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by

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Abstract

Australian local government has been subject to comprehensive and ongoing programs of reform aimed at enhancing efficiency. Partial performance indicators of municipal efficiency have been determined for specific local government services in the various states. This paper seeks to add to this literature by employing data envelopment analysis to provide holistic measures of allocative and productive efficiency in NSW wastewater services using 2001 data. It represents the first Australian attempt to incorporate service quality measures into efficiency indices. The results allow for the identification of "best-practice" councils and an examination of the various factors underlying wastewater service efficiency.

Key Words: data envelopment analysis; local government; wastewater services.

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1. INTRODUCTION

A dominant feature of contemporary Australian public policymaking has been an emphasis on public sector reform, including local government. A key strategy in improving local government performance has been the development of performance measures for use in the benchmarking of municipal services. In order to measure performance and assess the efficiencies of individual councils, the states and territories have required municipalities to provide information on key service areas. It was not until 1995 that national performance indicators were first proposed at the Local Government Ministers' Conference, and since that time the National Office of Local Government has facilitated a voluntary process of developing and adopting standard performance measures and indicators with state governments, peak industry bodies and technical committees.

To date, performance has almost exclusively been assessed by comparing performance indicators against an "average council" statistic for a given state. For example, the performance of Tamworth City Council's domestic waste collection service is assessed by comparing the cost per service for domestic waste collection for Tamworth against the NSW state average. Moreover, performance indicators used by state authorities have been single input/single output indicators. In the Tamworth example, for instance, total collection cost is the input and total number of services represents the output. As a result more than one indicator is often applicable to a single service area. Thus in the waste services area single input/output performance indicators can apply to waste disposal, recycling and waste management as well as collection. Each measure is thus obviously only a partial appraisal of the overall performance of the service in question.

In order to compare the performance of particular council services there is therefore a need to calculate performance indicators that encompass multiple inputs and outputs. The Data Envelopment Analysis (DEA) method can be used in these circumstances to measure technical and scale efficiencies, as well as productivity changes in municipal services over time (Coelli *et al.*, 1998).

Wastewater services delivered by NSW councils is an obvious candidate for empirical analysis since it is one of the primary functions of non-metropolitan councils. Moreover, water services, including wastewater, constitute a considerable proportion of municipal activity in NSW and had a combined turnover of $569 million in 1998/99 (DLWC, 2000: Table 5). This represents around 12% of the total outlays for councils, which is almost equal to each of the other two major municipal activities - roads ($654 million) or recreation and culture ($654 million) (NOLG, 1999, p.194). In addition, recent changes in the water industry, as well as stricter environmental controls through the development and review of licences to operate by the NSW EPA, have made this an active arena for service provision over the latter half of the 1990s.

The major objectives of this paper are threefold. Firstly, partial performance measures have been calculated in many previous Australian water industry performance studies (WSAA, 1999; ARMCANZ, 2000; AWA, 2000). However, only a limited number of studies to determine total factor productivity (TFP) have been carried out in the water industry, both in Australia and abroad (SCNPMGTE, 1992; ACT Auditor General, 1995; Saal and Parker, 2000). This paper thus seeks to provide the first holistic measure of efficiency and productivity for NSW local government waterwaste services by employing DEA methodology.

Secondly, previous DEA studies for the public sector have exclusively used quantitative data as measures of output (Worthington and Dollery, 2000). This paper introduces service quality measures into the assessment of overall efficiency. Whilst the method of treatment of service quality measures in DEA used in this study is not meant to be definitive, our results may nonetheless provide a better representation of the efficiency and effectiveness of wastewater services.

Finally, we examine the results of the DEA methodology to determine those factors specifically affecting efficiency. This procedure, together with the identification of similar councils which have been assessed in the DEA as employing best practice (known as "peers"), provides the next step encouraging municipalities to improve their performance through detailed benchmarking.

2. LOCAL GOVERNMENT WASTEWATER SERVICE PROVISION IN AUSTRALIA

The water industry in Australia consists of a diverse array of organisations undertaking a wide range of activities. In the first place, there are 14 Government Trading Enterprises (GTEs) across the Australia which include the large metropolitan and state water authorities. Some are involved in all aspects of the water industry from bulk water reticulation to retail sales (like the Hunter Water Corporation), while others are only concerned with the provision of bulk water (such as State Water Projects in Queensland). These enterprises generated income of over $4.9 billion in 1999/2000 (Productivity Commission, 2001, p.105). State regulatory authorities, like IPART in NSW, strictly control fees and charges for these GTEs. Secondly, there are non-metropolitan urban and regional water authorities which are smaller than the GTEs and have a single focus on water and wastewater services. Finally, local government, as well as providing a multitude of other services, offers wastewater collection and treatment for its local population where they are not supplied by one of the other two types of water authorities.

Wastewater services comprise a major proportion of municipal activity across NSW. For example, NSW wastewater services provided by local government had a turnover of $277 million in 1998/99 (DLWC, 2000: Table 5). This represented 12% of the total outlays for NSW councils in (DLWC, 2000: Table 2.2). Of the 685 reported local government business activities, as classified under the NSW Policy Statement on the National Competition Policy to Local Government, 260 (or 38%) were water and wastewater activities (NOLG, 1999, p.194).

Over the past several years, state water authorities and water industry bodies have placed a priority on the development of appropriate performance measures and the coordination of technological transfer to all participants in the water industry. Data consistency, quality and completeness have been significant concerns.

