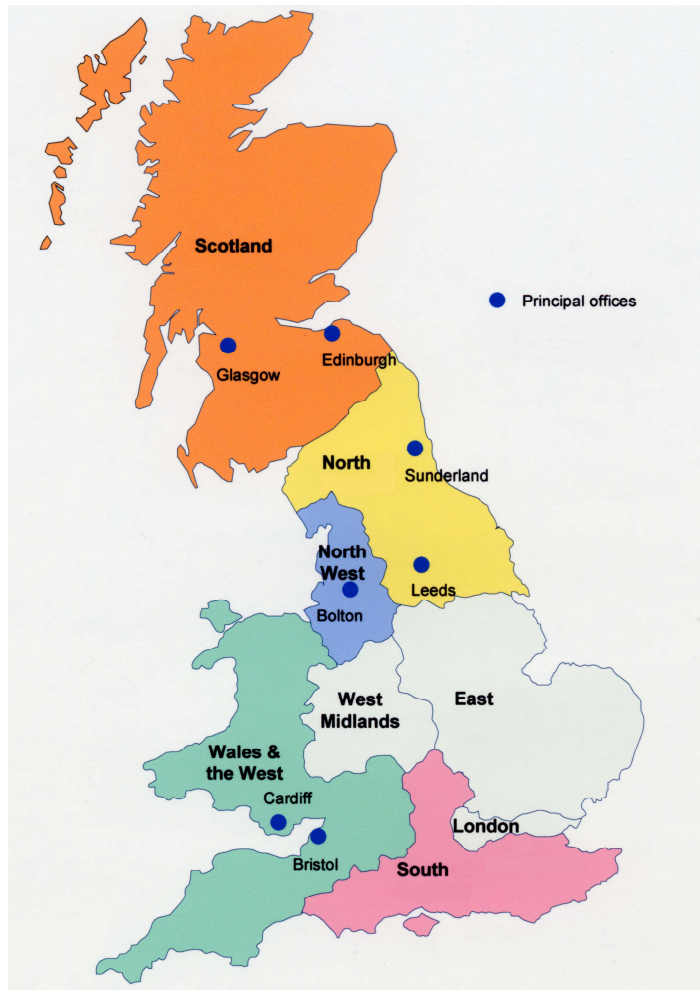
It is possible to assess the effect of these shapes on travel times by using a “bottom up” practical approach and by looking at the “form factor” of the specific area.

Form factor is the ratio of the length of the area to the average width. Thus an area with a form factor of 3 has a length 3 times the average width



## Form Factor - The Other GDNs

---



The map shows very clearly the large contrast in the shape, size and proportions (form factor) between GDNs.

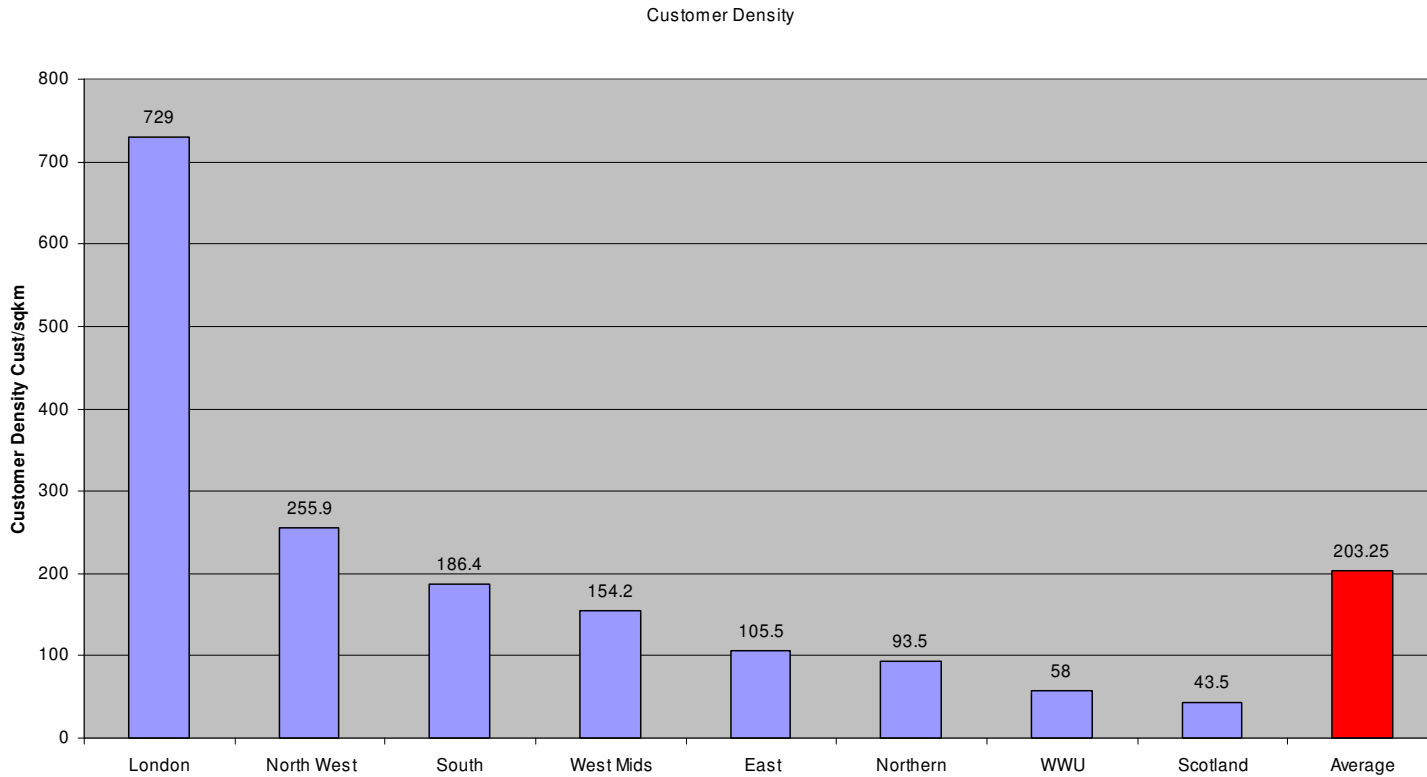
At one extreme, there is West Midlands whose shape is very close to the ideal square and at the other there is WWU whose straggly and lengthy shape is completely different to any other GDN.

Using a similar approximation that has been done for WWU the form factors for other significant GDNs are assessed as approximately:-

West Midlands	NGG	1.0
North West	NGG	2.0
Northern	NGN	2.7

These are very different and much smaller than the overall figure for WWU of about 7

# Customer Density



The geographic spread and the shape, or Form Factor of the area sets the broader travel requirements, but the density of the customers within the service area also has a major impact on travel distances.

