

Total cost of ownership: A review of the literature

A report to the DfES by Peter Scrimshaw



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Declaration of interest

The author holds some shares in RM plc, a provider of managed services to UK schools.
Neither he nor his immediate family has a financial interest in any other companies
providing ICT services or equipment to schools.

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Executive summary

The brief for the external reviewer and colleagues from Becta was to:

- carry out a survey of the extant published literature on total cost of ownership (TCO)
- refine this to those publications that bear directly on education, or offer useful insights
- prepare a report that summarises and interprets present views on TCO.

This report is based on some 135 documents identified by Becta through a literature search and on the subsequent review of the relevance of the items found. The documents come from both business and educational sources, are published mainly in the UK and USA and range in style from popular articles to academic research. A distinctive feature is that virtually all the texts are either business-related or discuss US schools. Given this, the literature review reported here is in two main parts; one is a descriptive analysis of what the documents contain, the second an extrapolation from this to the relevance of these findings for schools here.

The introduction makes up Section 1 of the review, covering purpose and methodology. Section 2 begins with an analysis of the various uses for TCO, and the differences in scope and conceptualisation of TCO to be found in the documents. Important distinctions here include those between TCO approaches that:

- take the individual institution as the unit of account and those that range wider
- use only quantifiable costs and those that include others
- restrict themselves to monetary costs only and those that take in other kinds of costs too.

The relationships between TCO and such concepts as cost-benefit and cost effectiveness are also touched on.

The review then reports what the literature has to say on how to implement TCO in practice. This includes both educational and (where relevant) business texts. Planning the introduction of TCO is very little covered in the document set, but there are a number of sources on ways of carrying out a TCO analysis and then subsequently making use of it. Nearly all the literature reviewed is favourable to TCO in principle, but there is a

wide recognition that implementation is not straightforward. However, a number of ways of overcoming obstacles to implementing TCO are also identified.

The final section in this part of the review considers what is reported about the actual costs of TCO. The various US and UK studies were carried out at different times and there have also been differences in relative inflation and exchange rates, as well as in the underlying staffing and equipment costs in the two countries. It is concluded therefore that there are serious difficulties in transferring the information about TCO in business situations to the educational context, and that the US figures for schools and school districts can give only very general guidance.

Section 3 of the review comprises a discussion of how the earlier material might be brought to bear upon TCO in schools here. It identifies the kinds of TCO models that could be made available for use in education and considers what should be included in the element common to all such models, namely the monetary costs within a single school. The advantages and disadvantages of two different possible strategies for collecting TCO data are then compared. One of these starts from single-school data and aggregates this into local and national totals, while the other starts with national data and disaggregates this into figures for representative kinds of school. Finally, some of the implications of the review for choosing which kinds of TCO analysis to use in schools and LEAs are briefly summarised.

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1. Introduction

In recent years there has been a massive and continuing expansion of government expenditure on providing the preconditions for the effective use of ICT in schools.

This has included direct central funding for:

- a series of research and evaluation initiatives to identify ways of improving practice and policy
- the near-universal provision of training in the classroom use of ICT for teachers and student teachers
- very substantial expenditure on the development of the National Grid for Learning (NGfL)
- the physical infrastructure needed to make use of ICT in the classroom.

In addition, LEAs, schools, teachers, parents and other members of the community have contributed funding, time and other resources to achieve the same end. In that context it becomes important to establish what the total cost of this initiative might be, and how schools can make best use of that funding. This review forms part of that programme.

1.1. Purpose of the review

The brief that was set for the external reviewer and colleagues from Becta was to:

- carry out a survey of the extant published literature on total cost of ownership (TCO)
- refine this to those publications that either bear directly on education or offer useful insights
- prepare a report that summarises and interprets present views on TCO.

1.2. Methodology employed

The review was conducted in two stages. In the first, Becta staff undertook an extensive literature search. An experienced Becta team, including members of the Schools Directorate, then reviewed the initial document set of some 135 items and picked out those that appeared potentially relevant to the study. This literature review is based on that selection, although not all texts included are referenced here as there was a substantial degree of overlap in content. Superscript numbers in the main text refer to the relevant sources; these sources are provided in the references list at the end of the review.

The document set was not restricted to academic research papers. There were rather few of these, mostly concentrating on the role of TCO in business and the relevance of this to the work of purchasing and accounts departments. There were, however, a few academic papers on the use of TCO in UK post-compulsory education. The document set also included texts providing practical advice on the technical implementation of TCO and related tasks such as carrying out audits. In addition, it contained summaries for business or education professionals of the evidence about, or the case for, establishing TCO procedures and how to make use of the findings in practice.

Most of the business studies reported were carried out by independent organisations funded by ICT companies, or were reports on the use of various TCO systems, sometimes by end-users, sometimes by consultants or freelance writers, and sometimes by the firms providing the systems.

Nearly all the non-academic texts were from the UK or the USA, with those countries and continental Europe providing the academic research element. The American sources include nearly all the business-based contributions and a number of reports on the application of TCO in US schools. The UK sources, by contrast, included little that was directly centred on identifying TCO in schools, though there were contributions on its use in post-secondary contexts. Instead, the UK school and college-related texts dealt with the techniques and procedures for assessing more broadly the effectiveness of using ICT to support school development. This UK literature thus covers such issues as financial auditing and inspection procedures, with costs as only one aspect of the development of ICT-based training.

Reviewing this document set presents two problems. The first is that the literature varies very considerably in depth, purpose and independence of judgement. The second is that very little of it deals directly with the topic of the review, namely identifying the total cost of ownership of ICT in schools and LEAs in England.

The presentation of the findings (Section 2 of this report) is therefore divided into three parts. The first reports on the range of conceptual frameworks represented in the literature, and how they vary. This allows the use of both educational and business texts as sources of concepts or to identify issues that need to be addressed, bypassing the question of the reasons for which

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particular issues are highlighted or downplayed by particular authors. The second part reports on what has been found out about the practical implementation of TCO. Here the weight of emphasis moves more strongly to the educational sources, as the differences in scale and ethos of schools and businesses make the business literature less relevant. In the third part, the limited evidence on actual costs is reviewed. This is almost all school related, but is nearly all drawn from US sources.

Finally, in Part 3 the relevance of all this to schools in England is discussed. Here the reviewer's own interpretation is unavoidably brought into play in terms of selection, relative emphasis and comment.

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2. Findings

2.1. Understanding total cost of ownership

Total cost of ownership (TCO) is potentially a key concept in the whole area of improving the provision and use of ICT in schools. Put at its most general, total cost of ownership is the sum of all the costs associated with a given aspect of an organisation's work. This is of course an incomplete definition. The remainder of this section uses the literature reviewed to fill out what this involves.

2.1.1. What can TCO be used to do?

In a business context¹⁸ a TCO analysis can be used to:

- select suppliers (e.g. by evaluating bids or challenging costs)
- communicate with suppliers and others
- carry out on-going management of suppliers (e.g. by evaluating supplier performance)
- drive improvement (e.g. by reducing costs^{27 39} or improving processes)
- create understanding within the organisation (e.g. of the critical or major cost factors).