The data collected from councils to date in the area of water and wastewater is generally more detailed than for other council services. For example, in DLWC has introduced extra information through special schedules as part of the DLG annual submission from councils. In addition to the costs and the number of properties receiving the service, which represented the standard level of detail reported on other council services, these schedules now quantify aspects of water quality, complaints, environmental / license breaches and levels of service. Nevertheless, data consistency, quality and completeness, while generally better than for other municipal services, still require further improvement.

3. CONCEPTUAL MODEL OF WASTEWATER SERVICES IN NSW LOCAL GOVERNMENT

While wastewater services is only one of the many services undertaken by municipalities in NSW, it can be investigated separately for various reasons. Firstly, the regulatory environment is different for wastewater services in comparison with most other municipal services. Council wastewater services are provided under the Water Act (1912), the Water Supply Authorities Act (1987), the Local Government (Water Services) Regulation 1999, as well as the Local Government Act (1993). The Local Government Act specifically requires wastewater services to be undertaken as an independent enterprise to other council functions, stipulates that individual wastewater funds be established, and prohibits any cross subsidization between funds.

Local government has been compelled to implement activity-based costing to meet the competitive neutrality requirements of National Competition Policy. Activity-based costing involves the appropriate distribution of overheads to all activities undertaken. This seeks to ensure that the full costs of services are disclosed and that all wastewater expenses are assigned separately. This regulatory framework attempts to generate management decisions that optimize outcomes for each of the separable fund areas, including wastewater, rather than to optimize outcomes for all of the council functions as a single entity.

Secondly, wastewater services have different inputs and outputs compared to other council functions and employ different technologies. Wastewaster systems usually include a gravity (i.e. un-pressurized) reticulation system to collect the wastewater from all customers (residential, commercial or industrial), pumping stations, (pressurized) rising mains, treatment works (i.e. micro-biological treatment), and either effluent reuse or discharge into a river or the ocean.

Assessing performance in wastewater services requires information on both the effectiveness and efficiency of the service. The Steering Committee for the Review of Commonwealth/State Service Provision (SCRCSSP, 2001, p.10) argued for the use of the following indicators to assess the performance of government services: Overall outcomes; access and equity; appropriateness; and quality. It need hardly be added that any analysis of local government wastewater services will be constrained by data availability, data quality, the assumptions invoked, and the extent to which councils face different operating environments.

The selection of the variables used defines the conceptual model adopted for the assessment of performance. In this paper, the analysis of wastewater services in NSW local government employed DEA and used the following variables: Quantitative outputs; wastewater quality as an output; service reliability as an output; operating costs as inputs; rental on capital as an input; as well as a number of environmental variables for regression with the calculated efficiencies.

The conceptual model is limited by at least two factors. Firstly, suitable measures for access and equity were not available and so could not be incorporated into the analysis. Secondly, factors such as the conservation of water for other economic and environmental reasons (like effluent reuse) may affect the appropriateness of some of the quantitative output measures.

4. DATA CONSIDERATIONS AND VARIABLE SELECTION

Various factors influence watewater services data in NSW. Firstly, each council compiles aggregate data as part of its annual reporting requirements to the state government. This includes financial information, business characteristics, fees and charges, and operating costs for various services, including wastewater services.

Secondly, for our 2001 data set, the NSW DLG then collated much of this aggregate data from the 177 councils to produce state wide tables in a printed annual document (Comparative Information on NSW Local Government Councils, 2001). Key performance information is reproduced in *inter alia* wastewater services. In the water and wastewater areas only the average water account, water operating costs per connection, average wastewater account and wastewater operating costs per connection are included. In addition, council data such as population, area, population density, population growth, aboriginal population and non-English speaking background population can be obtained from the Australian Bureau of Statistics and council statements.

Thirdly, more detailed state wide data is available in wastewater services from the DLWC which collates information provided by the 126 NSW water authorities, consisting of councils and the two metropolitan water authorities (Sydney Water and Hunter Water). Information going back to 1995/96 is now documented each year (such as Performance Comparison: 1999/2000 NSW Water Supply and Sewerage). Earlier data is also available, but it is not as comprehensive or as sound as later data.

Fourthly, the AWA has gathered data from 67 water authorities across the country serving between 10,000 and 50,000 assessments (Performance Monitoring Report, 1998/99). Much of the information duplicates the DLWC data, but does not cover all NSW councils, although some additional data is presented.

Of these four data sources the most detailed and comprehensive for NSW councils was the DLWC data. Further comprehensive investigation of unpublished information from this Department revealed additional useful information on the decomposition of input costs and factors. Data quality and completeness has improved over the years, and for this reason only data from 1995/96 was considered further for this study.

The relevant information available from the above sources is outlined in Table 1. From Table 1 it is clear that there are a number of possible variables that could be considered for the DEA, or for analysis of DEA results using Tobit regression analysis. The range in the “number of firms with data” generally corresponds with increasing number of municipalities supplying data over the period. Additional variables that relate directly or indirectly to the income for the service are also available. However, since income has no bearing on efficiency (i.e. the ratio of aggregate outputs to inputs), these variables were not relevant.