The figures for Scotland have been adjusted to allow for the large areas of the highlands that are not serviced by gas. Without this adjustment the figure would be about 22customers/km<sup>2</sup>

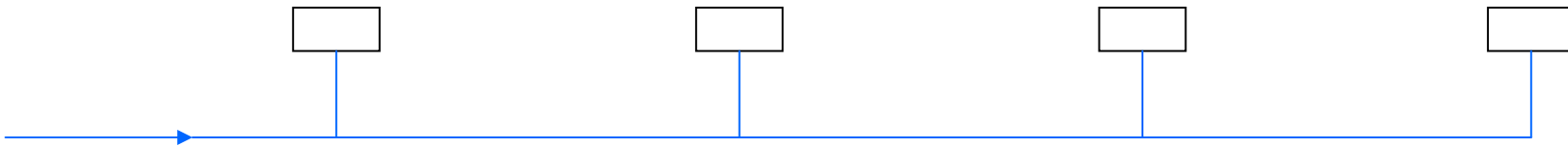
**WWU has the second lowest customer density to Scotland and is about 62% less than the next highest GDN, Northern.**

## Customer Density – (cont'd)

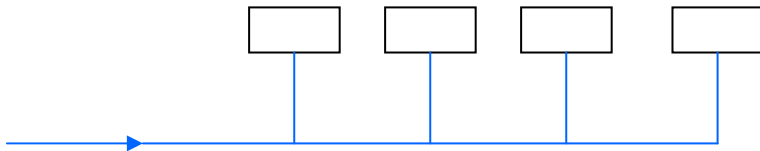
---

The following three examples for 4 customers show the effect of pipe length on customer density:

**WWU Low customer density**



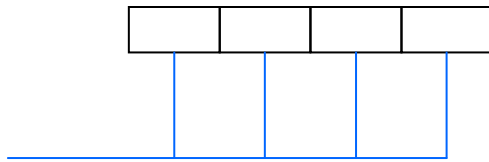
**West Midlands 3 times the customer density of WWU**



## Customer Density – (cont'd)

---

**North West 4½ times the customer density of WWU**



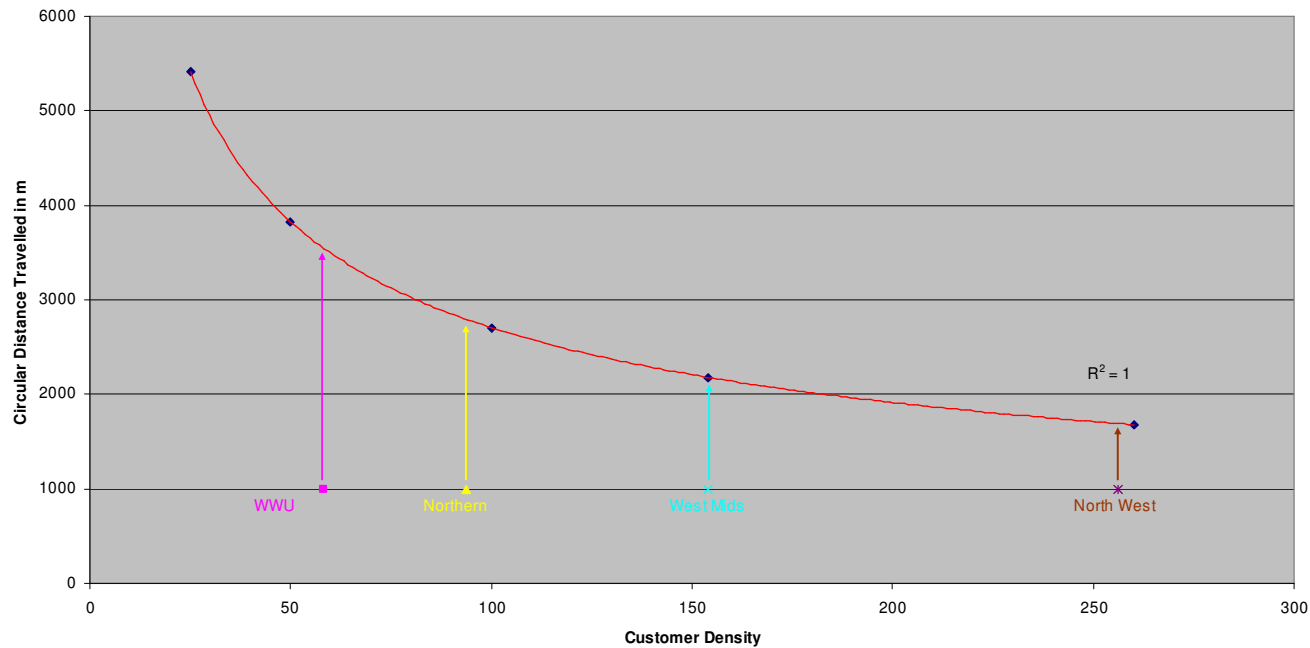
The above basic diagrams show very clearly that customer density plays a large part in determining the length of pipework (or cables) involved in providing supplies to customers.

However, it has also been shown that the form factor of the area also impacts on the distances between customers and increases the overall length of pipework.

**Thus customer density, aided by form factor drives network length and network length drives operating costs.**

# Studies - Customer Density

Perimeter Distance Travelled Around Area V Customer density



## STUDY

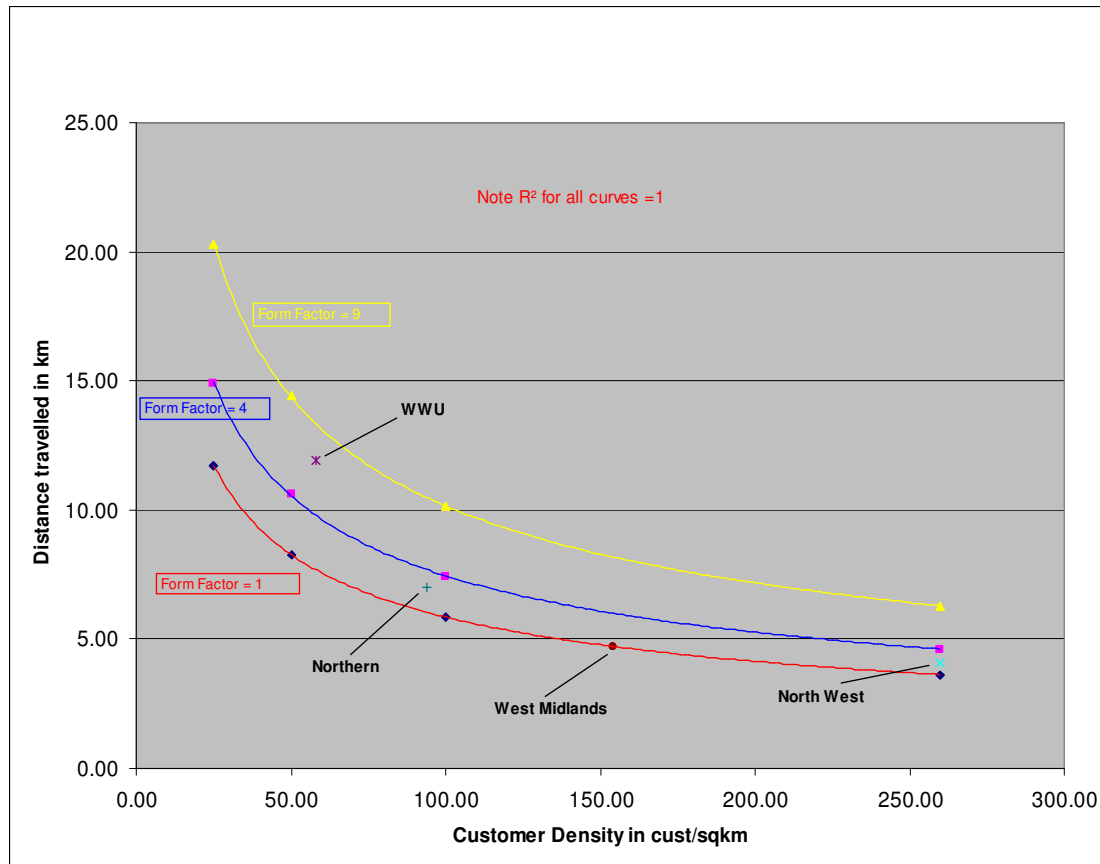
This study represents the relationship between customer density and distance travelled to customers.