In a school context this relates to such matters as the choice between a single-sourced managed service for ICT and the use of a variety of suppliers, the initial and on-going negotiations with the suppliers. It also points towards the potential value of an analysis in reducing initial or on-going costs, and assisting heads in identifying the most significant of the costs involved.

2.1.2. How widely can a TCO analysis extend?

This has two dimensions; identifying the boundaries of the institution being considered and determining whose costs are to be included.

Delimiting the institution

In delimiting the institution to be dealt with, nearly all the papers reviewed take the individual business, school or university as the unit of account. However, a few take other units as the basis for analysis, such as US school districts⁶, or identify separate costings for both schools and US school districts³³.

In the case of large businesses, many are obviously multisite¹⁵ and have thousands of computers, so in terms of scale are more like LEAs than schools, or (in the case

of very large multinationals) are of roughly comparable scale to the entire education system of a small nation. As represented in the literature, TCO analysis is therefore an approach that has mostly been used in organisations very different from schools.

Delimiting whose costs to include

Another dimension of the TCO analysis concerns whose costs are to be included. If countable costs are restricted only to those incurred by the organisation as a formal entity, then the accounting for these is somewhat less difficult than if costs incurred by individual workers in, so to speak, their own right are also allowed. However if, for example, staff work additional unpaid hours or take part in self-funded training that increases the success of the organisation, then it is not clear whether this cost should or should not be included.

Beyond that, a case is made in some papers for a wider perspective still. As one higher education study⁷ notes:

Spillover costs, otherwise known as external effects or externalities, are costs and benefits which accrue to agents other than those originally involved in the decision to undertake an investment project.

Where schools are concerned, for example, there are other stakeholders (such as parents and governors) who contribute time and home-purchased equipment to supporting the school. It is open to the designers of a given costing exercise to decide whether to include the costs incurred by such groups.

2.1.3. How can cost categories be conceptualised?

This section covers a range of dimensions along which cost categories are conceptualised in the literature.

The hard/soft problem

One approach to this identifies three kinds of impact that a TCO analysis can have on costs and benefits. As one paper¹⁴ puts it, there is a need to:

...classify each cost or benefit according to its quantifiability and predictability. Hard impacts, such as the cost of new hardware or the savings in personnel costs after a process has been automated, are controllable and easily quantified. Soft impacts, such as market share or productivity gains, are less certain and depend on uncontrollable factors such as consumer response, but can and should be quantified through simple analysis. Unquantifiable impacts, such as improved

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competitive position or increased customer satisfaction, are uncertain and difficult to quantify, but must be described and debated if companies are to reach the right decision.

The money/non-money and direct/formula cost problems

Another related aspect of defining cost categories is to decide whether these are to be restricted to money costs or are also to include financially unquantifiable costs such as the work teachers have to do at home as part of their ICT training: what one author¹⁷ calls the dollar-based and value-based approaches. This issue is related to the question of the extent to which apparently value-based benefits, such as levels of qualification gained, can be usefully translated into money equivalents, such as the estimated increased income that a person might gain through being awarded a given qualification.

A linked issue is whether, in calculating costs, to use actual costs for each item or a general (but evidence-based) formula. Thus, for example, rather than calculating precisely how much time an ICT co-ordinator spends on network maintenance over a year, an approximate figure could be found if he or she kept a rough log over a much shorter but reasonably representative period. This could then be translated into a general formula to calculate the approximate annual cost of that time. These approaches are respectively known as the direct-cost and formula versions of dollar-based approaches.

The advantages and disadvantages of these approaches are summarised¹⁷ in one US source (Table 1).

Table 1: Comparison of relative advantages of dollar-based and value-based TCO models

Type of model	Model advantages	Model disadvantages
Dollar-based – direct cost	Tailor factors considered to decision Very flexible Alter level of complexity to fit decision Help identify critical issues	Time consuming Does not make sense for repetitive decisions Not cost beneficial for low-dollar buys
Dollar-based – formula	Easy to use once system is in place Excellent for repetitive decisions where costs for key factors can be determined	Time consuming to establish system Formulae need to be periodically reviewed and updated Inflexible to different types of decisions Considers a limited set of factors
Value-based model	Can incorporate issues where costs cannot be determined Considers the importance of factors using weighting Easy to use for repetitive decisions	Time consuming to develop: only good for important and/or repetitive decisions Much judgement in establishing weightings

In essence, using actual costs is time consuming and complex, but precise. Using a formula-based approach is far quicker but less accurate. The choice between a purely monetary assessment of costs and one involving other kinds of costs is rather different. The former is simple to carry out but can give a misleading picture in educational contexts, where some of the key costs are not simply financial. As the Audit Commission¹¹ observes, it is important to:

Avoid just measuring things that are easy to measure, for example routine work, rather than those that have the greatest potential value, such as the outcome of services.

Nor is it essential to use the same approach to TCO for all purposes. One study¹⁷ looked at which of these approaches the businesses researched used for which purposes. Deleting purposes not relevant to educational contexts gives the modified version of this finding shown in Table 2.

Table 2: Primary uses of various types of model

Type of model	Primary uses
Dollar-based – direct cost	Supplier selection Process improvement
Dollar-based – formula	On-going supplier evaluation Process improvement
Value-based model	Supplier selection Process improvement

In terms of ICT procurement, this suggests that either a dollar-based direct cost or value based model should be considered when choosing between different types of ICT provision (such as a networked suite or the distribution of computers in classroom clusters). Once the basic choice is made, selecting from a range of possible providers again gives scope for using a TCO comparison for on-going evaluation of the supplier or suppliers. Here the quicker and more approximate formula method may be all that is required to check that costs are remaining within acceptable bounds.

Finally, where TCO is to be applied across a range of institutions or activities, there is a choice to be made between using a standard TCO model for all cases or developing a unique model for each separately. The advantages cited for the standard model approach¹⁶ is that it is faster, and it is generally easier to train people in its use. Conversely, unique models generate a great deal of user support and co-operation.

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How detailed should TCO categories be?

TCO gives no direction in itself as to what level of detail of analysis is best. Generally a two-level hierarchical system is used, in which costs are allocated to a small number of major categories and then to subcategories within these. Clearly the optimal level of detail depends both on the reason for carrying out a TCO study and such practicalities as the time available and the ease with which available information can be used for the analysis.

The specific headings included vary from study to study, but Table 3 shows a broadly representative example. Whilst this illustration³² is from the business world, it contains much that is comparable with the situation facing schools. The staff costs in particular are revealing, as they imply that a school needs, for instance, to identify how much time the head, the IT co-ordinator and the staff responsible for staff development will need to allocate to planning, supporting and judging the success of, the introduction of new ICT systems. As the New Opportunities Fund (NOF) experience (or indeed any major curriculum development) shows, these demands are substantial, both at school and LEA level. Adding such expenditure to the picture (especially where on-costs are included) can make a significant difference.

How can an organisation's costs best be categorised?

This question has two components:

- how, if at all, to subdivide the ICT-related activities
- how to categorise the various costs relative to each of these subdivisions.