Table 1. Summary of Relevant Available Data for NSW Water and Wastewater Utilities from 1995/96 to 1999/2000

Category	Indicator / Variable	Service Applicable	Years Coverage	No. of Councils with Data
Business Characteristics	Population Served	Both	5	120
	Properties Serviced	Both	5	115-121
	Assessments	Both	5	115-121
	Total Annual Consumption	Water	5	84-119
	Consumption by sector	Water	2	48 - 56
	Total Annual Collection	Wastewater	5	91-119
	Total Annual Treatment	Wastewater	5	89-123
	Trade Waste Quantity	Wastewater	1	19
	Properties per km of Main	Both	5	118-120
Levels of Service	Compliance with Drinking Water Guidelines	Water	5	62-113
	Average Customer Outage	Both	4	46-85
	Service Complaints	Both	5	29-112
	Water Quality Complaints	Water	5	61-104
	EPA Licence Compliance	Wastewater	5	85-103
	Confirmed Sewer Chokes	Wastewater	5	106-120
	Sewerage Overflows	Wastewater	5	77-95
	Odours	Wastewater	5	106-120
Costs	Total Operating Costs	Both	5	112-121
	Management Costs	Both	5	105-119
	Treatment Costs	Both	1	111-115
	Pumping Costs	Both	1	111-115
	Maintenance Costs	Both	1	111-115
	Operational Costs	Both	1	111-115
	Energy Costs	Both	1	111-115
	Chemical Costs	Both	1	111-115
Asset Value	Asset Replacement Cost	Both	1	118

Source: DLWC (2001) and additional data supplied confidentially by the NSW DLG (2001).

It is evident from Table 1 that the completeness of data set varies significantly across the range of partial performance indicators. The number of councils capable of analysis depended upon having complete data sets for all of the relevant inputs and outputs. There was a trade-off between maximising the number of councils with adequate data for the DEA and being able to incorporate a sufficient number of appropriate inputs and outputs. Of the (then) 177 councils in NSW, some 117 provided wastewater services, including the two metropolitan water corporations (Sydney Water and Hunter Water). These councils are primarily the non-metropolitan councils. In total, 85 councils were analyzed for wastewater services, with 32 discarded due to incomplete data.

Sydney Water and Hunter Water, the two biggest water authorities in NSW by far, were eliminated for having provided an insufficient breakdown of their costs. Whilst it would have been advantageous to have included them, the magnitude of the difference in size compared all other water authorities in NSW, and to each other, may been problematic for the DEA.

5. SELECTION OF OUTPUTS AND INPUTS

The selection of the variables used defined the conceptual model adopted for the assessment of performance in this study. All outputs were obtained from data contained in Tables 5 to 12 of the 1999/2000 NSW Water Supply and Sewerage Performance Comparisons (DLWC, 2001). While the data improves with each passing year, the incompleteness of data for earlier years has restricted either the number of councils or number of years that can be considered in the analysis.

The outputs used in the analysis consisted of:

Quantitative Outputs (1 & 3 year analyses)

- Output 1: number of assessments;
- Output 2: annual wastewater volume collected;
- Output 3: annual wastewater volume treated;

Service Quality Outputs (1 year analysis)

- Output 1: Wastewater Quality Index;
- Output 2: Wastewater Service Index (reliability);

The service quality indices were each complied from a number of service quality measures:

Wastewater Quality Index: Compliance with organic (BOD) requirements; Compliance with suspended solids (SS) requirements.

Wastewater Service Index: Confirmed sewer chokes; Service complaints; Sewerage overflows; Odor complaints.

The data available for the service quality measure were less complete than for the quantitative outputs; accordingly averages over the last three years were employed. This meant that averages (by arithmetic means) were sometimes calculated using one or two year's data. Other service quality measures, such as the "average customer outage" for wastewater services, could not be factored into the indices without a substantial further reduction in the number of councils able to be analysed.

There are three significant issues to be considered in relation to these indices. Firstly, the weights for each measure making up the indices are not known. This could only be assessed through surveys of consumers as to their relative preferences in relation to the measures. Equal weights for all measures making up each index were therefore adopted.

Secondly, the service quality indicators need to be converted to indices with similar scales and direction. The raw indicators which make up the two "quality indices" were already presented in index form with a range from 0 to 100 (with 100 representing the "best" quality) and so were used in that configuration. However, the raw indicators which make up the two "service indices" were required to be each converted to matching indices. To achieve this, the raw figures were converted so that the worst council score used in the analysis was assigned 50 for each index. Average scores for each of the indices ranged from 86 to 98.

Thirdly, a number of techniques can be employed to calculate the aggregate indices. In order to compare the impacts and assess the suitability of using different methods, the following options were used to obtain these aggregate indices: Arithmetic mean of the indicator indices; geometric mean of the indicator indices; multiplication of the indicator indices (adjusted back to a scale from 0 to 100); and minimum of the indicator indices. It is likely that the latter two of these methods to obtain aggregate indices will be more punitive for councils with lower service quality indicators.

Two procedures were employed to incorporate service quality indices into the DEA. Firstly, together with the quantitative measures, the aggregate indices were used as separate outputs in the DEA. Secondly, quantity measures - namely the wastewater collected and wastewater treated - were quality adjusted using the aggregate indices, which was then used as an output in the DEA. The "quality index" was multiplied by the quantity of water treated, and the "service index" was multiplied by the quantity of water collected. The multiplication of quantity of water by a quality index is similar to the index number approach adopted by Saal and Parker (2000).

Input data was obtained from more detailed spreadsheets provided by DLWC. Since this data was only available for 1999/2000, more general data (DLWC, 2001: Tables 5-12) was used in the 3 year DEA, which calculated total factor productivity (TFP):

Inputs (1 year analysis): Input 1: Management costs; input 2: Maintenance and operation costs; input 3: Energy and chemical costs; and input 4: Capital replacement costs;

Inputs (3 year analysis): Input 1: Management costs; and input 2: Maintenance, operation, energy and chemical costs;

Management, energy and chemical, and capital replacement costs were taken directly from the DLWC data sets. The maintenance and operation costs were calculated by subtracting these three costs from the total operating costs. The maintenance and operation costs therefore represent all other operating costs not covered, and included treatment, pumping and reticulation main maintenance, but excludes the energy and chemicals used.