A square shape has been assumed with 25 customers evenly dispersed.

The travel distance is that from a central depot around the perimeter customers and back to the central depot

**It can be seen that for WWU to visit the same number of customers as the North West would take 2.2 times the travel distance.**

## Studies – combining customer density and form factor



To visit 25 customers from a central base, WWU would have to travel about 3 times further than North West and 1.7 times further than Northern.

To offset this, additional staff and materials are located in outbased depots

What is being plotted here is the total distance to be travelled to visit all 25 customers (evenly spread over the area) from a central depot with a single visit but with different network shapes or form factors. Visits to all customers are measured so as to ensure that the study comparison is done on a “like for like” basis

Further details of the methodology and examples are given in Appendix A to this paper.

### Notes:

**1** The relationship is exponential and not linear i.e. as the customer density decreases so the travel distances increase exponentially.

**2** The greatest change in the slope of the lines takes place below the 100 customers/km<sup>2</sup> point

**3** Bearing in mind that Northern is close to 100, it means that only WWU and Scotland are on the point of the graphs where they begin to rise more steeply and the effect of customer density has more impact.

## Effects on the Business

---

### **EFFECTS ON THE BUSINESS**

The effects of the greater spread, low customer density and form factor impacts on the direct and indirect operating costs of the GDN. Direct costs are those associated with the physical aspects of the business whilst indirect cost are the back office or support costs of the organisation.

### **AREA SPREAD, SHAPE AND CUSTOMER DENSITY**

The spread, shape and low customer density all combine to determine that travel distances from the central location to customers or network assets will be much longer than for more compact GDNs (study demonstrates this point).

The only way to meet the customer 1 hour response times is therefore to have outbased depots, staffed up with the appropriate tools, materials and IS and frontline support. This is the main cost impact of area spread, shape and customer density and is quantified in this report.

Travel distances and times from the outbased depots to customers and network assets will tend to be similar to other GDNs but only materially affected by the local customer density.

### **NETWORK ASSETS**

Spread, shape and customer density will also impact on the key operational assets in the business with the result that there is a higher proportion of pipework and pressure reduction stations (PRSs) required to service customers. These will require extra costs to be incurred. See later section.

### **LIMITATIONS ON ORGANISATIONAL SAVINGS**

The opportunities to centralise depots and stores to minimise costs are limited due to the need to meet customer and network emergency and service response times.

These opportunities to centralise are also limited by the poor road systems throughout the area – particularly in Wales and the need to maintain outbased stocks and frontline support staff.

## Area Spread, Shape and Customer Density - Indirect Penalty Costs - Properties

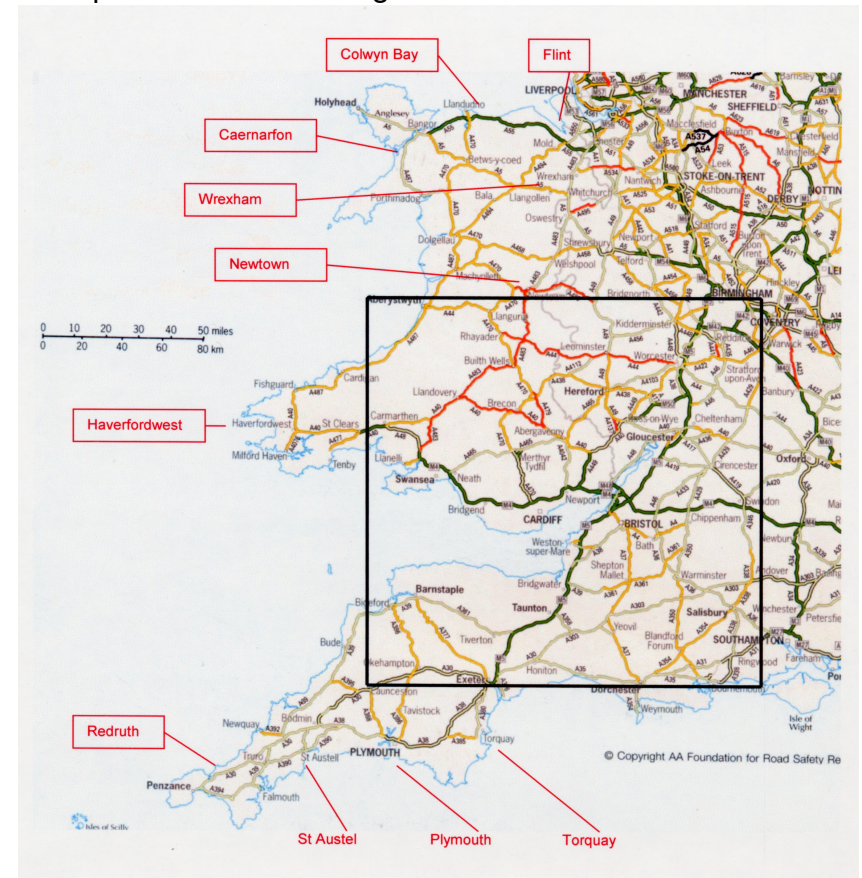
### PROPERTIES

The longer distances involved in reaching the extremities of the WWU network require more outbased offices/depots to be maintained in order to meet emergency and customer standards.

One high level way of assessing the number of offices/depots that have to be maintained due to the extremity lengths and form factor of the service area, is to plot the equivalent size of the service area as a perfect square centred on the HQ/Logistics Store. The offices/depots (in red) located outside this square would be deemed to be required due to the longer distances and the form factor involved.

The penalty cost of maintaining these additional depots is:-

Depot	Total Property Costs £
Flint	19,522
Colwyn Bay	16890
Caernarfon	9177
Wrexham	135433
Newtown	7500
Haverfordwest	17516
Torquay	48060
Plymouth	42486
St Austell	11702
Redruth	11174
<b>TOTAL</b>	<b>319,460</b>



## Area Spread, Shape and Customer Density - Indirect Penalty Costs - HQ and Logistics

### HQ and LOGISTICS

The separation created by the Severn Estuary means that a central HQ and Store for WWU can only economically be located along this estuary. This has already been done with a new HQ at Newport and a Store at Avonmouth near Bristol on the other side of the estuary.

There are extra costs incurred to maintain stocks in the outbased depots and there are consequential additional stock delivery costs as shown below:

The stock levels maintained in the outbased depots are:

Depot	Stock Level in £
Flint	63,616
Colwyn Bay	31,983
Caernarfon	21,348
Wrexham	25,740
Haverfordwest	3,388
Torquay	27,520
Plymouth	32,992
St Austell/Redruth	5,706
<b>TOTAL</b>	<b>212,293</b>

The additional costs for deliveries of materials etc to the outbased depots are:

Depot	Annual Costs £
Flint	8,736
Colwyn Bay	12,230
Caernarfon	10,400
Wrexham	5,907
Haverfordwest	15,205
Torquay	3,094
Plymouth	6,277
Redruth	13,348
St Austell	10,608
<b>TOTAL</b>	<b>85,805</b>

## Area Spread, Shape and Customer Density - Indirect Penalty Costs - IS Costs

---

### IS COSTS

The additional IS costs, per year, that WWU has to incur due to the outbased depots are as follows:-

(i) Network leasing and PABX support	£50,000
(ii) General network upgrades	£35,000
(iii) Hardware, printers & desktop computers £63 over 3 years	£20,000
(iv) Support team	£140,000
(v) Licence fee reduction	£7,000
(vi) SAP reduction	<u>£14,000</u>
TOTAL annual reduction	£266,000 per year

Thus the additional IS cost that WWU has to incur through maintaining the outbased depots is £266,000 per year.

