

Evaluating computerized health information systems: hardware, software and human ware: experiences from the Northern Province, South Africa

Kobus Herbst, Peter Littlejohns, Jakes Rawlinson, Mark Collinson and Jeremy C. Wyatt

Summary

Despite enormous investment world-wide in computerized health information systems their overall benefits and costs have rarely been fully assessed. A major new initiative in South Africa provides the opportunity to evaluate the introduction of information technology from a global perspective and assess its impact on public health.

The Northern Province is implementing a comprehensive integrated hospital information system (HIS) in all of its 42 hospitals. These include two mental health institutions, eight regional hospitals (two acting as a tertiary complex with teaching responsibilities) and 32 district hospitals. The overall goal of the HIS is to improve the efficiency and effectiveness of health (and welfare) services through the creation and use of information, for clinical, administrative and monitoring purposes. This multi-site implementation is being undertaken as a single project at a cost of R 130 million (which represents 2.5 per cent of the health and welfare budget on an annual basis). The implementation process commenced on 1 September 1998 with the introduction of the system into Mankweng Hospital as the pilot site and is to be completed in the year 2001.

An evaluation programme has been designed to maximize the likelihood of success of the implementation phase (formative evaluation) as well as providing an overall assessment of its benefits and costs (summative evaluation). The evaluation was designed as a form of health technology assessment; the system will have to prove its worth (in terms of cost-effectiveness) relative to other interventions. This is more extensive than the traditional form of technical assessment of hardware and software functionality, and moves into assessing the day-to-day utility of the system, the clinical and managerial environment in which it is situated (humanware), and ultimately its effects on the quality of patient care and public health. In keeping with new South African legislation the evaluation process sought to involve as many stakeholders as possible at the same time as creating a methodologically rigorous study that lived within realistic resource limits.

The design chosen for the summative assessment was a randomized controlled trial (RCT) in which 24 district hospitals will receive the HIS either early or late. This is the first attempt to carry out an RCT evaluation of a multi-site

implementation of an HIS in the world. Within this design the evaluation will utilize a range of qualitative and quantitative techniques over varying time scales, each addressing specific aims of the evaluation programme. In addition, it will attempt to provide an overview of the general impact on people and organizations of introducing high-technology solutions into a relatively unprepared environment. The study should help to stimulate an evaluation culture in the health and welfare services in the Northern Province as well as building the capacity to undertake such evaluations in the future.

Keywords: health information systems, formative and summative evaluation

Introduction

Throughout the world information technology has revolutionized the way people think and act in many spheres of their life. However, in the field of health care, although few would deny the value of information for planning, implementing and monitoring health systems, the introduction of computers has made a hesitant start.¹ The greatest progress has been made in the introduction of administrative systems, where the need for accurate utilization data for budget setting has provided the

¹Department of Community Health, Medical University of Southern Africa (MEDUNSA) Polokwane Campus, Pietersburg-Mankweng Hospital Complex, Northern Province, South Africa.

²Health Care Evaluation Unit, St George's Hospital Medical School, London SW17 0RE, UK.

³Health Systems Development Unit, University of Witwatersrand, Johannesburg, South Africa.

⁴Health Knowledge Management Centre, School of Public Policy, University College London, UK.

Kobus Herbst¹, Head of Department

Peter Littlejohns², Professor of Public Health

Jakes Rawlinson¹, Evaluation Coordinator 1998–9

Mark Collinson³, Evaluation Coordinator 1997–8

Jeremy C. Wyatt⁴, Director

Address correspondence to Professor Littlejohns.

stimulus. The balance between the costs and benefits of computerizing clinical information remains unclear. Most countries can provide examples of healthcare computer systems that have not realized the expectations placed on them. Indeed, an estimated two-thirds of all systems that have been evaluated are deemed to be unsuccessful.² Why is this?

How do you evaluate information technology?