Some previous studies have employed the total length of mains as a measure of capital (ACT Auditor General, 1995). The use of the estimated capital replacement costs provides better coverage of all capital infrastructure since it includes dams, treatment works, pump stations and reservoirs, as well as the reticulation system. On the other hand, the length of mains is easier to measure and less prone to inaccuracies from variations in estimating current construction rates. For this reason the DLWC provides guidelines and suggested construction rates to aid councils in the capitalisation of their wastewater assets.

A detailed decomposition of input costs for the 1997/97 and 1998/99 years was not readily available. Service quality indicators also had to be averaged over the 3 years for the one-year analysis due to data incompleteness. This meant that a smaller number of input and output variables were used the 3 year DEA.

Some adjustments were made to the data. Firstly, all input costs were deflated to 1996/97 prices employing the Construction Industry Producer Price Indices (ABS, 2001). Using different deflators was not possible since each element of the input cost included a mixture of labor, plant and materials, and other suitable deflators were only commenced for the year 1998/99. Secondly, there were some inconsistencies in the breakdown of costs between data sets, which involved the minor adjustment of input costs for 10 councils. Since in 12 cases inputs costs or quantitative outputs were missing for one year, interpolation and assignment of a cost equivalent to the same deflated cost (or output amount) as the following year was undertaken.

6. DATA USED IN TOBIT REGRESSIONS

The data compared against the DEA results using Tobit regression were:

- Population – to account for variations in average size of households and businesses;
- properties per kilometre of main – indicator of population density;
- location (coastal or not) – to account for differences in community acceptance of effects on the environment, and/or large seasonal variations in population;
- rainfall – indicator of higher quantities of wastewater collected through ingress into pipes;
- percentage of residential assessments – to account for variations in the residential and industrial/commercial mix;
- whether water is filtered or unfiltered (water only) – one indicator of the level for treatment required; and
- whether groundwater is used (water only) – another indicator of the level for treatment required;

All data was sourced from the DLWC except for rainfall figures which were taken from the Bureau of Meteorology (www.bom.gov.au – 3 September 2001) for the three year period 1999 to 2001. The Tobit models were calculated using the SHAZAM computer program with truncation set at one.

7. DESCRIPTION OF SIX ALTERNATIVE DEA MODELS USED

A number of techniques were used to calculate the aggregate "quality index" and "services index". This produced six alternative models that are described below:

- Model A – quantitative outputs only used (no service quality measures used);
- Model B – quantitative outputs augmented with the two indices as separate outputs (calculated using arithmetic mean of the indicator indices);
- Model C – quantitative output(s) multiplied by the quality index (which were obtained from using the arithmetic mean of the quality indicators), thus leading to quality adjusted output levels;
- Model D – quantitative output(s) multiplied by the quality index (which were obtained from using the geometric mean of the quality indicators);
- Model E – quantitative output(s) multiplied by the quality index derived as a product of the quality indicators;
- Model F – quantitative output(s) multiplied by the quality index defined as the minimum value of the quality indicators;

8. RESULTS

These alternative models were used consistently for wastewater in the one-year DEA computations. It is to be expected that models E and F would be more punitive against lower service quality indicators than models C and D.

A summary of the technical and scale efficiencies is contained in Table 2. The average technical efficiencies for the councils analysed were 0.730 and 0.819

for constant returns to scale (CRS) and variable return to scale (VRS) respectively using Alternative A. This marginally changes to 0.735 and 0.823 using model C. The average scale efficiency was 0.895 and 0.896 for models A and C respectively. This means there is scope for improvements in efficiency in local government wastewater services of 26.5%, of which 8.8% is due scale inefficiencies and 17.7% is due to purely technical inefficiencies (using model C). Average efficiencies weighted by the number of assessments and volume of wastewater treated are also given in Table 2.

An interesting feature is that the average technical efficiencies increased when service quality indicators were incorporated into the analysis. This feature is also seen for individual wastewater authorities where technical efficiency scores are consistently slightly higher for models C, D, E and F when compared to model A. The reasons for this are discussed below.

Table 2. Efficiencies in NSW Council Wastewater Services in 1999/2000

Alternative Model Specification	A	B	C	D	E	F
Minimum technical efficiency (crs)	0.416	0.449	0.416	0.416	0.416	0.416
Unweighted average technical efficiency (crs)	0.730	0.754	0.735	0.736	0.764	0.751
Weighted average technical efficiency by assessments (crs)	0.663	0.665	0.667	0.667	0.702	0.679
Weighted average technical efficiency by water treated (crs)	0.667	0.668	0.671	0.672	0.712	0.686
No. of fully efficient councils (crs)	17	21	18	18	19	18
Absolute average difference to model A (crs)	N/A	4.1%	1.0%	1.1%	5.9%	3.5%
Spearman's rank coefficient compared with model A (crs)	1.000	0.895	0.991	0.991	0.916	0.961
Minimum technical efficiency (vrs)	0.495	0.507	0.495	0.495	0.495	0.495
Unweighted average technical efficiency (vrs)	0.819	0.881	0.823	0.824	0.836	0.831
Weighted average technical efficiency by assessments (vrs)	0.865	0.915	0.868	0.868	0.875	0.873
Weighted average technical efficiency by water treated (vrs)	0.865	0.917	0.868	0.868	0.876	0.874
No. of fully efficient councils (vrs)	27	38	30	30	32	31
Spearman's rank coefficient (vrs)	1.000	0.785	0.981	0.980	0.939	0.961
Minimum scale efficiency	0.544	0.500	0.544	0.544	0.544	0.544
Average scale efficiency	0.895	0.859	0.896	0.897	0.915	0.906
No of scale efficient councils	17	20	18	19	21	18
No of peers (including default peers)	24	29	25	25	26	25

Distributions of the CRS and VRS technical efficiencies as well as scale efficiency are illustrated in Figures 1, 2, 3 and 4.