#### Summary Total Indirect penalty costs

Additional properties	£319,000
Increased transport to replenish stocks	£86,000
Additional IS Costs	<u>£266,000</u>
<b>TOTAL INDIRECT</b>	<b>£671,000</b>

**In addition stocks of £291,000 are maintained in the outbased depots to support the outbased staff**

## Area Spread, Shape & Customer Density –Direct Costs - Extra Standby Costs

### Standby Costs

There are two main levels of staff on standby to deal with emergencies, the First Call Operative (FCO) and the repair teams. Numbers at the various outbased locations are as follows:

LOCATION	FCO Nos	REPAIR TEAM STAFF Nos
Cornwall Bottom	5	13
Cornwall Mid	4	
Cornwall East	5	
Plymouth & Launceston	21	21
Flint 7 Rhyl	15	15
Llanfair & Caernarfon	8	7
Llandudno & Colwyn Bay	5	12
Wrexham/Oswestry	9	13
Aberystwyth/Rhayader	8	8
<b>TOTAL</b>	<b>80</b>	<b>89</b>
Reduction if more compact area	70	50
Total reduction in standby	120	
Annual standby payment 1 in 4	£4056	
<b>Total reduction in standby costs</b>	<b>£0.487m</b>	

The reduction in people on standby if a more compact area is serviced has been estimated at about 90% for FCOs and 50% for Repair Teams.

**Thus the extra standby costs incurred to meet emergency and customer service standards in the outlying areas is £0.487m**

## Area Spread, Shape & Customer Density – Direct Costs - Work Management

### WORK MANAGEMENT

In a similar way to that already shown for Indirect Support costs, we have examined the number of outbased staff involved in Work Management activities in WWU against their location.

The work management staff, based in locations outside the square of 41,000 sq km, are shown below:

The additional support staff and supervisors required due to the need to have outbased staff has been estimated as those that would be saved if it was possible to move the customers and locations to be within the square shaped 41,000 km<sup>2</sup>.

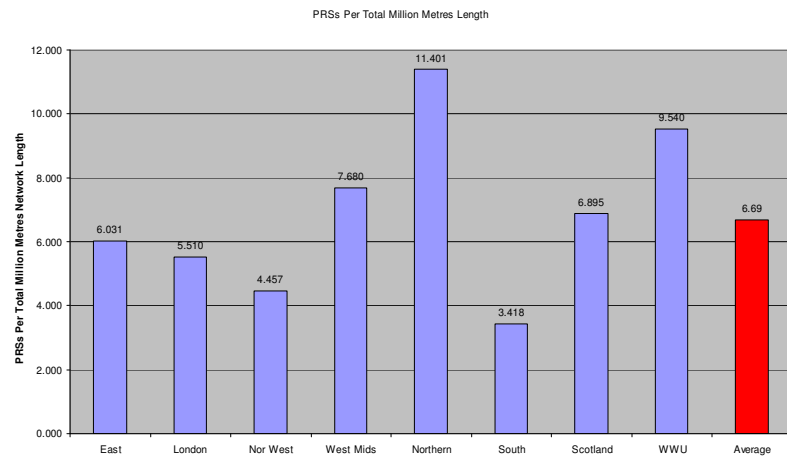
This gives a reduction of 100% for support staff because their roles would be absorbed by staff at other adjacent locations. For supervisors, the smaller travel distances would enable 50% of their work to be absorbed by other supervisors.

Location	No. Support Staff	No. Supervisors	Additional Staff Required	Additional Supervisors Required
Flint	1	3	1	1
Colwyn Bay	1	8	1	4
Wrexham	6	12	6	6
Haverfordwest	0	2	0	1
Torquay	1	6	1	3
Plymouth	1	7	1	4
Redruth	1	6	1	3
<b>Total</b>	<b>11</b>	<b>44</b>	<b>11</b>	<b>22</b>

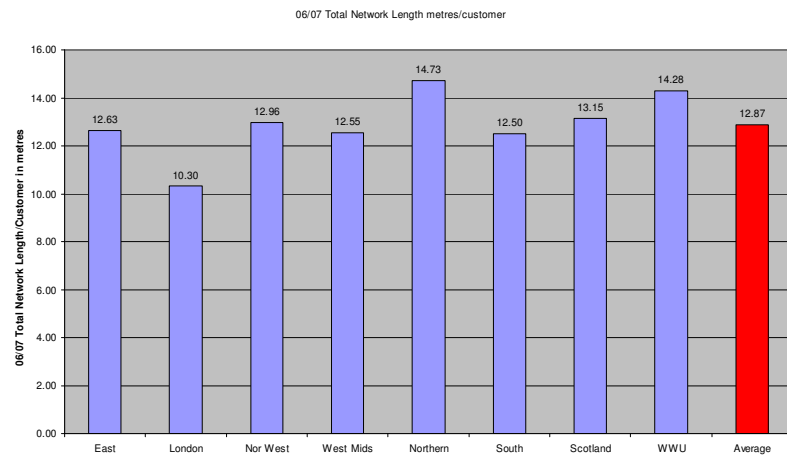
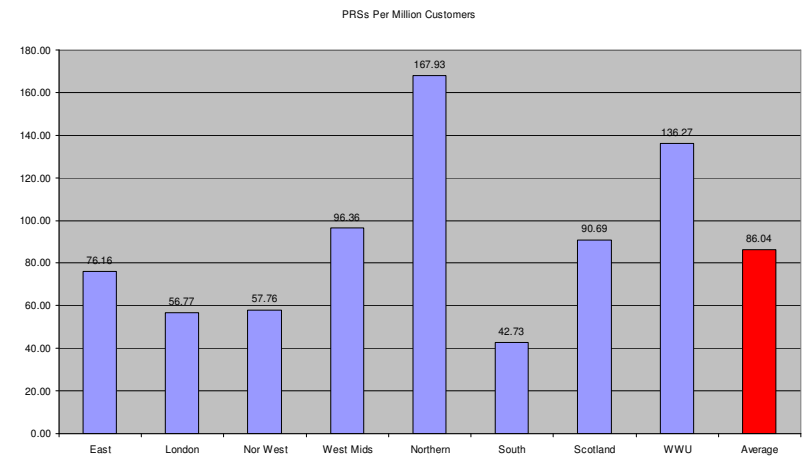
Using the average cost for an FTE from the PB Rune report of £35,000 the additional work management staff cost due to its geography equates to £1.155m

# Extended Network Length and Configuration

WWU has about 43% more Pressure Reduction Stations (PRs) per million metres of main than the average GDN



WWU has about 58% more Pressure Reduction Stations (PRs) per customer than the average GDN