Answers are not easily come by, as very limited methodologically sound evaluative research has taken place. A recent review³ concluded that there was nothing in this literature on the evaluation of single or multiple hospital clinical management systems in terms of their impact on the cost-effectiveness of health care. The vast majority (more than 90 per cent) were evaluations of computer systems integrated into the operation of complex items of diagnostic or therapeutic equipment such as pathology analysers, or imaging equipment.⁴⁻⁶ Others related to single departmental information systems, such as in diabetic clinics, or imaging departments^{7,8} but these tended to be more than 5 years old. In the last 2 or 3 years the use of teaching packages available on the Internet^{9,10} has also been evaluated. Decision support systems have been well evaluated by randomized controlled trials.¹¹

In a paper in the *British Medical Journal* in 1996,¹² Lock highlighted the lack of evidence to support the vast investment in information technology in the UK. This is particularly ironic as the systems, once installed (but unevaluated), are then used to monitor the cost-effectiveness and performance of others.¹³ It is difficult to identify clear outcomes and benefits from such information systems. Particularly difficult is the quantification of any improvements and establishing the causal link directly with the use of the computer systems. For instance, the Hospital Information Support System (HISS) introduced into a single UK hospital cost over £12 million in capital and revenue during development, but the only quantified savings were £86 000 per annum in Radiology and £40 000 in Pharmacy.

The same lack of evidence applies to primary care. There has been one systematic review of the effect of computerization in primary care.¹⁴ This found that of 30 studies (published world-wide between 1984 and 1994), only three measured the impact on patient outcome. Consultation took longer, with the doctor-medical component increasing at the expense of the patient-social component. The authors decided that the effect on patient outcomes was inconclusive. There have also been some evaluations of nursing systems.^{15,16} A review of European literature also found few studies, with only 13 of the 108 identified including any economic analysis.¹⁷

Evaluation is a rather misused word in this context. In the literature it rarely means the systematic appraisal of the effectiveness of an information system that has already been installed, to determine whether it represents value for money,

or has been instrumental in improving patient care. Rather 'evaluation' is used as part of the assessment process that potential system purchasers should undertake, before or as part of the procurement or tendering process. Thus there are papers on what to consider,¹⁸ but not on whether any implementation really works in practice. A US consortium of organizations has even developed a guideline for responsible monitoring and regulation¹⁹ but recognizes that the Food and Drug Administration cannot begin to regulate computer systems in healthcare.

A major difficulty has been that too much emphasis has been placed on seeking a single solution, to the detriment of exploring multi-pronged approaches.²⁰ Heathfield *et al.*^{21,22} reinforced Kaplan's^{23,24} view that the problem of methodology can be addressed by using a framework for evaluation, especially in complex multidisciplinary healthcare situations. The gold standard of modern evaluative research 'the randomized controlled trial' may not always be appropriate. These tend to produce negative results, which then remain unpublished, and do not provide constructive criticisms and directions for improvements. Although Heathfield *et al.* suggested that to look for evidence of cost-effectiveness is actually to ask the wrong question, those involved in paying for or using such systems may not necessarily agree. Clinical informatics needs to develop multi-perspective evaluations integrating a range of qualitative and quantitative methods.²⁵

A new approach

Implementing a computerized system into a healthcare environment provides a unique and major challenge. There are many issues that have to be successfully addressed if a new computer system is to be effectively implemented.²⁶ In South Africa we are seeking to undertake an evaluation in which the system is treated as a form of health technology that has to prove its worth (in terms of cost-effectiveness) relative to other interventions. This is more extensive than the traditional form of technical assessment of hardware and software functionality and moves into assessing the day-to-day utility of the system, the clinical and managerial environment in which it is situated (human ware), and ultimately its effects on the quality of patient care. This approach draws on research paradigms from many disciplines seeking to change professional behaviour.²⁷

This paper describes the creation of an evaluation programme (see ref. 3 for more details), established to assess a major new information initiative in South Africa. In doing so it discusses the interaction between the computer implementers, the health service and the evaluators, and identifies lessons already learnt.

