PERFORMANCE AND SUSTAINABILITY INDICATORS FOR CLINICAL ENGINEERING SERVICES

by

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SYNOPSIS

INTRODUCTION

In support of the focus on improved performance of health systems[1] this study forms part of an on-going project aimed at establishing indicators for the performance and sustainability of **Clinical Engineering Services**[2], as an integral part of cost-effective healthcare service delivery. The study itself develops a working **framework** for achieving the objectives of the project.

The general function of a Clinical Engineering Service is to provide a supportive role in the planning, evaluation, procurement, installation, utilisation and maintenance of medical devices (defined as including all medical/surgical devices, equipment and instruments). However, the boundaries of these support roles are not clear and well-defined, as what applies to one country or institution does not necessarily apply to another. Also, a clinical engineering service can range from one isolated but dedicated individual to a fully equipped department with professional and technical/artisan staff, supported by adequate technological and administrative infrastructures, to a shared regional/central resource centre.

Alongside the change in scope and function of Clinical Engineering Services over the years, is the shift from being primarily task-driven to being more business-oriented and cost-justified. A further development has been the adoption (sometimes imposed) of various international trends in business and management, e.g. total quality management, benchmarking, re-engineering, outsourcing of non-core business activities and most recently, ISO9000 standard accreditation. As sustainability is often dependent on issues of cost-effectiveness and relevance, and associated perceptions of institutional /

[1] The World Health Report 2000 - Health Systems: Improving Performance. World Health Organization, Geneva (2000)

[2] Units responsible for providing this service are known variously as Clinical Engineering Departments, Health Care Technical Services, Medical Physics Departments, Biomedical Technology / Engineering Services, Medical Apparatus / Equipment Workshops, etc

organisational stakeholders, these considerations may threaten otherwise successful departments or services with closure.

Rationale for the Study

The 200 World Health Report suggests four key *functions* of a health system, viz. service delivery, capacity building, financing and stewardship, and three key health system *inputs*, viz. human resources, capital investment (in physical assets such as buildings and equipment) and consumables (including drugs).

Many countries (and notably developing and emerging economies) are under-resourced in terms of what is needed for equitable service delivery of acceptable quality, as well as the management-level skills needed to maximise the impact of healthcare technologies on service delivery. Within this context healthcare technology management (HTM) practitioners and activities are being increasingly recognised for their contribution to health system performance. There is thus an urgent need to (i) build HTM management capacity and (ii) develop effective HTM tools while at the same time (iii) developing indicators for HTM performance and sustainability.

This study, which follows and complements previous work by Frize (1990) and Glouhova (1999), focuses on the last-mentioned and specifically on the development of indicators for Clinical Engineering Services, be they situated within a health facility or a shared / regional resource centre. These indicators will form qualitative and quantitative components of a tool for objective assessment and comparison of Clinical Engineering Services in different settings, as well as identifying pointers to performance, cost-effectiveness and sustainability. This in turn will contribute to improved management of these services, with the overall aim of improving the performance and quality of healthcare delivery.

LITERATURE REVIEW

As a background and theoretical framework for the methodology, the literature review is divided into three sections:

I. A background to the field of Clinical Engineering

II. A background to developments in management and measurement of service performance

III. Literature on the performance and sustainability of Clinical Engineering Services

I Background: Clinical Engineering

Following the history and evolution of the field, major findings were that clinical engineering is a new and continually evolving field – with its role and function changing over time. It is however, developing at different rates, depending on such factors as region, available infrastructure, health policy, recognition, socio-political and economic environment.

The rapid infiltration and increasing necessity for medical equipment in healthcare dictate a need for well-managed medical equipment management and maintenance systems. This is compounded – especially in developing countries – by the large percentage of inoperable equipment due to malfunction and lack of maintenance. Commonly identifiable factors for this include: lack of awareness and management expertise, lack of organisational policy, technical services infrastructure, qualified manpower and information support. Clinical engineering services, by their definition and as part of the Healthcare Technology Management spectrum, have a crucial role to play in improving healthcare service delivery.

Clinical engineering services are shifting from being primarily task-driven to being more business-oriented, cost-justified and bottom-line-focused. The existence of clinical engineering services is thus being threatened by such trends as downsizing, outsourcing, and budget constraints. This is true for both developed and developing countries. There is therefore need for CES's to justify their performance and sustainability on the same basis as any business. Indicators are essential for the survival of any organisation, and are a necessity for effective management of change. However, universal standards for clinical engineering do not exit. While studies have been performed on the status of clinical

engineering at a given time, little research has been conducted on their performance and sustainability. There is thus a need to identify critical and universal indicators for clinical engineering – and a comprehensive methodology required to develop these measures.

II Background: Developments in Management and Measurement of Service Performance

It is important to look at international trends in the business/engineering management world as a whole. Four trends prevalent in the 1990's are outlined, namely: benchmarking, re-engineering, quality (total quality management / quality assurance) and outsourcing. Two common themes emerge as being relevant and crucial to the study – **performance measurement** and **quality**.

Performance measures are vital for the effective management of any organisation, and include such benefits as: (i) establishing an initial baseline "as is" performance level, establishing desired goals and determining the "gap' between the two, (ii) tracking progress, (iii) enabling comparisons and benchmarking with competitors, (iv) identifying problem areas and (v) increasing awareness of stakeholders and decision-makers and thus assisting in planning for the future.

Effective performance measures, apart from being accurate, should satisfy certain criteria, namely: (a) they should reflect and respond to the needs and expectations of the customer/client receiving the service; (b) they should be integrated with the institutional/departmental mission, vision, strategy and objectives; and (c) they should be aligned with the major functions and business processes aimed at fulfilling the first two criteria.

In addition, it is imperative to identify measures that provide the greatest information and are most usable. Key factors in the 'family of performance measures' typically include: productivity, quality, timeliness, resource utilisation, costs and cost-effectiveness, cycle time and outcome or outputs of the system.

Quality, which has various definitions depending on its context – and can simply be described as 'conformance to requirements', is a comprehensive and multifaceted concept. Experts generally recognise several distinct dimensions of quality, which specifically for health services include: technical competence, access to service, effectiveness, interpersonal relations and communication, efficiency, continuity, safety and amenities.

Quality Assurance describes all the planned and systematic actions that are carried out to set standards, and to monitor and performance so that the service provided is as effective and safe as possible, i.e. 'doing the right thing, the right way'. Four basic principles should be adhered to in an ideal quality assurance programme, viz: (i) a focus on client needs, (ii) a focus on systems and processes, (iii) a focus on data to analyse service delivery processes and make decisions and (iv) a focus on participation and teamwork in quality improvement.

It is evident from the literature that performance measurement (and hence indicator development) and quality are interdependent.

III Performance and Sustainability of Clinical Engineering Services

This section of the literature review focuses on **developing** and **defining** indicators for Clinical Engineering Services.

As a precursor to **indicator development**, certain data elements have to be collected, stored and analysed and stored in a Clinical Engineering Database on a continual basis. These include information on service provided, in-house labour, medical equipment inventory and parts lists and timeliness.

In order to develop performance indicators a step-by-step methodology has to be developed, including: mission statement, customer expectations, key outputs, major functions, output & input measurement selection and index construction.

While it is important to measure all the right variables, in addition there are certain operational requirements for an effective measurement system, including: validity, completeness, accuracy/reliability, effectiveness, quantifiable, long-term consistency, accountability, sufficient detail and easily understood terms.

Once indicators have been defined, a threshold must be established and indicators monitored and evaluated on a continual basis, while identifying and implementing quality improvement opportunities.

A general **definition of an indicator** is that it is an objective, quantitative measurement of an outcome or process that relates to performance quality. There different types and classifications of indicators, serving different functions, viz.: programme, outcome, process, structure indicators and individual event or aggregate data indicators.

A large number of potential indicators have been proposed in clinical engineering literature, but not tested or validated. The WHO has also established the need for indicators – specifically the role of physical infrastructure and technology - associated with certain key factors, to ensure the sustainability of health systems.

As cost-effectiveness / affordability is a major consideration in determining sustainability of CES's, both in developed and developing nations certain costs need to be considered i.e. medical equipment life-cycle costs, labour costs and pricing options of the various clinical engineering services and their competitors.

METHODOLOGY

The methodology is described as a 3-phase process, including the (i) development and testing of a preliminary questionnaire, (ii) the development and administration of four questionnaires aimed at specified target groups, and (iii) the analysis and reporting of the results.

Phase 1: Definition of Research Problem and the Preliminary Questionnaire

Various research methods for obtaining the necessary information/data were considered at the outset of the study, including the use of secondary data, observation (through site visits) and extensive interviews. The survey method was finally considered to be the most appropriate research methodology for collecting primary data for the study based on the following considerations: (i) the need to collect large amounts of previously unavailable information from a variety of sources, (ii) the need for the collected information to be in a standardised format, given the fact that the field is still evolving and that there are region/institutional-specific differences in clinical engineering practice and (iii) the fact that both qualitative and quantitative data was required.

The next step in the design of the research methodology was targeting relevant participants for the study. **Relevant participants** are described as those individuals, units or organisations that have a significant impact (direct or indirect) on the performance and sustainability of clinical engineering services. Due consideration identified four discrete target groups:

- Institutional / health facility management (including nursing management)
- Clinical Engineering Service personnel (both managerial and technical)
- Clinical Engineering Service clients, i.e. users and beneficiaries (including doctors, nurses, allied health professionals)
- Representatives of national/provincial ministries of health and international HTM experts (including representatives of multilateral organisations and bilateral agencies, as well as technical consultants).

As a prerequisite for the design of the survey instrument, objectives for the questionnaires were defined as:

- Obtain general mission and basic strategy of Clinical Engineering Services
- Gather information about the functions and services of different Clinical Engineering Services

- Determine general expectations and perceptions of clients employing Clinical Engineering Service services
- Develop a general consensus on the importance of Clinical Engineering Services in any institution, organisation, region or socio-political environment
- Gather information pertaining to quality, performance, cost-effectiveness and sustainability of Clinical Engineering Services
- Challege the literature review observation on:
    - trends affecting Clinical Engineering Services in recent years (e.g. business-oriented focus, TQM)
    - sustainability of Clinical Engineering Services being threatened in the differing environments (e.g. due to downsizing, rationalisation)
- Develop a set of **standardised** key indicators to be used in assessing Clinical Engineering Services.

The objectives were subsequently translated into the development of the preliminary questionnaire, which included the following elements:

- General information about the institution being supported by/employing the Clinical Engineering Service
- Specific services provided and activities performed by the Clinical Engineering Service and their relevance to the institution it supports
- Mission, vision, objectives and strategic goals
- Customer expectations and perceptions
- Equipment management system used by Clinical Engineering Service
- Performance
- Budgets and cost-effectiveness
- Sustainability of Clinical Engineering Services
- Quality and Quality Assurance, including accreditation, certification
- Business/management trends affecting Clinical Engineering Services
- Measures of performance, cost-effectiveness and sustainability of Clinical Engineering Services
- Factors impacting on CES performance and sustainability

- CES indicators.

Testing the questionnaire proved that although the elements it contained were relevant and pertinent to the field of Clinical Engineering, the instrument itself was ineffective in providing useful data. Reasons for this varied, but of vital importance was that the questionnaire was specifically aimed at clinical engineering personnel and experts – and did not include the other three aforementioned target groups. The research methodology therefore had to be revised.

Phase 2: Developing and Administering the Final Questionnaires

Drawing on additional literature describing the design of performance measures in other fields, a new framework was developed. These studies provided a backbone for developing a methodology aimed at designing performance and sustainability indicators specific to Clinical Engineering and are as follows:

- **Rapid Evaluation Method (REM) (Anker et al, 1993),** which was developed by WHO in order to assess the performance and quality of health services, identify operational problems and assist in taking managerial action. REM consists of observation- and survey-based diagnostic activities, carried out mainly in healthcare facilities; and aims at bringing prompt and relevant information to planners and decision-makers. The methodology of REM consists of an 'Issue-Information Matrix' – a framework with three dimensions: (i) *dimension one* deals with issues reflecting specific health or programme problems, (ii) *dimension two* identifies information sources from stakeholders and (iii) *dimension three* describes the method of collecting the information.
- **The Management-by-Variance Tool (Hinks & McNay, 1999)**, which was created for performance assessment of the facilities management (FM) department of a major financial services company. This was driven by the absence of an acceptable set of standardised performance parameters or indicators for the FM function, and the need to clarify and prioritise the indicators that correlated the views of the customer and department in question. The methodology consists of (i) consultation of an expert group comprising of all stakeholders, (ii) definition of the research problem, (iii)

selection and short-listing of Key Performance Indicators (KPIs) (through frequency of votes, (iv) prioritising KPIs using a grading system and (v) rating of FM performance against the identified KPIs.

- **The Performance Measure Record Sheet (Neely et al, 1997),** which addresses the fundamental question "what does a well-designed performance measure constitute?". Drawing from an extensive literature review on performance measurement, the authors present recommendations for the design of performance measures. A framework, the performance measure record sheet, is then presented – based on the recommendations – that can be used to design and audit performance measures.

Drawing on relevant elements of these studies, plus the literature review and texts on questionnaire design, a framework for Phase 2 of the methodology was developed as follows:

1. Construction of an issue-information matrix, viz.: (i) *dimension one* consisted of a further refined list of the issues identified for the preliminary questionnaire, (ii) *dimension two* – information sources identified as the four target groups stipulated in the study and (iii) *dimension three* which was adapted to indicate the *structure of questions* asked in the instrument i.e. qualitative (open-ended) or quantitative (closed).
2. Decision to develop four separate questionnaires, specific to each target group – as opposed to a single questionnaire with branching of sections for different groups
3. The development of the four questionnaires, which were divided into two discrete sections:
    - **Part 1** of each questionnaire comprised mostly of open-ended (unstructured) questions, aimed at gauging opinions about Clinical Engineering Services (either specific or general) from the individual groups. The topics that were addressed for each group are specified in the *issue-information matrix*. The specific questions asked were developed from the preliminary questionnaire and the literature review. Part 1 formed the qualitative section of the study.

- **Part 2** was structured, requiring respondents to rate a list of proposed indicators according to a predetermined scale, as well as adding any additional indicators that they felt would be suitable. The list of indicators proposed was derived from the available literature and current best practice. The *management-by-variance tool* was used to develop the list, which was subsequently short-listed using the *performance measure record sheet*. This part was identical for all respondent groups (i.e. in all four questionnaires) and formed the quantitative section of the study.

4. Composition of cover letter, glossary and bibliography
5. Pre-testing, piloting and revising the questionnaires: The development of the questionnaires was cyclic, requiring repeated pre-tests and revisions until minimal problems and sources of error were detected. Numerous revisions were carried out during the development of the questionnaires. During the preliminary and intermediate stages of the questionnaire development, several people were consulted for their opinions and input. These consisted of research methodology experts in other fields, for their input on the **technical aspects** of the questionnaires; and clinical engineering/ HTM experts for their input on the **content** of the questionnaires and sample respondents for the **effectiveness** of the instrument.
6. The administration of the questionnaires: Three versions of each of the questionnaires were designed, namely a standard laser-printed mail (paper) version, and email (electronic) version and a web-based version. Lack of participation reduced the pilot study to four institutions within the Western Cape, South Africa, namely: Groote Schuur Hospital, Tygerberg Hospital, Vrijzee and Red Cross Children's War Memorial Hospital. Additional contributions were collated from HTM workshops that were held during the course of the study plus a few responses from the international community. The study canvassed a larger number of CES's through the PAHO Infratech list server / discussion group and has been put up on the IFMBE (International Federation for Medical and Biological Engineering) website, as part of an ongoing study.

Phase 3: Results

The final phase of the methodology consisted of analysing data and reporting the results of the pilot survey, and subsequent analysis of the questionnaires to determine the applicability and effectiveness of the developed instrument. Qualitative components of the questionnaires were analysed by categorisation (coding) of data, revealing dominant themes and trends. Due to the exploratory nature of the study, and low response rates, quantitative data was analysed using descriptive statistics. Although the study served as a pilot study - testing the developed framework - results proved to correspond with the objectives of the questionnaires and corroborated with evidence and speculation derived from the available literature.

GENERAL DISCUSSION

The questionnaires designed for this study produced a substantial amount of information regarding the Clinical Engineering Service function and general opinions of relevant stakeholders. An examination of the results revealed a fair number of recurring themes emerging from the different questions. These themes were drawn together and thus illustrated the significant findings of the study – particularly in the context of the literature review and objectives.

- Links were found between **CES mission, expectations of stakeholders** and **quality of service** provided. Dominant themes emerging were that CES's should (a) play a supportive (technical) role in improving healthcare delivery, (b) maintain optimum performance of medical equipment, ensure safety of healthcare delivery, (c) provide cost-effective service, (d) provide prompt, efficient and effective service and (e) provide professional, sustainable and quality service. All of this can be done via **essential** CES functions, which were identified as (i) specification, evaluation and procurement of equipment, (ii) inspection and preventive maintenance (IPMs), (iii) corrective maintenance (repair), (iv) functional/calibration checks, (v) strategic technology needs assessment and planning and (vi) safety checks. There was a general consensus that clinical engineering services have a positive and important

impact by enhancing healthcare service delivery, which is highly dependent on *functional* medical equipment.

- Using the methods of alternative question wording and test-retest questions, certain **advantages of in-house CES's** were found. Dominant themes occurring included: cost-effectiveness, fast response time, availability and accessibility, accountability and loyalty, knowledge of institutional needs and good communication opportunities.

- Having established that the function of an in-house clinical engineering service is important in supporting healthcare service delivery - with significant advantages over outsourced services - the questionnaires sought to identify institutional, organisational and socio-political factors that **support** the **sustainability** of CES's. Questions on factors supporting CES existence, sustainability factors and suggested sustainability indicators, yielded common themes. These were found to be (i) adequate financial resources, human resources, and physical infrastructure, (ii) awareness and commitment of institutional management and Departments of Health, (iii) stakeholder participation, (iv) performance CES technical staff, (v) incentives/career structure, (vi) policy, mission and strategy and (vii) cost-effectiveness of the in-house services. These themes concurred with questions on appropriate/relevant strategic objectives for clinical engineering services.

- By way of comparison or confirmation, factors **hindering** CES sustainability were identified and found to correspond to questions on disadvantages of in-house CES's and reasons institutional management or client expectations are not met. These factors were primarily a **lack** of the supporting elements listed. Other factors included (i) lack of specialised knowledge, (ii) management of trends and private market expansion, and (iii) liability for medical equipment-related injuries or death. These factors point towards perceived advantages of outsourcing – and trends such as downsizing and economic rationalisation occurring.

- Certain factors, which could not be translated into indicators – due to the framework presented – were found to have a significant impact on CES performance and sustainability as a whole. Of particular significance were: (i) adequate spare parts on

site, (ii) availability of service manuals, (iii) presence Quality Assurance programme, (iv) training, (v) a computerised and updated medical equipment inventory and (vi) level of participation and communication with stakeholders.

- Part 2 of the questionnaires, after a lengthy process of evaluation and prioritisation, presented all respondents with the task of rating the short-listed list of proposed indicators according to their perceived importance. **Seven** indicators were found to be **essential** to the CES function, plus **four** indicators of **very high importance.** These were:

  (i) cost of in-house service vs. cost of outsourced service per equipment type
  (ii) response time to service requests
  (iii) inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction (% of total no. clinical procedures)
  (iv) competencies/skills of CES personnel (assessed via level of education & evidence of continuing education)
  (v) patient (or operator) injury due to medical equipment malfunction or unavailability (number of incidents)
  (vi) patient (or) operator injury due to medical equipment misapplication
  (vii) allocated CES budget per year as a percentage of supported equipment inventory value
  (viii) evidence of proper documentation of all work done by CES providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc
  (ix) productivity
  (x) downtime of equipment due to IPMs or repairs
  (xi) percentage of repeat repairs.

Given the exploratory nature of this pilot study, statistical methods (e.g. correlation) could not be used to measure associations between the various components of the questionnaires. However, simple comparisons between dominant themes emerging from analysis of data shows a definite level of correspondence between them. This suggests

that the developed framework can be used to identify essential CES performance and sustainability indicators – thus fulfilling the objectives of the study.

This framework is presented as:

1. Collect three vital elements, specific to Clinical Engineering Service:
   - Mission statement, strategy and objectives, which conform to the overall strategic plan of the healthcare facility/institution
   - Expectations and perceptions of institutional management and CES clients
   - Identify **essential** CES services – as defined by all relevant stakeholders

2. Consider and align the elements with:
   - Specific CES performance and sustainability 'enabling' or supporting factors
   - Institutional, organisational and socio-political factors supporting CES existence

3. Integrate these and use to develop **critical CES performance indicators**

4. Use the indicators as a major contributor to policy and decision-making and thus point towards **CES sustainability.**

CONCLUSIONS AND RECOMMENDATIONS

A framework has been developed to describe performance and sustainability indicators for clinical engineering departments. A pilot study yielded results that correlated with literature and the objectives of the study, thus illustrating that it is a *working* framework.

Reliability and validity tests revealed a few problems with the questionnaires, however general correspondence between different issues and consistency of results suggested that reliability and validity could be increased with a few minor changes to the questionnaires.

The framework developed was found to be applicable and valid for developing performance indicators for CES's. As part of the 'bigger picture', if extended to the

international community and covering a larger sample, this methodology could therefore be used to establish **standardised** measures of performance, through a self-sustaining, on-going process, reviewed periodically – e.g. every 6 months. A longitudinal study on cases in differing regions and with differing infrastructure could be carried to establish the universality of the measures defined.

These could subsequently be used to guide decision-makers into assessing the importance, relevance and sustainability of in-house Clinical Engineering Services internationally.

TABLE OF CONTENTS

Title Page.....(i)
Acknowledgements.....(ii)
Synopsis.....(iv)
Table of Contents.....(xx)
List of Figures.....(xxvi)
List of Tables.....(xxviii)
Glossary of Terms.....(xxx)

1 INTRODUCTION.....1

1.1 Background and Definition of the Problem.....1
1.1.1 The Role of Clinical Engineering Services.....1
1.1.2 Rationale for this Study.....3

1.2 Objectives of the Study.....4

1.3 Methodology.....5

1.4 Scope of the Study.....5

1.5 Limitations and Delimitations of the Study.....6

1.6 Development of the Dissertation Report.....7

2 LITERATURE REVIEW.....8

I. BACKGROUND: CLINICAL ENGINEERING.....8

2.1 History and Evolution of Clinical Engineering.....8
2.1.1 Emergent Need for Clinical Engineering.....8
2.1.2 Evolution of Clinical Engineering.....9
2.1.3 A Definition of Clinical Engineering.....10

2.2 Clinical Engineering Today.....11
2.2.1 Health Systems Issues.....11
2.2.2 The Clinical Engineering Field.....13
2.2.3 International Developments and *Status Quo*.....15
2.2.4 Role of International Organisations and Agencies.....19
2.2.5 The Private Sector.....21
2.2.6 Professional Certification / Accreditation of CE Practitioners and Services.....21

2.3 The Need for Clinical Engineering Service Indicators / Relevance of Comparing Clinical Engineering Services.....23
2.3.1 Introduction.....23
2.3.2 Comparisons of Clinical Engineering Services.....23
2.3.3 Previous International Surveys of Clinical Engineering Services.....25
2.3.4 Productivity and Cost-Effectiveness in Clinical Engineering.....28
2.3.5 Sustainability of Clinical Engineering Services.....34
2.3.6 The Need For Clinical Engineering Service Indicators.....35

2.4 Summary of Section I of Literature Review.....37

II. BACKGROUND: DEVELOPMENTS IN MANAGEMENT AND MEASUREMENT OF SERVICE PERFORMANCE.....38

2.5 International Trends in Management.....38
2.5.1 Benchmarking.....38
2.5.2 Re-engineering.....39
2.5.3 Quality.....40
2.5.4 Outsourcing / Core Competencies.....41

2.6 Performance Measurement.....42
2.6.1 Introduction.....43
2.6.2 Key Performance Factors.....46
2.6.3 Developing Effective Performance Measures.....50
2.6.4 The Starting Point: Institutional/Departmental Mission.....54
2.6.5 Customer Needs and Expectations.....54

2.7 Quality and Quality Assurance.....58
2.7.1 Dimensions of Quality.....58
2.7.2 Defining Quality Assurance.....59
2.7.3 The High Costs of Low Quality.....60
2.7.4 The Quality Assurance Process.....62

2.8 Summary of Section II of Literature Review.....64

III. PERFORMANCE AND SUSTAINABILITY OF CLINICAL ENGINEERING SERVICES.....65

2.9 Developing Indicators.....65
2.9.1 Classification of Indicators.....65
2.9.2 Seven Steps to Developing Performance Indicators.....66
2.9.3 Operational Requirements for an Effective Measurement System.....67
2.9.4 Criteria for Appropriate Indicators.....69
2.9.5 Managing Indicators.....72

2.10 Defining Indicators for Clinical Engineering Services.....72
2.10.1 Clinical Engineering Database.....72
2.10.2 Performance Indicators.....74
2.10.3 Sustainability Indicators.....75

2.10.4 Cost-Effectiveness of Clinical Engineering Services.....77

2.11 Summary of Section III of Literature Review.....82

3 METHODOLOGY: PHASE 1 83

3.1 Overview of Methodology.....83

3.2 Definition of the Research Problem.....84

3.3 Selecting an Appropriate Research Design.....84

3.4 Description of Sample (Respondents).....87
3.4.1 Target Respondents Chosen for the Study.....87
3.4.2 Sampling Procedure.....89

3.5 Defining Objectives for the Questionnaires.....90

3.6 The Preliminary Questionnaire.....92
3.6.1 Specifying Themes for the Questionnaire.....93
3.6.2 Organisation of Questionnaire.....94
3.6.3 Formulating Questions for the Questionnaire.....95
3.6.4 Testing the Questionnaire.....99
3.6.5 Determining Applicability of the Questionnaire.....100

4 METHODOLOGY: PHASE 2 104

4.1 Background to the Methodology: A Literature Review.....104
4.1.1 Rapid Evaluation Method (REM) (Anker *et al*, 1993)..... 104
4.1.2 A Management-By-Variance Tool (Hinks & McNay, 1999).....106
4.1.3 The Performance Measure Record Sheet (Neely *et al*, 1997).....109

4.2 The Framework for the Study.....110

4.3 The Issue-Information Matrix.....110

4.4 The Development of the Questionnaires.....114
4.4.1 A Single Questionnaire or Four Separate Questionnaires?.....114
4.4.2 Structure of the Questionnaires 115
4.4.3 Pre-testing and Revising the Questionnaires.....116
4.4.4 'Piloting' the Questionnaires 117

4.5 Development of Part 1 of Questionnaires 1 – 4.....120
4.5.1 Themes and Organisation of the Questionnaires.....120
4.5.2 Language and Layout of the Questionnaires.....121

4.6 Quest1: Institutional Management.....122
4.6.1 Specifying Themes for the Questionnaire.....122

4.6.2 Organisation of the Questionnaire....123
4.6.3 Constructing Questions for Quest1....123

4.7 Quest2: CES Management & Personnel....131
4.7.1 Specifying Themes for the Questionnaire....131
4.7.2 Organisation of the Questionnaire....132
4.7.3 Constructing Questions for QUEST2....132

4.8 Quest3: Clinical Engineering Service Clients....136
4.8.1 Specifying Themes for the Questionnaire....136
4.8.2 Organisation of the Questionnaire....137
4.8.3 Constructing Questions for QUEST3....137

4.9 Quest4: Ministries of Health / International HTM Experts....139
4.9.1 Specifying Themes for the Questionnaire....139
4.9.2 Organisation of the Questionnaire....139
4.9.3 Constructing Questions for QUEST4....140

4.10 Development of Part 2: CES Indicators....142
4.10.1 Overview of the Development of Part 2....142
4.10.2 Details of the Development Process....144

4.11 Administration of the Final Questionnaires....148

5 RESULTS....150

5.1 Overview of Data Analysis Methods....150
5.1.1 Qualitative Data Analysis....150
5.1.2 Quantitative Data Analysis....152

5.2 Demographic Data....154
5.2.1 Distribution of Responses by Target Group....155
5.2.2 Distribution of Responses by Country....157
5.2.3 Distribution of Responses by Health Facility Type....158
5.2.4 Summary of Distribution of Responses....159

5.3 Mission and Strategy of Clinical Engineering Services....159
5.3.1 Identifying an Appropriate Mission Statement for a CES....159
5.3.2 Identifying Appropriate Strategic Elements for a CES....160

5.4 Services Provided by Clinical Engineering Services....160
5.4.1 Services Provided....161
5.4.2 Ratings of Services Provided by CES....163

5.5 Expectations and Perceptions of Stakeholders....165
5.5.1 Client and Institutional Management Expectations of CES....167
5.5.2 Reasons Expectations Are Not Met....167

5.6 Importance of CES and Impact on Healthcare Delivery....168

5.6.1 Advantages and Disadvantages of Clinical Engineering Services.....168
5.6.2 Impact of CES on Healthcare Service Delivery.....169
5.6.3 Implications of No In-House CES.....170

5.7 'Quality of Service' with Respect to CES.....171

5.8 Performance of Clinical Engineering Services.....172
5.8.1 Current Assessment of CES Performance.....172
5.8.2 Suggested CES Performance Indicators.....173

5.9 Sustainability of Clinical Engineering Services.....173
5.9.1 Are Clinical Engineering Services a 'Core' Function of Healthcare Service Delivery?.....174
5.9.2 Factors Supporting (or Hindering) the Existence of CES.....175
5.9.3 Sustainability Factors.....176
5.9.4 Suggested Sustainability Indicators.....178

5.10 Management Trends Affecting CES's.....179

5.11 Factors Impacting on CES Performance/Sustainability.....181

5.12 Part 2: Clinical Engineering Service Indicators.....183

6 GENERAL DISCUSSION 190

6.1 Revisiting the Objectives of the Questionnaires.....190

6.2 Significant Findings From The Survey.....190
6.2.1 Links between CES Mission and Function, Expectations of Stakeholders and the Impact of CES's on Healthcare Service Delivery.....191
6.2.2 Advantages of an In-house CES.....192
6.2.3 Sustainability of Clinical Engineering Services.....195
6.2.4 Factors Hindering CES Sustainability.....197
6.2.5 CES Performance/Sustainability 'Enabling' Factors.....198
6.2.6 CES Performance Indicators.....200