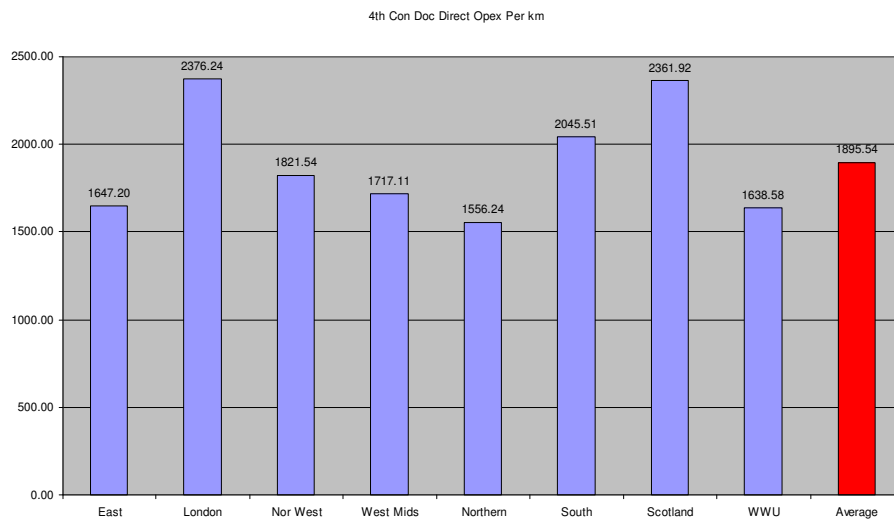


WWU has about 11% more mains per customer than the average GDN

## Key Point

**WWU has more assets per customer to repair and maintain than the average GDN**

# Extended Network Length and Configuration

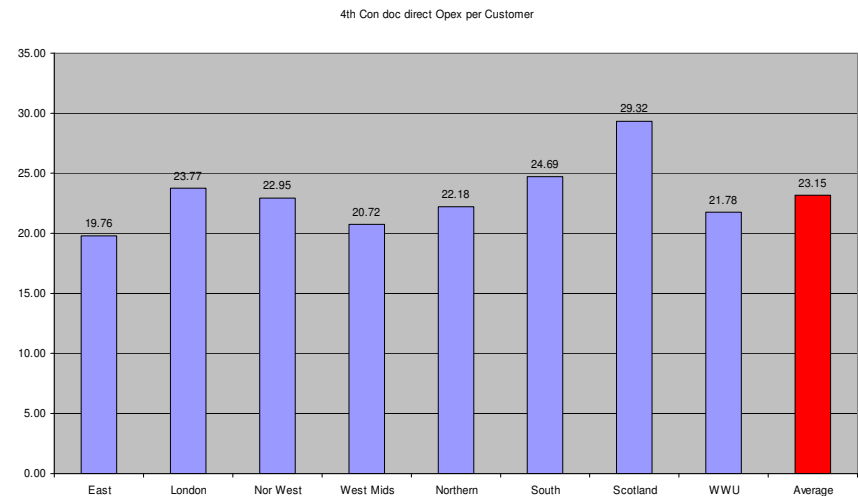


WWU has the second lowest 06/07 cost/km mains – and 14% below average

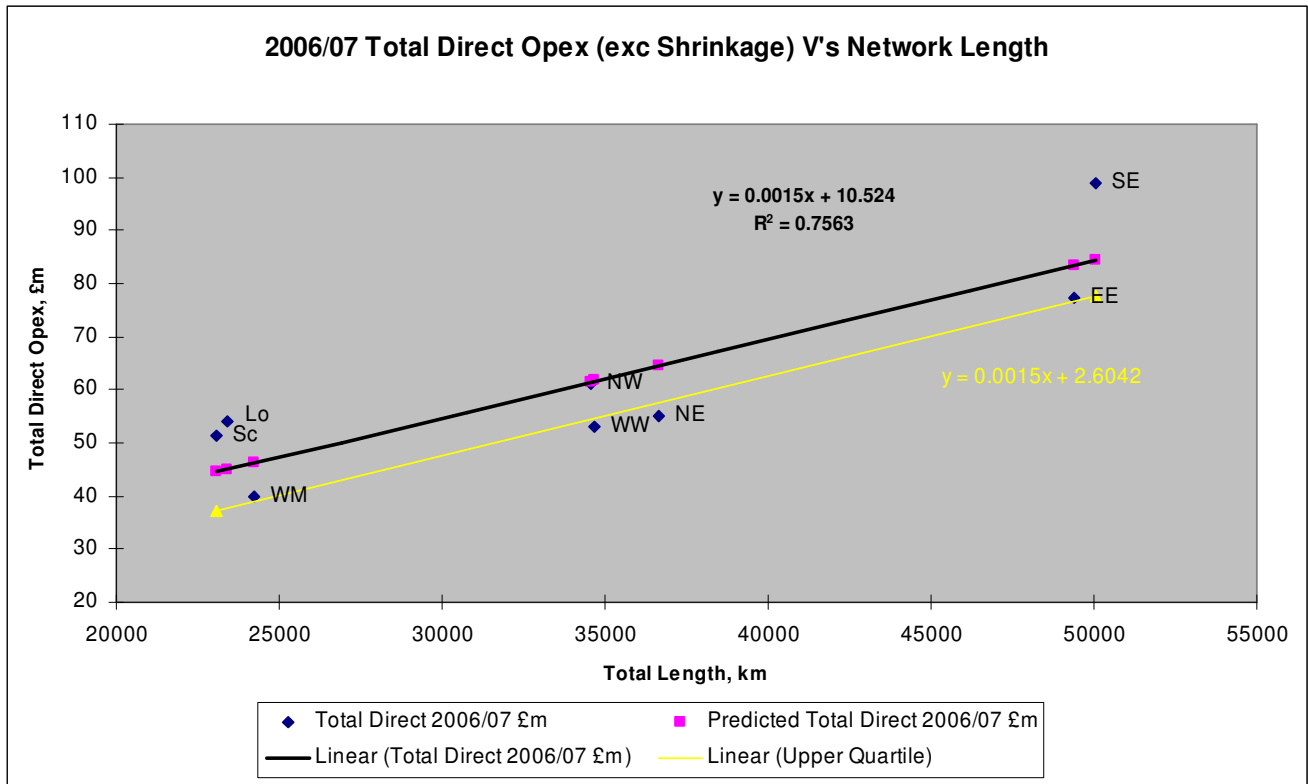
WWU has the third lowest 06/07 cost/customer – and 6% below average

## KEY POINT

Despite the handicaps of unfavourable geography and topography, WWU is a leading performer