The establishment of the hospital information system (HIS)

South African Health (and Welfare) Services are currently undergoing a major programme of restructuring. Changes

include shifting resources from tertiary and secondary to primary care, creation and devolution of management structures down to district level and redistribution of resources in response to perceived geographical and sectoral need in consultation with the affected communities. For the successful implementation of these initiatives, managerial, administrative and clinical processes need to be efficient, effective and equitable. An essential prerequisite is adequate information, not only to facilitate the original tasks, but also for short- and long-term monitoring. The generation of reliable, timely and useful information is expensive. In most developed and, increasingly, developing countries computerization is perceived as the most cost-effective means of achieving this. However, implementing such systems is difficult both technically and in human terms. Careful planning for a successful implementation is required as well as laying a solid foundation for sustaining the system after the initial phase is over. Success cannot be taken for granted on the basis of experiences elsewhere in the world with information systems.

In the Northern Province (NP) this process commenced with the decision to implement a hospital-based information system throughout all its hospitals. In addition to the HIS, a District Information System (DIS) development process was initiated, and several key components of a DIS core package are currently being field tested at selected clinics in two districts. The DIS will eventually interface with the HIS to assist with providing the overall information requirements to manage the health and welfare services in the Province as a whole.

The HIS was conceived in 1995 with the overall aim of computerizing all 42 hospitals as part of the same project over a few years. The design was such that each hospital will have its own application server managing local detailed data, but distributing some data at patient encounter level to other hospitals where the patient has been seen before, and to a central server at the Welfare and Health Technology Operations Centre (WHITOC). Patient demographic information and a problem list based on ICD-10 are replicated from the originating hospital to the WHITOC and all other hospitals. The WHITOC therefore contains a master patient index and data to encounter level from all 42 hospitals. This information forms the basis for a data warehouse to serve management reporting and epidemiological needs. At hospital level the system provides the following functionality: master patient index; admission, discharges and transfers; patient records; appointments; order entry; results reporting; laboratory; radiology; operating theatre; clinical services; dietary services; laundry; financial management; management information and hospital performance indicators. The objectives of the HIS are shown in Fig. 1.

The HIS Project is managed by a project team consisting of members from the Department of Health and Welfare (DHW) and IBM and its subcontractors: Intersolve Health Informatics (IHI), Faritec, and six local business partners (LBPs; Norprobs, Mvelaphanda, Northern Training Trust (NTT), Mameriri, Great North and STEP Ahead). This is part

1. **Improved patient care:**
 - i. By making information belonging to patients seen at other hospitals available at the hospital where the patient is currently being treated. This is particularly important in light of referral system for patients from district to regional and central hospitals in the province.
 - ii. By improving the accessibility of patient related information to health care professionals during the treatment process, through improved medical records handling and shorter turnaround time for the release of diagnostic information such as laboratory and special investigation results.
 - iii. By improving patient administration procedures resulting in shorter waiting times and better service to patients.
2. **To form an integral part of a larger quality improvement program in the department through:**
 - i. The re-engineering and standardisation of patient administration and management procedures across hospitals.
 - ii. Provision of information to do performance evaluation and health care audit
3. **To improve the management efficiency of hospitals through:**
 - i. The facilitation of decentralised financial management capacity at hospital level
 - ii. Improved revenue collection
 - iii. Improved management decision-making through the availability of integrated management information
 - iv. Cost savings through the identification of primary cost-drivers at hospital level and the monitoring of mechanisms introduced to lower costs.

Figure 1 Objectives of the hospital information system.

of South African policy to build local capacity into all major projects. Dr Kobus Herbst (Department of Community Health, MEDUNSA Polokwane Campus) is the project leader on behalf of the DHW and the project manager is Mr Andre van der Laar (IBM). The HIS Project is steered by a policy formulation and decision-making body, the HIS Steering Committee, where all stakeholders are represented. Dr V. Buthelezi, Chief Director: Hospital and Support Services Directorate, DHW, chairs the committee as system owner.

The project was initiated in 1997. The first pilot hospital went live in 1998. The remaining hospitals will receive the system over the next 18 months.