6.3 Evaluation of the Questionnaires.....206
6.3.1 Length of the Questionnaires.....206
6.3.2 Instrumentation Bias.....207
6.3.3 Response Bias.....210
6.3.4 Reliability and Validity.....211

6.4 Limitations and Delimitations of the Study.....213
6.4.1 Limitations.....213
6.4.2 Delimitations.....214

6.5 Applicability of the Framework.....215

7 CONCLUSIONS AND RECOMMENDATIONS.....217

7.1 Conclusions.....217

7.2 Recommendations for Further Work.....220

8 REFERENCES.....223

9 BIBLIOGRAPHY..... 229

APPENDICES

Appendix A: Preliminary Questionnaire.....A1

Appendix B: Complete list of indicators.....B1

Appendix C: Final questionnaires (paper version).....C1
Cover letter
[Quest1]
[Quest2]
[Quest3]
[Quest4]

Appendix D: Detailed Statistics.....D1

Appendix E: Revised Questionnaires (Electronic Version).....E1
Revised Cover Letter
Instructions
[Quest1]
[Quest2]
[Quest3]
[Quest4]

Appendix F: Questionnaire Design.....F1

LIST OF FIGURES

Figure 2.1: Summary of Section I of Literature Review.....37

Figure 2.2: Measurements Required to Monitor the Performance of any Production System (Kaydos, 1991).....48

Figure 2.3: Scorecard measures aligned with customers' needs and expectations, corporate vision and business processes (Chang & Morgan, 2000).....52

Figure 2.4: The SERVQUAL Model.....57

Figure 2.5 Summary of Section II of Literature Review.....64

Figure 2.6: Indicator Management Process (Autio & Morris, 1995).....73

Figure 2.7: Summary of Section III of Literature Review.....82

Figure 3.1: Overview of the Methodology.....83

Figure 3.2: Definition of the Research Problem.....84

Figure 3.3: Range of interactions of Clinical Engineering Service (adapted from Bronzino, 1992).....88

Figure 3.4: Development of the Preliminary Questionnaire.....93

Figure 4.1: Issue-Information Matrix.....106

Figure 4.2: Overview of Phase Two of the Methodology.....111

Figure 4.3: Decision – Single Questionnaire or Four Separate Questionnaires?...114

Figure 4.4: Structure of the Questionnaires.....116

Figure 4.5: Development of Part 1 of the Questionnaires.....120

Figure 4.6: Development of Part 2 of Questionnaires.....143

Figure 4.7: Administration of Final Questionnaires.....149

Figure 5.1: Steps involved in qualitative data analysis (Dey, 1993).....151

Figure 5.2: Qualitative analysis – categorisation of data.....151

Figure 5.3: Tool selection for descriptive analysis.....152

Figure 5.4: Relative distribution of responses by target group.....156

Figure 5.5: Relative Distribution of Responses by Country.....157

Figure 5.6: Relative Distribution of Responses by Health Facility Type.....158

Figure 5.7: Relative Percentages of CES Services provided.....162

Figure 5.8: CES Service Ratings: Medians and Ranges.....163

Figure 5.9: Service Ratings: Institutional Management.....166

Figure 5.10: Service Ratings: CES Personnel.....166

Figure 5.11: Service Ratings: CES Clients.....166

Figure 5.12: Factors Considered Significant to CES Sustainability.....177

Figure 5.13: Ratings of Factors with Significant Impact on CES Sustainability...178

Figure 5.14: Trends Affecting CES's (Perceptions of CES Personnel).....180

Figure 5.15: Percentages of Responses on Factors Impacting on Performance/Sustainability.....183

Figure 5.16: Composite Indicator Ratings: Medians and Ranges indicators as listed in Table 5.27.....186

Figure 5.17: Indicator Ratings for the Separate Groups (see Appendix D8).....188

Figure 6.1: Links between CES Mission and Function, Expectations of Stakeholders and Impact on Healthcare Service Delivery.....193

Figure 6.2: Advantages of In-house CES.....195

Figure 6.3: Sustainability of Clinical Engineering Services.....196

Figure 6.4: Factors Hindering CES Sustainability.....199

Figure 6.5: Framework for Developing CES Performance and Sustainability Indicators 202

Figure 7.1: Recommendations for further work.....220

LIST OF TABLES

Table 2.1: Problems and corresponding waste of health care equipment (Issakov, 1994).....12

Table 4.1: Issue-Information Matrix.....113

Table 4.2: Initial Rating Scale for Section 3.1.....126

Table 4.3: Final Rating Scale for Section 3.1.....127

Table 4.4: Rating of Significance of Impact of Factors on CES Sustainability....135

Table 4.5: Rating Scale for CES Indicators.....145

Table 4.6: Final Indicator Shortlist.....147

Table 4.7: Rating Scale for Additional Indicators Suggested by Respondents.....148

Table 5.1: Response Rates of the Questionnaires Distributed within South Africa 155

Table 5.2: Distribution of Responses by Target Group.....156

Table 5.3: Distribution of Responses by Country.....157

Table 5.4: Distribution of Responses by Health Facility Type.....158

Table 5.5: Suggested Elements in a CES Mission.....159

Table 5.6: Suggested Strategic Elements for a CES.....160

Table 5.7: Relative Percentages of CES Services Provided.....161

Table 5.8: Client and Institutional Management Expectations of CES.....167

Table 5.9: Reason Institutional Management/Client Expectations Not Met.....167

Table 5.10: Advantages of In-House CES.....168

Table 5.11: Disadvantages of In-House CES.....169

Table 5.12: Advantages of Outsourcing CE Activities.....169

Table 5.13: Impact of CES on Healthcare Service Delivery.....170

Table 5.14: Implications of No In-house CES.....171

Table 5.15: Quality of Service with Respect to CES.....172

Table 5.16: Current Assessment of CES Performance.....172

Table 5.17: Suggested CES Performance Indicators.....173

Table 5.18: Are CES's a Core Function of Healthcare Service Delivery?.....174

Table 5.19: Factors Supporting the Existence of CES's.....175

Table 5.20: Factors Hindering the Existence of CES's.....175

Table 5.21: Factors With Significant Impact on CES Sustainability.....176

Table 5.22: Suggested Sustainability Indicators.....179

Table 5.23: Management Trends Affecting CES's.....180

Table 5.24: Effect of Management Trends on CES.....181

Table 5.25: General CES Performance and Sustainability Factors.....182

Table 5.26: Percentages of Responses on Factors Impacting on Performance / Sustainability.....182

Table 5.27: Final Indicator Shortlist.....184

GLOSSARY OF TERMS

1. **ACCREDITATION:** certification by a duly recognised body of the facilities, capability, objectivity, competencies and integrity of an agency, operational group or individual to provide a service, usually specified in the form of standards.

2. **ASSET / INVENTORY MANAGEMENT**: Management of capital assets, including medical equipment, on the basis of asset registers (inventory).

3. **BENCHMARKING:** the gathering of quantitative data, either physical or financial, to compare the performance of different organisations in order to identify and understand elements of best practice / world-class performance in a particular work process.

4. **CERTIFICATION**: the procedure and action by a duly appointed body of determining, verifying and documenting the quality of personnel, processes, procedures or items in accordance with applicable requirements.

5. **CES PERSONNEL**: technical staff of a clinical engineering service. It is assumed that the CES has administrative and clerical backup.

6. **CLINICAL ENGINEERING SERVICE*** **(CES):** a service that provides a supportive role in the planning and development of facilities, technology and technical methods as they relate directly to healthcare delivery. In different environments CES's can fall under different names, e.g. *medical equipment workshop, medical physics department, biomedical technology service, health care technical service, etc.* The service can range in scope from one dedicated but under-resourced individual to an entire department, situated within a health facility or elsewhere as a shared regional/central resource centre.

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* *Such units are known variously as Clinical Engineering Departments, Health Care Technical Services, Medical Physics Department, Biomedical Technology/Engineering Services, and Medical Apparatus/Equipment Workshops.*

7. **CORRECTIVE MAINTENANCE / REPAIR:** Troubleshooting to isolate the cause of device malfunction and then replacement or subsequent adjustments of components or subsystems to restore normal function, safety, performance and reliability (Bronzino, 1992).

8. **COST OF OWNERSHIP:** Cost of ownership encompasses all direct and indirect expenses associated with medical equipment over its lifetime. It includes acquisition costs, operation and maintenance costs (i.e. installation, supplies, training, spare parts, test equipment, transport, etc.) (David, 1993).

9. **COST-EFFECTIVENESS:** The cost of a technology or of alternative technologies, compared to the resultant benefits, with costs and benefits not expressed by the same unit. Costs are usually expressed in a currency (or equivalent) while benefits/effectiveness are expressed in terms such as lives saved, disability avoided, quality-adjusted life years saved, etc.

10. **CLIENT / CUSTOMER:** an individual/group/organisation receiving, using or impacted by a product or service.

11. **DOWNSIZING:** intended reduction of personnel in an organisation, often as a consequence of economic rationalisation.

12. **DOWNTIME:** time during which medical equipment is not available for its normal function (e.g. due to IPMs or repairs).

13. **ECONOMIC RATIONALISATION:** management decisions based almost purely on the (short-term) "bottom-line" often with little or no regard for the wider (longer term) consequences.

14. **EFFICACY:** Benefit of a technology achievable under ideal conditions.

15. **EFFECTIVENESS:** Benefit of a technology achievable under average conditions of use.

16. **EQUIPMENT PERFORMANCE MONITORING:** Monitoring of equipment utilisation, cost-effectiveness, availability (uptime), etc.

17. **FACILITIES AND PLANT MANAGEMENT:** A support programme that provides and maintains the proper environment for the delivery of healthcare services. FPM programmes ensure that buildings and associated utilities, transport and communications systems are acquired, operated and maintained in a manner that promotes the most efficacious and productive environment for normal hospital operations and the delivery of quality medical care (Bronzino, 1992).

18. **FUNCTIONAL:** Equipment in good and proper working order, according to specification.

19. **GLOBALISATION:** extension of economic activity across national and regional boundaries, and the functional integration of such internationally dispersed activities.

20. **HAZARD NOTIFICATION SYSTEM:** Guidelines, procedures and mechanisms for informing clinical and technical personnel of emerging information on equipment-related risks, usually due to design flaws or production/manufacturing defects.

21. **HEALTHCARE TECHNOLOGY MANAGEMENT (HTM):** "An accountable, systematic approach to ensuring that cost-effective, safe, efficacious and appropriate equipment is available to meet the demands of quality patient care" (ECRI, 1989). Defined at the **national** level as "the goal of optimising the acquisition and utilisation of technology to achieve maximum beneficial impact on health outcomes" (Rakich, 1992). Such an approach requires that medical equipment resources be managed and that the management strategies have measurable outputs that are monitored and evaluated (COHSASA, 1997).

22. **HIGH RISK MEDICAL EQUIPMENT:** Equipment associated with a high risk to the patient in terms of either intended function or consequences of failure, such as electro-surgical units or life-support equipment.

23. **HOSPITAL ENGINEERING:** Management and maintenance of health facility infrastructure, including services, plant, machinery and buildings (synonymous with Facilities and Plant Management).

24. **INCIDENT:** An "incident" is defined as an event in which equipment or procedure has caused injury to a patient, and occasionally staff members (users/operators) or even visitors. The incident can be caused by specific equipment malfunction, user error or a combination of the two.

25. **INCIDENT INVESTIGATION** An incident investigation includes: preservation of evidence and assessment of the overall condition of the equipment; interviews with involved personnel; review of maintenance history and review matters related to training associated with the equipment.

26. **INDICATORS:** An indicator is an objective, quantitative variable that indicates or shows a given situation, and thus can be used to measure change. It is objective in that the same measurement can be obtained by different observers.

27. **IN-HOUSE CES:** A clinical engineering service based within or readily accessible to the institution / hospital benefiting from its services.

28. **INSPECTION AND PREVENTIVE MAINTENANCE (IPM):** There are three basic categories: (i) Periodic procedures to minimise the risk of failure and to ensure proper operation (including cleaning, lubricating, adjusting etc.); (ii) Functional testing, performance verification and calibration; (iii) Safety inspection. (Bronzino, 1992). IPMs are seen as lowering the total maintenance cost over the equipment lifetime, partly through extending this lifetime.

29. **LABOUR COST (VARIABLE COSTS):** Costs that are assumed to vary (linearly) with production volume or service output. They can be viewed as costs that would not exist if there were no labour force. These include salary and wages of active service staff, continuing education expenses, liability insurance costs, repair and service supplies, employee benefits, etc. (Bronzino, 1992).

30. **LITIGATION:** Legal action taken as a result of patient injury due to neglect of medical/nursing staff or equipment failure.

31. **LOGISTICS SUPPORT:** includes supply systems, information and communications systems, and transport.

32. **MEDICAL EQUIPMENT:** defined as including all medical/surgical equipment, devices and instruments used in healthcare delivery; the term is used interchangeably with 'medical devices' or 'medical technology'.

33. **NEEDS ASSESSMENT:** A formal process for assessing (equipment) needs, usually on the basis of audits of clinical services offered, on the one hand, and an audit of existing (equipment) inventory on the other.

34. **NORMALISED:** with respect to a specified time period or other appropriate unit.

35. **OUTSOURCING:** using the services of an outside contractor (private sector service provider) rather than in-house staff to accomplish an activity.

36. **OVERHEAD COST (FIXED COSTS):** Costs that do not fluctuate with the level of activity. These include effective cost of hospital floor space and utilities, capital depreciation; administrative and clerical labour cost, and costs of carrying a spare parts inventory (Bronzino, 1992).

37. **PERFORMANCE**: An actual work accomplishment or output (not to be confused with work behaviour). Quality and productivity are dimensions of a higher-level measure called 'performance' or 'effectiveness'.

38. **PHYSICAL INFRASTRUCTURE:** Includes health facilities (buildings and utilities) and hospital equipment, machinery and plant.

39. **PRODUCTIVITY:** the ability to combine and convert inputs (labour, capital, materials and other resources) into outputs (goods and/or services) which satisfy market needs. Productivity can also be seen as a relationship between output and input of a given process i.e. *P = Output/Input = (production of some desired result)/(consumption of resources).*

40. **QUALITY:** conformance to requirements (stated or implied). This includes internal measurements, e.g. number of rejects; and external measures such as customer satisfaction rating. Alternatively, the degree of excellence of a product or service.

41. **QUALITY ASSURANCE:** all the planned or systematic actions that are carried out to set standards and to monitor and improve performance so that the service provided is as effective and as safe as possible i.e. providing adequate confidence that a product or service will satisfy requirements for quality.

42. **RE-ENGINEERING:** "...changing processes, organisational structures, management style and behaviour, compensation and reward systems, as well as relationships with shareholders, customers, suppliers and other external partners" (Kelada, 1996).

43. **RESPONSE TIME**: the time between the receipt of a service call and the time the technician actually arrives at the equipment site (AAMI, 1990).

44. **RISK AND SAFETY MANAGEMENT:** An organised programme that removes and controls elements that can contribute to the avoidance of exposure to risks and the minimisation of liability exposure (David, 1993), i.e. minimises or prevents the occurrence of undesirable outcomes.

45. **STRATEGY:** A vision of the position the service is to reach in the market and of how to get there, including financial, personnel and other sub-plans, as well as service strategy and quality strategy.

46. **STRATEGIC PLAN:** "A continuous process of making present risk-taking decisions systematically and with greatest knowledge of their futurity; organising systematically the efforts needed to carry out these decisions; and measuring the results of these decisions against the expectations through organised systematic feedback" (David, 1993).

47. **SUSTAINABILITY:** Medium- and/or long-term continuity of a process or service, usually determined on the basis of factors such as cost of delivery, availability of inputs/resources, desirability of the process or service, benefits accrued, opportunity costs, etc.

48. **TECHNOLOGY ASSESSMENT:** A process used for examining and reporting properties of medical technology used in healthcare, such as safety, efficacy, effectiveness, feasibility and indications for use as well as social, economic and ethical consequences, whether intended or unintended (David, 1993). TA tools include cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA).

49. **TEST EQUIPMENT:** Any tools and equipment used by CE personnel to perform calibration checks, IPMs and corrective maintenance, e.g. oscilloscopes, digital multimeters, defibrillator testers, physiological simulators, etc.

50. **THIRD-PARTY SERVICE PROVIDER:** An independent medical equipment service organisation (i.e. not equipment supplier or in-house service). May be small and only specialise in a few types of equipment, or may be large enough to provide service for most equipment in a hospital.

51. **TOTAL QUALITY MANAGEMENT:** management-led philosophy of continuous improvement in every process of planning, production and service - a way of

managing to improve the effectiveness, efficiency, flexibility and competitiveness of the business as a whole.

52. **TRAINING EQUIPMENT USERS:** Establish and deliver instructional modules for clinical engineering staff as well as clinical staff on the operation of medical equipment (Bronzino, 1995)

1 INTRODUCTION

1.1 BACKGROUND AND DEFINITION OF THE PROBLEM

1.1.1 The Role of Clinical Engineering Services

Several definitions of Clinical Engineering exist. An early definition quoted by Caceres in 1977 is:

> *"The application of the art and science of industry, that is, technology, to the healthcare delivery and clinical problems in medicine."* (Caceres, 1977)

A more recent definition reads:

> *"The management, support, development and quality assurance of healthcare technology as part of safe, cost-effective and sustainable healthcare delivery".* (SA National Steering Committee on Clinical Engineering, 2000)

That there are many definitions of Clinical Engineering (e.g. Caceres, 1977; Webster, 1979; Bronzino, 1992; COHSASA, 1997) is not surprising, since this relatively new field is continually evolving.

The general function of a Clinical Engineering Service (CES) is to provide a supportive role in aspects related to the planning, needs assessment, evaluation, procurement, installation, utilisation and maintenance of medical equipment – which is defined as including all medical/surgical devices, equipment and instruments – as they relate directly to healthcare delivery. Units responsible for providing this service are variously known as Clinical Engineering Departments, Healthcare Technical Services, Medical Physics Departments, Biomedical Technology / Engineering Services or Medical Equipment Workshops, depending on historical precedent, region or health facility type.

An idealised role would include the following:

- Technology management (including needs assessment, specification, evaluation, installation and support of medical equipment, asset management and review of equipment replacement needs)
- Technology assessment (assessment of clinical efficacy, safety, and appropriateness of medical equipment; cost benefits and monitoring of emerging technologies)
- Risk management and safety checks (reducing medical equipment-related patient and staff incidents)
- Quality assurance and improvement
- Training of equipment users
- Inspection and preventive maintenance (IPMs)
- Corrective maintenance (repairs)
- Clinical research and development and modification of medical devices
- Project management.

In some cases, the role would also include Facilities and Plant Management and Maintenance, telecommunications and/as IT management and support.

However, the boundaries of these support roles are not clear and well defined, as what applies to one country or institution does not necessarily apply to another. Also, a clinical engineering service can range from one isolated but dedicated individual to a fully equipped department with professional and technical/artisan staff, supported by adequate technological and administrative infrastructures, to a shared regional/central resource centre.

In addition, the scope and focus of clinical engineering activities has changed considerably over the last 20 years or so; changing from being primarily concerned with patient and user safety in the early 70s, to being involved in all areas of healthcare technology management as listed above.

Alongside the change in scope and function of Clinical Engineering Services over the years, is the shift from being primarily task-driven to being more business-oriented and cost-justified. A further development has been the adoption (sometimes imposed) of various international trends in business and management, e.g. total quality management, benchmarking, re-engineering, outsourcing (of non-core business activities) and, most recently, ISO9000 standard accreditation. As sustainability is often dependent on issues of cost-effectiveness and relevance, and associated perceptions of institutional/organisational stakeholders, these considerations may threaten otherwise successful departments and/or services with closure.

1.1.2 Rationale for this Study

Many countries (and notably developing and emerging economies) are under-resourced in terms of what is needed for equitable service delivery of acceptable quality, as well as the management-level skills needed to maximise the impact of healthcare technologies on service delivery. Within this context healthcare technology management (HTM) practitioners and activities are being increasingly recognised for their contribution to health system performance. There is thus an urgent need to (i) build HTM management capacity and (ii) develop effective HTM tools, while at the same time (iii) developing indicators for HTM performance and sustainability.

This study follows and complements previous work by Frize (1990) and Glouhova (1999) and focuses on the last-mentioned, and specifically on the development of indicators for Clinical Engineering Services - be they situated within a health facility or a shared / regional resource centre. These indicators will form qualitative and quantitative components of a tool for objective assessment and comparison of the performance of CE services in different settings, as well as identifying pointers to performance, cost-effectiveness and sustainability. This in turn will contribute to improved management of these services, with the overall aim of improving the performance and quality of healthcare delivery.

The present study forms part of a larger ongoing project, with the following objectives:

i. Consider the historical evolution of the field of clinical engineering internationally, with due consideration to regional- and country-specific differences.
ii. Compare the functions and services provided by the clinical engineering services selected for the study in their respective environments.
iii. Develop and test appropriate indicators, as part of a broader methodology and framework, to describe the performance, cost-effectiveness and sustainability of clinical engineering services.
iv. Test these indicators to determine to what extent common indicators can be used in comparing and assessing the performance and sustainability of clinical engineering services in differing environments.

1.2 OBJECTIVES OF THE STUDY

The specific objectives of the study were to:

i. Consider performance measurement systems, as described in business management literature / other fields and evaluate their applicability to Clinical Engineering Services.
ii. Develop a framework, derived from the literature review, that can be used to identify performance indicators and assess sustainability of Clinical Engineering Services.
iii. Test the framework to determine its applicability to in-house Clinical Engineering Services at an international level.
iv. Develop a consensus on the importance of Clinical Engineering Services.

1.3 METHODOLOGY

Various research methods for obtaining the necessary information/data were considered at the outset of the study, including the use of secondary data, observation (through site visits) and extensive interviews. The survey method was finally considered to be the most appropriate research methodology for collecting primary data for the study. The specific progression of the methodology is as follows:

i. Extensive review of literature on medical equipment maintenance and management; previous research on Clinical Engineering Services (including the history and status of the field, productivity and cost-effectiveness); and business management literature on management trends, performance measurement, indicator development and quality/quality assurance.

ii. The development of a preliminary questionnaire, piloted at HTM expert workshops.

iii. The development of four questionnaires, targeted at (i) institutional management, (ii) CES management and personnel, (iii) CES clients and (iv) international HTM experts and representatives of national / regional Departments of Health, respectively. These comprised both qualitative and quantitative components.

iv. A pilot study, aimed primarily at the first three groups.

v. Analysis of responses from the pilot study, using descriptive statistics.

vi. The creation of a framework for developing CES performance indicators which can be used in assessing CES sustainability.

1.4 SCOPE OF THE STUDY

The scope of the study originally included in-depth analysis of four clinical engineering services at tertiary / academic institutions in four different regions viz. Southern Africa, the UK, Australia and the USA. These CES's were selected

on the basis of their initial willingness to collaborate in the study. However, lack of effective participation reduced the pilot study to four institutions within the Western Cape province of South Africa, namely: Groote Schuur Hospital, Tygerberg Hospital, Vrijzee and Red Cross Children's War Memorial Hospital. Additional contributions were collated from HTM expert workshops that were held during the course of the study plus a few responses from the international community.

The study focused primarily on public sector **in-house** Clinical Engineering Services, and included the input and perceptions of (i) institutional management, (ii) CES management and personnel, (iii) CES clients and (iv) international HTM experts and representatives of regional / national Departments of Health.

1.5 LIMITATIONS AND DELIMITATIONS OF THE STUDY

As mentioned previously, certain limitations were imposed on the original study, thus changing the focus of the study. Over and above those limitations, certain constraining factors influenced the outcome of the resultant study. These included time constraints, lack of participation of collaborators, certain institutions and target respondents (particularly CES personnel) within participating health facilities. This resulted in a low response rate. Non-co-operation from the international community limited the geographical scope of the study, as well as the ability to make relevant comparisons.

Delimitations were also imposed, given the limitations described. These included limiting the study to traditional **in-house** CES services, specifically within the public sector, and limited distribution of questionnaires to the fourth target group. Limited data also dictated the types of analyses that could be performed. Basic descriptive statistics were used. Finally, although a framework was developed, it was not tested on the participating CES's, as this would require a longitudinal study.

1.6 DEVELOPMENT OF THE DISSERTATION REPORT

The dissertation begins with a literature review, covering (i) a background to Clinical Engineering, including the history and evolution of the field, the current status and the need for CES indicators; (ii) a background of developments in management and measurement of service performance, including international trends, performance measurement, quality and quality assurance; and (iii) performance and sustainability of Clinical Engineering services, including the development and defining of indicators for the field.

The next phase describes the progression of the methodology, from the development of the preliminary questionnaire, the rationale behind including the four aforementioned target groups, to the design of the final questionnaires. The analysis and results of responses from these questionnaires are subsequently described.

A discussion chapter integrates themes emerging from the results and discusses them in the context of the literature and the objectives laid out. An evaluation of the validity and reliability of the questionnaires ensues, resulting in a discussion on the effectiveness and applicability of the developed framework.

Finally, conclusions are drawn from the study and recommendations for further work are presented.

2 LITERATURE REVIEW

The literature review is divided into three discrete sections, namely:

I. A background to the field of Clinical Engineering

II. A background to developments in management and measurement of service performance

III. Literature on the performance and sustainability of Clinical Engineering Services

I. BACKGROUND: CLINICAL ENGINEERING

2.1 HISTORY AND EVOLUTION OF CLINICAL ENGINEERING

The twentieth century has seen technological innovation that has reshaped the field of medicine and the delivery of healthcare services. Advances in medical technology have provided a wide range of diagnostic, therapeutic and rehabilitative instruments that are now routinely used in the treatment and management of specific illnesses and diseases (Bronzino, 1992).

2.1.1 Emergent Need for Clinical Engineering

The period after World War II, particularly in the 1960s, saw the beginnings of unprecedented advances in electronic instrumentation and the marriage of particular engineering fields with the medical field. This resulted in various innovations, including the intensive-care unit (ICU), the open-heart operation, the artificial organ and computerised electrocardiography (Caceres, 1977). According to Smith (1982), unlike industrial and scientific users, the healthcare delivery system was initially ill-prepared to manage this new technology.

On November 16 1970, an article reporting "1200 Silent Electrocutions in American Hospitals" appeared in *The Wall Street Journal*, subsequently launching an equipment safety scare. Hospitals and industry thus responded through various voluntary regulatory groups that randomly and hastily devised codes, standards and guidelines. A new engineering discipline was needed to provide the technical support necessary to meet the new safety requirements. In response to these newly defined needs, the **clinical engineering** profession was born (Smith, 1982).

2.1.2 Evolution of Clinical Engineering

Clinical engineering evolved from being primarily concerned with patient and user electrical safety in the early 1970s, to assuming responsibility for cost-effective maintenance, then equipment evaluation and procurement in the mid 1970s. According to Newhouse *et al.* (1989), by this time it was revealed that many devices did not perform according to manufacturers' specifications or users' expectations. Complete performance inspections before and after medical equipment installation became the norm, and much time was spent in developing sensible inspection procedures.

By the early 1980s, the health care delivery industry's increased concern over the cost, safety and performance of medical equipment caused many hospitals to rely heavily on clinical engineering departments for the selection and support of medical instrumentation (Smith, 1982).

Clinical engineering departments became the logical support centre for all medical technologies. Clinical engineers thus assumed additional responsibilities, including the management of complex devices and systems used in hospitals; the training of medical personnel in equipment use and safety; and the design, selection and use of technology to deliver safe and effective health-care (Bronzino, 1992).

Newhouse *et al.* (1989) further adds that from the early 1980s, as microcomputers began to proliferate into the healthcare environment, clinical engineering was now called upon to provide support for microprocessor-based equipment. By the late 1980s it was not uncommon to find clinical engineers involved in telecommunications and information technology.

More recently clinical engineering has included overall management, strategic planning, technology assessment, life-cycle costing, training of equipment users, research and development and quality assurance.

In short, the clinical engineering profession aims at supporting the process of delivering safe and effective health care.

2.1.3 A Definition of Clinical Engineering

In keeping with the evolution of the field, the definition of clinical engineering has also evolved with time. Several definitions exist.

An early definition given by Aller *et al* (in Caceres, 1977) is:

> *"The application of the art and science of industry, that is, technology, to healthcare delivery and clinical problems in medicine".*

Goodman (1989) quotes a definition of a clinical engineer, which the AAMI originally applied to certified practitioners as:

> *"A professional who brings to healthcare facilities a level of education, experience and accomplishment which will enable him to responsibly, effectively and safely manage and interface with medical device, instruments and systems, and the user thereof during patient care...".*

COHSASA (1997) define the field as:

"Medical equipment management and maintenance and equipment user support within a healthcare delivery institution or system".

A more recent definition reads:

"The management, support, development and quality assurance of healthcare technology as part of safe, cost-effective and sustainable healthcare delivery". (SA National Steering Committee on Clinical Engineering, 2000).

The terms 'clinical engineering' and 'biomedical engineering' are sometimes used interchangeably, although several authors (e.g. Bronzino, 1992) provide distinctions between the two. Units responsible for providing clinical engineering services are also known as Health Care Technical Services, Medical Physics Departments, Biomedical Technology / Engineering Services, Medical Apparatus / Equipment Workshops, etc.

Individuals involved in the management of medical technology are commonly referred to as clinical engineers, however the terms biomedical equipment technicians, equipment managers and healthcare engineers are sometimes used (David & Judd, 1993).

2.2 CLINICAL ENGINEERING TODAY

2.2.1 Health Systems Issues

The 2000 World Health Report[1] suggests four key *functions* of a health system, viz. (i) service delivery, (ii) capacity building, (iii) financing and (iv) stewardship; and three key health system *inputs*, viz. (i) human resources, (ii) capital investment (in physical assets such as buildings and equipment) and (iii) consumables (including drugs).