Several sources recommend activity-based costing for business use, largely because it allows easy cross-linking to cost-effectiveness and cost-benefit analyses. In most of the business examples cited, the TCO for ICT-system use is subdivided into the different activities involved in the creation and sale of different products. The school-based analyses by contrast all take TCO for ICT-related use as a single entity. However in one study of university costs²⁴, the costs of all the activities of given departments are separately established.

Another dimension along which an organisation's ICT-related activities and costs can be divided^{4 28} is in terms of the various stages of introducing and using the ICT system. One of the claimed advantages for a stage analysis is that it emphasises the importance of including pre-and post-use costs in the total.

Table 3: Illustration of hierarchical breakdown of cost components

Component	Items included	
Staff costs	Senior management time (directors etc.) IT manager/computer services manager Network manager Network technician(s) IT co-ordinator Training officer Calculated using formula: (Annual salary + on-costs) x proportion of time spent on IT-related issues On-costs are typically 20%–50%	
Capital costs	Hardware: Servers Stations Switches/routers/bridges Cabling infrastructure Cabinets Peripherals • printers • scanners • plotters	Software: Network operating systems Network management tools Client operating systems 'Standard' application software Specialist application software
Maintenance costs	Hardware maintenance contracts: • servers • active network components (switches, routers etc.) • stations Spare parts (if broken out separately from recurrent spend)	
Support costs	Support contracts Professional services (consultancy etc.) Training courses	
Recurrent spend	Consumables (printer cartridges, floppy disks etc.) Spare parts (unless covered under maintenance contract) Internet charges (ISP connection, JANET etc.) Communications costs (leased-line rental, ISDN connection etc.) Call charges	

Whichever way activities are subdivided, there is a need for a further level of detail in terms of dividing costs. Most of the papers use some variant on a classification that includes costs associated with such things as staffing, equipment, software, upgrading and training, but there are wide variations from one classification to another. In the business literature reviewed, the most widely endorsed approach of this sort is the Gartner model, developed by a US consultancy in the mid '90s and widely used and adapted since then.

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As described in one Microsoft paper²⁶, this model categorises costs as follows:

Budgeted costs are items that are typically budgeted to the IT cost centre, such as:

Hardware and software (capital expenditures and leasing fees for new installations, upgrades and updates)

Management (network, system, and storage administration labour and outsourcing fees; reactive and proactive management tasks)

Support (help desk, training, purchasing, travel, maintenance and support contracts, overhead labour)

Development (application and content development, testing and documentation, including new developments, customisations, and maintenance)

Communications fees (leased-line and server-access charges)

Unbudgeted costs are unbudgeted or indirect items often disregarded in most organisations, including:

End-user costs (peer- and self-support, casual learning, and repeated trial-and-error manipulation of the system)

Downtime (lost productivity due to planned and unplanned outages).

2.1.4. How is TCO related to other concepts?

One author³⁴ has argued that the case for establishing TCO of a company computer infrastructure is that it is a precondition for identifying the total benefit of ownership and the total return on ownership (i.e. total benefit less total cost). The latter is the key measure. In a school context this would place the focus not on getting the lowest possible cost of ownership for a given level of ICT provision, but in identifying, within the finances available, the form of provision and the ways of using it that provided the greatest educational benefit for its cost.

This in turn leads to consideration of the role of TCO in establishing the relationships between cost, effectiveness, efficiency and benefit. A number of different definitions of most of these terms are included^{7 22 36} in the literature reviewed. Arguably the most useful ones²⁹ for present purposes are these:

A cost/benefit statement would simply state the unquantifiable benefits which would be obtained for a net financial cost (costs less financial benefits). No attempt would be made to quantify the non-financial benefits and, consequently, management judgement would have to be used to assess the best option.

Cost/benefit analysis is a method of assessing which of a group of alternative options provides the best cost/benefit ratio. It is based on the assumption that a financial value can be applied to all benefits that arise from a course of action.

A cost/efficiency analysis is a simplified cost/benefit analysis, which can be done when either the benefits or the costs are the same for all alternatives.

A cost/effectiveness analysis (...) would be most effective in option appraisal where several competing options are assessed for their effectiveness in comparison to their cost. Their effectiveness is gauged by allocating a weighted grading to each of their potential benefits.

As this makes clear, one reason for establishing costs is to make it possible to carry out a cost-benefit study. This means that the structure of possible benefits also needs to be analysed. For the purposes of this report it is perhaps enough to say that all the issues raised above about the conceptualisation of costs arise in very similar ways in considering benefits, while there are, of course, additional issues involved in establishing relationships between the two.

TCO models vary considerably in what they cover and how they analyse it. These differences probably arise in part from the various purposes for which TCO is to be used, in part from different assumptions about what kinds of costs are important. Part 3 will look at how all this must be taken into account in planning a TCO analysis in an educational context, but the actual task of practical implementation raises additional issues, to which we must now turn.

2.2. Implementing TCO

As the previous discussion indicates, there is a range of ways of designing a TCO analysis. Here we look at how it has been implemented especially in the educational context.

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The practicalities of designing and carrying out a TCO analysis are discussed in many of the documents reviewed. In essence it is seen as a major organisational innovation in its own right. The information on this is thus best presented in terms of the stages through which the innovation needs to go as it moves from initial conception to becoming a built-in feature of the organisation's life. This section therefore covers:

- planning a TCO analysis
- carrying out the analysis
- making use of the analysis as part of a wider development programme
- building the on-going use of TCO procedures into the organisation.

2.2.1. Planning a TCO analysis

The planning of TCO is relatively little discussed in the literature, but in effect the literature reviewed in the previous section offers an agenda for such planning. The aspect of that planning not covered there is a review of the current situation within which the TCO work will need to be carried out. The issues this raises are picked up later in this section.

2.2.2. Carrying out a TCO analysis

In undertaking the analysis several problems have been identified.

In one study¹⁸ all the 11 companies researched reported that a TCO analysis was seen as being time-consuming to develop. Times quoted to produce a suitable model for a specific product ranged from hours to weeks. Some respondents also saw TCO as difficult to understand and to explain, sometimes complex and vulnerable to lack of user expertise.

None of the companies covered by this study had a system already in place that readily provided the figures on costs that TCO required. Another study¹⁰ suggests that there may be an even greater problem in public-sector education in the USA, as the role of and procedures for public and private sector accounts are very different.

In the public sector, accounts are designed to allow central staff to regulate spending and to check that money has been spent in accordance with proper procedures, rather than in order to inform management

choices. This means that there is little pressure to unify the information systems used so that the costs of particular activities can be kept under review. Again, within a regulatory system it is essential that the central office has oversight of everything, but those who actually use the resources often do not get an opportunity to see the overall picture. These differences¹⁰ would make it hard to use the outputs of public-sector accounts for the purposes of TCO, which is essentially a tool for management rather than regulation (see Table 4).