The evaluation

In view of the considerable expenditure and the importance of this system for national as well as provincial health care (and welfare) services, it was decided to undertake a formal evaluation.

In line with the current thinking on combined approaches, the design drew on a range of disciplines and involved representatives of all stakeholders. This is in sympathy with the evidence that 'top-down initiatives' are doomed to failure unless local ownership and understanding of the immediate benefits are achieved.

Aims of the evaluation programme

The overall aims of the evaluation programme are to increase the likelihood of success of the HIS through formative evaluation. In addition, its overall impact (benefits and cost-effectiveness) will be assessed through a summative evaluation.

The approach and the process of developing the evaluation programme are outlined below. The programme consisted of four separate, but inter-linked activities, as follows.

An orientation study

This was the first formal study conducted as part of the evaluation process. The aims were to identify local aspirations and expectations of the potential users and to give the implementers a detailed understanding of the magnitude of the task facing them. This included obtaining the views of users concerning what they thought the evaluation should address, potential problems where some preventive measure taken by the project might improve the outcome of the project, and a knowledge, attitude and perception analysis. A total of 250 potential users were interviewed, which generated 35 questions that should be addressed by the evaluation.

The creation of an evaluation framework

This aimed to incorporate as many of these ideas as possible and design the overall evaluation programme seeking to use as rigorous a technique as possible within resources available. The 35 questions were presented to a workshop supported by the Health Systems Trust (HST) containing representatives of ten stakeholder groups and resulted in an expansion to 114 questions. Through a process of collation and distillation these were incorporated into ten separate projects to create an evaluation framework (see Fig. 2 and ref. 3).

Designing the overall evaluation programme

A second workshop supported by HST was then convened to consider the overall design of the evaluation, determine priorities of the projects in the evaluation framework, agree specific outcome indicators, provide technical advice on the drafting of the final protocol and proposal for submission to

funding bodies, and discuss the required organizational structures to support and implement the programme.

The conclusion of the second workshop was that a randomized controlled trial (RCT) would be the most robust method for undertaking the summative component of the evaluation. The RCT will form the core of the summative evaluation and it is hoped to expand this component if and when additional resources (human and financial) become available. Other individuals and institutions will be encouraged to build and expand on the core.

Undertaking the evaluation

The formative evaluation component of the overall evaluation has been a continuing process. Aspects of the summative evaluation (RCT) are currently in a pilot phase to select the final outcome variables and refine their measurement.

The RCT is derived from the aim of the project that was given top priority in the second workshop: assessing the quality of decision-making information for clinicians, hospital management, provincial health executive and the public; and the accessibility and utilization of this information.

The specific hypothesis that will be tested is 'that the implementation of the HIS improves the quality of decision-making information available to clinicians, hospital management, provincial health executive and the public and is accessible and used to improve the efficiency and cost-effectiveness of the health (and welfare) services'. The outcome variables measured to test the hypothesis will also indirectly evaluate some aspects of the other projects in the evaluation framework.

Conclusions and lessons learnt from the formative evaluation

Three key issues have been identified so far.

First, it is highly desirable that with all new expensive interventions in health care an evaluation is designed at an early stage. Too often, evaluation is considered later and is forever trying to catch up. In this context, the formative evaluation and implementation process have been synergistic, e.g. the evaluation process identified that the physical and human environment within many of the hospitals would not be ready to receive the computers. This resulted in the roll-out time scales being modified, which in itself allowed a more robust design and piloting of the summative evaluation to take place.

Second, concentrating on the hardware and software to the detriment of human ware is a risky strategy. The human dimension covers two elements: effective training for the end users of the system is essential – not only to use the software and hardware, but also to understand why they need to use it and the likely benefits. Whereas the responsibility for the former obviously lies with the implementing project team, responsibility for the latter is more ambiguous. The balance probably lies closer to the commissioners of the information system – the

The following sub-projects make up the recommended framework of inquiry for the Northern Province HIS evaluation:

- 1) Assessing whether training, change management and support are optimal.
- 2) Assessing whether the reliability of the integrated HIS (including peripherals, network, hardware and software) is optimal.
- 3) Assessing the performance of project management.
- 4) Assessing whether the system improves the communication of patient information between health care facilities.
- 5) Assessing whether data protection is adequate.
- 6) Assessing the quality of decision-making information for clinicians, hospital management, provincial health executive and the public; and the utilisation of this information.
- 7) Assessing whether the patient administration processes are more standardised and more efficient.
- 8) Assessing whether costs per unit service are reduced.
- 9) Assessing whether revenue collection has improved.
- 10) Assessing whether information is used for audit and/or research.