[1] The World Health Report 2000 - Health Systems: Improving Performance. World Health Organization, Geneva (2000)

According to Issakov (1994) healthcare equipment, including transport vehicles, represents an important investment for health care systems in any country, including developing ones. The appropriate introduction and proper service, maintenance and use of this equipment are vital for efficient and cost-effective health care delivery at all levels of the health system. This is true for the most sophisticated hospital right through to the community health centre.

Medical equipment is often seen as a major factor in rapidly rising health care costs, but this technology also supports and strengthens medical progress and healthcare delivery. The overall management of this equipment requires sophisticated managerial and technical talent. Poor management skills and inadequate maintenance budgets lead to frequent equipment failure, shortage of active equipment life and the incurring of additional costs of between 20% and 40% of the equipment budget (WHO, 1999). Healthcare equipment management problems, which may vary qualitatively according to circumstances, are equally putting pressure on public health officials in both developed and developing nations.

The waste of resources, estimated by the WHO as the basis of field experience, is presented in **Table 1**(Issakov, 1994).

Problems	Waste
Inability to correctly specify and foresee total needs when tendering and procuring equipment	10 – 30 % extra cost
Purchase of sophisticated equipment, which remains unused due to lack of skill of operating and technical staff	20 – 40 % of equipment
Extra modifications or additions to equipment and buildings unforeseen at the initial tender stage due to lack of staff expertise	10 – 30 % of equipment
Maltreatment by operating and maintenance staff	30 – 80 % of lifetime
Lack of standardisation	30 – 50 % extra spare parts costs
Down time due to inability to use or repair, no spare parts or accessories	25 – 35 % of equipment

Table 2.1: Problems and corresponding waste of health care equipment (Issakov, 1994)

Issakov also states that all countries need to have an explicit policy on management of healthcare equipment, which is consistent with the countries' needs and priorities and is targeted to the solution of health problems of the majority. Such a policy is complex and multifaceted, and its establishment requires a high degree of awareness and strong political will.

David (1993) states that in an industry where the only constant is change, it is imperative that health care facilities have a programme that:

- provides for guiding resource allocation
- identifies and evaluates technological opportunities or threats
- guides capital prioritisation, facility preparation and staff planning
- maximises the value provided by resources invested in medical technology
- meets or exceeds standards of care
- reduces operating costs
- reduces risk exposure,

all of which can be addressed by a well-managed healthcare technology management programme – or specifically, a well-managed clinical engineering service.

Drawing from the various definitions of clinical engineering and the general functions provided by this service, it can be concluded that the field has a major role to play in alleviating equipment-related problems faced in health facilities and thus contributes significantly to improved health care delivery.

2.2.2 The Clinical Engineering Field

In many countries, the acceptance and recognition of clinical engineering has been slow and full of obstacles. According to Boström et al. (1993), clinical engineering has been (and sometimes still is) a "basement activity", little understood or recognised by physicians and hospital administrators.

Nevertheless, in countries where clinical engineering is accepted and recognised, it is taken to describe the same basic responsibilities, functions and activities.

The role of Clinical Engineering can be considered as including (Bronzino (1992), Glouhova (1999), Locke (1998), etc.):

- Technology management (including specification, evaluation, installation and support of technology, and review of equipment replacement needs)
- Technology assessment (assessment of clinical efficacy, safety, appropriateness and cost benefits and monitoring of emerging technologies)
- Asset/inventory management
- Risk management and safety (reducing technology-related patient and staff incidents)
- Preventive maintenance and repair
- Project management
- Quality assurance and improvement
- Training equipment users
- Management of service contracts
- Clinical research and development; modification of medical devices
- Project management

In some cases, the role would also include Management and Maintenance of Facilities and Plant Telecommunications and Information Technology systems.

However, the boundaries of these support roles are not clear and well-defined, as what applies to one institution does not necessarily apply to another. There are also historical differences in various countries and regions, e.g. in the UK, following on from the development of hospital physics in the early 1940s, clinical engineering is not considered as a separate entity, but as part of the responsibility of departments of Medical Physics. Also, a clinical engineering service can range from one isolated but dedicated individual to a fully equipped department with

professional and technical/artisan staff, supported by adequate technological and administrative infrastructures, to a shared regional/central resource centre.

Alongside the change in scope and function of Clinical Engineering Services over the years, is the shift from being primarily task-driven to being more business-oriented and cost-justified (Autio & Morris, 1995). A further development has been the adoption (sometimes imposed) of various international trends in business and management, e.g. total quality management, benchmarking, re-engineering, outsourcing (of non-core business activities) and, most recently, ISO9000 standard accreditation. As sustainability is often dependent on issues of cost-effectiveness and relevance, and associated perceptions of institutional/ organisational stakeholders, these considerations may threaten otherwise successful departments and/or services with closure.

2.2.3 International Developments and *Status Quo*

The healthcare delivery system, which includes the private and public sectors, is undergoing a transition driven by many forces including cost, technology, regulations, ethics, the legal justice system and society expectations (David & Judd, 1993). David & Judd further add that the factors that interact with these forces also change – thereby creating a crisis that is the subject of public debate. The healthcare delivery system is therefore under increasing pressure to (i) identify its goals, (ii) select and define priorities and (iii) wisely allocate limited resources.

A. Developed Countries

Apart from a few exceptions - especially pertaining to the 'lack of recognition-syndrome – the Clinical Engineering field is well-established and widely accepted in most western countries (Boström et al, 1993). However, in most of the industrialised countries, the containment of hospital costs – especially pertaining to medical technology and equipment – is a major concern.

Gordon (1995) states that the healthcare industry is therefore forced to follow the natural way of the marketplace, i.e. to share its risk and "depend less on reporting relationships and regulatory compliance".

The 1980's and 1990's saw a marked increase in the need for hospital-based technical services. Medical equipment numbers exceeded the numbers of healthcare professionals employed within healthcare delivery institutions; while governments and accrediting bodies increased demands for safer technology. These developments increased market costs for technical services and made it cost competitive to bring these services in-house (Gordon, 1995).

However, with this rapid development and infiltration of medical equipment into the healthcare delivery system, there has been a resultant expansion of the technical services market and in-house services have faced competition from medical equipment manufacturers, third-party service providers, maintenance insurance programs and medical equipment leasing agents (a growing trend in the USA).

In the mid- to late-1990's, CES's in countries such as the USA and Australia were threatened by economic rationalisation and outsourcing trends. This resulted in hospital-based CES's being closed because they are not perceived as being a "core" function of health care institutions.

This situation is now reversing and more and more in-house departments are being re-established (Locke, 1998). Reasons for this are varied and include the realisation that having an in-house service with quick response time is more cost-effective than relying on an external service provider. Another reason appears to be based on the ever-increasing cases of hospitals being found liable for the torts of their outside service contractors.

Dickey (1996) stresses that decisions about clinical engineering programmes, e.g. outsourcing, expanding, re-engineering, downsizing, rightsizing or elimination,

should only be made after careful assessment of the existing CES's capabilities, limitations and cost-saving opportunities. The author further adds that:

> *"Executives considering downsizing or outsourcing their existing CES's should determine whether short-term savings from downsizing may be less than potential long-term savings that can be achieved by investing in a comprehensive equipment-management programme. Prior to any decision to downsize, an organisation's executives should assess whether their existing clinical management services are cost-effective and of measurable value. If not, executives should consider how to enhance, redesign or otherwise acquire those services to best manage all facets of equipment acquisition, use and maintenance."*
> (http://www.accenet.org/clinengrweek/page3.html)

B. Developing Countries

The widespread introduction and increasing influence of medical technology is a reality experienced even in developing countries. Its appropriate introduction and proper service, maintenance and use are crucial for efficient and cost-effective healthcare service delivery at all levels of the health system (Issakov, 1994).

According to Issakov (1994), in many developing countries the most obvious symptom is not the lack of medical equipment, but medical equipment that is not usable or simply unused. At any given time, up to 50% - 75% of medical equipment inventory is inoperable, resulting in high wastage of resources and poor quality of healthcare delivery.

Regional and national variations due exist, however identifiable factors are globally common and contribute to the current situations. Underlying reasons for this include:

- Lack of awareness and management expertise
- Lack of organisational policy

- Lack of health care technical service's infrastructure
- Lack of qualified and effective manpower development and training
- Lack of information support.

CES's in developing countries often face the problem that most of their equipment is imported from the developed world, resulting in problems obtaining spare parts at reasonable cost and speed, and obtaining service support (Clin. Eng. Q&A, 1996). What has become a matter for increasing international concern is the amount of this equipment that quickly falls into disuse due to malfunction and lack of maintenance. This is further justified in developing countries, as the equipment represents a considerable expenditure of valuable (and scarce) foreign exchange (Statham, 1990).

Taylor et al (1999) stress the need for clinical engineers to apply their expertise in technology management in developing countries, while relying on a multidisciplinary approach by consulting traditional healers, national healers and social scientists, for most appropriate integration of this technology into the recipient culture.

CES's in developing countries experience many of the pressures faced by the developed countries, but these are further compounded by severe budget constraints. Due to this, maintenance activities are often the first to be cut and the long-term consequences of doing so are not taken into consideration.

This situation was evident even in the USA, during cost-cutting period accompanying recessions and other environmental influences (Furst, 1986). According to Furst, support services such as clinical engineering and physical plant often took disproportionate cuts in comparison to direct patient care departments (e.g. nursing) and to ancillary departments (e.g. clinical laboratory). Reasons for this included the concept of revenue versus non-revenue departments, the profitability of these departments and quality of care issues.

Some of these countries are also seeing the introduction of systemic processes such as public service downsizing and retrenchments, resulting in a shortage of qualified personnel, which is threatening the existence of clinical engineering departments and hampering the training of those entering the profession.

Glouhova et al (1999), however, observed in a recent study, that while the profession is still new in Latin America, it is in fact active and evolving.

2.2.4 Role of International Organisations and Agencies

However advanced, no country in the world is able to provide health services to meet all the needs of its population. This failure results not only because of limitations of currently available technology, but specifically from lack of sufficient resources.

In efforts to address this problem, the WHO and various multi-lateral and bilateral agencies have actively supported developments in the area of Healthcare Technology Management (HTM), particularly in developing countries, over the last two decades.

The WHO has been actively promoting and strengthening HTM activities globally, and especially in developing countries. At the Inter-Regional Meeting on the Maintenance and Repair of Healthcare Equipment held in Nicosia, Cyprus (November 1986), four key topics were addressed, namely: (i) national policy, (ii) national infrastructure, (iii) development of manpower training and (iv) use of computer-based information systems.

In 1989, the American College of Clinical Engineering (ACCE) was established to promote the profession of clinical engineering, increase transfer of knowledge and to increase manpower. The specific mission of the ACCE is:

- *To establish a standard of competence and to promote excellence in clinical engineering practice.*

- *To promoted safe and effective application of science and technology in patient care*
- *To define the body of knowledge on which the profession is based*
- *To represent the professional interest of clinical engineers.*

(ACCE, http://www.accenet.org/acceinfo.html)

The International Federation for Medical and Biological Engineering (IFMBE) has established a Clinical Engineering Division aimed at strengthening clinical engineering globally. Through workshops and conferences; collaboration with regional organisations such as AFTH (African Federation for Technology in Health Care) and the ACCE, and cooperation with multinational and bilateral organisations such as WHO and PAHO (Pan American Health Organisation); the IFMBE-CED has focused on capacity building, networking and increasing the visibility of the clinical engineering profession. In addition, as major contributions to the field, the organisation has been involved in the finalisation of donation guidelines for medical equipment and the framework for health technology policy development (Heimann, 2000).

Donor and technical agencies have been involved in the transfer of used medical equipment from developed countries to their less-developed counterparts for decades. Such recycling of goods serves important objectives, such as reducing waste and landfills in developed countries due to rapid infiltration of new technologies; and giving access to sophisticated technologies to medical practitioners and patients in developing countries, for better healthcare. However, not all donations achieve their goals, for reasons such as lack of communication between donor and recipient, inappropriate and incompatible technology, non-functional equipment and lack of training and knowledge.

In attempts to address these problems the ACCE (1995) (and other organisations such as the WHO) have provided guidelines for both donor and recipient organisations. These aim to achieve the following objectives:

- *Better match between need and availability*
- *Improved pre-donation planning and preparation*
- *Assurance of completeness and quality of donated goods*
- *High likelihood that received equipment will be installed and used*
- *Assurance of maintainability of donated equipment*
- *Continuous quality improvement through follow-up evaluations.*

The contributions of these and other organisations assist providing essential elements, such as capacity building, networking, expert support and formulation of policies to the clinical engineering field globally.

2.2.5 The Private Sector

Clinical engineering in most countries has its roots in the **public sector**, particularly in tertiary health facilities (Poluta, Heimann; 1998). With the growth of the **private sector** in recent decades has come an increased demand for clinical engineering practitioners. In some cases this need has been met by attracting practitioners from the public sector with higher salaries and better working conditions, impacting negatively on public sector Clinical Engineering Services.

In many instances little or no organisational structures exist to handle equipment-related matters (Locke, 1998) and there are no formal in-house CES's. The situation is changing, however, partly due to litigation scares after patient injuries as a result of faulty equipment, and partly due to increased pressure in the private sector towards accreditation of health services. Most accredited private sector organisations now have access to – if not their own – Clinical Engineering Services.

2.2.6 Professional Certification / Accreditation of CE Practitioners and Services

In an effort to standardise qualifications and enhance professionalism, several organisations provide/offer certification and/or accreditation of CE practitioners.

A. Certification

According to Roy (1982) reasons for *certification* lie in the fact that the practice of engineering within the clinical environment is intimately related to the welfare of the patient, and the efficacy of health-care delivery. For this reason, healthcare professionals have seen the desirability of peer review and certification of competency of those practicing in the area.

Within the clinical engineering context, certification of clinical engineers takes place through bodies such as the US-based ICC (International Certification Commission for Clinical Engineering and Biomedical Technology). This organisation and its various regional representatives has an overall interest in the advancement of health care and in ensuring quality provided by CE practitioners globally.

Unfortunately, an independent market survey conducted by the AAMI has shown that (within USA and elsewhere) there is little interest in clinical engineering certification. This could be due to many factors, including severe limitations for funds in health-care, lack of formal legal requirements and lack of financial incentives (Wang, 1999).

B. Accreditation

Within the South African context, the Council for Health Service Accreditation of Southern Africa (COHSASA) applies organisational standards to define systems and processes that should be in place to ensure that patients receive quality care and that facilities and staff are managed according to agreed professional and management standards (COHSASA, 1997). It has been the experience of COHSASA that accredited facilities have better team work and are more efficient and effective that they were on entry into the programme. This has undoubtedly led to cost savings and improved safety and availability of medical equipment. COHSASA has now incorporated CES/HTM into their standards following the

lead of the Joint Commission for Accreditation of Health Organisations (JCAHO) in the USA.

2.3 THE NEED FOR CLINICAL ENGINEERING SERVICE INDICATORS / RELEVANCE OF COMPARING CLINICAL ENGINEERING SERVICES

2.3.1 Introduction

Comparing the functions, performance or quality of Clinical Engineering Services in different hospitals, and certainly different regions, can be a very difficult task. According to AAMI (1990) certain factors have to be taken into consideration, such as the differences in department mission; variations in the spectrum or scope of services provided; and different approaches to equipment and supply evaluation and purchase, incident investigation, engineering consultation, strategic planning, technology management activities and risk management activities.

However, good management of any department, in any field, requires that its strengths and weaknesses are constantly evaluated. In this way, the clinical engineering manager is in a position to actively control departmental activities to respond positively to the challenges and opportunities presented by changes in the hospital environment. It is also important that management is aware of the activities of its peers (AAMI, 1990). Developing performance and sustainability indicators for the clinical engineering department can facilitate these comparisons.

2.3.2 Comparisons of Clinical Engineering Services

Clinical engineering departments vary widely in function, quality and size. According to Frize (1990), the evolution of the clinical engineering field has taken place mainly on an individual basis, i.e. institutions and CES managers have individually established their departments' functions and priorities, seeking appropriate resources to support their role and work volumes.

Smith (1982) states that many hospitals have well-established in-house departments, containing adequate qualified staff, floor space and instrumentation. Other institutions have joined together to share the activities of a well-equipped clinical engineering staff, thus also sharing in capital and operating costs. Some hospitals, particularly in developing countries, only have a skeleton CES, if at all.

Other variations exist, particularly in the types of CE services employed by the institution. There have traditionally been three options: (i) in-house CES's, (ii) manufacturers or their agents/distributors and (iii) third-party service providers, which may be either a shared clinical engineering service or a commercial firm. A fourth option, maintenance insurance, combines use of any of these service modalities with financial protection against high service costs (ECRI, 1989). In the latter two options, the clinical engineer serves primarily as a manager of these contracts (Smith, 1982).

ECRI state the major advantages of in-house CES's as:

i. the immediate availability of service
ii. cost containment
iii. the facilitation of other aspects of equipment support (e.g. user training) and
iv. the fact that an in-house staff can provide expertise on a broad range of equipment and technology management issues.

Major disadvantages include:

i. the continual institutional commitment required to maintain a clinical engineering department (e.g. personnel costs, space, parts inventory investment)
ii. lack of financial protection or "insurance" against the cost of catastrophic equipment failure and
iii. capital investment needed for test equipment.

2.3.3 Previous International Surveys of Clinical Engineering Services

Although the organisational structure and function of CES's appeared very similar in the various industrialised countries in the mid 1980s, there was little evidence to support this conclusion.

A. Pacela

According to Bronzino (1992), Pacela (1986) - in cooperation with the Joint Commission on Accreditation in Hospitals (as it was known then – now JCAHO) - conducted a study which provided some quantitative information regarding the structure and function of clinical engineering in the USA, but no data comparing the level of development of CES's in other countries was available.

B. Frize

In order to obtain information on the development of clinical engineering internationally, Frize (1990 a,b) conducted a survey comparing the development of the field worldwide. She followed this up with a longitudinal study (Frize & Shaffer (1991), (1994)), to observe the progression of the field over the period 1988 to 1991.

Through the use of questionnaires sent directly to CES's in Canada, USA, the EEC and Nordic countries, the following parameters were investigated:

- Organisational setting: including hospital type and size, equipment base supported by the CES and type of reporting authority
- Level of functional involvement in: corrective maintenance, acceptance testing, user training, pre-purchase consultation, clinical research and development and clinical measurement, quality assurance, staff productivity assessment
- Budget, staffing and other resources

- Educational level of clinical engineering staff
- Level of recognition achieved by the department

Results of these studies were presented in the form of percentage of involvement by the department. The survey allowed the author(s) to assess the extent of technology management provided by CES's in the regions studied.

The results of the first survey showed that there was a significant correlation between the extent of involvement of clinical engineering departments in the various functions studied and organisational factors, such as teaching versus non-teaching institutions, the choice of reporting authority (e.g. a senior administrator, medical director), whether departments felt their role was recognised and whether there were university-degree engineers in the department (Frize, 1994).

The follow-up comparative study showed minor variations in several of the parameters analysed. While there was an upward trend in workload indicators, i.e. number of devices and equipment replacement value supported, and budget allocation increases to the order of 12 to 16 %, many of the departments surveyed had not obtained recognition – even those from the most developed countries.

Frize concluded by emphasising the need for clinical engineering departments to clearly state their mission, objectives, workloads and resource requirements, and become increasingly involved in both clinical and research activities. She felt that in doing so, and by matching their activities to the constraints and needs of the health care facilities they serve, CES's could enhance their profile and obtain recognition from hospital administrators and other health care professionals.

C. Glouhova *et al*

As the clinical engineering field is still developing and evolving, Glouhova *et al* (1999) saw it fit to update the findings of Frize ten years prior. Their survey was performed in two successive stages, using structured questionnaires. The first stage aimed at identifying the structure, personnel, responsibilities and resources

of the departments in different countries. The second stage had the objective of investigating trends in current practices and it addressed selectively those institutions identified from the first stage as having well-established clinical engineering services. It was divided into three parts viz. a) *practice profile,* b) *quality assurance* and c) *general.* The first part, practice profile, was further divided into ten categories, corresponding to services that are generally accepted as being core tasks of clinical engineering services. These were:

i. equipment inventory,
ii. preventive maintenance (PM),
iii. corrective maintenance (CM),
iv. acquisition of biomedical equipment,
v. acceptance testing (incoming inspections),
vi. management of service contracts,
vii. risk management,
viii. quality control (QC),
ix. education and training and finally,
x. research and development.

The findings of the study revealed that most departments in North America, the Nordic countries and Australia have been functioning for more than 20 years. Consequently, they are involved in a wide range of services and provide them to a very high percent of available equipment. In Latin America, the profession is still new and thus the extent of service provision is not at the same level as the above-mentioned regions. No conclusions could be reached from West and South Europe, due to low response rates.

The study also showed that computerised systems for equipment management and quality assurance have widely penetrated the departments in the more developed regions, and that fewer CES's are using a productivity index to measure staff performance. The reverse is true for CES's in Latin America.

The majority of departments that responded felt that they were well accepted and recognised in their institutions. The main problems faced at this stage are, lack of highly qualified personnel and cost constraints. Clinical engineers and BMETs (Biomedical Engineering Technicians) felt a need for a global official certification for both professions.

Judging from the progression of results of all the surveys in this section, it is evident that clinical engineering is still evolving and developing at different rates in differing regions. There is therefore a need for more research on performance and standardisation of clinical engineering departments at an international level.

2.3.4 Productivity and Cost-Effectiveness in Clinical Engineering

Although Glouhova *et al* found that fewer CES's are currently using the productivity index to measure staff performance, it would be useful to review some earlier studies performed around the subject of productivity, in order to aid the development of a methodology for the present study.

A. Neuhausel

Neuhausel (1985) begins his article with the statement: 'There does not appear to be any universal method for the measurement of *productivity* in Clinical Engineering.'

At the time of writing, there were various methods of computing productivity in Clinical Engineering.

The first of these, utilising data from the *Medical Equipment Management in Hospitals* manual (ASHE, 1978), included a method of manipulating the annual *preventive maintenance* times (excluding vacations, sick days etc) for the hospital's complement of equipment. These times were divided by or multiplied by certain variables (e.g. number of devices in the inventory) and the results were used to justify employing an additional technician.

By 1982 the then upgraded manual included measures of average repair and inspection times by clinical engineering technicians. These were calculated by charting, on a monthly basis, such factors as *number of inspections, time spent on each repair,* as well as the support duties.

Through empirical studies performed in a group of hospitals, Neuhausel, later developed an algorithm based on times allocated to each activity (i.e. technical and support duties) performed by clinical engineering personnel. Certain standards were developed (e.g. 0.526 hrs per inspection, 1.039 hrs per repair) for each hospital. Each standard factored in such considerations as *personal, fatigue,* and *delay* (P, D, F factors expressed as a percentage).

The author concludes that the standards developed depend on other factors such as hospital size, ratio of staff to equipment, etc. and an expanded database of studies would be required before a universal standard, if feasible, could be adopted.

B. Furst

Given the growing concern about finances that was (and still is) evident among hospital administrators and department heads at the time, Furst (1986) states that Clinical Engineering could make significant contributions to the financial health of a hospital. This could be achieved by increasing CE departmental productivity and by improving the utilisation of resources in clinical departments.

Furst defines *productivity* as 'the number of "units of product" the department turns out for a given amount of effort'. His suggestions to improving productivity include:

- avoiding the purchase of redundant medical equipment
- use of external vendors if the service can be offered at a lower cost
- decreasing work on simple devices

- replacing unreliable devices (therefore reducing repair costs)
- measure of labour required per repair
- improving personnel qualifications and training
- improving management tools based upon extensive computer support
- an optimal mix of engineering and technician skills.

In order to improve *cost-effectiveness*, which he considers to be measured and improved within the narrow confines of the department, he suggests the need to identify and quantify most costs. This requires extensive record keeping. Through a study at a certain hospital he suggests the following indicators of cost-effectiveness:

- average hourly rate
- stability of hourly rate in the face of wage and operating cost increases
- cost of each area of responsibility (e.g. preventive maintenance [PM])
- the ratio of PM and repair costs to original acquisition cost
- rapid turnaround time
- reduced investment in capital equipment
- cost-benefit analyses.

Non-financial indicators include: quality of support, interdepartmental cooperation and useful communication.

Furst's findings when applying these concepts to a certain hospital revealed major financial savings on the bottom line by reducing capital costs, extending equipment lifetime, reducing maintenance costs and increasing hospital cost-effectiveness.

C. Al-Fadel

Al-Fadel (1986), looking at productivity from a business management angle, defines productivity as "A state of efficiency or the rate and quality of output based on the rate and quality of input".

He states that identifying deficiencies in productivity or non-productive areas (e.g. extended tea breaks, lack of parts or tools) yields half of the solution to productivity maintenance. Management plays the biggest role in identifying and correcting these productivity problems.

Drawing from a variety of disciplines, the author suggests six basic elements to facilitate increased productivity. These are:

1. Good communication and counselling
2. Reviewing interpersonal skills
3. Goal setting
4. Delegation
5. Continuous training
6. Recognition.

If engineering management (in cooperation with administration) is successful in these areas, high staff morale and productivity will follow.

In addition to the previous tools, Al-Fadel suggests that clinical engineering departments should provide *productivity improving programs*. These include the use of (i) Quality Circles, (ii) Task Changes and (iii) Shop Automation. At the time of going to press, the application of these interventions to his clinical engineering department was still in the trial stage, so no conclusive evidence for their use could be drawn.

D. David & Rohe

David & Rohe (1986) state that the utilisation of technologies in the clinical environment is perpetually growing, and has created a need for professional technical management – a task for Clinical Engineers.

Techniques for monitoring productivity have been suggested by the previous authors. In addition to this, David & Rohe go on to give sample performance indicators. These include:

- % Quality (average of quality observations specified in a departmental Quality Control Sheet)
- % Productivity ([total productive hours] / [available hours])
- % Overtime ([Overtime hours] / [available hours])
- % Labour Recovery ([charged hours] / [available hours])
- Repair Turnaround Days (average length of time a piece of equipment is out of client's department for repair).

The authors then suggest management strategies for improving productivity. These include accountability and expectations, management information reporting, productivity monitoring, manpower scheduling, quality monitoring (including client's perceptions) and systematic improvement. These techniques lead to optimal resource utilisation. Definitive lines of communication and responsibility create a foundation for proper decision-making. Establishing only those measures of performance that are practical to maintain, yet sensitive to the operational changes, provide managers with tools for analysing the impact of their decisions. The authors conclude that a successful productivity improvement program never arrives at perfection, yet it is in a continual stage of adjustment dedicated to achieving maximum quality of output and resource utilisation.

E. Ibrahim & Arthur

Following on from Pacela's work in 1986, Ibrahim & Arthur (1989), performed a study within the USA to examine the statistical significance of several cost-based measures of clinical engineering service effectiveness. The results of the study showed a positive relationship between the CES budget and certain variables investigated. These variables were, in order of correlation: total number of department personnel, number of devices serviced, value of devices serviced and finally, hospital bed count. The authors suggested that future research could consider other variables, such as number of repairs, required calibrations, quantity of responses to trouble calls and finally statistics relating to service contract budget amount versus comparable cost of in-house service.

F. Johnston

In this special issue on Productivity and Cost-Effectiveness in the Journal of Clinical Engineering, Johnston (1987) poses the question, "Are Productivity and Cost-Effectiveness Comparisons between In-house Clinical Engineering Departments possible or useful?"

In answer to this question, the author states that inter-institutional comparisons of productivity and cost-effectiveness can be a valuable source of feedback to the in-house clinical engineering services management. Such information could be of considerable value in promoting funds to upgrade a department, to maintain the current level of funding or to seek funding for new ventures. Thus, inter-institutional comparisons can be useful to clinical engineering managers when they can point to successes of similar programs to justify a budget request – or simply to justify the existence of the department. This is especially evident when institutional administration opts to outsource equipment maintenance and management services, based on comparisons of in-house clinical engineering costs with available outside alternatives.

However, as Bauld (1985) stated, universally accepted standards for clinical engineering do not exist. For these departments to make useful comparisons, they must:

1. define the desired types of comparisons
2. determine the required set of data elements
3. develop unambiguous data element standards
4. keep the required data.

The most crucial and difficult step is to agree on comparison standards.

According to Johnson, it is possible to keep data on the variety of tasks common to all clinical engineering departments that can then be used inter-institutionally. As task comparisons become more common, "norms" will evolve, which can then become standards for the profession.

2.3.5 Sustainability of Clinical Engineering Services

Irrespective of the performance of a CES, there are environmental factors (eg institutional, governmental and/or industry trends), which may influence the sustainability of the respective department. Institutional factors may include the hospital's decision on the type of equipment service it prefers, budget constraints and (non-)availability of facilities. The government, particularly in developing countries, may also impose financial constraints due to insufficient provincial budgets or lack of consideration of the importance of CES's to the healthcare system. Trends such as outsourcing, downsizing and economic rationalisation may threaten the existence of a department. As sustainability is ultimately dependent on affordability, these considerations may threaten an otherwise successful department with closure.

2.3.6 The Need For Clinical Engineering Service Indicators

The Joint Commission on Accreditation of Healthcare Organisations (JCAHO, 1997), whose mission it is to improve the quality of care provided to the public through the provision of healthcare accreditation and related services that support performance improvement, have established that there is a need for the development of healthcare indicators. These indicators - which include those that cover the full spectrum of hospital care - can be used by health plans and networks to:

- gather data to assess performance and enhance internal quality improvement efforts;
- generate performance information to assist consumer and purchaser decision-making; and
- benchmark performance against other networks and health plans.

Many countries (and notably developing and emerging economies) are under-resourced in terms of what is needed for equitable service delivery of acceptable quality, as well as the management-level skills needed to maximise the impact of healthcare technologies on service delivery. Within this context healthcare technology management (HTM) practitioners and activities are being increasingly recognised for their contribution to health system performance. There is thus an urgent need to (i) build HTM management capacity and (ii) develop effective HTM tools while at the same time (iii) developing indicators for HTM performance and sustainability (WHO, 2000).