Figure 1. Distribution of Technical Efficiencies (CRS) in NSW Council Wastewater Services in 1999/2000 using Model C

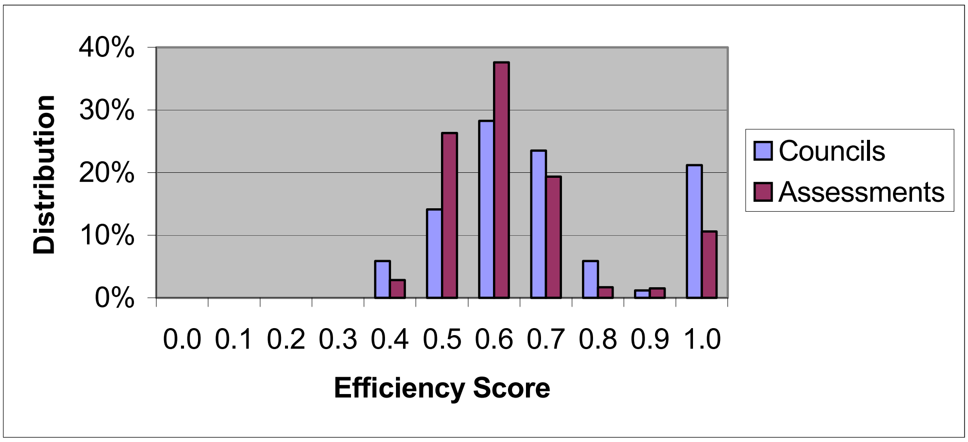

Figure 2. Distribution of Technical Efficiencies (VRS) in NSW Council Wastewater Services in 1999/2000 using Model C

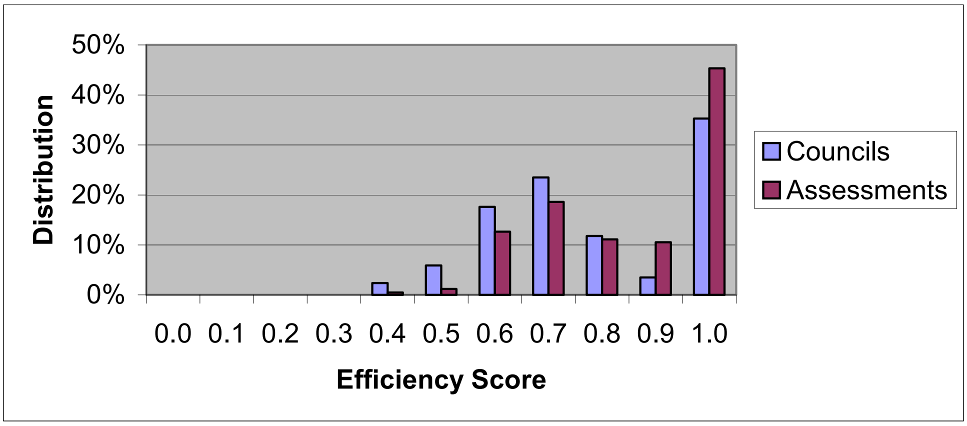

Figure 3. Distribution of Scale Efficiencies in NSW Council Wastewater Services in 1999/2000 using Model C

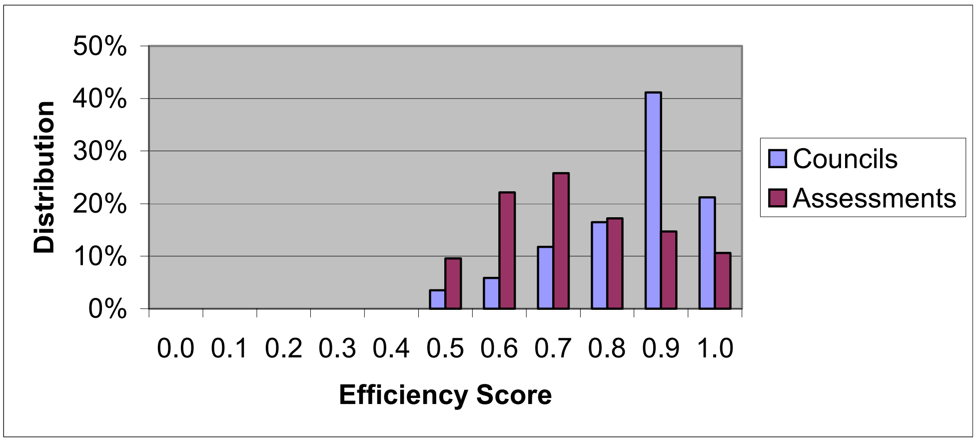

Figure 4. Average Technical Efficiencies by Council Size (number of assessments) in NSW Wastewater Services in 1999/2000 using Model C