Figure 2 An HIS evaluation framework.

health authority. It is essential that the enthusiasm and understanding of the need for the systems at head office is diffused down to managers and clinicians at all levels. In practice, this presents a new and unique challenge to the implementation of computerized information in developing countries. The management capacity at local level is only just being established; indeed, one of the reasons for the use of information systems is to facilitate and aid this process. This produces a tension in the system that needs to be addressed on a continuous basis. The other human dimension relates to the complex milieu in which health services function. The political, professional and managerial environments in all countries are in a constant state of flux. Long-term major interventions such as information systems have to be sensitive to these as they change over time and be flexible enough to respond. This requires a mutual understanding between the commissioners of the system and the implementers of each other's perspectives and priorities, and effective channels of communication have to be developed and maintained. These need to be independent of individuals.

Third, continuing interactive health service evaluations, where the evaluators 'influence' the intervention and the people they are evaluating, moves outside the normal paradigms of medical research. Methods of communication between the implementers and evaluators have to be carefully thought out and formalized to ensure that the usefulness of the formative components is not perceived to (or actually does) invalidate the summative components and the generalizability of their results.

Over the next 2 years as the computer system is rolled out we anticipate that the formative evaluation lessons already learnt will increase the likelihood of the system being successfully implemented at the same time as creating generic solutions to how such systems should be evaluated in the future. The summative results will be available much later and should affect any subsequent investment in health information technology.

Acknowledgements

K.H. initiated the ideas that culminated in the development and implementation of the Hospital Information System Project (HISP) (specification available on <http://www.sghms.ac.uk/phs/hceu/index.htm>) and the establishment of the evaluation. He was supported by the Provincial and National Departments of Health (and Welfare). The superintendent general in the Northern Province at the time of commissioning the system was Dr Nicholas Crisp. Dr V. Buthelezi is chairman of the HISP steering committee. We thank all the participants of both workshops and the Health Systems Trust for funding them. The attendance list and a report of the first workshop is available on <http://www.sghms.ac.uk/phs/hceu/index.htm>. M.C. undertook the orientation studies and wrote the first workshop report. The second workshop was organized by J.R. and P.L. Ms Tercia West summarized the proceedings. The RCT was initiated by J.C.W. and designed by him in conjunction with

J.R. and P.L. The overall evaluation programme protocol was prepared by J.R. and P.L. They were supported by members of the Scientific Advisory Group of Experts (SAGE). Its members are listed on <http://www.sghms.ac.uk/phs/hceu/index.htm>. Dr Linda Garvican undertook the systematic review that underpinned this paper (available on <http://www.sghms.ac.uk/phs/hceu/index.htm>). Merck Sharp & Dohme contributed to travel costs.