Autio and Morris (1995) state that with the shift of CES's from being task-driven to being more business-oriented, cost-justified and bottom-line-focused, certain indicators have to be developed to assess a department's performance and function. Changes in the health care delivery system will dictate that clinical engineering departments justify their performance and existence on the same basis as any business. Indicators are essential for establishing the survival of organisations and are necessary for effective management of change.

As Bauld (1985) stated, universally accepted standards for clinical engineering do not exist. Johnston (1987) reiterates by pointing out that the most crucial and difficult step is to agree on comparison standards for the field.

This study, which follows and complements previous work by Frize (1990) and Glouhova (1999), focuses on the development of indicators for Clinical Engineering Services, be they situated within a health facility or a shared/ regional resource centre.

Section I of the literature review has laid the groundwork to justify the need for clinical engineering indicators. This is summarised in Figure 2.1. The following sections draw on current best practices in business and management and medical equipment maintenance and management literature to formulate a framework for developing **critical, comprehensive, reliable** and **valid** indicators of performance and sustainability for clinical engineering services.

2.4 SUMMARY OF SECTION I OF LITERATURE REVIEW

The following flow diagram outlines the findings of Section I of the literature review.

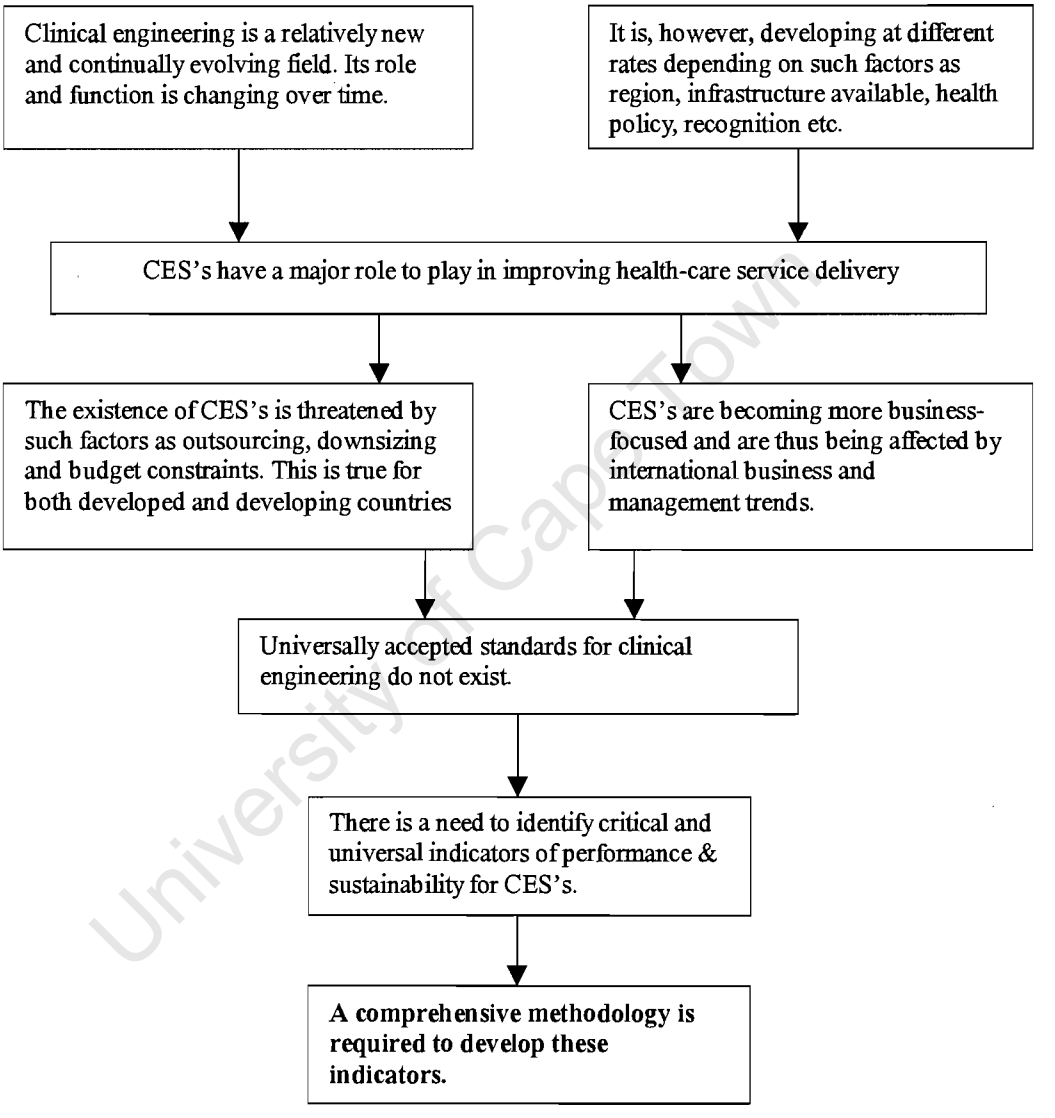


Figure 2.1: Summary of Section I of Literature Review

II. BACKGROUND: DEVELOPMENTS IN MANAGEMENT AND MEASUREMENT OF SERVICE PERFORMANCE

The health care industry is being forced to face commercial and global realities. In-house clinical engineering services face significant competition from third-party service providers, manufacturers and maintenance insurance programmes. With the shift of Clinical Engineering Services to a more business oriented focus (Autio & Morris, 1995), it is important to look at international trends in the business/engineering management world as a whole.

2.5 INTERNATIONAL TRENDS IN MANAGEMENT

The 1990s have seen several buzz words taking the management world by storm namely: change management (e.g. benchmarking, re-engineering), total quality management / quality assurance and outsourcing.

2.5.1 Benchmarking

Business process benchmarking, as defined by Thor and Jarrett (1999), is:

> *"the systematic comparison of elements of the performance o an organisation against that of other organisations, usually with the aim of mutual improvement".*

Benchmarking is the continuous process of identifying, analysing and adopting the best competitive practices in related industries. It is best seen as a part of the continuous process of total quality improvement, which identifies, prioritises, implements and monitors change in the delivery of services to provide the greatest benefit to the customer (Gordon, 1995).

Forms of benchmarking include financial benchmarking, product or service benchmarking and strategic benchmarking.

Benchmarking has become recognised in recent years as a valuable performance and evaluation technique. It has contributed to the critical challenges of many organisations in the improvement of competitive business performance and in the management of change (Dence, 1995). In order to achieve and sustain such improvements, organisations are now seriously looking into strategies to improve productivity – usually in response to some threat. Such strategies include the utilisation of processes such as ergonomic interventions, outsourcing, rationalisation and downsizing.

2.5.2 Re-engineering

Thor and Jarrett (1999), quoting Hammer (1995), define re-engineering as:

> *"the fundamental rethinking and radical design of business processes to achieve dramatic improvements in ... performance such as cost, quality service and speed...."* (Hammer, 1995).

Or less dramatically it can be defined as:

> *"...changing processes, organisational structures, management style and behaviour, compensation and reward systems, as well as relationships with shareholders, customers, suppliers and other external partners."* (Kelada, 1996).

Re-engineering is about stripping away what a company does, analysing the core processes which make up its business, and then reassembling them more efficiently in a way which is free of functional divides and bottlenecks. Re-engineering returns organisations to first principles (Crainer, 1996).

According to Thor and Jarrett, Leth (1994) constructively divides reengineering into four types: (i) structural design, (ii) technical design, (iii) managerial change and (iv) behavioural change. Unlike continuous improvement, reengineering is

synonymous with innovation. Many organisations are taking part in re-engineering initiatives in order to remain abreast with the general management trends.

However, according to Crainer (1996), practical implementation of re-engineering concepts has been held back by two central pitfalls:

- The human implications are often ignored, overlooked or underestimated
- The revolution does not affect the attitudes and behaviour of managers – thus exacerbating the problem.

2.5.3 Quality

When the International Organisation for Standardisation released the ISO9000 series of quality management in 1987, the world was for the first time provided with a common definition of what a minimum quality management system should consist of (Zairi, 1996). Many organisations were thus forced to re-evaluate the standards they had developed for themselves in an effort to keep in line with the general international standards.

De Cock and Hipkin (1997) give a definition of Total Quality Management (TQM) as:

> *"TQM... refers to a management process directed at establishing organised continuous improvement activities, involving everyone in an organisation in a totally integrated effort towards improving performance at every level" (Almaraz, 1994)*

TQM implementation tends to incorporate the following principles:

1. the generation of objective data ('facts') for the systematic improvement of work processes and products as a prerequisite for taking actions

2. focus on key problem areas (frequently where it is likely that a dramatic increase will result
3. employee involvement and empowerment

Professionals in all industries worldwide have come to consider ISO9000 certification as a critical competitive advantage, and healthcare is no exception. Certification assists in increasing both real and perceived value of organisations. ECRI has developed the ISO9000 Quality System for Medical Equipment Service, including a 'Quality Manual' and "Quality Procedures and Work Instructions' to put biomedical / clinical engineering service providers on the fast track towards 9001 or 9002 certification.

A key feature of all quality initiatives has been a focus on the requirements of the **customer/client** receiving the service of the organisation.

2.5.4 Outsourcing / Core Competencies

Outsourcing, according to Gay & Essinger (2000), is a relatively new term for a strategy that has been used for many years in organisations. It can be applied to many different types of commercial relationships between purchasers and suppliers – co-sourcing, subcontracting, partnering, joint ventures, third party contractors, etc. Different types of outsourcing include: (i) contracting out the activities, (ii) outsourcing the service, (iii) insourcing, (iv) co-sourcing and (v) benefit based relationships.

According to the authors, studies have shown that the main benefits derived from outsourcing are:

- Reduction in the cost of obtaining the service
- Reduction in the headcount of the organisation
- Flexibility in terms of service delivery
- Access to expertise
- Improved service

- Extra management time
- Focus on core services
- Improved quality
- Less need for capital investment
- Cash inflow

Unfortunately, many outsourcing ventures prove to be unsuccessful – and fall under the umbrella of 'failure to achieve benefits'. This is because organisations fail to take into consideration ten 'success factors' outlined by the Outsourcing Institute (Gay & Essinger, 2000) namely:

1. understanding company goals and objectives
2. a strategic vision and plan
3. selecting the right vendor
4. ongoing management of the relationships
5. a properly structured contract
6. open communication with affected individuals/groups
7. senior executive support and involvement
8. careful attention to personnel issues
9. near-term financial justification
10. use of outside expertise.

A number of these trends are presently being applied to the clinical engineering field internationally (Autio & Morris, 1995; Gordon, 1995).

2.6 PERFORMANCE MEASUREMENT

The available management literature only described methods for developing measures of *performance* or *quality*. No literature was found for sustainability measures. Given that performance and quality play a major role in the sustainability of any institution, it is assumed that the methods described in this chapter can be extended to the development of sustainability indicators.

2.6.1 Introduction

According to Kaydos (1991), performance measurement is essential for achieving and maintaining high levels of productivity and quality, for good management control and planning, and for developing and motivating an organisation. However, the most valuable benefit of proper performance measures is a sound understanding of how a production system works – be it a department, a person or a physical process - and the forces that drive it.

A. Key Concepts and Definitions

By way of introduction, terms that will be used in the following section are defined as follows:

a. **Performance:** An actual work accomplishment or output (not to be confused with work behaviour) (Harbour, 1997). Quality and productivity are dimensions of a higher-level measure called 'performance' or 'effectiveness' (Kaydos, 1991).

b. **Performance Measurement:** The process of measuring work accomplishments and output, as well as measuring in-process parameters that affect work output and accomplishment (Harbour, 1997).

c. **Process:** A process represents the transformation and blending of a set of inputs into a more valuable set of outputs. Outputs can be products, services or accomplished tasks. A process can further be subdivided into a series of interrelated activities. Activities can in turn be subdivided into individual process steps (e.g. operation, transportation, delay, inspections, storage and rework) (Kaydos, 1991).

   A 'core process' is the sequence of work activities that provides goods and/or services to customers.

d. **Productivity:** The ability to combine and convert inputs (labour, capital, materials and other resources) into outputs (goods and/or services), which satisfy market needs (Harbour, 1997). Productivity can also be seen as a relationship between output and input of a given process, i.e. *P = Output/Input = (production of some desired result)/(consumption of resources)* (Brinkerhoff & Dressler, 1990).

Distinctions can be made between:

- *Technical productivity*: associated with the workplace; concerns direct goods or services
- *Economic productivity*: concerned with long-term cost effectiveness
- *Social productivity*: desirability and/or usefulness of products or services produced.

e. **Quality**: conformance to requirements (stated or implied) (Kelada, 1996). This includes internal measurements, e.g. number of rejects; and external measures such as customer satisfaction rating. Alternatively, quality can be defined as the degree of excellence of a product or service.

f. **Indicator**: An indicator is an objective, quantitative variable that indicates or measures a characteristic of a system. It is objective in that different observers can obtain the same measurement. Also known as a comparative metric, an indicator is a measure of performance and function, and is often used as part of a quality assurance programme.

B. Why Develop Performance Measures?

According to Harbour (1997) companies are discovering that performance measures can help any organisation:

- Determine where they are - that is, establish an initial baseline "as is" performance level

- Establish goals based on their current performance
- Determine the gap between a set of desired goals and current performance levels
- Track progress in achieving desired performance goals
- Compare and benchmark their competitors' performance levels with their own
- Control performance levels within predetermined boundaries
- Identify problem areas and possible problem causes
- Better plan for the future.

In addition, Brinkerhoff and Dressler (1990) state that frequent applications of *productivity* measurement specifically (as a dimension of performance) include:

- Spotting productivity declines to give "early warning" signs
- Comparing productivity across individuals, units, organisations and industry to make management decisions
- Linking management and labour in productivity improvement efforts to build common awareness and responsibility
- Demonstrating productivity gains to interested stakeholders
- Conducting research and evaluation related to new or experimental methods
- Supporting incentive and bonus plans with objective productivity data.

C. General Types of Measures

a. Partial versus Total Measures

According to Brinkerhoff & Dressler (1990), the distinction between total and partial measures relates entirely to the level of analysis. Specifically addressing the issue of productivity, the authors state that a total measure reflects productivity at the level of the whole organisation, while a partial measure reflects productivity at a lower or unit level. Partial measures can

be added to create aggregate measures of productivity. "Aggregate" partial measures are especially useful when the output is heavily dependent on several inputs.

Partial measures are often more useful than total measures, because they isolate one, or few, inputs or outputs. Thus, they help managers to understand the role of discrete inputs as they impact on productivity, and thus enable fine level adjustments and improvements in operations.

With respect to performance of a clinical engineering service, an example of a total measure could be: Total overhead (fixed) cost per hour, while a partial measure would be: Labour cost per repair per equipment type.

b. 'Family' Measures versus Single Measures

The science of measurement requires that large, complex phenomena be "reduced" to objective, operational, and measurable dimensions that can be quantified (Brinkerhoff & Dressler, 1990).

Where there is a rigid demand for a single, unitary indicator of performance, a single measure is clearly the choice. However, single measures rarely reflect the true state of things, as there are always multiple interests, goals and values.

A family of measures, which represents a group of interrelated aspects of performance, provides more discrete information about total unit performance than a single measure, and is thus more compatible with decision making in a context where trade-offs are common.

2.6.2 Key Performance Factors

Kaydos (1991) states that without a clear definition of institutional strategy and what "performance" means for each department to support that strategy, there is a

real danger of "sub-optimisation", or of "spending $1.15 to save $1.00", for example. This occurs when the department objectives are not consistent with the needs of the whole institution and each other. Maximum performance of the whole does not result from trying to independently maximise the performance of each of the parts.

Achieving maximum performance is a balancing act, not a simple problem of optimising one variable. Management must determine the most important factors for the entire institution, then assign departmental objectives and performance measures that are consistent with them.

A. Variables to Measure

Figure 2.2 shows the variables that must be measured in order to properly monitor performance of any production process - be it a department, a person or a physical process.

The variables are defined as:

- **Work inputs**: demands made on the production system
- **Quality inputs**: measures of the quality of incoming work
- **(Operational) variance inputs**: unrecognised quality problems generally not directly associated with the product
- **Resource inputs**: money, manpower and materials used to produce the products
- **Environmental factors**: forces or conditions outside the production system which affect its performance
- **Constraints**: variables that must be held within certain limits e.g. capacity limits (real) or maximum order processing time (conceptual)
- **Product outputs**: useful products or services produced
- **Quality outputs**: measure how well the goods or services produced conform to their specifications
- **Variance outputs**: as with variance inputs

- **Waste**: any resource that does not result in useful output
- **Productivity**: ratio of output to input
- **Performance measures**: top level gauges of how well the production system is operating in a good/bad sense (depends on point of reference)
- **Behaviour measures**: second level factors that explain how the major parts of the production system interact (depends on point of reference)
- **Diagnostic measures**: used to isolate problems to their actionable level (depends on point of reference).

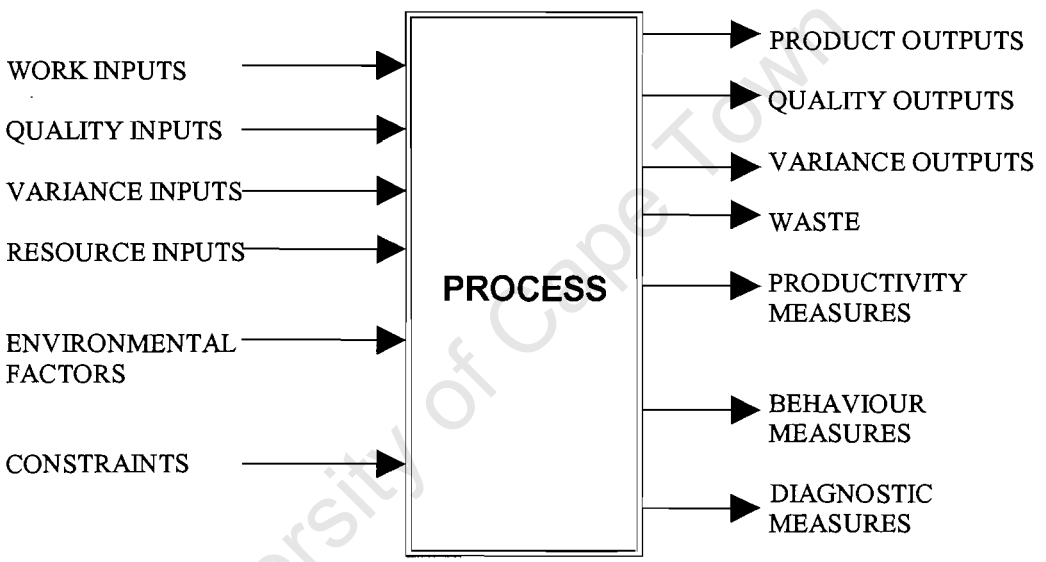


Figure 2.2: Measurements Required to Monitor the Performance of any Production System (Kaydos, 1991)

According to Kaydos, the key to having a cost-effective performance measurement system is to measure everything that matters and not much else. Experience indicates that with a well-designed system, ten to thirty variables are usually sufficient for a department, business unit, institution or organisation.

B. A Family of Performance Measures

Harbour (1997), concurs with Kaydos, and states that the key to collecting performance measures is to identify those measures (and only those) that provide the greatest information and are most usable. In keeping with the concept of a family of measures for performance, these typically include:

- **Productivity:** (as defined in 2.6.1 A)
- **Quality:** (as defined in 2.6.1 A)
- **Timeliness:** assesses whether process takes place at the time intended
- **Cycle time:** amount of time to proceed from one defined point in a process to another (or same point in the next cycle) i.e. how long a process takes
- **Outcome:** measures of the effects of the outputs of the system. Outputs often represent the various objectives of the system and may be used as intermediate indicators of sub-optimal performance by the system (Thor, 1993)
- **Costs:** this is especially useful if calculated on a per unit basis
- **Resource Utilisation**: the measure of resources used vs. resources available for use (Thor, 1993)

Correlation refers to the degree of relatedness between two (or more) variables. Positive correlation means that as one variable increases or decreases, another variable increases or decreases in the same fashion - i.e. a direct relationship. Negative correlation describes inversely related variables. Correlations range from 0 (no correlation) to 1 (perfect correlation).

Therefore a family of measures should contain separate measures that are not closely correlated, i.e. focus on a critical few and not a trivial many.

2.6.3 Developing Effective Performance Measures

Brinkerhoff & Dressler (1991) state that it is a basic tenet that any measure should be *accurate*. However, measures must be more than simply accurate if they are to be constructively used in a complex organisational setting.

A. Criteria for Measurement Effectiveness

In order for measurements to be successfully adopted as part of a continuing performance improvement process, they should satisfy certain criteria. These criteria are outlined in this section and then discussed in more detail in subsequent sections. Creating successful measures takes time, and especially takes careful consideration of organisations, their goals and the people who work in them.

a. Quality

The measure must define and reflect quality of production or services as well as quantity. A measure that assesses only quantity of outputs can lead to reduced productivity.

b. Mission and Goals

The measure must define and assess only outputs and services that are integrated with organisational mission and goals. Measures directed to products and services that are not consistent with mission and goals threaten productivity.

c. Rewards and Incentives

Measures must be integrated with performance incentives, reward systems and practices. Measures that have no important contingencies will not work to improve productivity.

d. Employee Involvement

There must be involvement of organisation employees, and other direct stakeholders, in the definition and construction of productivity measures. Job-holders themselves are most knowledgeable about the details of the jobs, and are thus best able to conduct the sort of analysis that leads to the identification of critical work dimensions and measures. Employees are much more likely to use, and much less likely to sabotage, a system that they themselves have helped to build. Involvement also achieves the necessary goal of awareness and understanding of productivity measurement purposes and procedures in the organisation.

B. Inputs for a Performance Measurement System

Chang and Morgan (2000) state that organizations that effectively manage measures achieve superior business results. To this end, the authors describe a "scorecard" system for managing performance measures. Simply defined, a scorecard is a set of measures – linked to organisational strategies and goals – that provides a balanced and timely view of business performance specific to an area of responsibility, i.e. it used to evaluate and manage a business.

Chang and Morgan propose a six-step methodology for developing scorecards. These steps are: Collect, Create, Cultivate, Cascade, Connect and Confirm. The first two steps provide some useful information for the development of performance indicators.

Collect Phase

1. Obtaining top-level objectives, measures and targets
2. Identifying customers and key requirements
3. Defining core process chains, where a 'core process' is a sequence of work activities that provides goods and/or services to customers

4. Documenting high-level process flows
5. Gathering existing measurement data for core business processes.

Outcomes of this phase include:

- A 'snapshot' of business customer-supplier process chains
- High-level flow charts of core processes.

It is imperative to be aware of the needs and expectations of the customers. Without them there is no business. Figure 2.3 summarises the key inputs of the "collect" phase of a performance measurement system, described by Chang and Morgan.

Figure 2.3: Scorecard measures aligned with customers' needs and expectations, corporate vision and business processes (Chang & Morgan, 2000)

Create Phase

During this phase a scorecard is developed that:

- supports management commitments and plans
- monitors work processes
- relates to customer needs

- measures achievement of key business goals
- clarifies responsibility and ownership.

The steps involved in developing a performance scorecard are:

1. Review scorecard development planning inputs. This can be done by reviewing institutional goals and measures, to identify the priorities for the department's outputs and contributions.
2. Define key result areas[2].
3. Relate business objectives to key result areas. This can be done by reviewing performance contracts and service agreements to identify requirements and designated work outcomes.
4. Brainstorm potential measures.
5. Select the key indicators for performance scorecard.
6. Develop action plans for compiling and reviewing the key indicators.

Guidelines for identifying key result areas are:

- What primary products or services are delivered to customers?
- What business results are emphasised by management?
- What results consume the majority of team resources?
- What categories of results are defined in customer agreements?
- What categories of results are defined by corporate strategies?

Typical result areas include financial success, customer loyalty, market leadership, employee development, operational effectiveness and community impact.

Outcomes of this phase are a set of performance measures that are linked to institutional goals, business objectives and customer requirements. Combining

[2] Key result areas are critical, must-achieve, make-or-break business outcomes

this with the four criteria suggested by Brinkerhoff and Dressler produces an effective performance measurement system.

2.6.4 The Starting Point: Institutional/Departmental Mission

The starting point towards achieving superior performance in any organisation is the establishment of a **statement of purpose** or **Mission** (Christopher & Thor, 1993).

The mission is a statement defining the dimension and scope of responsibility of the organisation or business unit. Basically, what products and services, for what markets and which customers, will build the success of the particular organisation or business unit?

According to Christopher (1993) the essentials are to:

1. Define the Mission
2. Make the Mission specific through strategic goals and performance measures.
3. Integrate the Mission with subordinate unit goals and measures.
4. Develop the organisational effectiveness that will make the goals attainable.
5. Design the information system and feedback measures.
6. Involve everyone in the process.
7. Recognise and reward performance achievement.

Bronzino (1992) further adds that the mission statement and list of objectives of a CES must conform to the overall strategic plan of the hospital.

2.6.5 Customer Needs and Expectations

The concept of "customer" or "client" is integral to performance measurement, even though the customer does not appear in the measure itself (Brinkerhoff &

Dressler, 1991). The customer is defined as an individual or organisation that receives, uses or is impacted by a product or service.

A. Why Measure Customer Expectations?

Important reasons why customers must be identified and considered include:

- Identifying customers helps to clarify which outputs of a unit are important
- Customer needs and expectations are the basis from which measurable quality criteria are derived.

Scheuring (in Christopher & Thor, 1993) further adds that organisations measure customer expectations and perceptions to achieve four basic benefits, namely:

1. understanding and gauging customer requirements and views
2. achieving optimal resource allocation
3. achieving continuous performance improvement
4. obtaining a sustainable competitive advantage.

B. How to Measure Customer Expectations and Perceptions

Scheuring adds that there are basically two types of approaches that can be used to measure expectations and perceptions of the customer:

- **Qualitative research** is used to develop insights about the nature and content of customer expectations and perceptions and the forces that drive them. Its most significant, versatile and useful technique is the focus group interview.
- **Quantitative research** aims to quantify criteria, considerations and relationships in order to deliver factual data in the form of frequencies, percentages, indices etc. Its most frequent use is in the self-administered questionnaire survey.

Questionnaires can be used to measure any and all of the following:

- content of expectations
- level of expectations
- importance of individual expectations
- potential trade-offs
- influences shaping customer expectations
- company performance as perceived by customers.

C. Measuring Performance Against Customer's Expectations: SERVQUAL

One very popular method for measuring customer expectations and perceptions of service quality – and the subsequent gap between the two – is the **SERVQUAL** instrument.

The authors Parasuraman *et al* (in Christopher & Thor eds, 1993) have shown in their research that customers evaluate a firm's service quality by comparing service performance (perceptions) with what they think performance should be (expectations). In effect, customers' service expectations provide a context for their assessment of the service. When service performance falls short of expectations, a service quality gap results. A SERVQUAL model is outlined in Fig. 2.4

The 22 paired questions (expectations vs. perceptions) in SERVQUAL reflect specific attributes within each of five broad service dimensions that the authors' research has shown to represent the criteria customers use to judge service quality. The five dimensions are:

1. **Tangibles:** the appearance of physical facilities, equipment, personnel, and communication materials.

2. **Reliability:** is the ability to perform the promised service dependably and accurately
3. **Responsiveness:** the willingness to help customers and provide prompt service.
4. **Assurance:** the knowledge and courtesy of employees and their ability to inspire trust and confidence.
5. **Empathy:** the caring, individualised attention the firm provides its customers.

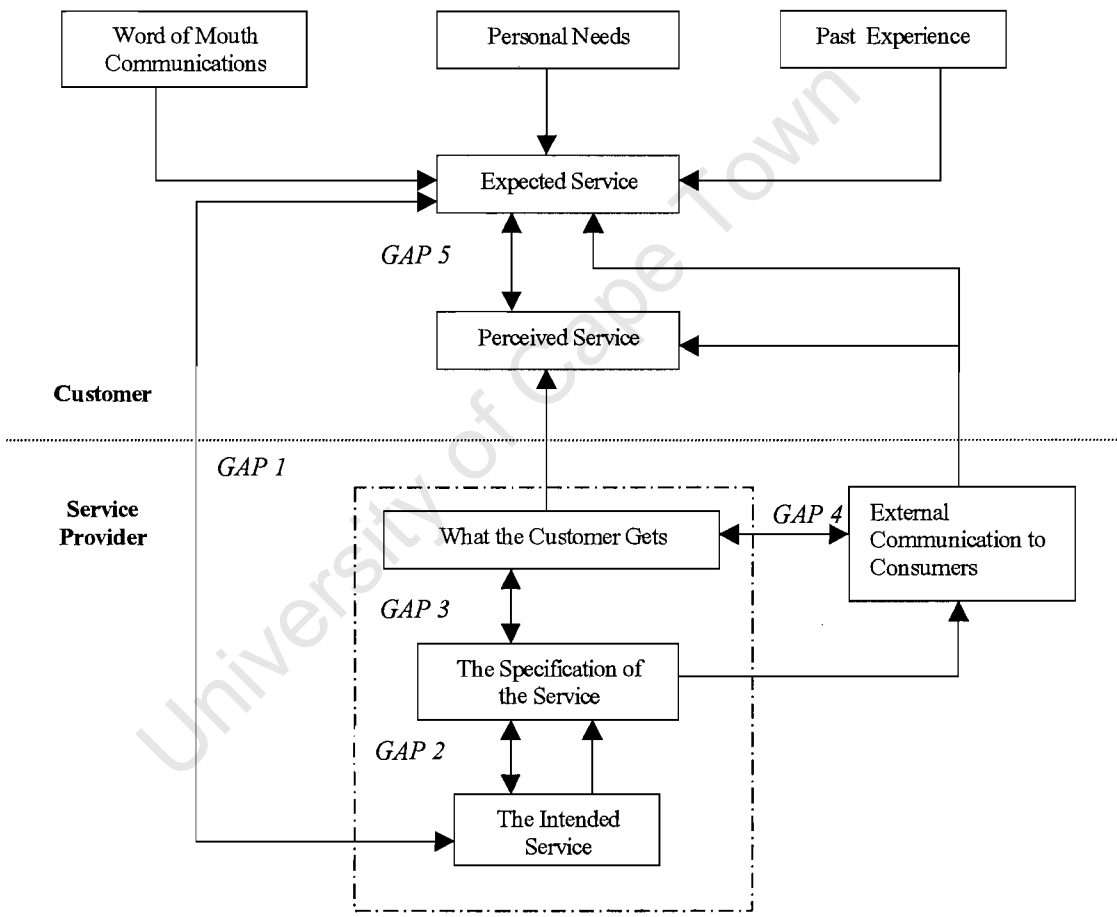


Figure 2.4: The SERVQUAL Model

(from: www.mngt.waikato.ac.nz/depts/mnss/courses/emba/sqm/sld002.htm)

GAPS	
GAP 1	What managers **and** customers see as important
GAP 2	What managers see as important **and** the specifications
GAP 3	The specification **and** the delivery
GAP 4	The delivery **and** the claim/promise
GAP 5	Expectation **and** perceptions

It is important to measure the relative importance of these dimensions. This can be done by using the Likert Scale i.e. a five or seven-point scale anchored at the ends by the labels: Strongly Disagree (= 1) and Strongly Agree (= 7).