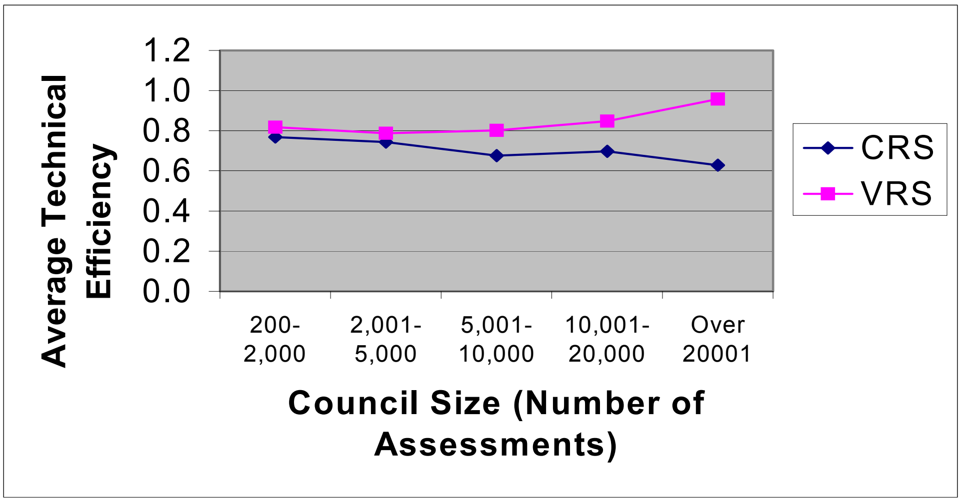

Figure 4 indicates that larger councils have, in general, lower efficiencies under constant returns to scale and higher efficiencies and variable returns to scale. This suggests that scale efficiencies are the main source of inefficiency for the larger councils in providing wastewater services. This is also borne out in Figures

1, 2 and 3 by comparing the distributions by council and by assessments. This is consistent with the differences in weighted and unweighted average efficiency given in Table 2.

A large number of councils face decreasing returns to scale. This is highlighted in Table 3. This suggests that technologies could be upgraded for many councils, especially where significant growth is expected, or smaller treatment plants should be constructed in the future. There was considerable stability between alternative models in the individual council results for returns to scale.

Table 3. Number of Councils by Returns to Scale in NSW Wastewater Services in 1999/2000

Alternative Model Specification	**Alternative A**	**Alternative C**	**Alternative E**
Constant returns to Scale	19	20	23
Increasing returns to Scale	19	20	17
Decreasing returns to Scale	47	45	45
Total Number of Councils	**85**	**85**	**85**

Table 4 summaries the input slacks calculated for wastewater services. The highest number of slacks was for management costs, where 28 councils had input slacks for model C. The number of slacks in management costs suggests a need for further future investigation.

Table 4. Input Slacks in NSW Council Wastewater Services in 1999/2000

Input Slacks	Input Costs	Management	Operational & Maintenance	Energy & Chemicals	Plant Replacement
Model A	Count	26	12	16	12
	Mean	$28,354	$20,466	$14,132	$543,000
	Max	$498,113	$856,759	$256,789	$25,006,000
Model C	Count	28	14	17	8
	Mean	$29,441	$25,824	$12,701	$564,000
	Max	$498,113	$856,759	$256,789	$25,006,000
Model E	Count	30	12	16	8
	Mean	$30,179	$24,714	$10,770	$605,000
	Max	$498,113	$856,759	$256,789	$27,885,000
Average Input Cost		$457,554	$759,422	$109,234	$42,309,000

The councils with the largest input slacks for Management, Operational and Maintenance, Energy and Chemicals, and Plant Replacement costs were Bega, Midcoast, Midcoast and Wingecarribee respectively. This was the case for each of the three alternative models indicated in Table 4.

8.1 Comparing the Alternative Methods for Incorporating Service Quality

The differences in individual and average efficiency scores between models A and C for wastewater services were notable (maximum individual variation for CRS of 9.9% for Bingara, with the next highest being 8.4% for Muswellbrook, an absolute average difference for all councils being 1.0%, and Spearman's rank coefficient of 0.991 for CRS). Model E, the most punitive alternative, gave a 33.5% and 12.2% variation in technical efficiency (CRS) for Bingara and Muswellbrook respectively. The absolute average difference between models A and E was 5.9%, and the Spearman's rank coefficient was 0.916 for CRS. This again indicates high stability between the DEA models with and without service quality measures.

The feature of rising average scores for more punitive services quality alternative is interesting. To see why this is the case, the four councils with the lowest service quality indices were examined and the constant returns to scale technical efficiencies are recorded in Table 5. Three of these councils (Coolah, Parkes and Weddin) are both technically and scale fully efficient for all alternative models. This means that they are on the frontier for all alternatives even though they were penalised for low service quality. Other councils for which these three are peers in model A should rate better for the other alternative models where service quality is incorporated. The observation that many of the more efficient councils in wastewater have low service quality indices from the detailed results is consistent then with the average scores increasing in the more punitive alternatives.

Table 5. Technical Efficiencies in Selected NSW Councils having Low Service Quality Indices (CRS) in 1999/2000

Alternative Model Specification	A	C	D	E	F
Coolah	1.000	1.000	1.000	1.000	1.000
Goulburn	0.911	0.909	0.910	0.888	0.905
Parkes	1.000	1.000	1.000	1.000	1.000
Weddin	1.000	1.000	1.000	1.000	1.000

Looking at the other end of the scale, the technical efficiencies of the larger councils supplying wastewater services is contained in Table 6. These bigger municipalities generally have very high service quality indices, but lower efficiencies is consistent with the explanation provided when looking at the smaller councils of rising average efficiencies as quality is introduced and as more punitive methods are employed. All of the larger councils contained in Table 6 face decreasing returns to scale, except for Wagga Wagga which confronts constant returns to scale.

