Identification of resource needs for learners with vision impairment: Using DEA in a mixed method approach

Nicola Ward Petty
Department of Management
University of Canterbury
Christchurch NZ
n.petty@mang.canterbury.ac.nz

Abstract

Identification of resource needs for learners with vision impairment is one of a class of problems that occurs in areas such as social work, special education, rehabilitation and health. The problem is to identify needs and allocate scarce resources in an efficient and equitable way. A mixed method approach is developed, using qualitative interviewing to inform the development of a DEA model. The use of DEA on data relating to individuals, rather than organisational groups, is illustrated, with parallels drawn from similar studies in the education and health sectors.

1. Introduction

Many of the applications of Data Envelopment Analysis have been in the area of measuring educational effectiveness. See Boussofiane et al. [1], Charnes et al. [2]. In most of the papers the unit of assessment has been a school, and academic results have been the main outcome measures. This paper addresses a more micro level, namely the education of individual children with special educational needs, specifically learners with vision impairment in New Zealand, of whom there are approximately 1000. As the study is in the qualitative stage, this paper concentrates on the reasons for using DEA in a mixed method approach, and the process of the analysis.

First the problem itself is identified, and the methodology outlined. Next the question of why DEA is proposed for the analysis is addressed. The problem in question is compared and contrasted with two other studies which use an individual person as the unit of assessment or Decision Making Unit (DMU). The use of mixed methods or multi-methodology is discussed, including the motivation for a mixed approach in what is seen as fairly 'hard' OR.

2. Introduction to the problem

2.1. General class of problems

Identification of resource needs for learners with vision impairment is one of a class of problems that occurs in areas such as social work, special education, rehabilitation and health. The issue is to identify needs, and allocate scarce resources in an efficient and equitable way. Teachers providing an itinerant service, social workers, and nurses all

serve a variety of clients, children or patients with varying needs, and make decisions about the allocation of their time.

There are often several inputs in these problems, and the outcomes in these problem areas are often multiple, ill-defined, and difficult to quantify. The multiple nature of the inputs and outcomes indicates the potential usefulness of DEA. The process of initiating, performing and analysing a DEA project leads to better definition of the desired outcomes and potentially useful outcome measures. The identification of peer groups, a key result of DEA, may be instructive in terms of setting service benchmarks for clients with similar needs. The ranking of cases or clients according to 'efficiency' can inform decisions on future practice with regard to allocation of time within caseloads.

2.2. The Learners with Vision Impairment (LVI) problem

The management of learners with vision impairment needs to be considered in the context of the change from providing education in an institutional setting to a community setting. In recent times there has been a general move within areas such as health, social services and special education to provide services in the community rather than in institutions. In special education this is known as 'mainstreaming' or 'inclusion' and results in children with special needs, such as vision impairment, being taught in their neighbourhood school, supported by resources such as specialist teachers and para-professional help.

In New Zealand this inclusion has happened in a piecemeal fashion, resulting in unevenness of service provision. Coinciding with the move to 'normalisation', there has been a change in attitude towards people with disabilities. Until recently, children with disabilities were treated as "objects of charity", rather than as people with the right to education. However the general principles documented in Special Education Policy Guidelines for New Zealand state: "Learners with special education needs have the same rights, freedoms and responsibilities as people of the same age who do not have special education needs." [3] This shift in philosophy changes the motivation from altruism to the drive for equity, constrained by resource limitations.

Children with vision impairment require extra resources to enable them to have access to the curriculum on a par with their sighted peers. These resources include time with a specialist teacher, teacher aide support, orientation and mobility instruction, and materials converted to large print or braille. Their needs and their expectations differ according to their level of schooling, age, degree of vision impairment, other physical disabilities and various other factors. All of these children are served by (usually) itinerant resource teachers who are required to provide a service in an equitable manner to a disparate group of learners. However there are at present no caseload guidelines in New Zealand.

Internationally the caseloads are extremely variable. Olmstead [4] found a wide range of caseloads for teachers of learners with vision impairment in California. The caseloads ranged from 5 to 61. A large majority of teachers questioned in the study agreed that maximum caseload sizes for itinerant teachers should be mandatory. Pagliano [5] states that "differences which do occur in Australia appear to be mainly owing to the lack of national legislation and the absence of a strong research base. Decision-making in Australia has tended to be regional and primarily determined by a combination of demand, availability of human and material resources, and international trends." In New Zealand there is a general feeling among specialist teachers and parents

that the service provided is not meeting the needs of all the children, due to under-funding in most geographical areas, and a lack of co-ordination and consistency between centres. Requests for extra funding are less successful because they are not seen as supported by research. Following a survey of professionals and parents in the field, Pillay and Thorburn [6] considered that "how to develop a New Zealand-wide system, so services can be delivered effectively and fairly to students wherever they live" is a top priority for future research in New Zealand.