2.7 QUALITY AND QUALITY ASSURANCE

Franco *et al* (1997) state that quality deficiencies can be found in any health care setting, from the most sophisticated urban hospital to the village clinic. Poor quality reduces the benefit to clients, frustrates health care providers and wastes scarce health resources. A systematic, ongoing process of ensuring and improving quality is therefore an essential component of an effective, efficient and responsive health care system.

Such an approach in a health care delivery system dictates that clinical engineering departments justify their performance and existence on the same basis as any business: the performance of specific functions at a high quality level and at a competitive cost (Autio & Morris, 1995).

2.7.1 Dimensions of Quality

According to Kaydos (1991) quality has several meanings depending on the customer's needs and wants. Recognised quality factors for a physical *product*

include: performance, features, reliability, conformance, durability, serviceability, aesthetics, value and perception. For *services*, quality includes: availability, regularity, reliability, responsiveness, assurance, empathy, cost and value.

Quality is a comprehensive and multifaceted concept. Experts generally recognise several distinct dimensions of quality that vary in importance depending on the context in which a Quality Assurance effort takes place. Brown *et al* (1999) define these dimensions specifically for health services as:

- **Technical competence**: the skills, capability and actual performance of health providers, managers and support staff.
- **Access to service**: health care services (or support services) that are unrestricted by geographic, economic, socio-political, cultural, organisational or linguistic barriers.
- **Effectiveness:** the extent to which a service, product or intervention achieves the desired results or outcomes.
- **Interpersonal relations**: the interaction between providers and clients, managers and health care providers, and the health team and the community.
- **Efficiency**: providing the greatest benefit within the resources available i.e. *optimal* benefit.
- **Continuity:** providing the complete range of services required without interruption, cessation or unnecessary repetition.
- **Safety**: minimising the risks of injury, infection, harmful side-effects, or other dangers related to service delivery.
- **Amenities**: the features of health services that do not directly related to clinical effectiveness, but may enhance the client's satisfaction and willingness to return to the facility.

2.7.2 Defining Quality Assurance

Quality Assurance describes all the planned and systematic actions that are carried out to set standards and to monitor and improve performance so that the

service provided is as effective and safe as possible, i.e. providing adequate confidence that a product or service will satisfy requirements for quality.

Within the health care delivery system, Brown *et al* point out that quality assurance (QA) has primarily been used by hospitals in developed countries and they have relied heavily on standards developed by accrediting agencies such as JCAHO. However, there has recently been an explosion of interest in developing national QA programmes – even in developing countries. Reasons for this includes:

- Democratisation movements have led politicians to consider more carefully the demands of citizens for better quality care.
- Economic problems in all countries have limited their ability to improve quality by spending more. There is thus the realisation that quality improvement can only be achieved by improving the efficiency and effectiveness of current resources.
- Managers see the need for more cost recovery; however, they realise that services can only be charged for if the quality is improved.
- The success of quality management approaches used by industry in Japan, and more recently in the USA and Europe, has inspired health care organisations to apply these methods to their QA programmes. It has been found that dramatic improvements in quality and efficiency can be achieved in only five years.

2.7.3 The High Costs of Low Quality

Many managers believe that there is a cost-quality trade off, i.e. raising quality will cost more or that reducing costs means lower quality. Many organisations are now realising that, in the long run, low quality has high costs (Ovretveit, 1992). It is therefore important to identify areas contributing to low quality, which Christopher (1993) describes as Non-Quality Costs. Measuring and reducing Non-Quality Costs produces high quality, improves productivity, strengthens market

position and can significantly improve profitability. It focuses efforts on the actions needed to:

- eliminate error
- reduce waste
- shorten cycles and delays
- satisfy customers.

Christopher (1993) subsequently provides a guideline for thinking about and identifying Non-Quality Costs and thus help in the development of suitable indicators:

a. Internal Costs of Non-Quality Performance

Research and Development
- New product failures
- Project five-year savings or income less than satisfactory
- Engineering change orders
- Troubleshooting or failure analysis
- Missed project benchmark deliverables

Executive Management
- Cost of restructuring
- Lengthy planning and budgeting processes
- Redoing budget proposals
- Lengthy capital appropriation procedures
- Inappropriate management strategy

General
- Corrective action, cost to fix
- Cost of injuries
- Absenteeism
- Employee turnover
- White collar, professional and management rework
- Meetings that don't accomplish a needed result
- Data entry errors
- Non-value-adding travel
- Doing work not needed
- Rework
- Re-inspection, retest
- Downtime not scheduled

b. External Costs of Non-Quality Performance

- Warranty costs
- Recalls
- Field failures
- Customer complaints
- Field-installed engineering changes
- Lost customers
- Loss of share with target customers
- Product liability cost, insurance premiums
- Regulatory fines and corrective actions

2.7.4 The Quality Assurance Process

The Quality Assurance Project (QAP), an organisation initiated in 1990 to develop and implement sustainable approaches for improving quality of health care in developing countries (Brown *et al*, 1999), suggest that four principles should be adhered to in an ideal quality assurance programme:

1. A focus on client needs (both external and internal)
2. A focus on systems and processes
3. A focus on data to analyse service delivery processes and make decisions
4. A focus on participation and teamwork in quality improvement.

The following are the 10 steps of the Quality Assurance process that the QAP suggests:

DESIGNING FOR QUALITY

1. **Planning for QA**: Develop a vision and strategy for QA activities, assign duties and allocate resources.
2. **Developing guidelines and setting standards**: Define expectations for quality health services.
3. **Communicating guidelines and standards**: Ensure that those who must apply the standards are aware of them, understand them and believe in them.

MONITORING

4. **Monitoring quality**: Develop indicators and collect data to measure performance and to identify current or impending problems.

PROBLEM SOLVING AND IMPROVING PROCESSES

5. **Identifying problems and selecting opportunities for improvement**: Examine information through monitoring, talking to people, conducting special

surveys in order to identify existing or ongoing problems. Then select the most important problem(s) or problematic process(es) to tackle.

6. **Defining the problem operationally:** Develop a clear statement of the problem in terms of its measurable effect on health service processes.
7. **Identifying who needs to work on the problem**: Determine which persons or groups should take part in the problem-solving process to help in analysing the problem and in developing and implementing solutions.
8. **Analysing and studying the problem to identify major causes**: Gather and analyse data to understand the nature of the problem and its principal or "root" causes.
9. **Developing solutions and actions for quality improvement:** Generate a list of likely solutions, choose the one(s) which best address the principal causes and design a practical, feasible solution.
10. **Implementing and Evaluating QA efforts**: Plan the implementation of the solution (who, what, where, when, how) execute the test, and determine implemented solutions to ensure they are working. Care needs to be taken to ensure both that sufficient data is collected to have the essential facts and that too much time not be spent collecting more data than really needed.

Step 4 highlights the importance of developing performance indicators as a method of monitoring quality.

2.8 SUMMARY OF SECTION II OF LITERATURE REVIEW

Following on from Section I of the literature review, several key points can be picked up from the business management literature reviewed in Section II:

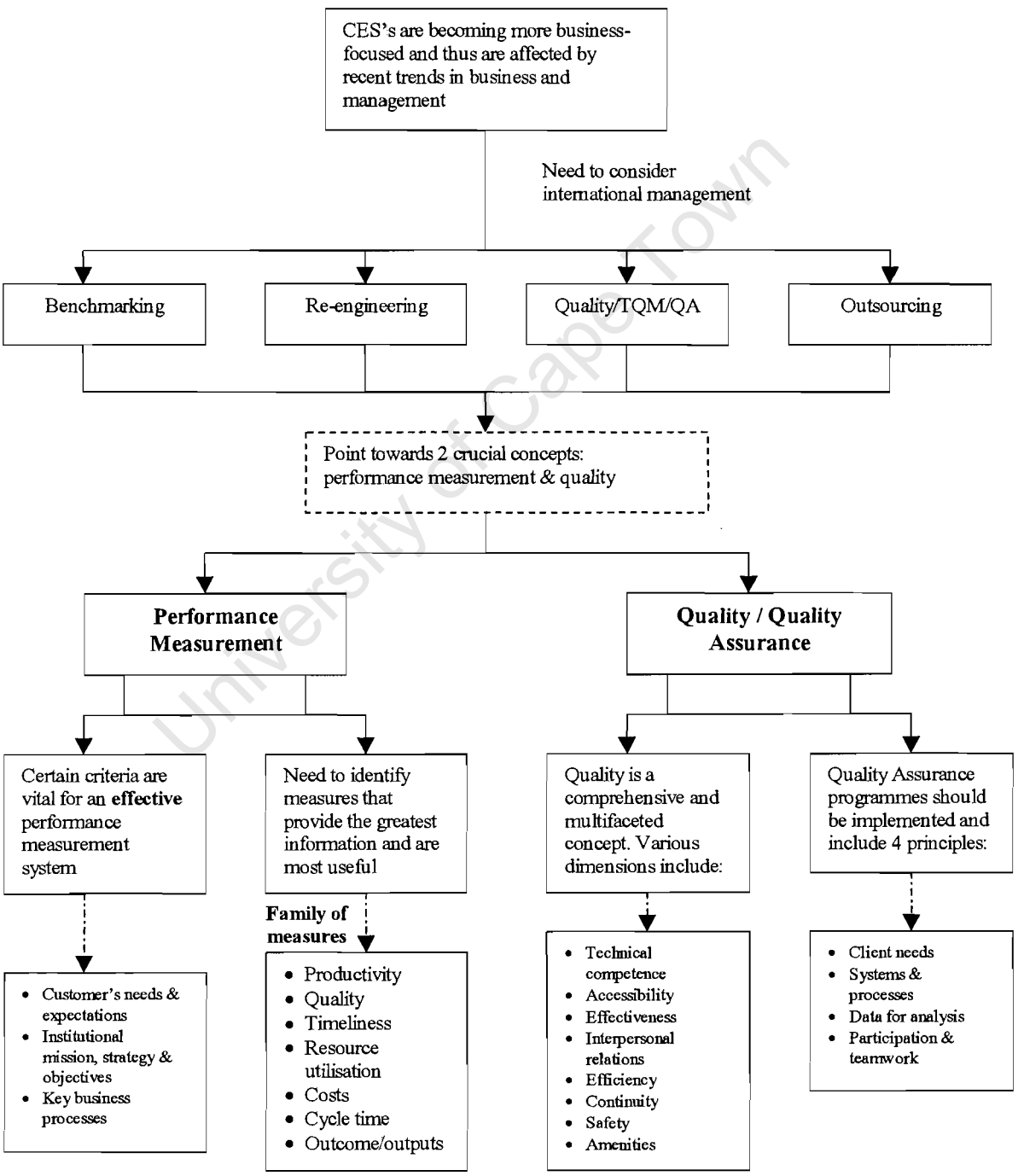


Figure 2.5 Summary of Section II of Literature Review

III. PERFORMANCE AND SUSTAINABILITY OF CLINICAL ENGINEERING SERVICES

2.9 DEVELOPING INDICATORS

An *indicator* is an objective, quantitative measurement of an outcome or process that relates to performance quality. It is objective in that different observers can obtain the same measurement. Indicators can assess many different aspects of quality, including accessibility, appropriateness, continuity, customer satisfaction, effectiveness, efficacy, efficiency, safety, prevention/early detection and timeliness (Autio & Morris, 1995).

2.9.1 Classification of Indicators

There are different types of indicators, as described by AAMI (1990) and Autio & Morris (1995) i.e.:

- A *Programme indicator* is used as a performance measure. The indicator is:
  - **reliable** if the same measurement can be obtained by different observers
  - **valid** if one can identify opportunities for quality improvement
  - **relevant** if it is applicable/pertinent to its users and customers.
- **Discriminatory capability** is the extent to which the indicator demonstrates variation in performance within the same sector.
- An *Outcome indicator* assesses the results of a process or direct outcome.
- A *Process indicator* assesses an important and discrete activity that is carried out during the process.
- A *Structure indicator* is a measure of the element within a department or organisation that provides the capacity to perform a process.

Indicators can also be classified as sentinel-event indicators and aggregate data indicators.

- A *sentinel-event indicator* is a performance measurement of an individual event that triggers further analysis.
- An *aggregate data indicator* is a performance measurement based on collecting data involving many events. These events occur frequently and can be presented as:
    - *a continuous variable indicator* where the value can fall anywhere along a continuous scale or
    - a *rate-based variable indicator* which is the value of a measurement that is expressed as a proportion or ratio.

Finally, indicators can also be classified as (Packer MB, in Christopher & Thor, 1993):

- *Direct,* i.e. measure performance clearly and explicitly
- *Indirect/proxy,* when performance cannot be easily or completely quantified
- *Objectively* assessable
- *Subjectively* assessable.

General indicators should be developed to provide a baseline monitoring of performance.

2.9.2 Seven Steps to Developing Performance Indicators

Brinkerhoff & Dressler (1990) suggest a seven-step method for developing productivity measures. These have been adapted for developing performance indicators as a whole:

1. **Mission statement**. Write a mission statement for the unit that identifies the major goals and customers of the unit. The mission statement must be complete and be compatible with the mission of the larger organisation.
2. **Expectations**. Identify for each customer the unit's products and/or services. Expectations must clearly identify and explain quality needs and expectations held by each major customer group for the unit's products and services.
3. **Key outputs**. Identify outputs that are important to the unit's mission, responsive to customer needs and expectations, and account for the majority of expenditures of the unit's resources.
4. **Major functions**. Identify and describe the major functions of the unit. These must clearly represent unit operations and inputs and explain how key outputs are produced.
5. **Output measurement selection**. Construct measurement techniques for one or more key outputs that will produce the most practical and useful quality and productivity information.
6. **Input measurement selection**. Construct measurement techniques for one of more key inputs that are critical to the production of the outputs selected in Step 5.
7. **Index construction**. Construct one or more performance measures to incorporate the output and input measures into a sensitive, practical and useful index.

2.9.3 Operational Requirements for an Effective Measurement System

While it is important to measure all the right variables for an effective performance measurement system, it is not sufficient. Kaydos (1991) suggests that to be **effective** – i.e. it is used to improve the organisation's performance and competitiveness – the measurement system will also have to meet the following requirements:

- **Validity**: the performance measures must measure what counts and must be accepted and understood by the users. It must also not be easily manipulated to achieve desired results (Harbour, 1997).
- **Completeness**: the productivity and quality measures must be "closed" in the sense that they consider *all* aspects of the balancing act that have to be performed.
- **Sufficient detail**: Tthe Law of Requisite Variety states that if a system is to be controlled, the controlling system must have at least as much variety as the system to be controlled.
- **Accounting for the performance gap:** the measurement system must account for at least 80% of the gap (or variation) between actual and desired or normal performance.
- **Sufficient measurement frequency**: if measurements are not taken often enough (low sampling frequency) the information can be misleading.
- **Timeliness**: information loses its value very quickly - timeliness is essential for diagnosing problems and for reducing the delay between a stimulus and the corresponding response.
- **Useful accuracy/ reliability**: the absolute value of a performance measure is not necessary for identifying problems and guiding behaviour. What is important is whether or not its trend is up or down, and how its current value compares with historical performance.
- **Long-term consistency**: the measurement units must not be affected by changes in any factors that may change with time. This will make historical comparisons possible. Percentages or ratios are usually best.
- **Accountability**: the system will not be of much value unless there is strict answerability for each and every measure.
- **Trust and credibility**: the output of an information system can be no better than its input. Without trust and credibility, data reported and information exchanged is likely to be filtered and distorted.
- **Efficient:** the measurement used must be easy, cost-effective and focus exclusively on essential information to eliminate any waste in the process (Scheuring, in Christopher & Thor, 1993).

- **Effective:** the measurement is only productive if it is used to improve the organisation's performance and competitiveness (Scheuring, in Christopher, 1993).
- **Quantifiable**: employ ratios rather than absolute numbers.

2.9.4 Criteria for Appropriate Indicators

In addition to requirements for an effective measurement system, Packer (in Christopher & Thor, 1993) states that there are several criteria for determining if indicators are appropriate:

1. Indicators should be **comprehensive**, measuring all aspects of their associated organisational functions.
2. Indicators should **focus on organisational functions**, not current activities. This means that indicators should concentrate on results or ends, not on the specific procedures or means currently employed.
3. Indicators should describe functions in terms that are **familiar** to those who will use the measures.
4. Whenever possible output indicators should be **comparable** to input indicators in scope. This facilitates the creation of valid data.
5. The indicators should be adopted to ensure **comparability with outside organisations.**

Recommendations for the Design of Performance Measures

Drawing from an extensive literature review on performance measurement and testing them on five specific applications in the aerospace and automotive sectors, Neely *et al* (1997) present the following recommendations for the design of performance measures. Performance measures should:

1. **be derived from strategy**
2. **be simple to understand**
3. **provide timely and accurate feedback**

4. **be based on quantities that can be influenced, or controlled by the user alone or in co-operation with others**
5. reflect the "business process" – i.e. both the supplier and customer should be involved in the definition of the measure
6. **relate to specific goals (targets)**
7. **be relevant**
8. **be part of a closed management loop**
9. **should be clearly defined**
10. have visual impact
11. focus on improvement
12. be consistent (i.e.. maintain their significance as time goes by)
13. **provide fast feedback**
14. **have an explicit purpose**
15. **be based on an explicitly defined formula and source of data**
16. employ ratios rather than absolute numbers
17. use data which are automatically collected as part of a process whenever possible
18. be reported in a simple consistent format
19. be based on trends rather than snapshots
20. **provide information**
21. **be precise – be exact about what is being measured**
22. be objective – not based on opinion.

Where: **bold** = recommendations found to be important in all sectors studied

Neely *et al* summarise this by providing a 'performance measure record sheet', specifying what a 'good' indicator constitutes.

1. **Title:** Should be clear and self-explanatory i.e. explains what the measure is and why it is important.

2. **Purpose**: The rationale underlying the measure has to be specified. If a measure has no purpose, then one can question whether it should be used.

3. **Relates to**: The business objectives to which the measure relates should be identified.

4. **Target**: The objectives of any business are a function of all stakeholders (owners, customers etc.). To satisfy these objectives, an appropriate target, which specifies the level of performance to be achieved and a time scale for achieving it, should be recorded.

5. **Formula**: The formula, i.e. the way performance is measured, affects the way people behave. It is thus one of the most challenging elements to specify.

6. **Frequency**: Should be recorded and reported as a function of the importance of the measure and the volume of data available.

7. **Who measures:** The person who is to collect and report the data should be identified.

8. **Source of data**: The source of raw data should be specified – a consistent source of data is vital if performance is to be compared over time.

9. **Who acts on the data**: The person who is to act on the data should be identified.

10. **What do they do**: Defines in general the management process that will be followed should performance appear to be either acceptable or unacceptable. This is the most important element because it makes explicit the fact that unless the management loop is closed, there is no point in having the measure.

2.9.5 Managing Indicators

Once suitable indicators have been defined, a threshold must be established and then the indicators should be monitored and evaluated on a continuous basis. Autio & Morris (1995) give a flow diagram to illustrate this (Figure 2.6).

2.10 DEFINING INDICATORS FOR CLINICAL ENGINEERING SERVICES

2.10.1 Clinical Engineering Database

Autio and Morris (1995) suggest that certain data elements have to be collected, stored and analysed before CE performance indicators can be evaluated. These would be stored in a database and could include:

- Service provided including:
    - equipment maintenance tasks
    - equipment management tasks
    - technology management tasks
- In-house labour including:
    - number of hours spent providing a particular service
    - associated labour rate
    - identification of the individual providing the service
- Vendor labour including:
    - hours spent and rate
    - travel and zone charges
- Parts list including:
    - part number, description and cost
- Timeliness
- Problem identification
- Equipment identification
- Service requester.

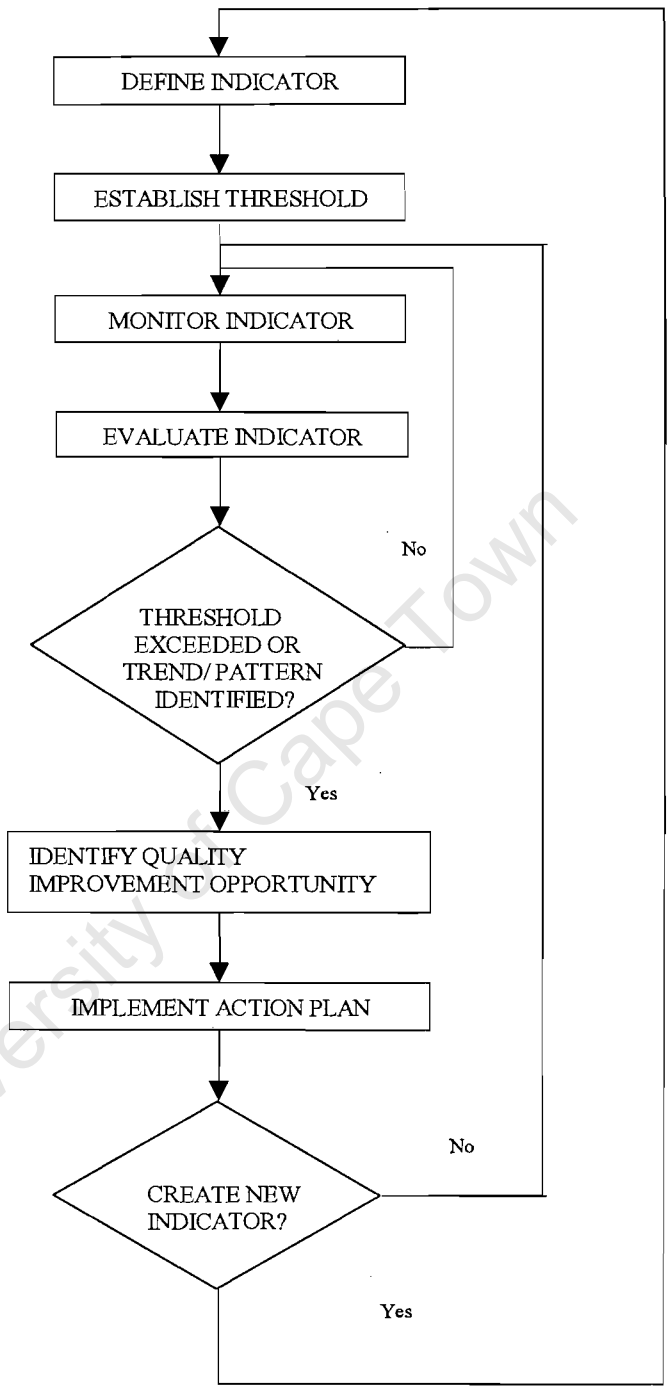


Figure 2.6: Indicator Management Process (Autio & Morris, 1995)

These standard data elements must be carefully defined and understood, and should be accurate and complete. This is especially pertinent if the department wishes to make comparisons with other clinical engineering services. Such a database would allow rapid, retrospective analysis of the data to determine specific indicators of performance and sustainability. Furthermore, using existing data for the purposes of performance measurement is cheaper than collecting data specifically for the measurement (Brinkerhoff & Dressler, 1990).

2.10.2 Performance Indicators

Autio & Morris (1995) subsequently suggest that certain indicators could be developed from the database, e.g.:

- Internal operations, consisting of: productivity, percentage scheduled IPMs completed within scheduled period, mean time per job activity, etc.
- Process for quality improvement, including comparisons against pre-determined threshold values
- External comparisons, including: labour cost per hour, total cost per repair, percentage of time devoted to repairs vs. IPMs vs. consultation, cost of support as a percentage of acquisition value of capital inventory, etc.

The Association for the Advancement of Medical Instrumentation (AAMI, 1990) proposed certain quality indicators that could be measured when evaluating a CES. These include:

- compliance measurements;
- counts of inspections performed;
- quality of documentation;
- number/quality of repairs;
- specific equipment failures;
- repair turnaround time;

- customer complaints;
- activities carried out by the department and
- technical competence of personnel.

In addition, Judd & Painter (2000) have proposed the following indicators:

- Interruption of patient care due to failure in technology
- Interruption of patient care due to failure of user to correctly apply technology
- Tests requiring devices (devices not available)
- Conditions preventable by proper application of devices (bed sores, infection)
- Availabilities of home care technology (not available).

It is important to differentiate between quality and performance measurements, e.g. speed of resolution of problem vs. number of inspections performed.

The use of these indicators reduces data to meaningful information that can easily be monitored and analysed. They can then be used to determine departmental/service performance, identify opportunities for quality improvement and in external comparisons with other departments.

A full list of all available indicators derived from the literature is given in **Appendix B.**

2.10.3 Sustainability Indicators

According to WHO (1999), there is quantitative evidence in various fields of the physical infrastructure domain which shows that the sustainability of health systems is affected by inappropriate physical infrastructure and technology. Typical examples are lack of maintenance which leads to additional costs of 20% - 40% of the equipment budget and lack of inventory which increases the utilisation and service component of facilities by anywhere between 60% and

80%. More tools are needed to measure and document the contribution of physical infrastructure to the attainment of health system objectives.

The 1998 WHO Consultation on Physical Infrastructure and Technology identified certain key factors that ensure sustainability of health systems. These factors include:

- physical resources,
- financial resources,
- human resources,
- political commitment,
- conducive environment,
- legal framework,
- logistics support,
- cultural considerations,
- stakeholder participation,
- governance,
- donor policies and
- public/private partnerships.

The Consultation proposed a number of indicators, including:

- % budget spent for maintenance,
- value of installed base,
- capital budget,
- cost per person for physical infrastructure per year,
- operational budget,
- total population,
- number of health practitioners,
- productivity of services;
- building,
- equipment,

- aggregate capacities / technology level,
- essential list of *operational* technology.

With respect to indicators, the report further states:

> *"WHO should provide support for further development of the model of sustainability of health systems proposed. The model should show measurable influence pathways between various elements of physical infrastructure and technology on the one hand, and sustainability and other desirable attributes for health systems of the future such as quality of care and service, effectiveness and efficiency, on the other. A parallel development should focus on tools which translate the concepts and methodology of the model into a practical guide for decision making by health care professionals."*

2.10.4 Cost-Effectiveness of Clinical Engineering Services

The cost of any in-house service must be known in order to compare it with other service options. One way to determine costs is to set a price or value on services provided to users. To establish the price of clinical engineering services, it is necessary to do the following:

- Determine life-cycle costs of medical equipment supported by the service
- Determine actual hourly labour costs of the service
- Establish pricing options and service contract rates.

The cost-effectiveness of the clinical engineering service is critical to its sustainability.

(i) Health Care Equipment Life-Cycle Costs

Referring specifically to developing countries, Issakov (1994) states that a general lack of awareness, understanding, management expertise and technical

competence often leads to unsystematic purchasing policies based on guesswork, rather than careful assessment of the equipment requirements based on the analysis of health needs and related health service functions. As a result the recurrent cost implications (life-cycle costs) of purchasing medical equipment are often ignored and there is often inadequate budget provision for these costs. Issakov uses the "iceberg syndrome" to illustrate these hidden costs which include: operating costs, maintenance costs, staff costs, training costs, transport and installation costs, administration and supply costs, costs of recording and evaluating data and costs of removal from service.

(ii) Labour Costs

According to Bronzino (1992) this cost represents the total effective hourly cost of doing business and becomes the hourly labour rate at which the department's services are billed. It is particularly effective when applied to CES's because:

- It permits direct comparisons between the costs of the CES and those of equipment manufactures, other CES's and third-party service providers.
- It represents the single best aggregate measure of overall department efficiency by acknowledging all department costs and the effects of staff productivity.
- It becomes a useful measure of CE management effectiveness.
- It serves as a basis for all service cost estimates or contracts.

Despite institutional variations in financial reporting systems, available data and terminology, the hourly labour cost method is based on standard (yet simple) cost accounting principles. In using this method, every effort should be made to do the following:

- Minimise the use of unsubstantiated estimates or assumptions.
- Identify accurately and use all of the applicable cost factors associated with the hourly labour rate equation (as incurred over a reasonable time period):

Hourly Labour Rate ($/Hr) = (Variable Costs + Fixed Costs)/Chargeable Hrs

where:

Variable Costs (or direct/incremental/marginal costs) are the costs assumed to vary (linearly) with production volume or service output. Typically these costs include:

- Salary and wages (including overtime, on-pay call, bonuses or shift premiums) of active service staff.
- Employee benefits (% total salaries and wages).
- Continuing education expenses (eg service schools, technical meetings, short courses, journal subscriptions).
- Office supplies and forms.
- Liability insurance costs.
- All non-fixed telephone charges.
- Repair and service supplies (usually charged back to customer, therefore typically not included).
- Other costs varying with departmental workload (eg travel, fuel).