References

- Wyatt J. Four barriers to realising the information revolution in health care. In: Lenaghan J, ed. *Rethinking IT and health*. London: Institute for Public Policy Research, 1998: 100–122.
- Willcocks L, Lester S. *Evaluating the feasibility of information technology*. Research discussion paper DDP 93/1. Oxford: Oxford Institute of Information Management, 1993.
- Papers on the specification of the HIS; the first workshop; the overall evaluation, including a systematic review of evaluations of multi-site information systems; and the RCT protocol. <http://www.sghms.ac.uk/phs/hceu/index.htm>
- Michell H, Medley G. Detection of laboratory false negative smears by the PAPNET cytologic screening system. *Acta Cytol* 1998; **42**: 265–270.
- Stamminger G, Koppel C, Schaub A, et al. Performance of the SE-9000 automated haematology analyser in a laboratory serving a haematological oncology unit. *Clin Lab Haematol* 1998; **20**: 143–149.
- Pace ME, Krebs TL, Wong-You-Cheong JJ, et al. Comparison of three display methods for evaluating CT angiography data for the vascular assessment of renal donors. *J Digit Imaging* 1998; **11**: 145–148.
- Donaldson LJ, Thomson RJ, Cook A, Raymakers R. Eight years experience of clinical activity in an outpatient fracture clinic. *Injury – Int J Care Injured* 1992; **232**: 363–367.
- Langley JD, Botha JL. Use of record linkage techniques to maintain the Leicestershire diabetes register. *Comput Meth Prognosis Biomed* 1994; **41**: 287–295.
- Veldenz HC, Dennis JW. The Internet and education in surgery. *Am Surg* 1998; **64**: 877–880.
- Clark DJ. Course redesign. Incorporating an Internet web site into an existing nursing class. *Comput Nursing* 1998; **16**: 219–222.
- Hunt DL, Haynes RB, Hanna SE, Smith K. Effects of computer-based clinical decision support systems on physician performance and patient outcomes: a systematic review. *JAMA* 1998; **280**: 1339–1346.
- Lock C. What value do computers provide to NHS hospitals? *Br Med J* 1996; **312**: 1407–1410.

- 13 Donaldson L. From black bag to black box: will computers improve the NHS? *Br Med J* 1996; **312**: 1371–1372.
- 14 Sullivan F, Mitchell E. Has general practitioner computing made a difference to patient care? A systematic review of published papers. *Br Med J* 1995; **311**: 848–852.
- 15 Peters AL, Davidson MB. Application of a diabetes managed care programme. The feasibility of using nurses and a computer system to provide effective care. *Diabetes Care* 1998; **21**: 1037–1043.
- 16 Marek KD, Jenkins M, Westra BL, McGinley A. Implementation of a clinical information system in nurse-managed care. *Can J Nurs Res* 1998; **30**: 37–44.
- 17 Van der Loo JA. Overview of published assessment and evaluation studies. In: Van Gennip EMSJ, Talmon JL, eds. *Assessment and evaluation of information technologies*. Amsterdam: IOS Press, 1995.
- 18 David G. Radiology information systems: evaluation and selection issues. *Radiol Technol* 1998; **69**: 406–410.
- 19 Miller RA, Gardner RM. Recommendations for responsible monitoring and regulation of clinical software systems. American Informatics Association, Computer-based Patient Record Institute, Medical Library Association, Association of Academic Health Science Libraries, American Health Information Management Association, American Nurses Association. *J Am Med Inform Assoc* 1997; **4**: 442–457.
- 20 Sackett DL, Wennberg JE. Choosing the best research design for each question. *Br Med J* 1997; **315**: 1636.
- 21 Heathfield H, Peel V, Hudson P, *et al*. Evaluating large scale health information systems: from practice towards theory. *Proc AMIA Annu Fall Symp* 1997; 116–120.
- 22 Heathfield H, Pitty D, Hanka R. Evaluating information technology in health care: barriers and challenges. *Br Med J* 1998; **316**: 1959–1961.
- 23 Kaplan B, Duchon D. Combining qualitative and quantitative methods in information systems research: a case study. *MIS Quart* 1988; **12**: 571–586.
- 24 Kaplan B. Information technology and three studies of clinical work. *ACM SIGBIO Newslett* **19**: 86–88.
- 25 Wyatt JC. Clinical data systems, part III: Development and evaluating clinical data systems. *Lancet* 1994; **344**: 1682–1688.
- 26 Friedman C, Wyatt J. *Evaluation methods in medical informatics*. New York: Springer-Verlag 1997 (reprinted 1998).
- 27 *Effective health care. Getting evidence into practice*, Vol. 5, No. 1. York: NHS Centre for Reviews and Dissemination, University of York, 1999.

Accepted on 31 March 1999