Table 4: Comparison of public- and private-sector accounting methods

Public-sector accounting	Private-sector/corporate accounting
Regulatory accounting. Reports to government agencies; fulfils fiduciary responsibilities.	Managerial accounting. Data are made available to improve efficiency and productivity and for use in making management decisions.
Separate information systems. Often uses different systems for personnel, operations, accounting, and education services.	Integrated information systems. Systems produce integrated information on production, personnel, productivity, and costs.
Generalised information. Often issues broad and general data on spending and costs, mainly to get the budget passed, not to inform the public about the costs and productivity of the system.	Focused/activity-based costing. Spending is related to production using activity-based costing (also called responsibility-centred accounting).
Centralised information. Most accounting information is kept at the central office; principals, teachers, and parents participate only in basic budgeting, not in accounting oversight.	Decentralised information. Each production unit has its own budgeting and accounting role to control costs.
Control-driven accounting. Accounting is for administrative control and to inform the superintendent and central office staff.	Mission-driven costing. Spending is related to mission, not simply to regulations and controls.

However, it is less clear that in the English context this public/private distinction is now so evident, at least at the national and LEA levels in the public sector. Thus for example, the Chartered Institute of Public Finance and Accountancy⁹ defines the total cost of a service to include all costs that relate to the provision of the defined service (whether directly or bought in) or to the undertaking of the defined activity. The Institute points out that the total cost must reflect all the costs associated with that service or activity, wherever in the management structure they arise. This kind of analysis could clearly support an activity-based approach to TCO.

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That does not, however, imply that what is required is a move to replace regulatory accounting with managerial accounting, as what is needed is an approach that combines both. As the Audit Commission¹¹ observes:

Public funds need to be used wisely as well as in accordance with the law, so today's auditors have to assess expenditure not just for probity and regularity, but also for value for money.

Several ways of solving these problems in carrying out a TCO analysis were identified in the literature.

One was to use an approach³¹ that was situation specific and therefore responsive to users' concerns and local problems of implementation in accounting procedures. In principle this could be done in a school context too, but this approach would probably need to be combined with local and central support plus advice of the kinds described below.

Another strategy was to create a better understanding of TCO within the organisation. In some cases¹⁸ this was achieved through training sessions with a core group who could subsequently be called upon to provide guidance on developing the TCO framework and, more generally, to act as a support group for those developing or using TCO models. One way of doing this³⁷ was to set up value-analysis workshops. In these, key staff were brought together over three to five days to develop the organisation's approach to TCO, to establish the reason for employing it and to identify likely implementation problems. In an LEA context this might, for example, involve starting with a planning group of heads to develop the approach, with the members subsequently being available for consultation by fellow heads.

Another widely advocated approach in business was the external provision of organisation-specific advice and support using web sites of resources and consultancy advice, while the provision of TCO analysis tools^{3 12 19 20} offers another way of handling the complexities of the task. A variant on this approach has been for external agencies here^{5 38} and in the USA^{19 20} to publish, in print or electronically, advice for schools on how to implement TCO. These reports illustrate various ways of blending provision of a framework for analysis with guidance on how to implement it.

This guidance may take the form of a checklist¹⁹ as in this example:

A quick checklist for technology budgeting

After a district has purchased computers and installed a networking infrastructure, here are the major expenses and technology decisions for which school administrators must be prepared.

Retrofitting: *When your district is ready to build a network, has it budgeted adequately to upgrade electrical capacity, improve heating, cooling and ventilation systems, beef up security systems and remove asbestos and lead found in older buildings?*

Professional development: *Has your district budgeted an adequate amount for staff training, including the cost of trainers, materials and substitutes if training is conducted during school hours?*

Software: *Has your district budgeted adequately for network-management software, computer-based curriculum materials, applications and productivity software and the software needed to adapt technology to the special needs of users?*

Support: *Has your district budgeted adequately for staff to maintain the network and other hardware and to help others solve their software and hardware problems?*

Replacement costs: *Has your school district budgeted adequately to cover the costs of replacing computers and other peripherals?*

Connectivity: *Has your district budgeted adequately to cover the costs involved with connecting schools to each other and to the Internet? Lower-bandwidth connections will generally cost less but will involve a tradeoff in the complexity of the information that can be shared and the amount of time it will take to download files or access information.*

Alternatively, the framework for analysing current costing practices can be implicitly combined with guidance on how to improve them.

One American author, for instance, characterises²⁰ the problems that TCO should help to address as follows:

For many school districts, the technology portion of the budget is regarded as a 'frill', or something that they will worry about once they get all of their initial

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purchases made. Faced with the substantial expense of wiring their schools and installing computers, districts nevertheless manage to find the money from a variety of sources (...) But many are ill-prepared for the long-term costs involved with operating that equipment effectively.

If school officials don't provide adequate funding, computers will sit idle because teachers don't know how to use them. If they don't budget enough money for tech support, the reliability of the district's network could be compromised. And if school officials don't make plans to replace the computers they are now installing, they will end up, five or six years from now, with a district full of rapidly ageing, if not obsolescent, equipment.

If that happens, a backlash against educational technology could easily develop when taxpayers

discover that the investment they made less than a decade before has been so poorly managed that it needs to be made all over again.

The author then presents a solution²⁰ in the form of a table of options (Table 5) that allows the reader to benchmark the performance of their own school district against the three models given.

2.2.3. Making use of a TCO analysis

As several papers point out³⁴, there is no point in establishing the total cost of ownership of ICT unless there is a clear wider purpose for doing so. Without a prior view about the point of doing the analysis, it will be impossible to decide what kind of analysis is required or how the results are to be used. In both educational and business contexts, TCO is generally seen as contributing in two main ways:

Table 5: What is your school district's total cost of ownership type?

	The 'TCO-Savvy' District	The 'Doing the Best We Can' District	The 'Worry About It Tomorrow' District
Professional development	Devotes 15–30 percent of its budget to staff development.	Provides some staff training, but not at times that are convenient or when staff are ready to put the lessons to work.	Assumes that teachers and staff 'will learn on the job'.
Support	Provides computer support at a ratio of at least one support person for every 50 to 70 computers or one person for every 500 computers in a closely managed networked environment.	Relies on a patchwork of teachers, students, and overworked district staff to maintain network and fix problems. Does not track the amount of time its network is down or computers are not in use.	Relies on the 'Hey, Joe' sort of informal support.
Software	Recognises that the greater diversity of software packages and operating systems, the more support will be required. Makes provision for regular upgrading of software packages.	Uses centralised software purchasing, but choice of application and respective support left to individual schools and/or staff members.	Expects support personnel to manage whatever software happens to be installed on a district computer.
Replacement Costs	Budgets to replace computers on a regular schedule, usually every five years, whether leased or purchased.	Plans to replace computers when they no longer can be repaired.	Assumes that when computers are purchased with 20-year bonds that they will last forever.
Retrofitting	Recognises that many school buildings will require recommended modifications of electrical, heating, and cooling systems, infrastructure as well as asbestos removal, to accommodate new technology and budgets accordingly. When possible, makes these improvements when schools are being built or renovated.	Understands minimum and requirements for electrical and other improvements, and incorporates them when funding is available.	Pulls the wires and then blows the fuses.
Connectivity	Plans its network to provide connections that provide enough bandwidth to manage current – and future – needs, especially multimedia applications.	Has the bandwidth it needs today, but has no plan for scaling it upward as demand grows.	A phone and a modem, what more do you need?

Total cost of ownership

- as an aid^{13 19 23} to improved procurement of ICT systems
- as part of an overall strategy^{20 21 31} for improvement.