2.3. Overview of the process

A mixed method design is being used to address this problem of identification of resource needs for learners with vision impairment (LVI). A thorough qualitative phase, interviewing and surveying relevant stakeholders, precedes the building of a model based on the data on individual children. The aim of the qualitative study has been to identify potential determinants of need and categories, and to clarify the goals and objectives in order to find potential outcome measures. Specialists in the area of vision impairment were interviewed and surveyed to identify how they perceive their role, and to elicit a comprehensive list of possible determinants of need, potential resource needs, categories and outcomes. Some expert informants were identified for consultation in the later stages of the analysis.

In the quantitative phase, data will be collected to form a database of all or a sample of the 1000 learners with vision impairment in New Zealand. The information gathered may include the following for each learner:

- measures of the determinants of need identified in the first phase of the study,
- levels of resource the learner is receiving at present,
- perceived level of access to the curriculum.

This set of data will be analysed using DEA in order to identify individual learners for whom the process is working well, categories of learners who may sensibly be grouped together, and the inputs which have most impact on the achievement of desired outcomes for a learner.

There will be a high degree of consultation within the modelling phase, followed by reflection on the validity of the final model and the effectiveness of the research method as a whole.

3. Rationale for the use of DEA

Data envelopment analysis (DEA) is a linear programming based technique for measuring the relative performance of organisational units where the presence of multiple inputs and outputs makes comparison difficult [1]. The traditional use of DEA is in efficiency comparisons between organisational units such as banks, schools and hospitals. Organisational units are similar in terms of their inputs and outputs, but have different elements, such as size, customer base, staffing level, demographic area and history. Single indicative output/input ratios do not capture the complexity required, so a ratio of the weighted sum of outputs over the weighted sum of inputs is used. Linear programming is used to identify sets of imputed weights which make each unit of assessment or decision making unit (DMU) appear as efficient as possible.

There are two elements in the use of DEA that inform the decision: the outputs from the model (such as the efficiency scores, the ranking of the units and the weights attached to each factor for each unit) and the process of building the model, which

involves clarifying goals and objectives, measuring inputs and outputs, and deciding between different models. DEA can also be used in conjunction with other methods, such as regression and non parametric measures, to identify differences between pre-defined groups such as types of hospitals or levels of care [7]. Hollingsworth et al. [8], who reviewed 91 applications of DEA, identified over 30% which used additional methods, such as using the efficiency score as the dependent variable in secondary regression analysis.

3.1. Use of DEA for studies of Educational Efficiency

In their study of efficiency evaluation in secondary schools, Mancebon and Eduardo [9], provide an extensive discussion on the rationale for using DEA in the analysis of efficiency in education. They identify peculiarities of the education service's production process, which can be summarised as follows:

- There are intangible multiple outputs.
- The impact of education continues over the lifetime of the individual.
- The production process is cumulative.
- An indeterminate part of the education received is not related to the effects of the education system.
- The pupil can be input, output and the unit of assessment.
- Each pupil is different.

One aim of building a model is to identify good practice with regard to the provision of service, in this case for the learners with vision impairment. The group under consideration is quite heterogeneous, with differing levels of vision, other disabilities, age, and type and level of schooling. This heterogeneity is recognised by the use for many of the learners of an "Individual Education Plan" (IEP) which identifies his or her particular needs and goals. These plans are reviewed and upgraded at least twice a year. However it is proposed that there are sufficient similarities in inputs and outputs for comparison to be relevant.

Mancebon and Eduardo [9] discuss the choice of a measurement model, which can be either parametric, based on regression techniques, or non-parametric, namely DEA. They discard the parametric approach, as it limits the form of the model and assumes that all units will operate in a similar way. Other reasons for preferring DEA are the capacity to work simultaneously with multiple inputs and outputs, and respect for the individual practices of each unit of assessment (school in this case). They summarise the latter as follows:

> *"In an idiosyncratic context such as education, in which differences between the production practices of the organisation could be both important and difficult to understand and standardise, and where, furthermore, there is no consensus on the relative importance of the different productions, the envelopment approach is clearly very appropriate. The impositions of homogeneous and rigid patterns of behaviour, inherent to the parametric approach does not fit well with the nature of education services."*

This statement can apply also to the 'production practices' of individual children and their IEP teams, upon whom it is also not educationally appropriate to impose a homogeneous and rigid pattern of behaviour.