Table 6. Technical Efficiencies in NSW Councils providing Wastewater Services and having more than 19,000 Assessments (CRS) in 1999/2000

Model	Assessments	A	C	D	E	F
Coffs Harbour	19600	0.529	0.534	0.534	0.612	0.560
Gosford	59700	0.740	0.743	0.743	0.750	0.744
Hastings	22300	0.675	0.680	0.681	0.824	0.719
MidCoast	27600	0.535	0.538	0.538	0.592	0.550
Shoalhaven	37000	0.613	0.613	0.613	0.613	0.613
Tweed	24100	0.615	0.623	0.623	0.695	0.638
Wagga Wagga	19500	1.000	1.000	1.000	1.000	1.000
Wyong	51500	0.566	0.571	0.572	0.614	0.576

8.2 Peers and Special Councils

Table 7 gives the number of peers for each alternative model. Excluding model B, the number of peers ranges from 24 to 26 councils. Of these Coolah, Mulwaree, Parkes, Shoalhaven and Tallaganda are peers by default using model C. Different input/output mixes may apply to this default council compared to all others.

Councils listed in Table 7 are peers of more than 20 other municipalities. These four councils are considered special councils for wastewater services, and should be the subject of detailed benchmarking by other local governments as part of their continuous improvement program.

Table 7. Special Councils for NSW Wastewater Providers – Peers for Many Other Council in 1999/2000 using Model C

Council	Number of Councils	Size (Number of Assessments)
Wagga Wagga	28	19,500
Glenn Innes	28	2,580
Queanbeyan	23	13,000
Jerilderie	23	420

8.3 Explaining Efficiency Scores in Wastewater Services

Tobit regression analysis was carried out to ascertain if there was any relationship between the calculated individual council technical efficiencies and various potential influencing factors for which data was available. Table 8 summarises the calculated coefficients of correlation.

Table 8. Regression Analysis of CRS and VRS Technical Efficiency in NSW Council Wastewater Services for 1999/2000

Variable	**Constant Returns to Scale**			**Variable Returns to Scale**		
	Regression Coefficient	**T-Ratio**	**Elasticity of E(Y)**	**Regression Coefficient**	**T-Ratio**	**Elasticity of E(Y)**
Population	0.13E-06	0.13	0.0026	0.45E-05	2.96	0.0624
Properties per km of main	0.21E-02	0.89	0.0934	0.11E-02	0.39	0.0347
Location (coastal)	-0.11	-1.03	-0.0324	-0.17	-1.3	-0.0335
Rainfall	-0.35E-04	-0.77	-0.1059	-0.14E-04	-0.28	-0.0322
% Residential	-0.49E-02	-0.69	-0.5358	-0.28E-02	-0.35	-0.2231
Constant	1.23	1.94		1.09	1.5	
Squared Correlation between Observed and Expected Values			**0.194**			**0.161**

Only the variable for population had a T-ratio greater than 1.96 when compared to technical efficiencies under VRS - the figure required at the 5% level of significance. However, this variable had low elasticity (0.06 for VRS), indicating that changes in population influences efficiency scores under VRS by some 6% of that change.

The squared correlation between observed and expected values of 0.19 and 0.16 shows that factors other then the five variables used in the regression analysis are needed to account for a major part of the variations in efficiencies calculated by the DEA. Further investigations along these lines could be undertaken into other possible factors in some future study.

8.4 Efficiency Change, Technical Change and TFP Change

Malmquist indices were calculated over a 3 years time period (1997/98 to 1999/2000) for efficiency and technology changes and TFP. A summary of the efficiency and productivity changes is contained in Table 9.

Table 9. Total Factor Productivity in Council NSW Wastewater Services from 1997/98 to 1999/2000

Malmquist Index – Summary of All Councils	**Year 2**	**Year 3**	**Mean**
Efficiency change	1.316	0.828	1.044
Technology change	0.742	1.287	0.977
Total factor productivity	0.977	1.065	1.020
Weighted TFP by assessments	-	-	1.017
Weighted TFP by quantity of wastewater treated	-	-	1.022

TFP increased by 2.0% over the 3 years. Technological change accounted for a 2.3% decrease in TFP offset by a 4.4% increase in efficiency (rounding off error of 0.1%). Wild swings in both technological and efficiency in each of the two yearly changes may suggest problems in data quality. The mean trend of negative technological change may be explained by the continued implementation of stricter environmental licensing by the EPA. Lack of complete data sets, for earlier years, for the councils used in the one-year analysis prevented a longer time period being used. Weighting individual council TFP figures by assessments and the quantity of wastewater treated increased the average growth to 1.7 per cent and 2.2 per cent respectively. These weighted figures provide a better representation of TFP growth in wastewater services provided by local governments across the state.

8.5 Comparison Using only Two Inputs

To examine whether the choice of using four inputs has masked possible differences in results under alternate models, a two-input model was developed. The inputs used were the same as that used for the three year DEA, all outputs remained unchanged. Table 10 gives a comparison between the two and four input DEA models.