The texts on improved procurement range from academic studies of ways of choosing between different suppliers¹³ through general advice on public service procurement strategies²³ and discussions of the relative merits of purchase, leasing and managed services^{11 38} to school-related^{19 33} studies.

The place of managed services³⁸ within the TCO debate is also mentioned. One contributor¹¹ argues that there is no need for systems purchasers to carry out complex TCO reviews, as a school or school district can instead agree a managed service contract defined in terms of a price per end-user desktop (or seat price) for a fixed period. This approach appears to transfer the TCO calculation (or more precisely, the total cost of providing ownership calculation), to the vendor of the managed service. However, such a transfer, in the absence of any internal TCO exercise, gives the purchaser no independent point of reference for evaluating the price proposed.

Furthermore, early indications from the Pathfinder evaluation³⁵ are that even with managed service provision, schools can still incur management costs:

Schools do not appear to be making the best use of managed service providers. Such a service should free senior staff and ICT co-ordinators to focus more attention on the curriculum uses of ICT. However, there is evidence that in many schools senior staff have not 'saved' time on technical issues, but are now dealing with them indirectly through negotiations with the managed-service provider...

The use of TCO as part of a general strategy for curriculum development and improvement sets the approach within a still wider framework. As one writer²¹ puts it:

Too often well-meaning school districts may plunge into a major technology project without fully understanding what the project will cost – or, more importantly, what they hope to achieve by making technology improvements.

UK contributors^{1 9 31 36} usually deal with costing as a small part of a broader discussion of performance indicators, best value or financial management. The US contributors

by contrast generally move from TCO as a practice into some briefer consideration of these wider issues. Both kinds of approach, however, emphasise that there is a role for cost analysis within these wider strategies.

This means that in addition to the intrinsic problems of introducing TCO, the innovator is also faced with the need to do this while introducing a wider change in the management process. The practical difficulties of introducing large-scale ICT-related management changes are picked up in the US business literature. Referring to one such general innovation (introducing enterprise systems management, or ESM) one author²⁵ observes:

In the rush to achieve the benefits of ESM technology, managers consistently overestimate the ease of implementation and underestimate the TCO of the software, focusing on the purchase price but ignoring the costs and challenges of implementation and daily operation.

The same author²⁵ lists the following obstacles to productive use of ESM:

- lack of skilled/experienced staff
- failure to demonstrate quick results
- over-ambitious implementations
- failure to perform adequate vendor/software evaluation
- failure to tie ESM to business requirements
- lack of effective processes/organisation.

A very similar list of obstacles could be generated from the curriculum development research, and indeed the preliminary Pathfinder report³⁵ shows that some of these obstacles have already been encountered by some LEAs:

The Pathfinder LEAs, having had no experience of implementing similar large-scale technology initiatives, did not have personnel in leadership roles at the outset with the prior experience needed to lead the NGfL initiative.

One issue has been that personnel involved in strategic planning are not necessarily those with the necessary skills to take forward implementation. One approach adopted in a number of LEAs has been to appoint a project manager to this link role with specific responsibility for liaising between schools and LEA strategy groups. Other LEAs have set up working parties with school representation.

Total cost of ownership

However, in general, across the Pathfinder LEAs the potential mismatch of skills and responsibilities has not been sufficiently recognised.

2.2.4. Embedding TCO procedures into the organisation

For some, TCO analysis is not a technique for occasional use in connection with major purchases, but should become an integral and widespread part of the organisation's approach to its work. For supporters of this view, TCO's lack of fit with the organisational culture was another obstacle to implementation. In some companies researched in one study¹⁸, there were anxieties that TCO would eliminate jobs, that those making purchasing decisions needed new skills to use the approach, that internal users needed to be convinced of its benefits and that it needed to be seen by the rest of the organisation as more than just a purchasing programme.

In this same study, user resistance, fear and lack of user confidence were also mentioned, as was a concern that using a standard system might lead to loss of flexibility and loss of individual control. There were also some fears that TCO would be used negatively against suppliers rather than positively to improve things, and conversely that some suppliers would manipulate the results because they were now aware of the cost implications.

To meet these difficulties, some informants in that study suggested that the right model was one that was flexible, responsive both to the situation and to the corporate culture, user friendly and capable of evolving over time.

Others emphasised the importance of obtaining support from the right people, with top management and the TCO users seen as the key groups. For these firms, one of the longer-term goals was to have TCO accepted across the organisation as a model to be used in supporting sourcing decisions.

For implementation, then, the literature indicates that there are major problems to be addressed although ways of doing this have also been identified.

2.3. Identifying actual costs

Some of the business-related documents in the literature reviewed^{16,30} contained detailed sets of TCO figures, but this was unusual. It was also notable that only a small proportion of sets of costings included from any source

appeared to be based on analysis of costs for specific institutions. However, one example was an RM study³² of a sample of FE and sixth-form colleges. This reported that:

Based on an analysis of data received from a sample of approximately 10% of UK colleges in 1998, the following conclusions and observations may be drawn.

- 1. The total annualised costs of purchasing, maintaining, supporting and operating a networked PC in the FE sector was approximately £1,100 per year. This ranged between about £800 and £1,400 per annum, depending on the scale and complexity of the network, and type of institution.*
- 2. Smaller establishments such as sixth-form colleges had a lower TCO (less than £1,000 per PC per annum) than the larger FE institutions. The reasons appear to be that these networks tend to be relatively simple LANs based on a single site, and many of the staff costs were hidden through the use of teaching staff to support the networks on a part-time basis. The larger institutions were typically spread across more sites and offered a greater level of functionality (video conferencing, networked multimedia, intranet, etc.) and employed dedicated IT support teams to maintain and support the provision.*
- 3. The average level of investment in IT was about 4.7% of turnover for most colleges, although this varied significantly with a range of 3.3% and 7.8%.*
- 4. For colleges in England, the scale of the IT provision was in the order of one PC for every 1,000 learning units.*
- 5. Staff costs typically comprise 42% of the TCO.*

Another education-related report gave fuller information. This was a Scottish higher-education study²⁹ which generated figures based on hypothetical university departments to show the relative costs and benefits that might be involved in various kinds of new uses of ICT. Tables 6 and 7 show the figures for one of the examples.

Total cost of ownership

Table 6: Direct costs and financial benefits for hypothetical laptops initiative

Direct costs and financial benefits	
The costs which will be directly attributable to the teaching of class 1234 in physics are:	
Teaching of class 1234	Five-year cost (£k)
Direct capital costs	
400 laptops @ £1,000 each	400
Radio modems receiver towers	20
Direct revenue costs	
Operating system licences (one-off payment of £100 per machine)	40
Software maintenance licences (annual cost of £10 per machine)	20
Direct staff costs	
Course preparation time	0.8
Overheads	
Support services overhead (50% of direct staff time)	0.4
Financial benefits	
Reduced costs	0
Increased income	(25)
Total net cost	456.2

In the same report the costs of direct support to the use of these laptops in class is also estimated.