Fixed Costs (or overhead/burden) are costs that do not fluctuate with the level of activity. These include:

- Effective cost of hospital floor space and associated utilities.
- Capital depreciation (e.g. test equipment and machines).
- Fixed telephone charges.
- Administrative and clerical labour costs.
- Repair parts inventory carrying costs *

* Typical carrying costs for the manufacturing industry range from 20 - 40% of total inventory costs. The inventory represents a fixed cost for several reasons:

- It takes up space, which costs money
- Parts must be put into and taken out of storage (by paid labour)
- The inventory must be managed, counted and recorded
- It must be protected from pilferage
- It can be taxed as property within for-profit organisations
- It may deteriorate or become obsolete with age.

Inventory-carrying costs may be evaluated against the effective cost of not having the parts available.

Chargeable hours represent the maximum number of labour hours the department can realistically expect to charge in the financial year. Total chargeable hours (TCH) is defined:

TCH = (No. Employees) * (Available Labour Hrs/Employee) * Productivity

where:

- No. Employees or full-time equivalents (FTE) = full- + part-time staff whose time is charged out
- Available Labour Hrs/Employee includes only regular and overtime hours. This can be estimated by:

ALH/Employee = 2080 - (Vacation Hours) - (holiday hours) - (sick hours)

- Productivity is the number of chargeable hours divided by number of available hours for a given financial period

The challenge for the CES is to determine how to maximise chargeable hours without:

- Compromising work quality (by encouraging fast, careless work)
- Overcharging the customer (through exaggerated time reporting)
- Creating an anti-service, uncooperative environment
- Acquiring the image of a customer-insensitive, profit-only institution.

2.11 SUMMARY OF SECTION III OF LITERATURE REVIEW

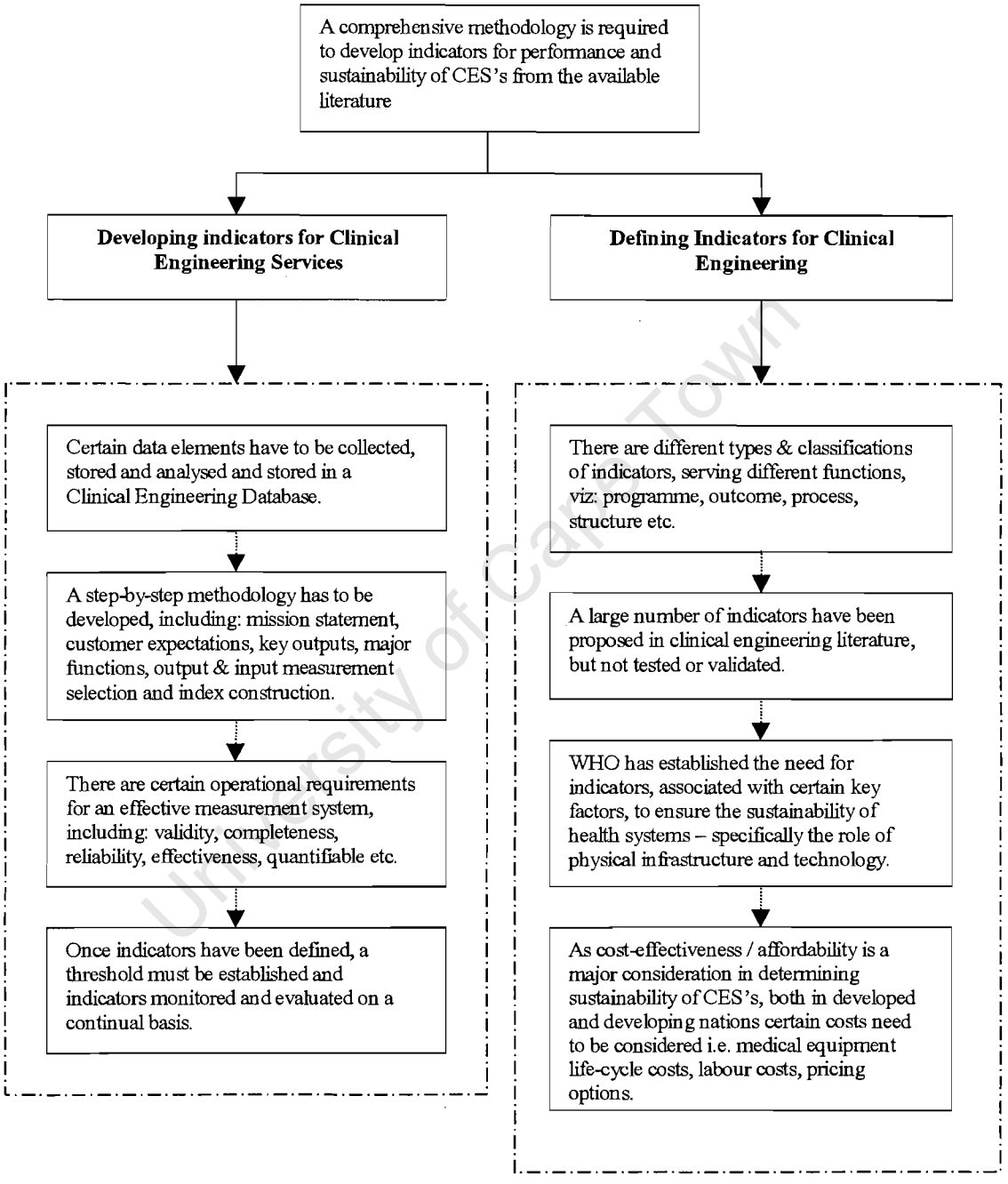


Figure 2.7: Summary of Section III of Literature Review

3 METHODOLOGY: PHASE 1

3.1 OVERVIEW OF METHODOLOGY

Chapter 1 included an outline of the progression of the methodology for the study. This is further illustrated in Figure 3.1, seen as a 3-phase process. Each stage of the methodology will be elaborated on in the following two chapters. Chapter 3 focuses on Phase 1 of the methodology.

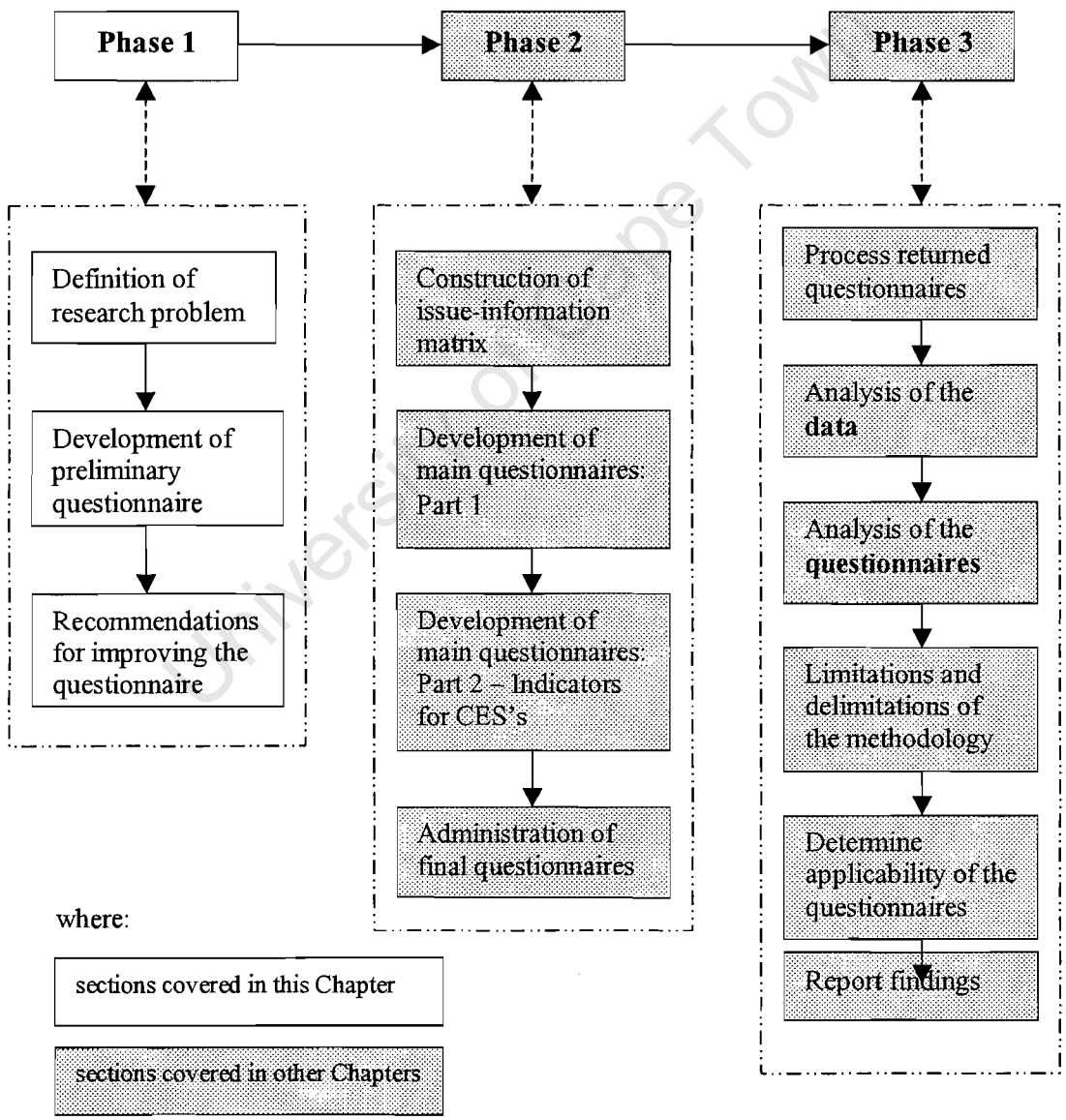


Figure 3.1: Overview of the Methodology

3.2 DEFINITION OF THE RESEARCH PROBLEM

Defining the research problem was a 4-step progression, as outlined in Figure 3.2.

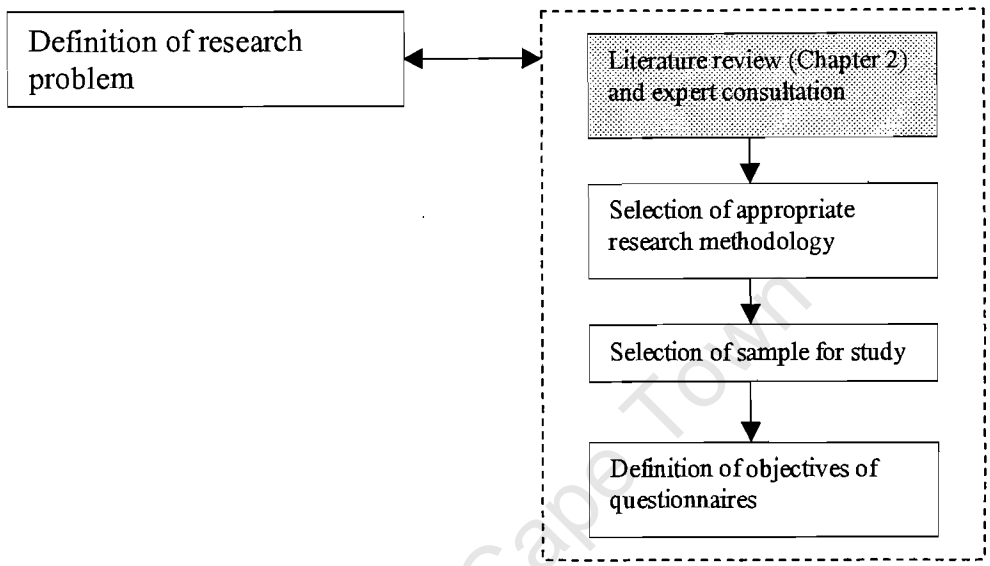


Figure 3.2: Definition of the Research Problem

3.3 SELECTING AN APPROPRIATE RESEARCH DESIGN

Various research methods for obtaining the necessary information/data were considered at the outset of the study.

The absence of information or previous studies on CED/CES performance and sustainability indicators ruled out the option of conducting a study based on secondary data. However, an extensive literature review was conducted around the topic of performance/sustainability measurement in general; and productivity and quality in clinical engineering specifically. This provided a background for developing the methodology and is described in the preceding chapter.

The use of observation techniques for collecting primary data was found to be inappropriate, because most of the information required depended on the

professional opinions of both experts in the field and users/employers of clinical engineering services, and not on factors that could be directly observed by the researcher.

The Delphi technique[1], used in the development of a Management-By-Variance Tool for facilities management performance assessment, described by Neely & McNay (1999) was considered. This method, however, was not feasible for logistical and other reasons. The main principles of the Delphi technique were however found to be highly relevant to the study and were therefore incorporated in the final methodology.

The survey method was then considered to be the most appropriate for collecting primary data for the study. Reasons for this were based on the following:

- The need to collect large amounts of previously unavailable information from a variety of sources.
- The need for the collected information to be in a standardised format, given the fact that the field is still evolving and that there are region/institutional-specific differences in clinical engineering practice.
- The fact that both qualitative and quantitative data was required.

Zikmund (2000) states that (well-designed) surveys can provide a quick, inexpensive and accurate means of obtaining information for studies containing a variety of objectives. Further advantages of surveys are their flexibility and versatility (Alreck & Settle, 1995), which includes their ability to measure a range of variables (simple to complex), their ability to collect large amounts of data and the different survey tools (e.g. personal interview or mail questionnaire) that can be used. Other advantages of surveys include the fact that they can be customised

[1] **Delphi technique:** a consultative research procedure - comprising of questionnaires, scenario workshops and focus group discussions – which is designed to gather expert opinion in areas where there is considerable uncertainty and/or lack of agreed knowledge. The constitutional requirements for a **Delphi group** are that members should all be reasonably knowledgeable about the issue, and should therefore represent all the key viewpoints. The objective of a Delphi exercise is to achieve a consensus view on an issue, whether this be the definition of the factors contributing to a phenomenon, or for the creation of quantitative or semi-quantitative data for such a model where no data existed previously (Hinks & McNay, 1999).

to fit both the needs and the budgets of the research project, and that through the use of sampling, information about extremely large populations can be obtained from a relatively small sample and then generalised.

The next stage in the research design process was determining the most viable method of data collection. Personal and telephone interviews were considered, but these methods were discarded mainly because of the cost and time implications of travelling to or phoning clinical engineering departments internationally.

The traditional self-administered questionnaire was therefore decided upon, with the options of distributing (and receiving) the final questionnaires via postal mail, email and fax. Reasons for selecting this method were:

- The ability to reach a large number of widely dispersed respondents at minimum cost, given that it is an international comparative study.
- The ability to incorporate both structured (quantitative) and open-ended (qualitative) questions in the same instrument.
- The fact that all respondents in the different categories are presented with a standard set of questions, i.e. lack of interviewer bias.
- The convenience to respondents, i.e. they could answer the questionnaire(s) in their own time. This was particularly pertinent, as some of the questions posed to respondents would require a substantial amount of thought.
- The ability for respondents to be anonymous.

The major disadvantages of mail questionnaires namely, low response rates (and the subsequent need for follow-ups and providing incentives to respondents) and misinterpretation of questions by respondents were taken into account. Rigorous attention to the design of the survey instruments and covering letter and frequent pre-tests were conducted as a means of increasing valid responses to the questionnaires.

A final method for distributing the questionnaires, namely via the Internet, was investigated. This method was put on hold because of technical problems, but it is recommended to use web surveys for ongoing research.

3.4 DESCRIPTION OF SAMPLE (RESPONDENTS)

3.4.1 Target Respondents Chosen for the Study

The next step in the design of the research methodology was targeting relevant participants for the study. *Relevant participants* are described as those individuals, units or organisations that have a significant interaction with, interest in or impact (direct or indirect) on the performance and sustainability of clinical engineering departments. Figure 3.3, adapted from Bronzino (1992), illustrates the range of interactions that of typical clinical engineering services within a health care delivery system.

From these interactions, target groups were chosen according to the following criteria:

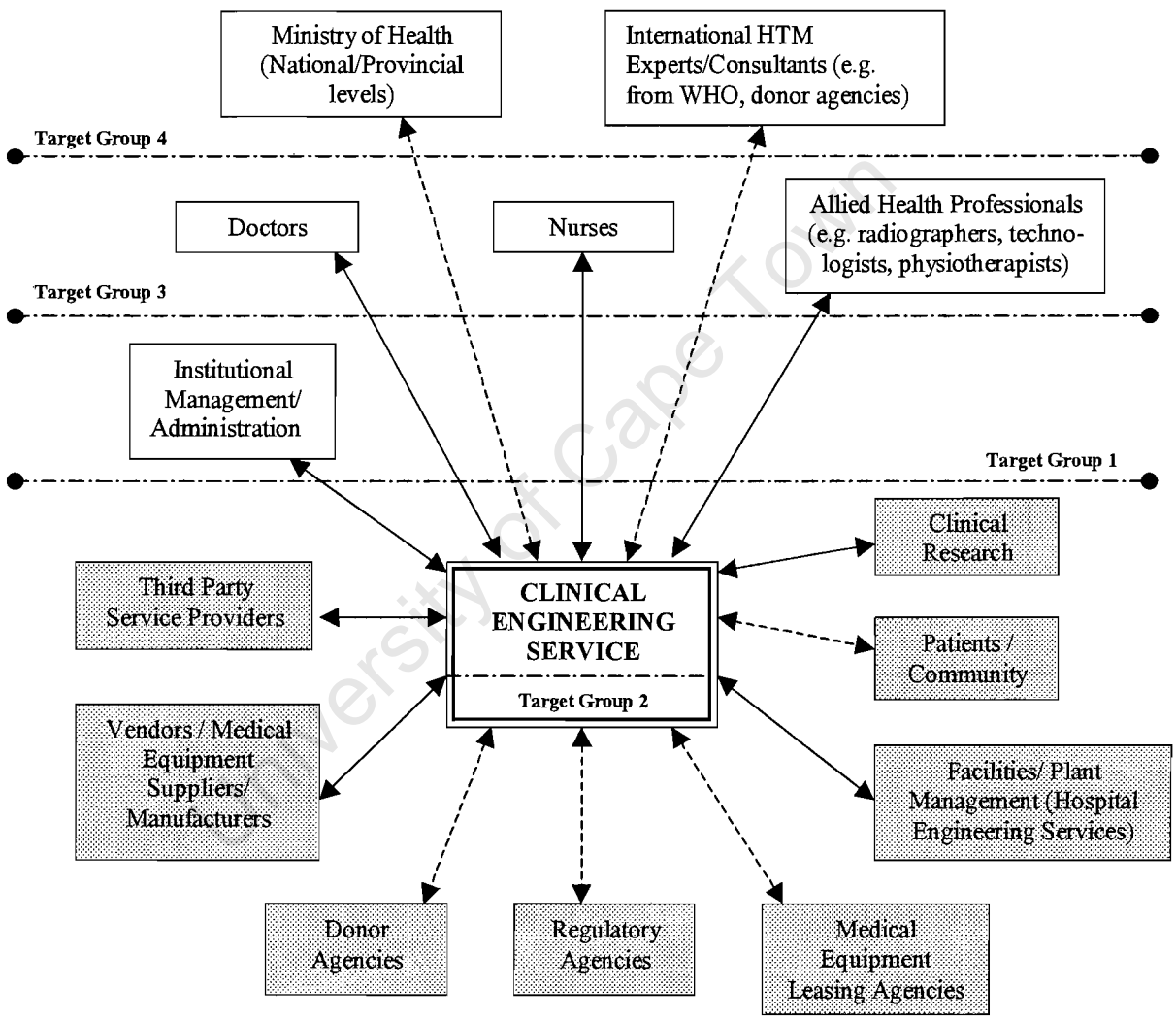
- Ability to provide substantial information about the function, performance or sustainability of a particular **in-house** clinical engineering service.
- Having a direct impact on the existence of a clinical engineering service, i.e. major decision- and/or policy-makers within the health care delivery system.
- Likelihood to benefit from the identification of CES performance and sustainability indicators, specifically; and from the improvement of clinical engineering services, generally.

This was in keeping with findings from the literature review, which states that an effective performance (and sustainability) measurement system:

- must be aligned to the major functions of the unit/department,

- must be integrated with organisational/departmental mission, strategy and objectives, and
- must respond to customer/client's expectations.

The un-shaded boxes shown in Figure 3.3 indicate the groups that were considered relevant for the study.



where:

Indicates direct interaction with CES

Indicates indirect interaction with CES

Indicates groups included in the study, according to criteria listed previously

Indicates groups not included in the study, including third-party service providers

Figure 3.3: Range of interactions of Clinical Engineering Service (adapted from Bronzino, 1992)

The target groups were subsequently arranged into four respondent categories, as shown in Figure 3.3, namely:

1. **Institutional / health facility management** (including nursing management)
2. **Clinical Engineering Service personnel** (both managerial and technical)
3. **Clinical Engineering Service clients** i.e. users and beneficiaries (including doctors, nurses, allied health professionals)
4. **Representatives of national/provincial ministries of health and international HTM experts** (including representatives of multilateral organisations and bilateral agencies, as well as technical consultants).

3.4.2 Sampling Procedure

Due to time and budget constraints and the highly specialised nature of clinical engineering, *non-probability*[2] (non-random) sampling methods were used at all stages of the study. This was considered acceptable because the study was focused on developing and testing a framework and not on producing statistically valid and conclusive results.

The sampling procedure can best be described as a combination of convenience[3] (specifically judgement/purposive sampling), snowball[4] and quota[5] sampling.

Within the Western Cape, respondents in all categories were selected by firstly consulting the Director of Engineering Services within the Department of Health, and subsequently identifying health facilities that had access to clinical engineering services. Through the Director of Engineering Services, the Chief Medical Superintendents at those facilities were approached for permission to

[2] **Non-probability sampling**: A sampling technique in which units of the sample are selected on basis of personal judgement or convenience (Zikmund, 2000).

[3] **Convenience sampling:** the sampling procedure used to obtain those units/people most conveniently available. **Judgement/purposive sampling** is a technique in which an experienced researcher selects the sample based upon some appropriate characteristic of the sample members (ibid.).

[4] **Snowball sampling:** initial respondent is selected and additional respondents are obtained by referral from initial respondents (ibid.).

[5] **Quota sampling:** sampling procedure that ensures that certain characteristics of a population sample will be represented to the exact extent that the investigator desires (ibid.).

conduct the study at their institution and also for assistance in distributing questionnaires to appropriate members of the institutional management and to clinical engineering service personnel and clients. Where possible, clinical engineering management was approached directly and asked to identify relevant members of their personnel and their clients.

A total of four institutions/regional CES's were selected, namely Groote Schuur Hospital, Tygerberg Hospital, Vrijzee and Red Cross Children's War Memorial Hospital. A minimum of five and maximum of ten questionnaires, in each respondent category (1 – 3) , were hand-delivered to the relevant respondents at each institution, depending on number of available personnel.

Outside South Africa, respondents were targeted by firstly identifying clinical engineering services management, in different regions, willing to participate in the study. To this end, suitable correspondents in Australia, Europe and the USA were emailed electronic copies of the survey instruments and asked to distribute them according to the criteria used in the Western Cape. This input was important since the objectives of the study seek to establish whether international comparisons between clinical engineering departments can be made.

Additional electronic questionnaires were distributed through the PAHO Infratech list server/discussion group. The questionnaires have also been put up on the IFMBE (International Federation for Medical and Biological Engineering) website and left as an open-ended exercise.

Formal procedures for determining sample size, error, validity and reliability were not considered due to the large qualitative component of the study, and also because the study is still at a conceptual and developmental stage.

3.5 DEFINING OBJECTIVES FOR THE QUESTIONNAIRES

The literature review revealed that there were no validated questionnaires available to use in developing performance and sustainability indicators for

clinical engineering departments. Previous international studies (Frize, 1990 & Glouhova, 1999) had only investigated the status of clinical engineering with respect to structure and function, and not the performance or sustainability of the respective departments. There was therefore a need to develop a new instrument, to complement the previous studies, and this became the focus of the study.

The objectives of the new instrument were based on:

a. The objectives of the study as a whole.
b. The variables required for an effective performance measurement system, as described in the literature review.

The specific objectives of the questionnaire(s) were:

1. Obtain information on the general mission and basic strategy of Clinical Engineering Services (CES's).

2. To gather information about the functions and services of different CES's.

3. Determine general expectations and perceptions of clients employing CES's etc.

4. Develop a general consensus on the importance of CES's in any institution, organisation, region or socio-political environment.

5. Gather information pertaining to quality, performance, cost-effectiveness and sustainability of CES's.

6. To challenge the literature review observation on:

    a. trends affecting CES's in recent years (e.g. business-oriented focus, TQM)

b. sustainability of CES's being threatened in the differing environments (e.g. due to downsizing, rationalisation).

7. Develop a set of **standardised** key indicators to be used in assessing CES's.

It should be noted that it was **not** an objective of the questionnaire(s) to measure the performance and sustainability of clinical engineering departments. The aim was to **develop** the measures to be used, by drawing on the professional opinions of clinical engineering personnel, their clients, employers, and international HTM experts.

3.6 THE PRELIMINARY QUESTIONNAIRE

The following section describes the development of the preliminary questionnaire, which can be found in Appendix A. This questionnaire was developed to determine the applicability and relevance of particular themes to the different sample groups, as well as testing broadly for validity and reliability of the instrument. The steps involved are summarised in the Figure 3.4 below, with a brief description of each stage. It should be noted that this questionnaire referred to Clinical Engineering Services, as Clinical Engineering Departments (CED), specifically. This term was revised following pilot testing of the preliminary questionnaire.

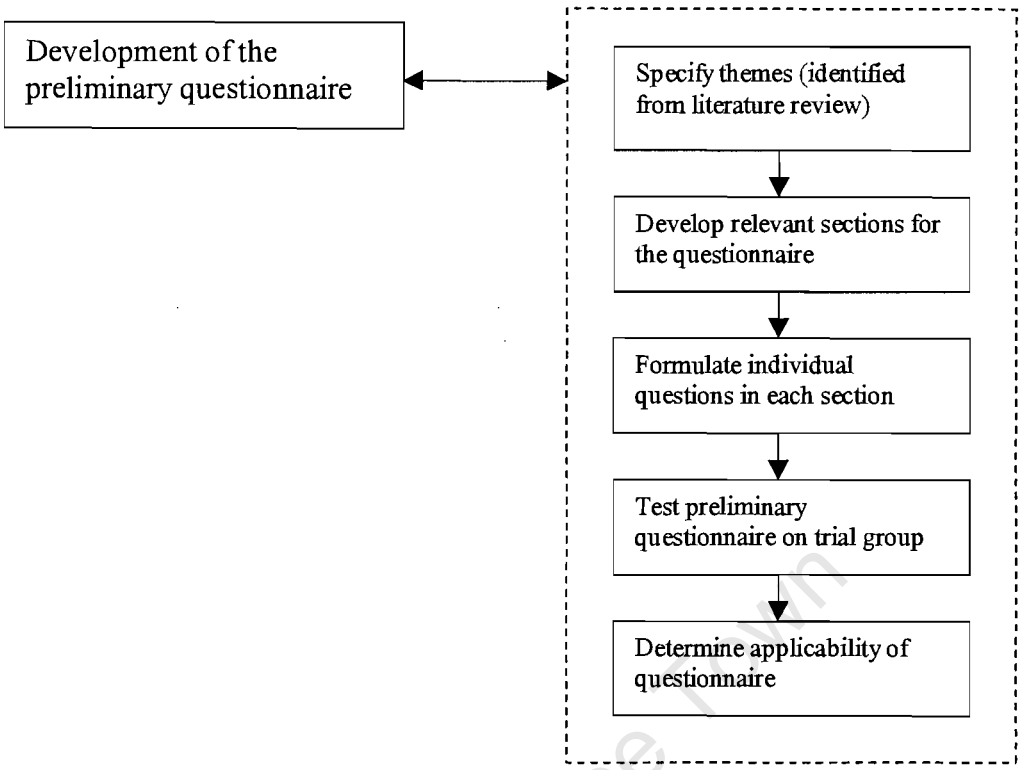


Figure 3.4: Development of the Preliminary Questionnaire

3.6.1 Specifying Themes for the Questionnaire

The initial step in developing the preliminary questionnaire was to specify themes that would be incorporated. These were derived from the literature review, and are as follows:

- General information about the institution being supported by/employing the Clinical Engineering Service (CES)
- Specific services provided and activities performed by the CES and their relevance to the institution it supports
- CES mission, vision, objectives and strategic goals
- CES customer expectations and perceptions
- CES equipment management system used by Clinical Engineering Service
- CES performance
- CES budgets and cost-effectiveness

- CES sustainability
- CES quality and Quality Assurance, including accreditation and certification
- Business/management trends affecting CES's
- Suggested measures of performance, cost-effectiveness and sustainability of Clinical Engineering Services

3.6.2 Organisation of Questionnaire

The questionnaire was divided into sections, with each section representing a particular theme or survey topic. A *funnel*[6] approach was used with respect to the order of sections within the questionnaire i.e. sections asking more general questions were placed at the beginning, and the most specific sections at the end of the questionnaire. There were eleven sections in total, namely:

1. Demographic data
2. Mission and Objectives
3. Service provided by the CES
4. Equipment Management
5. Performance Factors
6. Budget and Costs
7. Sustainability
8. Quality Assurance
9. General
10. Performance, Cost-effectiveness and Sustainability Measures
11. Comments and suggestions for questionnaire.

These will be described briefly in the next sub-section.

[6] **Funnel** technique: A procedure whereby general questions are asked before specific questions in order to obtain unbiased responses (Zikmund, 2000)

3.6.3 Formulating Questions for the Questionnaire

Having divided the questionnaire into relevant sections, individual questions were developed. Specific questions will not be described at this point, as this was not the final questionnaire distributed.

Formal language was used in the questionnaire and where necessary, definitions were provided in the Appendix.

Each section will now be addressed briefly.

1. Demographic Data

This section focused on general information about the institution supporting the Clinical Engineering Service and contact details of the respondent. The specific questions were adapted from surveys by Frize (1990) and Glouhova (1999) respectively, and included scope of service provided by CED, hospital type, number of beds supported by the hospital and number of devices supported by the CED. The questions were structured and respondents were asked to choose from the alternatives provided. An 'Other' option was provided in the event that all options had not been covered by the question. An *ordinal*[7] scale was used where appropriate.