The study by Mancebon and Eduardo [9] of Zaragoza Secondary Schools (ZSS) differs from the LVI study (learners with vision impairment) in several ways. The unit of assessment was a school rather than an individual child, the students were from

regular high schools, rather than having special needs, and the outcome measurements were based on academic achievement, whereas the LVI outcomes will be based upon access to the curriculum.

Where the two studies are similar, in addition to the educational context, is in the emphasis on the process of building the model and the extensive ex post analysis, rather than on a particular result. The ZSS study illustrates the high level of conceptualisation needed before applying the mathematical model. The LVI study has an extensive qualitative component where teachers and other stakeholders are interviewed to enable the conceptualisation to be firmly grounded in the context.

3.2. Use of Parametric models

By its nature, parametric modelling emphasises the mean. There must be observations that perform either side of what the model defines. Regression is used to identify the function between the controllable inputs and the outputs, having controlled for the exogenous variables. It assumes that the relationship is the same for all observations, or at least an 'average' of them. It is useful for determining which inputs best predict the level of a single, rather than multiple, output. For these reasons regression is judged less appropriate than DEA for the main analysis.

It is proposed that regression may rather be used in conjunction with DEA in the LVI analysis in order to study relationships between variables for pupils in 'peer groups' identified by DEA, and, as explored by Puig-Junoy [7], in identifying which inputs have the most influence on the efficiency level.

A database of learners with vision impairment will be developed in conjunction with the Vision Education Agency, a government funded organisation set up to advise on the education of learners with vision impairment. There will be extensive initial data analysis in order to gain an overview of the population before focussing on specific groups and objectives using DEA.

4. Similar applications

This section gives an analysis of two studies that also use individuals as the unit of assessment, followed by a summary, in table form, which provides a framework for comparing the main elements of these studies and the LVI study.

4.1. Setting Achievement Targets for School Children (ATSC)

Thanassoulis [10] used DEA to analyse data on 1000 children in the education system in the UK in order to "estimate the attainment level each pupil could reach were he/she to match the observed achievements of the best performing pupils and schools, after controlling for contextual factors." The aims included setting achievement targets appropriate for individual children and identifying 'benchmark pupils' who could be used as role models. The individual unit of assessment was a pupil. The inputs were gender, ethnicity, entitlement to free school meals, and a measure of prior attainment. The single outcome or achievement variable was the pupil's GCSE score.

A stated advantage of the use of DEA in this example rather than a parametric method such as regression is that the achievement targets estimated for a child relate to his or her innate identified potential, but reflect high rather than average achievement. The identification of realistic peer role models is stated as important also. It would be informative to see how useful these targets and peer groups are in practice.

It was unclear from the paper what the level of involvement or support from teachers was for this modelling effort. Without teacher involvement in the construction of the model there is less likelihood of their implementing the model.

4.2. Technical Efficiency in the Clinical management of Critically Ill Patients (CIP)

Like the ATSC and LVI studies, Puig-Junoy [7] also applied DEA to individuals rather than management units. The study involved the treatment of 993 critical care patients in intensive care units in Catalonia. The purpose was "to obtain empirical measures of performance… in the management of critically ill patients and to evaluate the factors that are contributing to hospital performance in treating these patients."

Individual patients were the unit of assessment, rather than broader groupings, such as the intensive care units. The author points out that health care is a very heterogeneous process. Aggregating data may hinder the effort to explain differences in results. The individual patient is chosen as the unit of assessment in order "to consider in detail the patient characteristics which constitute necessary dimensions of the input and output set." [7]

The measurement of input and output levels for individual patients, approximating the severity of the illness and the health status on discharge, is a major problem in health care provision. Existing measurement instruments were used in the CIP (Critically Ill Patients) study. There were two output measures chosen – length of stay and status on discharge (alive or not). The author used a weighting scheme to explore the impact of varying the relative importance of the two outcome measures. The higher the weighting for survival status, the more variable were the efficiency scores. This analysis identifies the effect of differing emphasis on survival rather than length of stay. It indicates that units which may appear to be at similar levels of efficiency when both length of stay and health status are important, appear less similar when the health status is given more emphasis.