Table 7: Apportioned costs for hypothetical laptops initiative

Apportioned costs		
The following costs are apportioned from the IT support cost centres which class 1234 draws on:		
Support cost centres	Basis of apportionment	Apportioned cost (five years) £k
Procurement and support of end-user devices	400 devices x £300 per device x 5 years	600
Access to network	£40 per user per annum x 5 years x 400 users	80
Support of student laptops	Allocate 100% of this new service to class 1234 in physics – one technician £30k per annum + 50% overhead	225
Total apportioned cost		905

Total cost of ownership

From the USA, the Consortium for School Networking report¹⁹ included tables of costings and brief summary details (Tables 8 to 12) from five American reports.

These comprised:

- the McKinsey report which presented four different models with varying levels of initial and on-going costs and provision
- the New Jersey State School Study, which seems, as described in the summary, to be based on averaging information from all New Jersey schools
- the California Department of Education benchmarks study – the basis for the estimates in this case cannot be deduced from the summary available
- the RAND Corporation data on eight pioneering high-tech schools – this is clearly based on actual school data
- the MIT study³³ based on a set of generalised models of average US schools; one of the five MIT models is presented here.

Table 8: McKinsey projection of the cost of connecting schools to the information superhighway, 1995 (four different models)

Model	Initial costs per school	On-going costs per school	Initial costs per student	On-going costs per student
Lab	\$125,000	\$45,000	\$225	\$80
Lab plus	\$255,000	\$85,000	\$460	\$150
Partial classroom	\$340,000	\$90,000	\$610	\$155
Classroom	\$555,000	\$165,000	\$965	\$275

Table 9: New Jersey school study 1997

Cost per school over five years		
Component	Cost	Share of total
Computer equipment	\$346,125	32%
Distance learning equipment	\$83,850	8%
In-school network	\$39,220	4%
District network	\$32,132	3%
Internet connection	\$27,810	3%
Telephone system – on premises	\$31,200	3%
Training	\$137,500	13%
Support	\$377,814	34%
Total	\$1,075,652	100%

Table 10: RAND Corporation data on eight pioneering high-tech schools, 1995

	Lowest in range	Highest in range	Mean	Median
Annual cost/student	\$142	\$490	\$333	\$390.5
Number of students	310	1,800	977	850
Students: computers	11:1	1.5:1		
Hardware	29.64%	66.75%	46.11%	43.77%
Software	3.88%	10.40%	7.84%	8.61%
Infrastructure	2.19%	7.10%	4.89%	5.21%
Staff development	5.57%	22.29%	9.85%	7.73%
Support Personnel	3.28%	39.48%	27.4%	31.6%
Materials	1.75%	6.33%	3.83%	3.82%

Total cost of ownership

Table 11: California Department of Education: Four-year cost to reach benchmarks, 1996
(Assumes an average school with 700 students, 33 staff members, 27 classroom and two other networked rooms)

	Assumption for average school	Four-year cost, average room	Four-year cost, average school	Percent of total
I. Staff development and support				21%
Trainers	2,000 hours of training @ \$35 per hour	\$2,414	\$70,000	
Staff support, materials, mileage, etc.	\$2,000 per person (33 staff members)	\$2,276	\$66,000	
District-county technical support	.3 FTE=\$15,000 per year for 4 years	\$2,069	\$60,000	
School site technical support	.5 FTE=\$25,000 per year for 4 years	\$3,448	\$100,000	
Four-year total		\$10,207	\$296,000	
II. Learning resources				27%
Computer software	\$2,000 x 29 rooms for 4 years	\$8,000	\$232,000	
Upgrades	\$200 x 29 rooms for 4 years	\$800	\$23,200	
Other multimedia materials and services	\$500 x 29 rooms for 4 years	\$2,000	\$58,000	
Communications (connect charges, etc.)	\$1,265 per school per month x 12 months for 4 years	\$2,094	\$60,720	
Four-year total		\$12,894	\$373,920	
III. Hardware and telecommunications infrastructure				\$40%
Computers	6 computers @ \$1,525 x 29 rooms	\$9,150	\$265,350	
Special interfaces	\$700 for each of 29 rooms	\$700	\$20,300	
Scanners	\$675 for each of 29 rooms	\$675	\$19,575	
Networked laser printers	\$1,100 for each of 29 rooms	\$1,100	\$31,900	
Color printers	5 @ \$400 each (shared by school)	\$69	\$2,000	
Audio recorders and players	5 @ 75 each (shared by school)	\$15	\$375	
Headphones	174 (1 per computer) @ \$30	\$180	\$5,220	
Liquid-crystal presentation panels	5 @ \$1,100 (shared by school)	\$190	\$5,500	
Video-capture boards	5 @ \$350 (shared by school)	\$60	\$1,750	
Video cameras	5 @ \$600 (shared by school)	\$103	\$3,000	
Videodisc players	5 @ \$325 (shared by school)	\$56	\$1,625	
Television monitors	\$500 for each of 28 rooms	\$483	\$14,000	
VCRs	\$350 for each of 28 rooms	\$338	\$9,800	
Overhead projectors and screens	\$500 for each of 28 rooms	\$483	\$14,000	
Fax machines	2 @ \$400 (shared by 29 rooms)	\$27	\$800	
Telephones	\$50 for each of 28 rooms	\$48	\$1,400	
High-speed copiers	2 @ \$5,000	\$345	\$10,000	
Telecommunications infrastructure	\$74,000 per school	\$2,552	\$74,000	
Furniture and security equipment	\$2,700 for each of 29 rooms	\$2,700	\$78,300	
Four-year total		\$19,272	\$558,895	
IV. Maintenance, upgrades and replacements	Replacements represent 15% of installed hardware	\$5,844	\$169,475	12%
Grand total (four years)		\$48,217	\$1,398,290	

Total cost of ownership

Table 12: MIT (Rothstein and McKnight) projection for school-based LANs with central connection to the district and to the internet, 1994

One-time installation costs	Low	High
School level		
Local area network	\$20,000	\$55,000
Personal computers	\$60,000	\$120,000
File server	\$4,000	\$15,000
Connection to hub/district office	\$500	\$2,000
Router and CSU/DSU	\$2,600	\$5,000
Retrofitting (major)	\$10,000	\$25,000
Total	\$97,100	222,000
District level		
File server	\$2,000	\$15,000
Router	\$2,000	\$5,000
District LAN	\$2,000	\$5,000
Data line to WAN/Internet (T-1)	\$1,000	\$5,000
Dial-up capabilities (20 lines)	\$16,000	\$32,000
Training (40–50 staff/school)	\$50,000	\$150,000
Total	\$73,000	\$212,000
Annual operating costs	Low	High
School level		
Replacement of equipment	\$3,000	\$8,250
Connection to hub/district office (56Kb)	\$1,000	\$5,000
Total	\$4,000	\$13,250
District level		
Internet service (T-1)	\$10,000	\$42,000
Dial-up lines	\$3,000	\$5,000
Support (2–3 staff/district)	\$66,000	\$150,000
Training	\$15,000	\$35,000
Total	\$94,000	\$232,000
One-time costs per student	\$212.47	\$501.14
Annual costs per student	\$39.77	\$104.69

These detailed figures are not directly applicable to the present day situation in England, as inflation rates, exchange rates, and equipment and staffing costs have differed across the period between the two countries. However, it was possible that the percentage split of costings in the studies between cost categories might be comparable. If those appeared to fall within a limited range, then this could at least provide a starting assumption that English percentages might be broadly similar. In the event, only three of the sets of costings were in a format that allowed this comparison to be

made. Table 13 shows the percentages reported for items that appear to fall into six top-level categories.