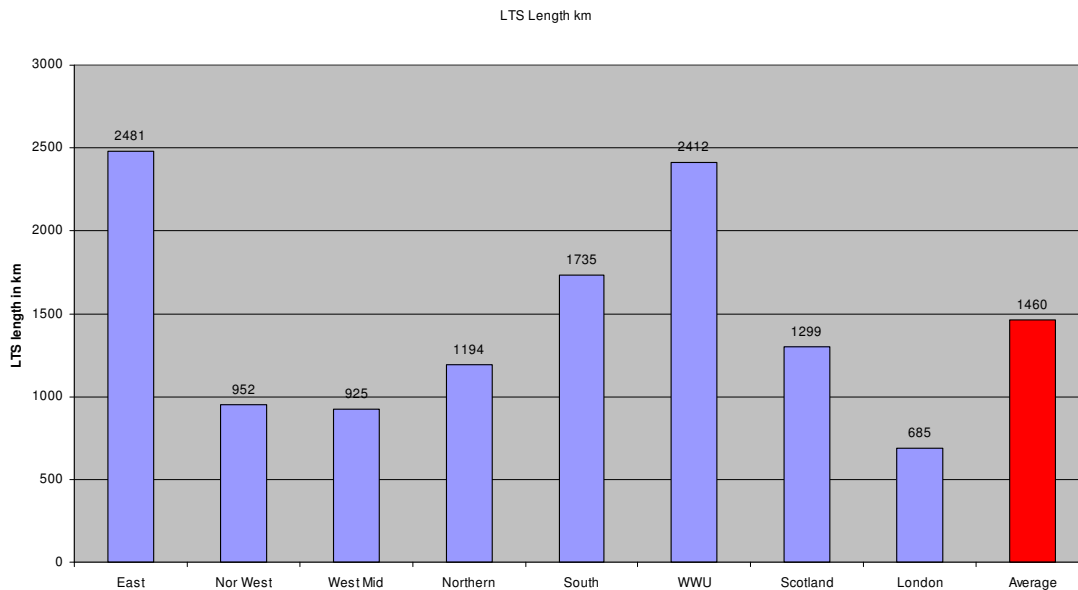
# Extended Network Length and Configuration - Regression



The figures are from the 4th Consultation Document and exclude shrinkage.

**This regression best represents network length**

## Extended Network Length and Configuration – Direct Penalty Costs – LTS Network



### LTS NETWORK

Average LTS length for all GDNs is 1,460.35. WWU has 2,412km of LTS main which is 952km more than the average

The LTS unit cost in PB Rune is understated by about £0.7m (£0.7m should be transferred from other to LTS). This gives a unit cost/km of LTS for WWU of £1620/km (and a cost/PRS of £11,804 close to the PB Rune figure of £12,000 in the report).

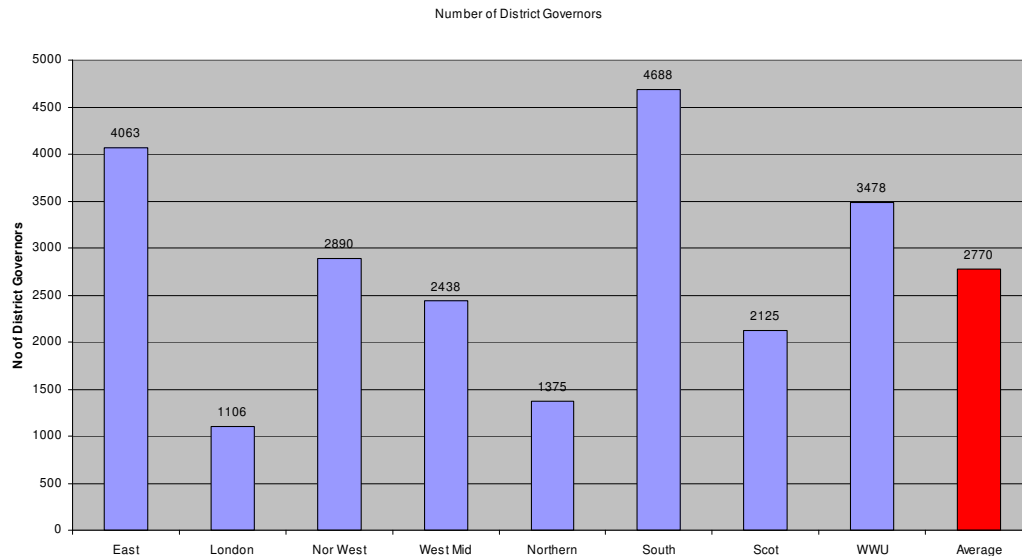
**Using the WWU cost/km of £1620 per km, this gives an additional LTS maintenance cost that WWU has to incur due to its geography of £1.542m.**

### LTS WAYLEAVES

The total wayleave payment cost for WWU is £0.7m in 05/06 of which about 75% is for LTS mains, which is about £217.70 per km of LTS.

**Thus the extra wayleave costs that WWU has to incur due to its geography is £0.207m.**

## Extended Network Length and Configuration – Direct Penalty Costs – District Governors



### DISTRICT GOVERNOR MAINTENANCE

The figures used are from the PB rune report Page 88. PB Rune produce a regression showing a trend with a maintenance cost/district governor of £220 with a fixed cost of £1.4m. This implies that to just carry out the maintenance on 1 district governor would require set up costs of £1.4m. In the real world this would imply a massive workshop or some other massive undertaking to require that investment. Clearly, this is not the case and we have calculated an equivalent average maintenance unit cost per district governor of £725.4 has been calculated from the PB Rune figures.

These PB Rune figures exclude both Scotland and WWU as outliers because their unit costs are alleged to be too high. The figure of £4m for total LTS maintenance is an error and it should be £2.4m – after the transfer of £0.7m to LTS).

This puts WWU just over the PB Rune regression line and gives a unit cost of £690/dg

### ADDITIONAL PENALTY COST of LTS MAINTENANCE

The average number per GDN is 2770 and thus WWU have 708 more district governors than the average. Thus the additional cost that WWU has to incur over the average GDN for District Governor maintenance is  $708 \times £690 = £0.489m$

## Extended Network Length and Configuration – Direct Penalty Costs – Repairs

Repair costs and unit costs/repairs from PB Rune are as follows:

	WWU	East	London	North West	West Mid	Northern	South	Scot
<b>Repair Opex £m</b>	9.93	10.22	9.90	10.82	7.10	10.69	25.28	13.77
<b>Number repairs</b>	19562	21450	15980	21330	13085	23825	33800	11590
<b>Cost/repair</b>	507.72	476.41	619.21	507.41	542.45	448.60	748.02	1188.4
<b>Transport/repair</b>	71.71	26.11	27.77	36.03	35.53	28.47	N/A	N/A
<b>Net cost of repairs</b>	436.01	450.30	591.44	471.38	506.92	420.13	-	-

### Note

The transport and plant cost per repair is obtained from some early benchmarking work which did not, unfortunately, include South or Scotland.

However, it can be seen that when the transport and plant amount is deducted from the total cost/repair that by and large the resultant unit cost figures are comparable (with the exception of London, which is a special case).

This confirms that WWU generally has higher than average travel costs and the figure of £71.71/repair from the above table is £34.1 higher than the average for the 6 GDNs.

**Thus the additional travel cost that WWU incurs on its repair costs caused by the extra travel due to local geography is  $19562 \times £34.1 = £667,060$ .**

## Proximity to Coastline – Direct Penalty Costs - Storage Costs

---

### **STORAGE MAINTENANCE**

Page 76 of the PB Rune report refers to the number of WWU holders compared with the average GDN. Although WWU has less number of holders than the average GDN, the holders it has are much larger than average. (Average is 52kcm compare with WWU's 62kcm, note kcm =kilo cubic metre).

Using the unit cost of £3250 developed by PB Rune the extra cost that WWU has to incur is  $10 \times £3250 = £32,500$  which for 20 holders is £650,000.

We do not accept the 13 year painting cycle for holders. As is seen from the maps used in this paper, the majority of the land mass of the WWU service area is close to the sea with strong prevailing winds bringing in a salty and corrosive atmosphere (there is nowhere in WWU's service area which is more than 90km from the coast. The WWU 9 year painting cycle is therefore fully justified.