This study also used the efficiency scores as an input to other analysis. The efficiency scores for the patients from the three different risk groups (Low, Moderate, and High) were tested to see if there was a significant difference in terms of efficiency. Results showed that there was a significant difference between the efficiency scores for the three groups. Low risk patients were treated the most efficiently and the high risk the least efficiently, with the medium risk scoring in between. Other factors were explored, including types of hospitals and surgical vs medical admission, none of which showed a significant difference with regard to the efficiency scores.

Clearly the contexts – medical and educational – are different for the CIP and LVI studies. Another difference was that the measurement scales used in the CIP study were well accepted, while the measurement methods in the LVI study are not yet defined. The similarities between these studies are illustrated in the next section.

4.3. Summary of comparison between three DEA applications

The following table provides a framework for comparing these and other DEA applications. It can be seen that there are strong similarities, particularly between the CIP and LVI studies.

	Achievement Targets for school children (ATSC)	**Management of Critically Ill patients (CIP)**	**Resources for education of vision impaired (LVI)**
Decision making unit/ unit of assessment	Child	Patient/team	Child/team
Data set	Results for about 1000 children from ten London schools at the same level of schooling.	993 patients from sixteen intensive care units in Catalonia.	1000 children from throughout New Zealand, being served by 12 centres – varying stages of schooling.
Inputs (uncontrollable)	Innate academic ability, gender, family background.	Survival probability at admission, mortality risk level.	Level of disabilities, school setting, age, family background.
Inputs (controllable)	None	Weighted ICU days, non-ICU hospital days, available nurse days per patient, available physician days per patient, technology availability.	Levels of resources provided.
Outputs	Pupil's GCSE score	Number of days surviving in the hospital, surviving discharge status.	Measure of perceived access to the New Zealand curriculum, possibly parent satisfaction.
Interpretation of 'efficiency'	A child on the efficient frontier has done better than his or her peers with the same starting level of achievement and background.	A patient on the efficient frontier had a better result than peers with similar levels of mortality risk at admission and other measured inputs.	The net results for an 'efficient' team were better than for a similar team working with a child of similar needs.
Level of involvement of key stakeholders.	None stated.	Not stated.	Consultation at all stages.
Implication of efficiency score of less than 1.	Reflects insufficient effort by the pupil and less than full effectiveness of the school.	The patient used more resources for a similar outcome than other similar patients, or given similar resources, achieved a worse outcome than other similar patients.	The team may be less effective, the resource level inappropriate, or another complicating factor may be at work.
DEA model	Output oriented variable returns to scale.	Input oriented, non-discretionary and categorical variables, and weight constraints under consideration.	Input oriented, variable returns to scale, non-discretionary and categorical variables, and weight constraints under consideration.
Adaptations to the model	Three-step process: Partitioning, Allow for random noise – remove 'super-efficient', DEA.	Uses log-linear regression model to identify predictors of efficiency. Analysis of efficiency scores by various categories.	Analysis of efficiency scores. Partitioning. Use of regression model to identify predictors of efficiency.

5. Multi-methodology/ Mixed methods

The LVI study uses a combination of qualitative and quantitative methods, which has been the subject of discussion in the literature of several disciplines. The two disciplines identified as most relevant to the application and context are discussed below: Operational Research (the source of DEA) and Educational Evaluation.

5.1. The Operational Research Approach - Multimethodology

Ackermann et al. [11] suggest that some Operations Researchers "are developing methods to try to resolve some of the limitations of the quantitative methods, to add to the power of quantitative methods and to provide further benefit to managers by

focussing on predominantly qualitative data and unstructured problems." They then give as examples, SODA, Strategic Choice and Decision Conferencing which are soft methods developed within the OR literature. In their study, "Modeling for Litigation: Mixing Qualitative and Quantitative Approaches", a combination of 'soft' and 'hard' Operations Research methods was used in order to meet the needs of the problem.

In "Multimethodology: Towards a Framework for Mixing Methodologies", Mingers and Brocklesby [12] take a closer look at the practice of combining different OR methods and how this can deal more effectively with the richness of the real world and better assist through the various intervention stages. They propose a categorisation of the phases of intervention as Appreciation, Analysis, Assessment and Action.

The LVI study illustrates a pluralist paradigm, by incorporating extensive qualitative research, comprising interviews and a case study analysis, alongside the quantitative analysis, using Data Envelopment Analysis, of 'hard' data about individual children. It is seen that the qualitative analysis will be involved more in the Appreciation and Action phases, while the DEA will come to the fore in the Analysis and Assessment aspects of the problem. Whether in fact this presents a pluralist or pragmatic paradigm depends on the worldview of the reader.