For what it is worth, the crude range for those categories in Table 7 where there is some broad equivalence is:

Hardware and network infrastructure	40%–50%
Software and learning resources	3%–27%
Training and professional development	10%–13%
Support	11%–34%

Total cost of ownership

Table 13: Comparison of percentage distribution between TCO categories in three US studies

	New Jersey school study	California Department of Education	MIT study
Hardware and network infrastructure	Computer equipment 32% Distance-learning equipment 8% In-school network 4% District network 3% Phone system on premises 3%	Hardware and telecommunications infrastructure 40%	Hardware 36% Telecommunications 11%
Software and learning resources	Internet connection 3%	Learning resources 27%	(Software costs not included)
Training and professional development	Training 13%	Trainers and non-technical staff support 10%	Training 13%
Support	Support 34%	Technical support 11%	Support 33%
Maintenance and upgrading		Maintenance, upgrades and replacements 12%	
Initial cost of building work and refitting			Retrofitting 7%

These variations are very large but it should be noted that the equivalencies between categories are not always close, and, even where two studies use very similar labels, these may well conceal significant differences in the specific subcategories beneath. Furthermore, given that the studies actually deal with very different kinds of ICT systems, uniformity is perhaps not to be expected.

There is one final issue to consider. All the US costings (except possibly the RAND data) ask what various schools (real or hypothetical) were spending on ICT. Yet this is a very different question from asking what they *needed* to spend, in what ratios and on what, if they were to succeed in improving attainment. In short, what these US studies aim to identify is the total cost of actual ownership, not the total cost of *educationally productive* ownership. Yet it is this latter question which is obviously crucial.

In this connection the figure of 10%–13% allocated to training in the US studies may be highly relevant, as it is one category where we do have a separate and authoritative US estimate of what would ideally be required. As one report¹⁹ notes:

The budget item that arguably is most critical to a school district's ability to achieve its technology goals is staff development. If teachers and other staff members do not understand how to use new technologies and incorporate them into the classroom, a district's technological investment will not achieve its desired results.

To underscore this point, the US Department of Education has recommended that school districts set aside 30 percent of their technology budgets for staff training and development. As the

Department noted in 1996, 'If there is a single overarching lesson that can be culled from research about teacher professional development and technology, it is that it takes more time and effort than many anticipate.' Today many state departments of education require that districts devote between 20 and 30 percent of their state technology grant money to staff development.

If the US Department of Education was right in believing that this was, in 1996, the optimal percentage of funding to allocate to training, then the difference between actual TCO distribution and optimal TCO distribution for the schools in these three studies may be very considerable indeed.

The message for the English context is that to base policy funding decisions (at school, local or national level) purely on current actual TCO distribution would be a major error, and might simply implement and endorse more generally a distribution of available resources that is itself inappropriate.

Total cost of ownership

3. Discussion

The earlier analysis presents a description of what the literature set has to say about the use to date of TCO. As indicated at the start, very little of this literature is directly about how TCO has been used in schools, LEAs or national educational organisations in England. This section therefore sets out to infer from the documents what messages they might contain for our situation. In this section, therefore, we move from description to extrapolation and interpretation.

The section is organised around three questions:

- What kinds of TCO models are available for use in education?
- What should be included in the single-school monetary TCO model?
- How could TCO data be collected to meet the main purposes identified for TCO?

3.1. What kinds of TCO models are available for use in education?

Using the distinctions drawn out earlier, it is possible to lay out a range of models for TCO. These can be generated through creating more or less inclusive subsets of the cells in Table 14.

The common core of any TCO analysis lies in the two shaded cells in Table 14. The monetary-based TCO for a school must figure in any school-level version of TCO. However, the scope of a TCO analysis could be extended sideways to include also, in varying combinations, the value-based costs to the school, and the monetary and value-based costs to the school's other stakeholders arising from the school's introduction and use of ICT systems.

Similarly, the analysis of both kinds of costs could be extended upwards to cover not a single school but to aggregate results from a set of schools (for example all the schools in an LEA). It could also include, if required, the additional TCO generated by the LEA's ownership of an ICT system and the costs that the LEA incurred through supporting the introduction and use of ICT systems in the schools it covered.

Given the centrality of the cells that deal with the school's monetary-based TCO, the next section is devoted to what can be included in these, while the reminder of this section briefly indicates some of the kinds of items that might fit into the remaining cells. It should be emphasised that these suggestions do not emerge strongly from the literature reviewed, as the document set contains little on costs as they relate to non-school levels, and less on value-based costs at any level.

Table 14: TCO cost structure, school to national levels, for monetary and value-based methods of analysis

National organisation's costs	Capital costs Administrative and operating costs End-user operating costs	Companies UDEs Government agencies (e.g. Becta, TTA) Relevant sections of DfES	Opportunity costs	Companies UDEs Government agencies Relevant sections of DfES
LEA's costs	Capital costs Administrative and operating costs End-user operating costs	Officers Advisers Support staff	Opportunity costs	Officers Advisers Support staff
School/classroom administration and management costs	Capital costs Administrative and operating costs End-user operating costs	Administrative staff Head	Opportunity costs	Administrative staff Head
School's curriculum-related costs	Capital costs Administrative and operating costs End-user operating costs	Head Teachers Parents	Opportunity costs	Head Teachers Parents Governors
	Monetary-based costs to the organisation	Monetary-based costs to other stakeholders	Value-based costs to the organisation	Value-based costs to other stakeholders

Total cost of ownership

Many of the monetary costs are covered within a school's budget, but various groups can themselves incur additional costs. For teachers and heads these might, to varying degrees, include:

- devoting out-of-school time unpaid to formal training or trial-and-error learning
- purchase and maintenance of a home computer partly for school-related work
- health costs arising from excessive use of poorly designed workspaces or, in the case of ICT-capable teachers, excessive workloads involved in bringing the use of ICT into general use at the school
- stress generated by the need to work with a new technology that in some cases the teacher neither wants nor feels comfortable with.

Rather similar costs might be incurred by LEA advisers and officers, and by individuals in national agencies of various kinds. Parents who provide computers at home and school also incur costs, as do governors who devote time in and beyond their meetings to dealing with ICT-related issues. It should also be noted that at every level there are also opportunity costs to consider. If staff are working on ICT-related projects they are not free to contribute to other initiatives or programmes. Opportunities in these other areas are therefore lost.

3.2. What should be included in a single-school monetary TCO analysis?

The University of California study⁸ contained a proposed schema for use in US schools, based on a review of experience there to date. This is the best approximation to a monetary single-school schema that the US literature reviewed offers. It divides costs into three main categories:

- capital costs
- administrative and operating costs
- end-user operation costs.

The contents of the schemas need some modification for use in English schools. Tables 15 to 17 show each of the three categories listed above in detail, with added items in italics.