Although literature on questionnaire design generally discourages placing the demographic section at the beginning of a questionnaire, the questions asked were of a general, non-threatening nature and therefore it was felt that they would not intimidate the respondent and could therefore be placed at the beginning.

[7] **Ordinal Scale:** A scale that arranges objects or alternatives according to their magnitudes (Zikmund, 2000)

2. Mission and Objectives

This section asked respondents to indicate whether their CEDs had a documented vision and mission statement, strategic goals, management values and objectives; and to elaborate on them. The questions for each variable had a dichotomous section (**Yes/No**) and also allowed open-ended answers for elaboration.

3. Service Provided by CED

This section sought to determine which of the typical CED activities, as listed in section 2.2.2 of the literature review, were performed by the respective CEDs. A simple checklist was provided, allowing respondents to tick as many options as relevant. Respondents were then asked to rank (in order of importance) each of the services provided by their department; and to estimate the percentage time spent by personnel on each activity and the percentage of the allocated budget spent on that activity (Glouhova, 1999). Respondents were also asked to indicate what proportion of equipment management/maintenance was provided by other service providers (i.e. manufacturer, third-party).

4. Equipment Management

In this section respondents were asked to indicate whether their CED had a computerised equipment measurement system, and whether the CED had an up-to-date database or documentation containing information on service provided, in-house labour, equipment inventory, budget etc. A simple checklist was provided, allowing respondents to indicate which data elements they documented. This data, as suggested by Autio & Morris (1995), could be analysed and used in determining indicators, thus eliminating the need to collect new data.

5. Performance Factors

As indicated in section 2.6 of the literature review, an effective performance measurement system addresses all the factors of performance, including productivity, quality, resource utilisation and outcome. This section sought to determine whether any programmes were in place to evaluate these factors, and if they existed, what the programmes consisted of. Respondents were also asked to indicate whether the CEDs measured performance against customer expectations and competition, and conducted employee satisfaction surveys. Several waste factors (e.g. absenteeism, unused resources) were listed and respondents asked to indicate whether these were experienced by the CED. All questions were simple-dichotomy[8] types, requiring respondents to either indicate **Yes** or **No**.

6. Finances

Finances are often a major factor in determining the sustainability of Clinical Engineering Services, in any socio-political environment. Referring to life-cycle costs of equipment that are often ignored when purchasing medical equipment (Issakov, 1994), this section first asked respondents whether there was adequate budget allocated for all equipment-related costs, e.g. maintenance costs, transport and installation costs, training costs. Regarding the service provided, respondents were also asked if any formal cost-analysis methods existed and whether there was any documentation, e.g. of hourly labour rates, total fixed costs, etc. Availability of such data would allow computation of hourly labour costs and cost-volume-profit relationships as indicators of cost-effectiveness (Bronzino, 1992). The final sub-section on cost-effectiveness was adapted from AAMI (1990), who suggested that certain questions had to be asked in order to evaluate a clinical engineering programme. Once again respondents were asked to indicate **Yes** or **No** to all the questions asked.

[8] **Simple-dichotomy Question:** A fixed-alternative question requiring the respondent to choose one of two dichotomous alternatives (Zikmund, 2000)

7. Sustainability

Sustainability of Clinical Engineering Services is a major issue addressed by this study. This section sought to identify the main factors contributing to sustainability (or lack thereof). Respondents were asked if they saw their CES's surviving in the next 5, 10 or 15 years (WHO, 1999) and what institutional, organisational or environmental factors would support/threaten their existence. Respondents were also asked to elaborate on whether they saw their CES as being a 'core' function of their respective health care institution. The issue of whether CEDs are recognised and accepted has been addressed by previous studies (Frize, Glouhova, Bostrom et al). This question elaborated on this by asking whether the CEDs in question were specifically recognised and accepted by medical staff, hospital management/administration and other technical departments. Finally, a list of factors contributing to sustainability (WHO, 1999) of CEDs was provided and respondents asked to check as appropriate, and to elaborate on the answers given.

8. Quality Assurance

The need for Quality Assurance programmes has become evident in all professions. To this end AAMI (1990) provide guidelines for establishing a Quality Assurance programme specifically for Clinical Engineering. This section sought to establish whether CEDs had formal QA programmes and if present, what dimensions and principles it addressed. Checklists were provided, allowing respondents to check as many options as relevant. Finally the section asked whether the departments were accredited and/or ISO9000 certified and what steps they were taking towards continuous quality improvement.

9. General

This section focused on the management trends that have been affecting CEDs in recent years (e.g. accreditation, downsizing, benchmarking) and respondents were asked to indicate which of these trends had affected their departments. A checklist and space for elaboration was provided.

10. Performance, Cost-Effectiveness and Sustainability Measures

In an effort to identify indicators for Clinical Engineering Departments, respondents were asked to suggest measures that could be used to assess performance, cost-effectiveness and sustainability of CEDs. They were further asked to indicate which of these measures were in use by their departments.

11. Comments and Suggestions for the Questionnaire

Respondents were finally asked to comment or provide suggestions for improvement on the questionnaire.

3.6.4 Testing the Questionnaire

The final version of the questionnaire comprised eleven sections, each with an average of five sub-sections, i.e. there were about fifty questions in total. A short covering letter was included, explaining the purpose of the questionnaire and requesting completion and return of the questionnaire.

The questionnaire was administered to participants at the EHTP Experts workshop, held at WHO-HQ in Geneva (2000) and to students of the Postgraduate Diploma in Health Care Technology Management at UCT. The groups comprised HTM experts at Ministry of Health level, clinical engineers, medical physicists, biomedical engineering technicians (BMETs) and institutional management.

According to the sample design for the study, this consisted of all groups except for **clients** of Clinical Engineering Services, and they were thus representative of the population that were likely to respond to the final questionnaire(s).

A total of 9 responses were received. A detailed analysis was not performed (and could not due to limited responses). However, the returned questionnaires were checked for the following:

- Were all questions answered?
- Were all questions understood by respondents?
- Were all questions relevant to the respondent?
- Were all questions relevant to the study objectives?
- What comments did respondents provide?
- What type of analyses could be performed?
- Did the questionnaire provide any useful information?

3.6.5 Determining Applicability of the Questionnaire

Although very few of responses from the trial run were received, a number of valuable conclusions could be drawn. These were as follows:

1. The questionnaire was too long and time-consuming, requiring at least an hour for completion. This was evident by the substantial amount of question non-response and decreasing quality of answers towards the end of the questionnaire.

2. A significant number of questions were not relevant to all the respondents. This was also evident by the number of unanswered questions. Most of the questions were directed towards personnel within a Clinical Engineering Service, and thus respondents from the other sample categories could not identify with them. There was also comment from the National Department of Health (SA) that it was important to have a section specifically directed at policy- and decision- makers.

3. Many questions were ambiguous and thus not answered correctly i.e. the instrument was not **reliable**. Particular attention would have to be paid to wording of questions, as well as providing necessary instructions for answering specific questions.

4. The questionnaire was generally confusing and misunderstood by respondents. It was evident that a number of the respondents could not understand the significance of many of the questions, and therefore failed to provide well-considered answers.

5. Some questions expected too much of respondents. An example of this was Section 3.2, where respondents were asked to a) rank fourteen items b) estimate percentage time spent on each activity by personnel and c) estimate the percentage of the allocated budget spent on each activity. According to literature on survey design, ranked items should, as a general rule, be less than ten in number. This is because respondents are required to keep referring to the entire list in order to rank a single item against the other items. As a result some items were ranked with the same number – thus not providing useful comparisons. With respect to the estimated percentages, most respondents' answers did not total 100 percent – in some cases being far more. Once again, this data was not useful.

6. Although a glossary of definitions was provided, some of the terminology was not understood by all respondents. An example of this was the term 'Clinical Engineering Department'. As indicated in the literature review, units providing basic clinical engineering services differ between regions and institutions, and are variously known as Health Care Technical Services, Medical Physics Departments and Biomedical Engineering Services, to name a few. Particular attention would have to be paid to defining the terms used in the questionnaire, in order for it to be understood by the wide range of respondents targeted.

7. Asking respondents to come up with measures/indicators for clinical engineering performance and sustainability was an onerous task that would require a substantial amount of thought and knowledge about clinical engineering management.

8. The objectives of the questionnaire were not very clear and well-defined. In some cases it tried to **measure** performance of CEDs, based on literature about performance measurement, as opposed to collecting information necessary for **developing measures.**

9. The questionnaire did not provide an option for anonymity, thus intimidating respondents to give 'right' answers or to avoid threatening questions. Also, most questions asked for a simple **Yes** or **No**, allowing respondents to answer according to what they perceived to be the correct answer, thus creating a major source of response bias. This reduced the **validity** of the instrument.

10. Given the large number of dichotomous-type and simple checklist-type questions, the majority of data produced by the questionnaire would either be **nominal**[9] and **ordinal**[10]. The only analysis that could be performed on the instrument would be descriptive statistics – specifically: frequency in each category, percentage in each category and medians. Even if valid statistical analyses could be done on the questionnaire, the information provided was not entirely useful in developing measures for performance and sustainability of Clinical Engineering Departments.

In conclusion, it was found that much revision would be necessary before valid and reliable questionnaires were ready for administering. Careful consideration to wording of the questionnaire, instructions and layout would have to be given. Steps for this, derived from the available literature, are given in the next section. However, general comments from respondents and some expert consultation

[9] **Nominal data**: data values that do not stand for any quantity – numbers or letters assigned to objects serve as labels for identification or classification. (Alreck & Settle, 1995).

[10] **Ordinal data:** data values show relationship in terms of sequence, order or magnitude (Alreck & Settle, 1995). (See definition at foot of p66)

suggested that all the topics included in the preliminary questionnaire were pertinent and needed to be addressed.

Suggestions for improving the questionnaire, as described in literature on survey/questionnaire design, are provided in **Appendix F.** Phase 2 – the design of the final questionnaires – will be described in Chapter 4.

4 METHODOLOGY: PHASE 2

4.1 BACKGROUND TO THE METHODOLOGY: A LITERATURE REVIEW

As mentioned in Section 3.3, the literature review did not revealed any studies describing the development of performance and/or sustainability indicators for Clinical Engineering Services. To this end, studies describing the design of performance measures in other fields were investigated. These provided a backbone for developing a methodology aimed at designing performance and sustainability indicators specific to Clinical Engineering. An overview of these studies will be described in the following sub-sections.

4.1.1 Rapid Evaluation Method (REM) (Anker *et al*, 1993)

This method was developed by the WHO in order to assess the performance and quality of health services, identify operational problems and assist in taking managerial action. REM consists of observation- and survey-based diagnostic activities, carried out mainly in healthcare facilities, and aims at bringing prompt and relevant information to planners and decision-makers.

Characteristics of REM

Sound management of health services requires relevant and timely information on the health status of the population and on the performance of healthcare institutions and staff. The most common alternative for collecting information needed for management purposes is to conduct a survey. However, according to the authors, surveys - though usually indispensable - require careful preparatory work, are generally expensive, usually provide too much data and take a long time to process. The Rapid Evaluation Method thus presents a method that accurately, quickly and economically assembles information for analysis and decision-making.

Characteristics of REM include:

- REM is planned and executed with the active participation of health programme and service managers, staff trainers and supervisors, and staff.
- Information produced by REM examines the quantity, quality and client satisfaction of health services, and to a lesser extent, health status.
- The results of the REM are very rapidly available to the decision-makers – within days or weeks after the end of the REM field survey.
- The REM exercise is tailored for and necessarily followed by managerial decisions and actions ranging from improvements in training and supervision to new service strengthening projects, and overall health development plans.

The Methodology: The Issue-Information Matrix

The various steps of REM include: (i) setting objectives and using an issue-information matrix, (ii) preparation of survey instruments, (iii) use of computer software, (iv) data quality control, (v) fieldwork and (vi) the use of data to produce useful information for decision-makers. Only the first of these steps viz. the setting of objectives and use of an issue-information matrix will be described, as it can be applied directly to the present study.

Acquiring information in REM is based on a framework with three dimensions, described as follows:

1. The **first dimension** deals with issues reflecting specific health problems (or programme problems), rather than overall healthcare concerns. The levels of detail at which issues are defined depends on the objectives of each REM and on a consensus reached by the core group on the concerns of individual programmes.
2. The **second dimension** identifies information sources from community, health staff and healthcare facilities. These can be specified further into different categories of the source. Inspection of health facilities provides information on policy implementation and on the technical and managerial aspects of the programme, while observation of equipment and supplies is

used to determine whether these necessary components of healthcare are available and functional.

3. The **third dimension** of the matrix describes the methods used to obtain the information. An appropriate and practical approach to data collection, using relevant sampling techniques where necessary, is determined for each data item, e.g. interviews, focus group discussions or observation etc.

These three dimensions are arranged into a matrix, as shown in Figure 4.1.

Issues	Information Sources				
	Information source 1		Information source 2		Info source 3
	Category 1.1	Category 1.2	Category 2.1	Category 2.2	Category 3.1
Issue 1	DCM1, DCM2	DCM1	DCM2	DCM1	DCM2
Issue 2	DCM2	DCM1, DCM2	DCM1	DCM1	DCM2, DCM3
Issue 3	DCM1	DCM2, DCM3	DCM2, DCM3	DCM1	DCM1, DCM2
Issue 4	DCM2, DCM3	DCM1, DCM2	DCM2	DCM2	DCM2
Issue 5	DCM1, DCM3	DCM1, DCM3	DCM2	DCM1, DCM3	DCM2

where DCM = data collection method (e.g. observation, interview, focus group discussion ,etc.)

Figure 4.1: Issue-Information Matrix

4.1.2 A Management-By-Variance Tool (Hinks & McNay, 1999)

The pilot version of a Management-By-Variance Tool was created for performance assessment of the facilities management (FM) department of a major financial services company. This was driven by the absence of an acceptable set of standardised performance parameters or indicators for the FM function, and the need to clarify and prioritise the indicators that correlated the views of the customer and department in question.

Background

The key functions of a facilities/premises management department include: maintenance management, space management and accommodation standards; project management for new-build and alterations; premises management; administration of associated support services and in some cases, catering. The

department in question provided an in-house service for core facilities management services, while external contractors provided additional services not provided by the in-house team[1].

The principle of management-by-variance is based on the monitoring and analysis of performance trends, which is done by monitoring changes in performance using a bespoke[2] (rather than generalised) set of performance indicators. Key requirements for the study were:

- to overcome the known difficulties with FM performance measurement caused by the lack of generalised sets of data or industry-wide sets of Key Performance Indicators (KPIs).
- to produce a realistic measure of FM performance that correlated with customer expectations.
- to produce a measure that was applicable for the purposes of strategically managing the FM function.

The primary goal of the study was therefore to clarify and prioritise the parameters and indicators that correlated the views of both the customer and the facilities management department.

The Methodology

The methodology consisted of assembling and consulting an expert group comprising members of the facilities management department, as well as their internal customers, in equal numbers. The experts were consulted within a methodological procedure known as the Delphi technique (see section 3.3). This procedure is outlined as follows:

[1] A direct parallel can be drawn between this scenario and CE services offered within a healthcare institution, as described in the literature review.

[2] **Bespoke**: (*past* of BESPEAK) **1** made to order. **2** making goods to order. **3** suggested
BESPEAK: **1** engage in advance. **2** order (goods). **3** suggest; be evidence of (Oxford Dictionary, 1992).

1. **Definition of the research problem**

   Literature review and interviews with local experts (Delphi group) to clarify nature and priority of parameters that should be used for performance assessment.

2. **Selection of Key Performance Indicators (KPIs)**
   - Long list of potential indicators assembled from literature review and categorised according to predetermined parameters.
   - Delphi group asked to indicate whether each of the proposed KPIs was essential, desirable or of tertiary/limited importance.
   - Group members add to list if necessary.
   - All indicators identified as *desirable* or of *tertiary importance* discarded.
   - Shortlist of KPIs created by assembling *essential* indicators into ordered list based of frequency of votes.
3. **Prioritisation of KPIs**
   - Group members allocate grade between 0 to 10 to each short-listed KPI i.e. (0 = minimal relevance ....4 – 7 = important .... 10 = supremely important).
   - KPIs prioritised in order of average grade allocated by Delphi group.
4. **Rating of FM performance**
   - Delphi group rates current level of FM service against each KPI identified on a semantic scale (i.e. unsatisfactory, satisfactory, good, excellent, world class).
   - Results illustrated graphically according to different constituent groups and differences in perception between the groups noted.

The concept behind the management-by-variance tool is to provide an "at a glance" picture of performance in key areas chosen by an organisation, as well as highlighting differences in perceptions of performance between different stakeholders. Although the methodology outlined above describes a pilot study, the authors suggest that it can form a framework which, if applied correctly, could be used to monitor levels current of performance, assess operational and strategic priorities, assess trends in performance and may be extended to the definition or

refinement of strategic objectives, policies and plans, specific to facilities management.

4.1.3 The Performance Measure Record Sheet (Neely *et al*, 1997)

The design of performance measurement systems is a topic of increasing concern to both academics and practitioners in many fields, for a variety of reasons, including: to know where they are, to know how rapidly they are improving, to enable comparison with other businesses, and even to influence individual behaviour. However, according to the authors, the fundamental question: 'What does a well-designed performance measure constitute?' fails to be addressed. The design of a performance measure involves more than simply specifying a robust formula. The framework presented by the authors, i.e. the Performance Measure Record Sheet, addresses this issue.

Framework: The Performance Measure Record Sheet

The performance measure record sheet can be used to design and audit performance measures. The framework was based on the recommendations drawn from literature and then tested through a series of action research studies. This is described in detail in Chapter 2.9.4, stating the criteria for appropriate performance measures.

In theory, the performance measure record sheet should help industries design better performance measures by ensuring that they consider all of the subtle implications of the measures being proposed. Testing of this framework has suggested that it valuable because it not only facilitates the design of performance measures, but also encourages the designers to consider the behavioural implications of the measures in particular settings. It also provides a framework that can be used to explore what constitutes a well-designed performance measure.

4.2 THE FRAMEWORK FOR THE STUDY

Using the three studies outlined in the previous section as a guideline, as well as the literature review and various texts consulted on questionnaire design, a framework for Phase 2 of the study was developed. An overview of the framework is illustrated in Figure 4.2, and each section is expanded and described in detail in the following sections. The definition of the research problem and the objectives of the study and the questionnaire(s) have been described in Chapter 1 (sections 1.1 and 1.2) and Chapter 3 (sections 3.2 and 3.5).

4.3 THE ISSUE-INFORMATION MATRIX

One of the major conclusions drawn from the preliminary questionnaire was that many of the topics addressed and questions asked were not relevant to the different respondent categories chosen for the study. Another problem with the questionnaire was that although the topics presented were important, the use of checklists and simple **Yes/No** answer categories prevented respondents from providing any useful information – particularly their experiences or opinions on the issue.

The objectives of both the study, in general, and the questionnaires specifically, suggest the need for a more qualitative component to the instrument – as is the case with most exploratory research – in order to 'get a better feel for the research problem', i.e. diagnose the situation and discover new ideas. A careful balance of both open-ended (unstructured) and closed (structured) questions would have to used in the questionnaire(s).

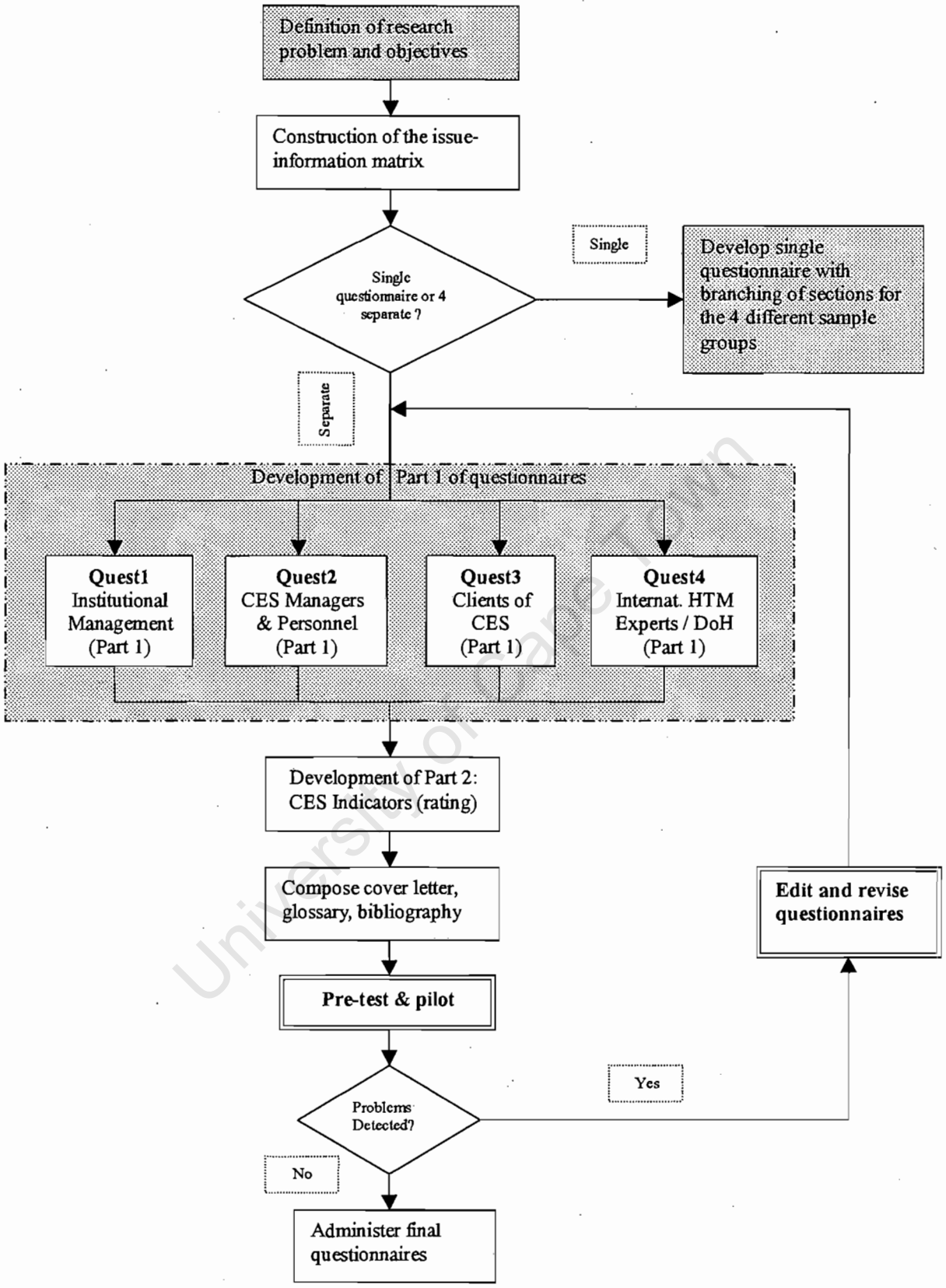


Figure 4.2: Overview of Phase Two of the Methodology

A systematic method would therefore have to be used, prior to constructing the questionnaire(s), to determine (a) which respondent groups are asked which questions and (b) how the individual questions or sections are structured. The issue-information matrix (as described in Section 4.1.1) – adapted for use in determining indicators for CES's – was therefore considered. The major reason for choosing this method was that the matrix allows for the three dimensions, namely: (i) issues to be addressed, (ii) information sources and (iii) methods of data collection, to be presented neatly and clearly in a single table.

The issue-information matrix developed for the study is presented in Table 4.1. Components of the three dimensions were identified as follows:

1. **Dimension One: Issues**

   The various issues to be addressed in the study were identified in the development of the preliminary questionnaire and described in Section 3.5. These were further refined following the findings and recommendations from the preliminary questionnaire.

2. **Dimension Two: Information Sources**

   The information sources are identified as the four respondent categories described in Section 3.4, namely: (i) institutional management, (ii) CES management and personnel, (iii) CES clients and (iv) representatives of national/provincial Ministries of Health and international HTM experts. Careful consideration was taken about the relevance of each issue to the different groups, i.e. would they be able to provide information on the issue?

3. **Dimension Three: Data Collection Method**

   Section 3.3 describes the rationale behind using self-administered questionnaires as the data collection method for the study. The issue-information matrix presented is adapted to indicate the **structure of questions** asked in each section of the questionnaire.

ISSUES	INFORMATION SOURCES			
	Institutional / Health Facility Management	Clinical Engineering Service Personnel	Clinical Engineering Service Clients	DoH Representatives / International HTM Experts
Demographic Data (type of institution, no. beds, no. devices, sector type, reports to?)	CL. QUEST	CL. QUEST	CL. QUEST	CL. QUEST
Mission/Strategy /Objectives	OP. QUEST	OP. QUEST		OP. QUEST
Services Provided by CES & Rating of Importance	CL. QUEST	CL. QUEST OP. QUEST	CL. QUEST	CL. QUEST
Outsourced CE Services (i.e. to manufacturers / third party service providers)	CL. QUEST	CL. QUEST		CL. QUEST
Business Benefit Issues • maintenance/litigation insurance • advantages/disadvantages of in-house CES	CL. QUEST OP. QUEST	CL. QUEST OP. QUEST		CL. QUEST OP. QUEST
Customer/Client Expectations & Perceptions	OP. QUEST SERVQUAL	OP.QUEST	OP. QUEST SERVQUAL	
Quality of Service Provided	OP. QUEST			OP. QUEST
Quality Assurance • Accreditation/Certification • Continuing education • Continuous quality improvement		CL. QUEST OP. QUEST		
Equipment/Asset Management (Database)		CL. QUEST		
CES Performance • current assessment • suggested indicators	OP. QUEST	CL. QUEST OP. QUEST		OP. QUEST
CES Cost-Effectiveness • AAMI recommendations • suggested indicators	OP. QUEST	CL. QUEST OP. QUEST		OP. QUEST
CES Sustainability • CES recognition & acceptance • factors supporting/threatening existence of CES • suggested indicators	OP. QUEST	OP. QUEST CL. QUEST		OP. QUEST
Business Management Trends Affecting CES		CL. QUEST		
Specific Factors impacting on CES performance/sustainability		CL. QUEST		
CES Indicators	CL. QUEST (rating)	CL. QUEST (rating)	CL. QUEST (rating)	CL. QUEST (rating)

Where:
CL. QUEST = Closed/structured questions
OP. QUEST = Open/unstructured questions
SERVQUAL = Service Quality Instrument (Zeithaml, Parasuraman, Berry 1990)

Table 4.1: Issue-Information Matrix

4.4 THE DEVELOPMENT OF THE QUESTIONNAIRES

4.4.1 A Single Questionnaire or Four Separate Questionnaires?

The issue-information matrix gave an indication of which of the issues, identified as important to the study, were relevant to each of the different respondent groups. A major decision had to be made at this point i.e. (i) whether to incorporate all the topics into a single questionnaire, with appropriate *branching*[3] to direct the different respondent groups to sections relevant to them; or (ii) whether to develop four separate questionnaires, specific to each target group.

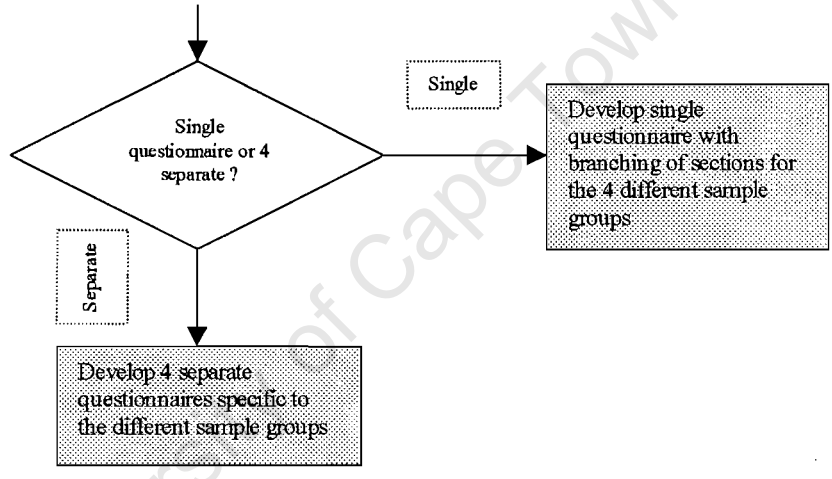


Figure 4.3: Decision – Single Questionnaire or Four Separate Questionnaires?

Initially, the first option was considered, with the same questionnaire being developed for all target groups, but incorporating different qualitative sections for the individual groups. While this seemed desirable because the same questionnaire would be sent to all respondents, the second option was eventually considered to the better of the two for the following reasons:

1. One of the findings from the preliminary questionnaire was that it was too long and time consuming. The various texts consulted on questionnaire design suggest that a questionnaire should be no more than six to twelve

[3] **Branching:** Directing the flow of questions according to specific criteria. Questions are typically directed using "If not / if so 'Go To' or 'Skip' " instructions. (Alreck & Settle, 1995)

pages. Given that the initial questionnaire was ten pages long, incorporating different qualitative sections for each of the respondent groups would significantly increase the questionnaire length, thus introducing respondent burden and intimidating prospective respondents.

2. The issue-information matrix suggests that a significant amount of branching would be required in a single questionnaire, with complex instructions to direct the flow of questions for the different groups. According to Alreck & Settle (1995), the use of branching should be strictly limited, as each branch adds to the complexity of the response task. Too many branches may introduce bias and error, thus reducing the validity and reliability of the results. The authors further add that if more than a few branches are required within the questionnaire, it is advisable to pre-qualify respondents and use *alternative forms* of the questionnaire for the different respondent groups.

It was therefore decided to develop four separate questionnaires, using the issue-information matrix as a guideline for the different sections in each.

4.4.2 Structure of the Questionnaires

As indicated in Figure 4.2, which illustrates an overview of the methodology, the questionnaires were split into two parts:

- **Part 1** of each questionnaire comprised mostly open-ended (unstructured) questions, aimed at gauging opinions about Clinical Engineering Services (either specific or general) from the individual groups. The topics that were addressed for each group are specified in the issue-information matrix. The specific questions asked were developed from the preliminary questionnaire and the literature review. Part 1 formed the qualitative section of the study.
- **Part 2** was structured, requiring respondents to rate a list of proposed indicators, as well as adding any additional indicators that they felt would be suitable. The list of indicators proposed was derived from the available

literature and current best practice. This part was identical for all respondent groups (i.e. in all four questionnaires) and formed the quantitative section of the study.