5.2. The Educational Evaluation Approach: Mixed methods

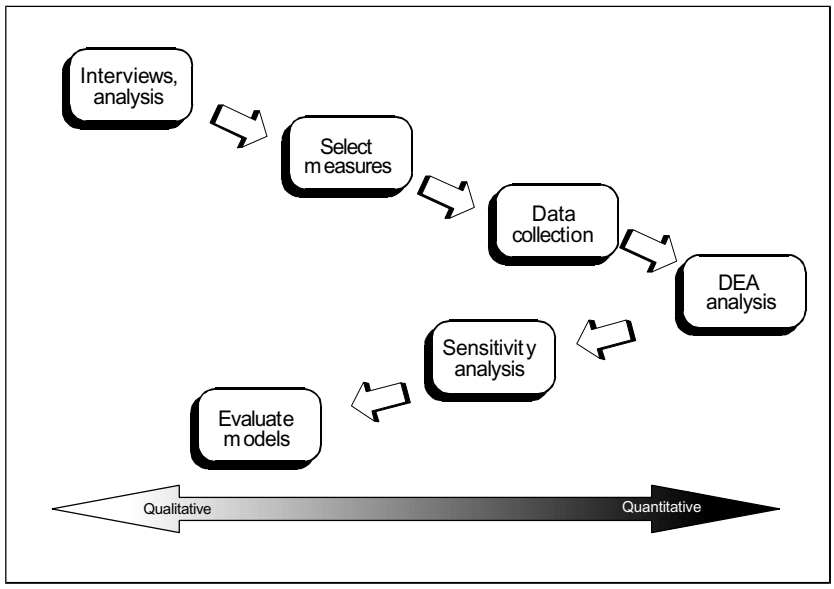
In the area of educational evaluation, there is a move towards mixed methods, which draw on the strengths of both qualitative and quantitative methods of enquiry. This comes from a practical need, similar to that of Operations Research, to capture the full picture in an evaluation, in a way that is richer than that which either the quantitative or qualitative paradigm individually can accomplish.

Greene and Caracelli [13] propose three stances on mixing paradigms in mixed-method evaluation. These are 'purist', 'pragmatic' and 'dialectical'. The purist approach states that paradigms cannot be mixed, and that qualitative and quantitative enquiry cannot be sensibly combined. The pragmatic approach maintains that paradigms are descriptive rather than prescriptive, and that inquirers should be able to choose what will work best in the particular circumstances. The dialectical position acknowledges and embraces the differences between the qualitative and quantitative paradigms. In fact the discussion between the two approaches results in a whole that is greater than the sum of the parts. The authors propose that "compared with knowledge claims produced in a single-method study, this multiplistic, mixed-method set of knowledge claims is likely to be more pragmatically relevant and useful, and more dialectically insightful and generative, even if accompanied by unresolved tensions." [13, page13]

The dialectic approach is attractive for the LVI study, in that the potential conflict between the reality as described by the two parts of the study will in itself inform decision making and enlighten the understanding of the problem. Originally a two-phase developmental approach was proposed wherein the first method is used sequentially to help inform the second method [14]. However as the study progresses, the design is evolving into a more iterative process wherein the qualitative informs the quantitative which in turn informs the quantitative, in a cyclical manner. This is described in "Crafting Mixed-Method Evaluation Designs" by Caracelli and Greene [15] as an integrated, iterative design, in which cyclical designs are characterised by "a dynamic and ongoing interplay over time between the different methodologies associated with different paradigms."

5.3. The Process

The relationship between the qualitative and quantitative aspects of the research and model building are illustrated in Figure 1. In this is shown the move from the qualitative approach, set in the 'real world' which shifts gradually into the world of modelling, where the DEA analysis takes place. This is followed by a shift back into the real world to perform sensitivity analysis and evaluate the model. This figure shows a rather sequential process, but as the thinking about the process begins at the end and works back, we oscillate gently between the 'real world' and the quantitative world of mathematical modelling.



1. The modelling process

6. Summary

This paper has used the specific case of identifying resource needs for learners with vision impairment to illustrate the potential use of a mixed method approach, using qualitative interviewing to inform the development of a DEA model. It has been shown that this is potentially a powerful combination, enriched by the tension between the qualitative and quantitative paradigms.

The use of DEA on data relating to individual people, rather than organisational groups is illustrated. Parallels have been drawn with similar studies in the education and health sectors, and a framework introduced for comparing DEA applications.

The proposed method has the potential to provide a model that is acceptable to the stakeholders and can improve use of resources. As such it has a multitude of future uses in health, special education and social work.

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