Table 15: Breakdown of capital costs in calculating TCO for educational technology

Cost categories	Costs
Hardware <i>(for teachers, pupils and administrators)</i>	CPUs Laptops Palmtops Monitors Printers <i>Special needs input and output devices</i> <i>Subject specific hardware (e.g. synthesisers, sensors)</i> Headsets Screens Projection equipment <i>Electronic whiteboards</i> Scanners Servers Routers Hubs
Software	Administrative applications Licensing fees Educational programs File and network security Virus protection
Facilities	Wiring Classroom modifications: • air conditioning • chalkboard removal • carpeting, shade • positive pressure rooms Security: • room and building • cables and locks for hardware Furniture and ergonomic considerations
Installation	Design specifications Contract oversight <i>(including on-costs)</i> Technical staff <i>(including on-costs)</i>

Total cost of ownership

Table 16: Breakdown of administrative and operating costs in calculating TCO for educational technology

Cost categories	Costs
Technology planning	Technical expertise Surveys Administrative and management time (including on-costs)
Upgrade and replacement	Memory CPUs, motherboards, video and sound cards Software Operating system Monitors Printers Headsets
Internal support	Internal support Technical staff (including on-costs) Replacement parts Consumable supplies: • paper • printer cartridges
Support contracts	Fees/payments Additional insurance
Facilities	Air conditioning Electricity Telecommunications charges Discard charges

Table 17: Breakdown of end-user operating costs in calculating TCO for educational technology

Cost categories	Costs
Staff development	Substitute teachers Teacher training Administrative staff training Management staff training Technical and classroom support staff training Peer support
Teaching costs	Curriculum development
User downtime	Technical problems Learning new applications (by teachers)

If a stage-based model is preferred, then an alternative (Table 18) is provided in the National Council for Educational Technology publication²⁸ on managing and integrating IT. This schema covers:

- research and development
- initial investment
- operating and support costs
- disposal and salvage.

Like the University of California schema, this is essentially a monetary-based model, and both more or less restrict their range to the direct costs incurred by people working in the schools themselves.

Table 18: NCET costing checklist

Research and development Costs associated with the introduction of IT resources	Staff time e.g. IT co-ordinator Books and stationery Administration time Research activities Displacement costs Public relations activities
Initial investment Cost associated with purchasing and initial set-up	Non-recurring costs • Building work • Electrical work and cabling • Furniture, fittings and fittings • Hardware and peripherals Recurring costs • Peripherals and IT supplies • Software • Support materials • Insurance premiums • Staff training • Support staff – technical • Support staff – other consultants • Travel expenses • Administrative support • Telephone charges
Operating and support costs Costs of operating and maintaining the IT resources per year or for the estimated lifetime of the system or project	Maintenance costs • Hardware • Software • Peripherals • Security system
Disposal and salvage Costs associated with the replacement and removal of equipment	Equipment value Disposal costs Staff retraining Other costs

Either of these schemas would appear to offer a sound starting point for developing the single-school monetary component of a TCO framework for use in the English context. However, they differ in two respects.

Firstly, the University of California schema is considerably more detailed. Not all the items are likely to be relevant

Total cost of ownership

for a given school's concerns, but it does offer a detailed and useful checklist to ensure that no significant items of expenditure are overlooked.

Secondly, although the NCET schema lacks this detail, it does, importantly, distribute costs over different phases of the planning, introduction, use and disposal of an ICT system. This is very helpful as a way of getting a preliminary grip on how expenditure is likely to fall across a number of years. The inclusion of the initial research and development costs is of particular note, as this is easily overlooked.

3.3. What broad strategies are there for obtaining TCO data?

This issue resolves itself into two interrelated questions concerning the relative merits of:

- using generic versus specific cost data
- using a top-down versus a bottom-up data collection strategy.

The distinction between specific and what we may call generic costs is that the former are actual costs from specific organisations, while the latter are general figures based only indirectly on specific costs. Generic costs may, for example, be averages from a set of real schools. Alternatively they can be based on, say, real vendor prices but applied to a hypothetical school with a representative type of infrastructure to generate overall cost.

The advantage of specific costs is that they are potentially closely grounded in reality. Discounts given, damaged equipment replaced and additional training costs for replacement teachers will not be overlooked. On the other hand, collecting specific costs is a costly and lengthy process that, by definition, needs doing on a case-by-case basis.

The advantage of using generic costs is that they either come with the details of the underlying specific costs already packaged up (e.g. as a multi-school bulk equipment purchase) or are simple school or LEA-level multiples of known figures, such as the cost per teacher of NOF training. This makes them far easier and quicker to collect, manipulate and analyse. On the other hand, they only approximate to the actual figures, even in aggregate.

The distinction between top-down and bottom-up methods of costing relates to where in a complex organisation you choose to collect information on costs.

In a centralised national system, most of the ICT infrastructure and support costs can be seen as being met either centrally or at school level, because the schools receive most of their funding from the centre.

A top-down approach would therefore start with known central funding and, using whatever information was available about distribution rules and practices, work out a generic-based calculation for what costs would be in, say, a typical comprehensive of a given size.

The advantages of this approach are that they minimise the demands on schools for additional information and require only one set of calculations to be carried out. The disadvantages are that many key costs for additional stakeholders are likely to be hard or impossible to obtain or estimate realistically, and the appeal offers only generic pictures of what provision would be like in types of schools rather than in actual ones.

In the bottom-up approach, actual or generic costs are established at school level and then, if required, aggregated successively into local and national total costs. The advantage of this is that the costs are likely to be more accurate and inclusive than for a top-down strategy. On the other hand they are massively more complex and costly to collect in any cost areas where there are not already returns made about them.

3.4. Conclusion

In the light of the literature reviewed there are four key areas where decisions would be needed before exploring the possibilities of TCO further.

The first is to decide whether the unit of account is to be the individual school or some larger aggregate. The second is to decide whether any TCO analysis should be framed in monetary terms only or be extended to also include other non-monetary costs. The third is whether to base any analysis on school or national level data.

Finally, underpinning choices on all of these is the importance of identifying clearly and explicitly what the planned analysis is designed to achieve.

If TCO is to be used as an aid to improved procurement of ICT systems for individual schools, then it is the costs to the school alone which would be considered. If the decision on the type and scale of provision has already been taken on educational grounds then TCO analyses of the relative costs of alternative methods of providing this funding would be sufficient. If provision is being

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organised at an LEA level, a similar approach is possible, but with the combined costs to the schools and the LEA being the object of analysis. In both cases, estimated costs for the whole life of the system and for its eventual replacement or upgrading would need to be included.

If TCO is being introduced as part of an overall strategy for improvement, whether at LEA or school level, then a more complex analysis will be required. This would need to include both monetary costs and benefits and also intangible ones, especially those relating to educational benefits to pupils.

The literature review suggests that establishing the total cost of ownership of ICT systems is well worth exploring. However, it also indicates the complexity and variety of purposes for this kind of analysis, and the almost complete lack of evidence on how and when it can be used most advantageously in the context of school education in England. An essential preliminary to any wider introduction of TCO would therefore be to carry out research focused on the principles and practicalities of its introduction and use.

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Note: Superscript numbers in the main text refer to the reference sources in this list.

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