**Thus the 9 year painting cycle by WWU produces an extra averaged cost of gas holder painting of £72,220 per annum.**

## Summary of Penalty Operating Costs

Shape and size factor	How this impacts costs	Impact £000 p.a.
<ul style="list-style-type: none"> <li>•Large and widespread network area</li> <li>•Irregular shape and form</li> <li>•Low customer density</li> </ul>	<p><b>Indirect</b>            Increased number of properties (depots &amp; stores) to service the customer base</p> <ul style="list-style-type: none"> <li>•Increased rental/utilities/maintenance</li> <li>•Increased transport to replenish stocks</li> <li>•IS costs to ensure all depots are technology enabled</li> </ul> <p>Total indirect</p> <p><b>Direct</b>            Additional staff to provide required service to outlying customers and locations</p> <ul style="list-style-type: none"> <li>•Extra standby staff</li> <li>•Additional supervisors</li> </ul>	319 86 <u>266</u> <u>671</u> 487 1,155
<ul style="list-style-type: none"> <li>•Extended network length</li> </ul>	<p>The extended network incurs cost in the areas of:</p> <ul style="list-style-type: none"> <li>•Extra LTS maintenance</li> <li>•Additional wayleaves</li> <li>•Maintenance of district governors</li> <li>•Mains repairs</li> </ul>	1,542 207 489 667
<ul style="list-style-type: none"> <li>•Proximity of network to coastline</li> </ul>	<p>Additional corrosion due to weather – storage tanks need repainting every 9 years compared with normal period of 13 years</p> <ul style="list-style-type: none"> <li>•Storage maintenance</li> </ul>	<u>72</u>
	<p><b>Total penalty costs</b></p>	<u><b>5,290</b></u>

## Capex and Repex

---

### CAPEX AND REPEX

The majority of capex and repex work is done by contractors who will also experience the same geographic effects on their operating costs as WWU. These issues will reflect through into the contract rates that they quote for the various activities within the contract.

The following sample of commonly used rates for work greater than 50m in length illustrate the point:-

Pipe/service Renewal	North Wales Rate/m in £	South Wales Rate/m in £	Devon/Cornwall Rate per m in £	% Difference North Wales to South Wales
Renew 75mm <sup>2</sup> in verge	39	30	34	+30
Renew 90mm <sup>2</sup> in verge	40	33	36	+21
Renew 120mm <sup>2</sup> in verge	46	36	39	+28
Renew 32mm <sup>2</sup> service	358	300	340	+19

**The above table shows that work done in North Wales by contractors requires additional costs of between 19 and 30%**

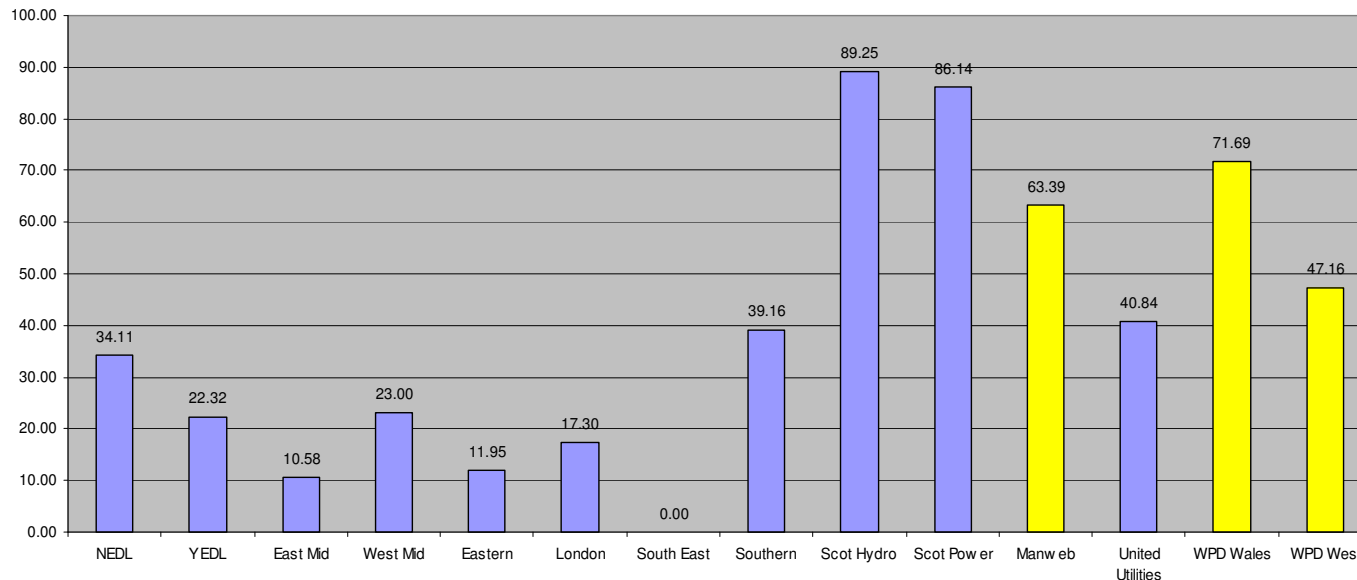
**A similar set of figures for work done in Somerset, Devon and Cornwall by contractors requires additional costs of between 8 and 13%**

# Other Utilities - Electricity

## Other Utility's Costs - Electricity

Use of system charges reflect operating costs and we have looked at the use of system tariffs for electricity.

Additional Electricity DUoS Charge Over South East as %



Based on 06 DUoS tariffs and on the average domestic customer use of 3300kWh/year

The % figures are the additional % cost of electricity over the cheapest which is South East

The additional costs over EdF South East for the WWU area DNOs are

**WPD Wales 71%**

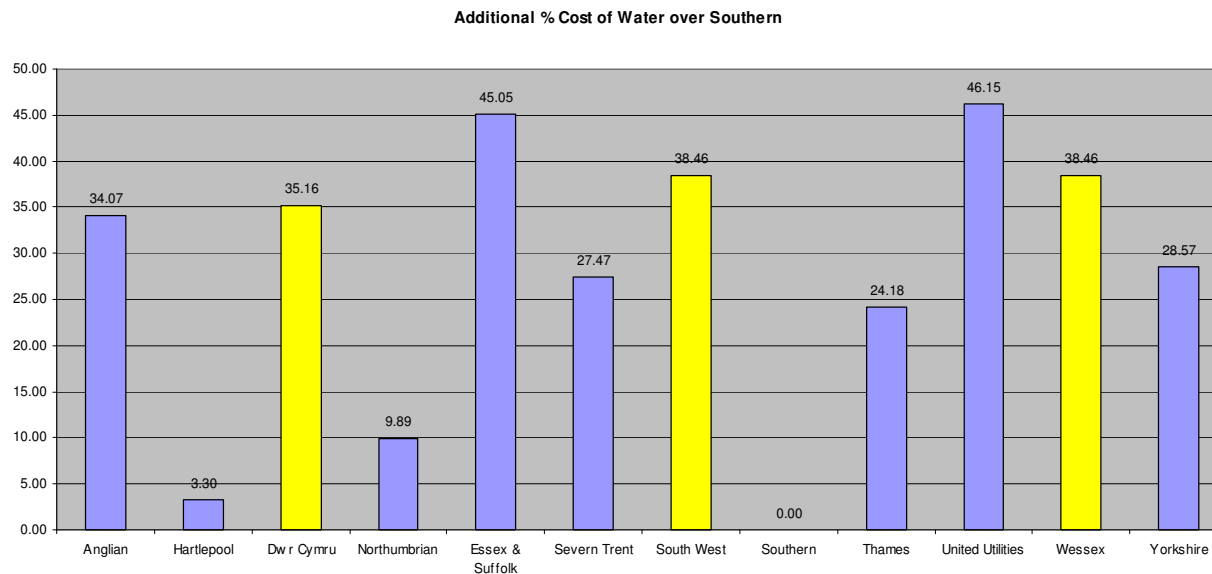
**WPD S West 47%**

**Manweb 63%**

## Other Utilities - Water

### Water

Water supply charges reflect operating costs and we have looked at the charges for the following water companies.