Table 10. Comparison of 4 and 2 Input Models for NSW Council Wastewater Services in 1999/2000

4 Input Cost Decomposition	**Alternative Model Specification**	**Model A**	**Model E**
	Mean technical efficiency (crs)	0.730	0.764
	Min technical efficiency (crs)	0.416	0.416
	Absolute average difference to Model A (crs)	N/A	5.0%
	Spearman's rank coefficient compared to Model A (crs)	1.000	0.916
	Spearman's rank coefficient compared to Model A (vrs)	1.000	0.939
	Number of peers	24	26
2 Input Cost Decomposition	**Alternative Model Specification**	**Model A**	**Model E**
	Mean technical efficiency (crs)	0.540	0.565
	Min technical efficiency (crs)	0.273	0.276
	Absolute average difference to Model A (crs)	N/A	4.5%
	Spearman's rank coefficient compared to Model A (crs)	1.000	0.954
	Spearman's rank coefficient compared to Model A (vrs)	1.000	0.956
	Number of peers	12	12

Table 10 shows that both the number of peers and average technical efficiency drops when a two-input DEA is used compared to the four-input DEA used previously. This is to be expected as the number of dimensions to the frontier is reduced.

However, the main finding on the impact of incorporating quality measures into the DEA is that there is no significant change in both the absolute average difference and Spearman's rank coefficient when comparing alternative models with and without quality. Model E, the most punitive of the alternative models employed, had slightly less change for the two-input model than the four-input model when compared to respective model A. This indicates that the choice of four inputs did not cause the average variations in efficiencies when including and excluding quality measures into the analysis to be smaller.

8.6 Comparison of DEA Results with Partial Performance Measures Currently Used

To assess the suitability of using partial performance measures to represent performance for wastewater services provided by councils in NSW, a comparison was undertaken comparing the technical efficiencies under CRS and VRS from the DEA (using model C) with three main partial performance indicators currently in use: Average operating costs per assessment; average operating costs per quantity of wastewater treated; and average operating costs per length of main;

Higher DEA efficiency scores indicate better performance. To ensure the partial indicators similarly gave higher scores for greater accomplishment, the reciprocals of the partial measures were used.

Comparisons were done in two ways. Firstly, Spearman's rank coefficients were calculated comparing each of the five measures using those 85 councils previously analysed. Secondly, councils were ranked by their performance scores, using each of the measures. The calculated Spearman's rank coefficients are given in Table 11.

Table 11. Comparison of Partial Measures and Calculated Technical Efficiencies using Spearman's Rank Coefficients for NSW Council Water and Wastewater Services in 1999/2000

Wastewater – Spearman's Rank Coefficients	Op costs / assess	Op costs / vol	Op costs / main	TE (CRS)	TE (VRS)
Operating costs per assessment	1.00	0.45	0.69	0.66	0.52
Operating costs per volume	-	1.00	0.25	0.50	0.29
Operating costs per length of main	-	-	1.00	0.51	0.32

Table 11 shows that no partial performance measure could produce similar rankings to either the CRS or VRS technical efficiencies in wastewater services. Operating costs per assessment was the partial performance measure with the highest Spearman's rank coefficient when compared to both CRS (0.66) and VRS (0.52) technical efficiencies for wastewater services.

To get some indication of the individual changes in rank, councils are listed by rank and the ranks are illustrated by means of three examples: Dubbo, Snowy River and Tamworth (shown in Table 12).

Table 12. Comparison of Partial Measures and Calculated Technical Efficiencies for Selected Councils – Wastewater Services in 1999/2000

Wastewater –Rank (of 85)	Op costs / assess	Op costs / vol	Op costs / main	TE (CRS)	TE (VRS)
Dubbo	43	50	43	45	14
Snowy River	66	73	44	82	84
Tamworth	60	45	71	55	56

From Table 12 it is evident that the ranks vary considerably for different partial performance indicators. This raises the issue of which performance measure, or combination of measures, should be used to represent overall efficiency. Some significant variations between partial and the technical efficiencies are also shown. For instance, Dubbo had a high ranking in wastewater (14) using the VRS technical efficiency result, but a highest partial measure ranking of 43. This demonstrates that a weighted average of a number of partial performance indicators cannot adequately account for the pure technical efficiency of a council.

These comparisons illustrate the limitations of using partial performance indicators as performance measures and highlight the additional dimension of scale efficiency when using the DEA method.

9. CONCLUDING REMARKS

Six alternative models were used to compare different ways of incorporating service quality measures into the DEA. The use of indicators for separate DEA outputs was unsatisfactory since their scale neutrality was inconsistent with the other outputs and inputs. The adjustment of quantitative outputs by multiplication with aggregate service quality indices proved a better method. Averaging of service quality indicators when compiling the aggregate indices was found, not surprisingly, to be less punitive than either multiplication of the indices or adopting the minimum index number. However, the differences between the more and less punitive alternative models were less than expected as indicated by the Spearman's rank coefficients and absolute average differences. This was explained primarily by the relative differences of council service quality measures and their relation to the different production frontiers. Examination of individual municipal results revealed that there were, in general, only minor variations between a council's service quality indices and that of its peers. The sample of NSW local governments used in this study may also have contributed to this result, since councils which did not provide complete quality data sets may have exhibitedlower levels of service quality. More complete data will remove any adverse selection effect and enable this question to be explored in future.

The DEA and other methods utilised in this paper generated opportunities to examine various factors affecting efficiency and productivity change in NSW local government wastewater services. Several wastewater authorities were identified as special cases: Wagga Wagga, Glenn Innes, Queanbeyan and Jerilderie. They represent peers for many other councils and so are critical in the next phases of the performance improvement process - detailed benchmarking between councils.

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