Based on 06 water charges

The % figures are the additional % cost of electricity over the cheapest which is Southern

<b>The additional costs over Southern Water for the WWU area companies are:</b>	<b>South West</b>	<b>38.5%</b>
	<b>Wessex</b>	<b>38.5%</b>
	<b>Dyr Cymru</b>	<b>35.2%</b>

Note: We are in the process of investigating the possibility of acquiring data from Royal Mail showing postal delivery comparative costs for the GDN areas

## Appendix A - Network Studies – Examples of Calculations for Form Factor and Density

---

### Studies

The factors of form factor and customer density need to be quantified in terms of how they effect operating costs.

We do not have the detailed metrics for the other GDNs but it is possible to carry out theoretical (but practical) examples of how customer density and form factor affect the distances to be travelled by a GDN in visiting its customers – and thus how they impact on operating costs.

The “bottom up” approach of this paper uses examples of 25 customers distributed over a standard 1km<sup>2</sup> with different form factors and measures the distance travelled to each customer from a single central base or depot.

Because this is a theoretical exercise the distance travelled is measured simply as a straight line from the central depot to the customer point and for comparison purposes, only one way travel to the customer is measured.

It is appreciated that in the real world, a gas distribution operative travels from one customer point to another and does not return to base in between visits. However, it is not possible to take this effect into account as many other assumptions would need to be made and the study would lose its objectivity. It would also be very difficult to ensure that the comparisons were done on a “like for like” basis.

The calculations assume that each customer (or could be a depot) is visited once from a central location.

For the purposes of keeping the practical analysis in this study as clear and simple as possible, customer densities of 25, 50,100 and 260 per km<sup>2</sup> are used in the calculations to produce the range of graphs showing the relationship between form factor, customer density and the distance to be travelled to visit all the customers in the study area.

## Studies (cont'd)

---

### **Form Factor**

The service area “shapes” vary widely from one GDN to another and a means of quantifying the differences needs to be developed. The concept of “Form factor” has been used to give an indication of how much the service area “shape” differs from the most economical service area of a square. (In fact a circle is probably the ideal but none of the GDN service area shapes approach that of a circle).

Thus an area with a form factor of 2 has its length twice that of its width, or vice versa, its width twice its length.  
Customer density

### **Customer Density**

Customer density is a key issue and this is allowed for in the study by maintaining the same number of customers (25), but the standard 1km<sup>2</sup> is reduced to give the higher customer density.

It is also important that the even distribution of customers is maintained as the various form factors change and this has been done.

Thus the distance travelled to visit the same number of customers in an area with a higher value of customer density is less – as you would expect.

### **Location of the depot**

The position of the depot in the area under study also plays a significant part in determining the total km travelled. For the purposes of this study and to ensure that a like for like comparison is achieved, the study assumes a base or depot centrally located in the study square.

# Studies (cont'd)

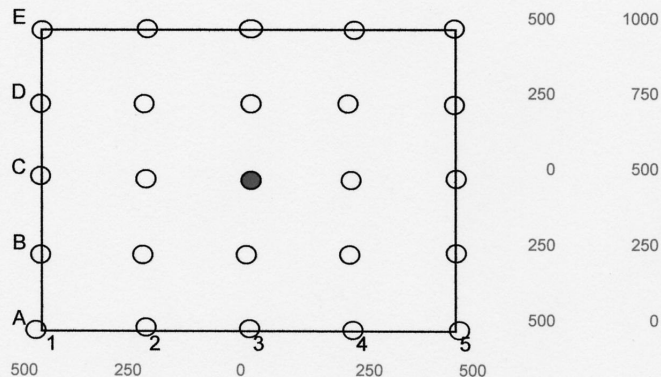
## Examples of Calculations

For Customer Densities of 25/km<sup>2</sup>  
and form factor =1

	A	B	C	D	E	
1	707.10	559.01	500.00	559.01	707.10	
2	559.01	353.55	250.00	353.55	559.01	
3	500.00	250.00	0.00	250.00	500.00	
4	559.01	353.55	250.00	353.55	559.01	
5	707.10	559.01	500.00	559.01	707.10	
	3032.22	2075.12	1500	2075.12	3032.22	<b>Total</b>
						<b>11714.68</b>

Figures are all from the solid circle in the centre at point C3

Size = 1km x 1km = **1sqkm**      Cust density = 25/1 = 25  
**Form factor = 1**

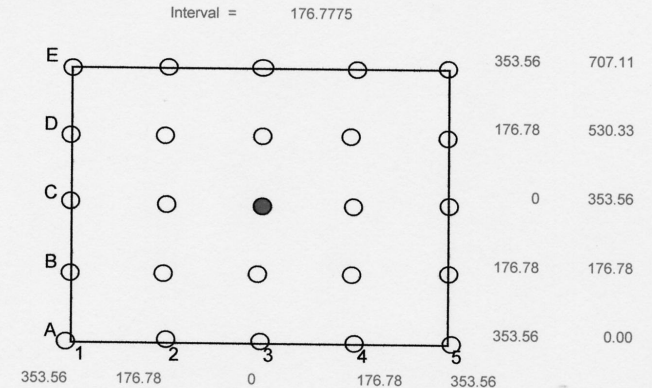


For Customer Densities of 50/km<sup>2</sup>  
and form factor =1

	A	B	C	D	E	
1	500.00	395.29	353.56	395.29	500.00	
2	395.29	250.00	176.78	250.00	395.29	
3	353.56	176.78	0.00	176.78	353.56	
4	395.29	250.00	176.78	250.00	395.29	
5	500.00	395.29	353.56	395.29	500.00	
	2144.14	1467.36	1060.68	1467.36	2144.14	<b>Total</b>
						<b>8283.68</b>

Figures are all from the solid circle in the centre at point C3

Size = 0.7071km x 0.7071km = **0.5sqkm**      Cust density = 25/0.5 = **50 per sqkm**  
**Form factor = 1**



# Studies (cont'd)

## Examples of Calculations

For Customer Density of 25/km<sup>2</sup> and form factor =4

	A	B	C	D	E	F	G	H	I	J	K	L
1	1030.78	855.53	683.72	518.76	369.98	266.02	266.02	369.98	518.76	683.72	855.53	1030.78
2	1030.78	855.53	683.72	518.76	369.98	266.02	266.02	369.98	518.76	683.72	855.53	1030.78
Total	2061.56	1711.1	1367.44	1037.52	739.96	532.04	532.04	739.96	1037.5	1367.4	1711.1	2061.56

Figures are all from solid circle centre

Size = 0.500km x 2km = **1sq km** = FF of 4

Interval = 181.8182

**Total  
14899.16**

FF = 4