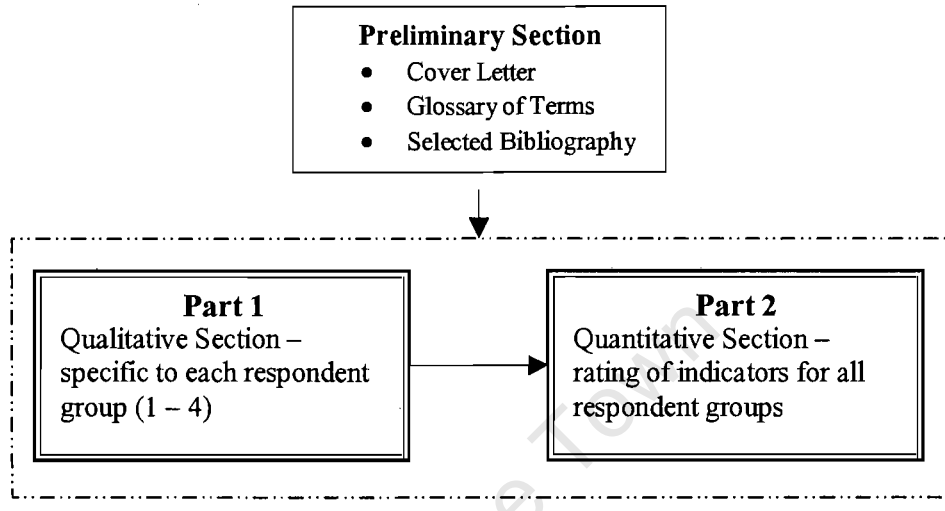


Figure 4.4: Structure of the Questionnaires

A preliminary section, comprising of the Cover Letter, Glossary of Terms and Selected Bibliography preceded each questionnaire. Each of these stages is described in the following sections of this chapter.

4.4.3 Pre-testing and Revising the Questionnaires

Figure 4.2 illustrates that the development of the questionnaires was cyclic, requiring repeated pre-tests and revisions until minimal problems and sources of error were detected. Numerous revisions were carried out during the development of the questionnaires. Formal pre-testing methods such as focus group discussions, 'think aloud' sessions[4] and expert panels[5] were not used for logistical reasons. However, during the preliminary and intermediate stages of the questionnaire development, several people were consulted for their opinions and input. These consisted of research methodology experts in other fields, for their

[4] **Think-Aloud session**: recruiting a group of respondents and asking them to think aloud as they answer each question. The technique is borrowed from cognitive psychology (Czaja & Blair, 1996)

[5] **Expert Panel :** A small group of specialists (both survey experts and subject-matter experts) brought together to critique a questionnaire (Czaja & Blair, 1996)

input on the **technical aspects** of the questionnaires; and clinical engineering/ HTM experts for their input on the **content** of the questionnaires.

In excess of ten revisions on each questionnaire were conducted prior to piloting them on prospective respondents. Issues addressed at each stage of the pre-testing are described in Appendix F, which provides suggestions for improving the questionnaire. Each questionnaire was therefore checked for instrumentation bias, including the following:

- Relevance of individual questions, i.e. whether they were directly related to the objectives of the study.
- Content of individual questions i.e. what information would it provide.
- Structure of individual questions (i.e. open-ended or closed).
- Wording of questions (e.g. ambiguity, use of double-barrel questions).
- Instructions provided – and subsequent wording of the instructions.
- Ease of comprehension.
- Order of sections and question sequence within the sections.
- Layout.

Following the feedback from each pre-test, each questionnaire was accordingly revised, and questions that could not be effectively revised were discarded.

4.4.4 'Piloting' the Questionnaires

In order to determine how respondents would receive and complete the questionnaires, each of the 'intermediate versions' of the different questionnaires were tested on potential respondents at Groote Schuur Hospital. These were (i) a member of institutional management (for **QUEST1**), (ii) management and personnel of the Clinical Engineering Department (for **QUEST2**) and (ii) a client of the Clinical Engineering Department (for **QUEST3**). The fourth questionnaire was not tested at this stage.

As with the preliminary questionnaire, each of the returned questionnaires was checked for response bias (described in Appendix F.5 and F.6) and for each question:

- Did the answers provided confirm that the question was directly related to the objectives of the study?
- Was the respondent able to **understand** it as it was intended?
- Was the respondent **able to answer** it?
- Was the question **relevant** to the respondent, i.e. were they able to provide valid information to the question?
- Was the respondent **willing** to answer it, i.e. did the question put the respondent into a compromising position?
- Could the responses given be analysed to provide useful information?

Although the number of questionnaires distributed at this stage would not constitute a valid 'pilot test' valuable information, which had been overlooked during the pre-testing, could be drawn from the responses in the trial run:

- **Part 1 of the Questionnaires**

1. All the questionnaires were too long, with some questions requiring a significant amount of thought and recall, therefore creating unnecessary respondent burden.
2. There were too few instructions, and those that were included were not clear enough.
3. There was a need to inform the respondents of the purpose and necessity of each section.
4. A number of questions were 'threatening' and therefore simply left unanswered.
5. There were a number of ambiguous, double-barrelled and loaded questions, i.e. more attention had to be paid to the wording of the questions.

6. Some questions, which had appeared to be well-constructed, were not fully understood by the respondents therefore requiring further revision and clarification.
7. A fair number of questions, which were included for the sake of comparing different CES's, were open to a significant amount of response bias – and therefore the validity of the responses was questionable.
8. The questionnaires tried to address a number of issues that were not central to the study objectives (including trying to measure performance); and trying to determine the gaps between client expectations and perceptions (SERVQUAL). These could be investigated as separate studies on specific CES's at a later stage.
9. As with the preliminary questionnaire, the responses provided indicated that some questions would either be difficult to analyse, or would not provide relevant information.

- **Part 2 of the Questionnaires**

The initial list of proposed indicators consisted of 110 items, and respondents were required to rate the importance of each, plus add any further indicators they deemed necessary. Although all the respondents rated each and every indicator, the list was far too long and intimidating. This was evident by the fact that indicators towards the end of the section were all rated in the upper extreme scale, suggesting that they were not being critically considered and therefore reducing the validity of the responses.

With the above information, the questionnaires were further revised and edited to remove all extraneous questions. The following sections describe the final questionnaires in detail.

4.5 DEVELOPMENT OF PART 1 OF QUESTIONNAIRES 1 – 4

As shown in Figure 4.2, the four questionnaires were differentiated according to the specified target groups, namely:

1. **QUEST1:** Institutional Management (including Nursing Management)
2. **QUEST2:** Clinical Engineering Service Managers and Personnel
3. **QUEST3:** Clinical Engineering Service Clients
4. **QUEST4:** Ministries of Health / International HTM Experts

A similar approach to that used in developing the preliminary questionnaire was taken in the development of Part 1 of the four questionnaires. Figure 4.5 shows the process taken for each questionnaire.

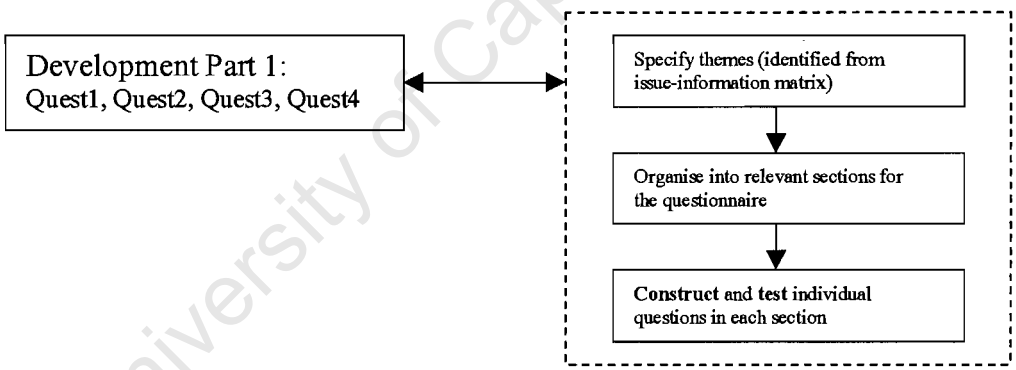


Figure 4.5: Development of Part 1 of the Questionnaires

4.5.1 Themes and Organisation of the Questionnaires

The themes addressed in each questionnaire were identified from the issue-information matrix and organised into comprehensive sections. As with the preliminary questionnaire, a funnel approach was used in arranging the (i) the sections throughout the questionnaires and (ii) the questions within the sections. Once again the demographic section was placed at the beginning of the questionnaire as it asked simple, closed-ended and general questions about the

institution supporting the CES in question. Questions pertaining to performance and sustainability of the CES were placed at the end of Part 1, as they were more specific to the research question. It was assumed that respondents were more likely be able to answer these questions, since a rapport had been established around the issue of Clinical Engineering Services through the general questions asked.

4.5.2 Language and Layout of the Questionnaires

Formal language was used and a Glossary of Terms was provided for all words or terms that were open to misinterpretation or misunderstanding. This was deemed necessary because, as indicated in the literature review, different regions use different terminology to describe functions or services provided by Clinical Engineering Services.

Particular attention was paid to the ergonomic design, i.e. the formatting and layout of the questionnaires in an effort to make them neat, attractive and easy to follow. This was particularly important, given the length of the questionnaires and the complexity of some of the questions. According to Alreck & Settle (1995) the format and layout of a questionnaire affect the response rate and bias, i.e. the likelihood that a respondent will complete the questionnaire with minimal error.

Each section was organised into a table to ensure that the progression from section to section was clear, and also for neat and consistent alignment of text and answer fields. General instructions for each section were printed in boldface and bulleted at the beginning of the section and instructions for individual questions were printed in a smaller typeface to differentiate them from the actual question.

4.6 QUEST1: INSTITUTIONAL MANAGEMENT

The following section describes **QUEST1** (see **Appendix C1**) which was targeted at institutional or health facility management. This included nursing management, as they were more likely to have contact with the Clinical Engineering Service at the institution. The input of this target group was considered to be crucial to the study because as the major decision-makers at a healthcare institution, they have a great impact on the **sustainability** of in-house Clinical Engineering Services.

4.6.1 Specifying Themes for the Questionnaire

As indicated previously, the themes for each questionnaire were identified in the issue-information matrix. The specific themes for **QUEST1** were:

- Demographic (background) information
- Mission, strategy and objectives of the CES
- Services provided by CES and rating of importance
- Services outsourced to alternative service providers (i.e. equipment suppliers or third-party service providers)
- Business benefit issues, i.e. advantages and disadvantages of the in-house CES
- Institutional management expectations and perceptions
- Quality of service provided by CES
- Performance of CES
- Sustainability of CES

Some themes (e.g. *cost-effectiveness of CES's)* were not included in the questionnaire, i.e. were discarded after the 'pilot' test, for various reasons including: (i) they were found not to be directly relevant to the study, (ii) they did not provide useful information, (iii) they would be difficult to analyse. These themes were incorporated into the list of proposed indicators.

4.6.2 Organisation of the Questionnaire

The questionnaire was subsequently divided into sections, namely:

1. Demographic data
2. Mission and strategy of CES
3. Service provided by CES
4. Assessment of service provided by CES
5. CES performance and sustainability

4.6.3 Constructing Questions for Quest1

1. Demographic Data

As with the preliminary questionnaire, this section focused on general information about the respondent's institution and the Clinical Engineering Service supporting it. The questions were adapted from surveys conducted by Frize (1990) and Glouhova (1999).

Sub-section 1.1

This sub-section asked respondents for their names and contact details, for the sake of record-keeping and in the event that they would require a copy of the results of the research. There was the option to remain anonymous and the contact details were optional. However, for the purposes of analysing respondent-type and region-specific differences (or similarities) data, as indicated in the objectives of the study, all respondents were required to indicate their **position/job description** and their **country**.

Sub-section 1.2

In this sub-section respondents were required to indicate their health facility type, number of beds supported by the health facility and whether the health facility was a public or private sector institution. All questions were structured, requiring the respondents to select one option from alternatives

provided. The residual 'Other' option was provided in the event that all options had not been covered by the question.

These questions provide ordinal data.

Sub-section 1.3

In an effort to determine some general information about the Clinical Engineering Service in question, respondents were asked to indicate whether the institution was supported by an *in-house* or external CES, whether it exists as a separate unit or part of another department and to stipulate the reporting authority. The questions were partly structured, offering alternatives to choose from, but also required respondents to provide information. These questions would provide nominal data.

Once again this question sought to determine and compare differences in CES organisational structure and terminology, from region-to-region, institution-to-institution and between the public and private sectors, respectively. This would facilitate investigating some of the observations made in the literature review.

2. Mission and Strategy of Clinical Engineering Service

As indicated in the literature review, the starting point towards achieving superior performance in any organisation is the establishment of a **statement of purpose or mission statement** (Christopher & Thor, 1993; Bronzino, 1992). Various authors subsequently stipulate that an effective measurement system must be integrated with institutional or departmental mission and strategy (Brinkerhoff & Dressler, 1990; Chang & Morgan, 2000, Neely et al, 1997). Section 2 therefore sought to establish general trends in mission statements and basic strategies of clinical engineering services. These would be used to determine the relevance of the key indicators identified from Part 2 of the questionnaires.

In this predominantly qualitative (unstructured) section, institutional management was asked to indicate whether they were aware of the mission statement and strategy, respectively, of the CES supporting their institution. Respondents were then asked to state what, in their opinion, would be an appropriate mission statement, and appropriate elements/objectives in the strategy or business plan. The last question asked whether the strategy (if it existed) of the CES supported the overall strategic plan of the institution – a factor vital to the sustainability of the Clinical Engineering Services (Bronzino, 1992).

3. Service Provided by Clinical Engineering Service

The second objective of the study, as stated in the research proposal, was to compare the functions and services of provided by Clinical Engineering Services selected for the study. Findings from the literature review showed that an effective measurement system must be aligned to the major functions and business processes of the unit, department or organisation. This section therefore focused on the services provided by the CES and the importance of the services to the healthcare institution.

Testing of the preliminary questionnaire had shown that the initial approach described in Chapter 3.6.3 was an incredibly difficult task, which exerted significant respondent burden. After a number of revisions, it was decided to use only closed-ended questions.

Sub-section 3.1

a. This question sought to determine which of the typical CES activities, identified from the literature review and current practice, were performed by the CES in question. A multiple-response checklist with twenty-one items was provided, allowing the respondents to check as many options as relevant. Respondents were also given the opportunity to add any other services not covered by the checklist. This question would yield discrete,

nominal data, allowing trends or profiles to be determined by the use of descriptive statistics (frequency or percentage in each category).

b. The preliminary questionnaire had asked respondents to **rank** services according to their perceived importance. Not only was this a difficult task for the respondents, but it was also difficult to analyse. Also, respondents could only rank the services that were provided by their institution. This question sought to determine trends in the perceived importance of **all** services offered by clinical engineering services in general. A **rating scale**[6] and specifically the **linear numeric scale**[7] was therefore considered to be a suitable option. According to Alreck & Settle (1995), the linear numeric scale is most appropriate when items are to be judged on a single dimension and arrayed on a scale with equal intervals. This scale provides both absolute measures of importance as well as relative measures, or rankings, if responses among the various items are compared, i.e. it can produce both ordinal and **interval**[8] data and is versatile in terms of the analyses that can be performed. In this question respondents were asked to rate all of the possible CES services, according to their perceived importance to the institution, by selecting a number from the scale.

The Scale

Initially a simple five-point scale of importance was used, as shown in Table 4.2.

SCALE				
1 Extremely Unimportant	2 Unimportant	3 Neutral	4 Important	5 Extremely Important

Table 4.2: Initial Rating Scale for Section 3.1

[6] **Rating**: a measurement task that requires the respondent to estimate the magnitude of a characteristic or quality that an object possesses (Zikmund, 2000)

[7] **Numerical scale:** a rating scale on which the categories or points are numerals, at equal intervals to each other. Three-, five-, or seven-point bipolar rating options are provided on the scale.

[8] **Interval scale:** A scale that not only arranges objects according to their magnitudes but also distinguishes this ordered arrangement in units of equal intervals (Zikmund, 2000)

However, pre-testing showed that typical respondents were not able to clearly differentiate between, 'Important' and 'Extremely Important' and likewise for the lower end of the scale. This would lead to significant response bias (as indicated in Appendix F), as respondents would be likely to opt for the extremes due to confusion, thus not producing valid and reliable data (Alreck & Settle).

As the scale incorporated both the numbers (weighting) and adjectives assigned to each rating, it was decided to change the wording of the adjectives to suit the target population. As indicated in Table 4.3, the term 'Extremely Important' was replaced with '**Essential**' – a term very often used in the healthcare environment, signifying an indispensable or absolutely necessary item, process or phenomenon. In this question an 'essential activity' referred to a service that was critical to the performance and survival of the CES or the health facility. Similarly, the term 'Extremely Unimportant' replaced with 'Irrelevant', i.e. a service that bore absolutely no relevance to CES and the institution it supported.

SCALE				
1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

Table 4.3: Final Rating Scale for Section 3.1

It should be noted that the final rating scale could be seen as attempting to measure more than one attribute, i.e. importance and relevance, and therefore the validity and reliability of the data produced could be questioned. While psychometric validation of the scale is beyond the scope of this study, careful analysis of the data returned for this question would have to be conducted in assessing the effectiveness of the questionnaire.

Sub-section 3.2

The literature review indicated that the sustainability of in-house Clinical Engineering Services is ultimately dependent on the cost-effectiveness (or cost-benefit) of that CES compared to external service suppliers. Outsourcing is a trend that has been affecting numerous CES' globally, for various reasons. This sub-section aimed at determining outsourcing trends with respect to common clinical engineering activities.

Respondents were asked to indicate whether the activities listed were outsourced to equipment suppliers or third party service providers (e.g. commercial firm or shared service). The intermediate version of the questionnaire had reproduced the twenty-one-item list generated in Section 3.2. However the trial run (pilot test) revealed that this was an onerous task for respondents – especially since in most cases they would only be aware of the status of the basic clinical engineering services, viz. training equipment users, acceptance training, inspection and preventive maintenance (IPM) and corrective maintenance. The list was therefore pruned to include only these tasks, with space for respondents to include any other services they deemed important.

Sub-section 3.3

In an effort to gauge institutional management's perceptions of the importance of in-house Clinical Engineering Services in general, respondents were asked to indicate the advantages and disadvantages of an in-house clinical service as opposed to outsourcing equipment management and maintenance-related services.

The question was left open-ended, allowing respondents to give their opinions without leading them in any direction, allowing for general trends to be determined.

4. Assessment of Service Provided by Clinical Engineering Service

Section 4 of the questionnaire was entirely qualitative, focusing on the institutional management's assessment of the service provided by the CES.

As indicated previously, Bronzino (1992) states that CES mission and strategy must be conform to those of the entire institution. The literature review revealed that customer or client needs and expectations are integral to performance measurement. According to Chang and Morgan (2000), without the customer, there is no business. In particular, gauging the expectations and perceptions of institutional management would assist Clinical Engineering Services in obtaining a sustainable competitive advantage.

Sub-section 4.1: Institutional Expectations of the CES

In an effort to determine trends in institutional management expectations, respondents were first asked to list, in order of preference, what they expected from a CES. The second question requested respondents to list what, in their opinions, were major factors contributing to their expectations **not** being met. A subsequent question asked for opinions on the impact the CES has on (a) clinical procedures specifically and (b) healthcare service delivery generally, in their institution.

Sub-section 4.2: Quality of Service Provided

It is important for CES's to pay attention to service quality, as perceived by their clients or reporting authority.

The section first asked institutional management to state what they understood by the term 'Quality of Service' with respect to a CES, and to indicate whether the quality of *other* services within their institution was assessed.

The data received from these questions would assist in determining whether the key indicators derived from the study are aligned with general trends in perceptions of CES service quality.

All questions in this section were open-ended and most were adapted from a study conducted by De Villiers (1998) in his investigation into perceptions of consulting engineering service quality.

5. CES Performance and Sustainability

The final section of **QUEST1** focused specifically on institutional management's opinions on the performance and sustainability of the CES supporting their institution – a major objective of the study. Once again this section was predominantly qualitative, posing open-ended questions to determine general and opinions.

Sub-section 5.1: Performance

In order to gauge general trends in performance measurement at an institutional level of a healthcare facility, the first question asked respondents to indicate how performance was assessed at their institution, if at all. Respondents were subsequently requested to suggest five important indicators of performance. This question was placed before Part 2 (which asked respondents to rate a list of proposed indicators) in order to obtain unbiased opinions on performance indicators. If not already addressed, the suggested indicators could be incorporated into the key indicator list if stated frequently enough. Also, Autio & Morris (1995) state the importance of using existing data or measures, thereby eliminating the extra costs and efforts of implementing an entirely new measurement system.

Sub-section 5.2: Sustainability

Sustainability of Clinical Engineering Services is a major issue addressed by this study. As in the preliminary questionnaire, this section sought to identify the main factors contributing to sustainability (or lack thereof). Respondents were asked to elaborate on whether they saw their CES as being a 'core' function of their respective health care institution – a major factor contributing to the closure of many CES's internationally. Respondents were subsequently

asked if they saw their CES surviving in the next 5, 10 or 15 years (WHO, 1999) and what institutional, organisational or (socio-political) environmental factors would support or threaten its existence.

This concluded Part 1 of QUEST2 and respondents were requested to proceed to Part 2 of the questionnaire.

4.7 QUEST2: CES MANAGEMENT & PERSONNEL

QUEST2, found in **Appendix C2,** was targeted at the management and personnel of Clinical Engineering Services. This was obviously the primary target group, as they would be able to provide the most information – and would also have the most to benefit from the study. The following section describes this questionnaire in detail.

4.7.1 Specifying Themes for the Questionnaire

Themes for the questionnaire were identified in the issue-information matrix. These were, specifically:

- Demographic (background) information
- Mission, strategy and objectives of CES
- Services provided by the CES and rating of importance
- Services outsourced to alternative service providers (i.e. equipment suppliers or third-party service providers)
- Business benefit issues (advantages and disadvantages of the in-house CES)
- Customer/client expectations
- Quality Assurance
- Performance of CES
- Sustainability of CES
- Business management trends affecting CES'

- Specific factors impacting on CES performance and sustainability.

Asset management and cost-effectiveness issues were later incorporated into the indicator-rating list.

4.7.2 Organisation of the Questionnaire

The final questionnaire was organised into the following sections:

1. Demographic data
2. Mission and strategy of CES
3. Service provided by the CES
4. Performance of CES
5. Sustainability of CES
6. Trends affecting CES
7. CES performance and sustainability factors

4.7.3 Constructing Questions for QUEST2

1. Demographic Data

Section 1 of QUEST2 was essentially the same as the one described for QUEST1 and will not be repeated. Specific differences were found in **Sub-section 1.3**, which asked (a) for the number of devices supported by the CES– a single-response multiple-choice question (Frize, 1990); (b) for the scope of service covered by the CES in terms of range of equipment supported and (c) for the scope of service in terms of service provided to other institutions. The latter two questions were left open-ended and all questions were asked to supplement previous questions for the purposes of comparison.

2. Mission and Strategy of Clinical Engineering Service

Section 2 was almost identical to that in QUEST1, asking respondents to indicate whether the CES had a documented mission statement and strategy; and to state their opinions on an appropriate mission statement and objectives in a strategic plan.

3. Service Provided by Clinical Engineering Service

Sub-section 3.1 and 3.2 in this questionnaire were exactly the same as those described previously for QUEST1.

Sub-section 3.3

This sub-section asked some general questions about the service provided by the CES in question. In order to determine trends in regulation of CES activities, respondents were asked to indicate whether there were any formal procedures and guidelines for each activity. A simple **Yes/No/I don't know** was required, yielding nominal data. Further open-ended questions asked (i) who the *clients* of their service were and (ii) if respondents were aware of the client's expectations. Finally, respondents were asked to indicate if there would be any advantages in outsourcing any of the CES services. These qualitative questions were asked in order to assess differences (or similarities) between opinions of CES personnel, their clients and institutional management.

4. Performance of Clinical Engineering Service

Section 4 focused on CES personnel's assessment of the performance of their CES and was entirely qualitative.

Observations from the literature review indicated that r Clinical Engineering Services are often not seen to be a 'core' function of healthcare institutions and therefore are often the first in line to be served with budget reductions,

downsizing and rationalisation. In an effort to collate opinions in justifying the existence of CES', respondents were asked to indicate what impact they felt their CES had on the performance of the healthcare delivery institution/system they supported. A subsequent question asked to what extent they believed their service was supported (or hindered) by external service providers. Answers to this question could be compared to institutional management's views on outsourcing equipment maintenance and management-related services.

Finally, as in QUEST1, respondents were asked how CES performance was assessed at that time, and what, if any indicators were used to assess performance. Once again, these indicators could be compared to or incorporated into the indicators identified from Part 2.

5. Sustainability of Clinical Engineering Service

This section focused on the respondent's opinions on the sustainability of their CES. **Sub-sections 5.1 and 5.2** were identical to those in the institutional management questionnaire. An additional sub-section was however included.

Sub-section 5.3

The WHO (1999) states that sustainability of **health systems** is affected by inappropriate physical infrastructure and technology. They subsequently propose that certain key factors – and their associated indicators – ensure the sustainability of health systems. This sub-section sought to determine which of these factors impact on the sustainability of Clinical Engineering Services specifically. A multiple response checklist was provided - with the option of adding extra factors – which would yield nominal data on analysis. In order to assess the **extent** to which the factors chosen impact on sustainability, a 5-point rating scale was also provided, as shown in Table 4.4.

SCALE				
1 Irrelevant	2 Insignificant	3 Neutral	4 Significant	5 Highly Significant

Table 4.4: Rating of Significance of Impact of Factors on CES Sustainability

As with the rating scale for section 3.1, the use of 'Irrelevant' on the lower extreme is open to criticism. Also, the mid-point scale 'Neutral' could give respondents an 'easy way out', introducing bias into the data received. This would be investigated when analysing the questionnaire.

Finally, respondents were asked to suggest five important indicators of sustainability to be compared with those derived from Part 2.

6. Trends Affecting Clinical Engineering Services

The literature review identified business/management trends that have affected CES's in recent years. This section aimed at qualifying these observations with evidence from a large spectrum of CES personnel.

The first question provided respondents with a multiple-response checklist to indicate which of the trends had been experienced by their CES, with the option of adding further trends. Respondents were then asked to expand on their experience of the trends, if at all. Simple frequency tables/graphs, compared from region-to-region, sector-to-sector and institution types could be derived, indicating general patterns.

7. CES Performance/Sustainability Factors

The final section in Part 1 of QUEST1 focused on specific factors that could have some impact on the performance and sustainability of the CES.

The list of factors was derived from the initial long list of proposed indicators shown in Appendix B, and were later discarded from the indicator list for

reasons described in Part 2. Although not considered to be valid indicators, it was believed that these factors had a significant role to play in CES performance and sustainability.

This section was completely structured. Respondents were firstly asked to indicate whether the factor was applicable at the institution, and subsequently whether the factor had a significant impact on the performance/sustainability of their CES. All questions were simple-dichotomy types, requiring respondents to indicate either **Yes** or **No.** The data provided would be ordinal allowing for percentile ranking operations to be performed.

This concluded Part 1 of QUEST2 and respondents were requested to proceed to Part 2 of the questionnaire.

4.8 QUEST3: CLINICAL ENGINEERING SERVICE CLIENTS

QUEST3, found in **Appendix C3,** was targeted at clients or customers of Clinical Engineering Services. These were defined as users or beneficiaries of CES's and included doctors, nurses and allied health professionals. Ultimately, the client defines the reason for any business and therefore, as mentioned previously, client expectations and perceptions are integral to effective performance and quality measurement.

4.8.1 Specifying Themes for the Questionnaire

The themes for QUEST3 were identified in the issue-information matrix and included:

- Demographic (background) data
- Services provided by the CES and rating of importance
- Client/customer expectations and perceptions

4.8.2 Organisation of the Questionnaire

The questionnaire was organised into the following sections:

1. Demographic data
2. Assessment of clinical engineering service
3. Expectations and perceptions of CES service quality *(which was initially included in QUEST3)*

4.8.3 Constructing Questions for QUEST3

1. Demographic Data

Section 1 of QUEST3 addressed the same issues brought up in the institutional management questionnaire (see section 4.6.1), QUEST1 and will therefore not be repeated.

2. Assessment of Clinical Engineering Service

In essence, QUEST3 was a shorter, adapted version of QUEST1. Questions on CES mission and strategy were deemed inappropriate for clients, as they would most probably not have the information or knowledge to answer them.

Sub-section 2.1 of the questionnaire was identical to sub-section 3.1 in the previous questionnaires, and is described in detail in section 4.6.3 of this chapter.

Sub-section 2.2

This sub-section was completely qualitative, asking only open-ended questions to gauge general opinions of CES clients.

In an effort to determine trends in CES client expectations, respondents were first asked to list, in order of preference, what they expected from a CES. The

second question requested respondents to list what, in their opinions, were major factors contributing to their expectations **not** being met.

A question not asked of institutional management, but included here was how respondents believed the service offered by the CES influenced their own abilities to carry out their jobs in (a) performing clinical procedures, specifically or (b) providing healthcare services in general. Respondents were subsequently asked their opinion on the implications of **not** having an in-house service. The purpose of these questions was to determine CES client's perceptions of the importance of Clinical Engineering Services.

This concluded Part 1 of QUEST3 and respondents were asked to proceed to Part 2 of the questionnaire.

3. Expectations and Perceptions of CES Service Quality

An additional section, which was initially included in the intermediate version of the questionnaire, made use of a widely utilised instrument, **SERVQUAL**, developed by Zeithaml, Parasuraman and Berry (1990). This method of determining gaps between customer expectations and perceptions is described in the literature review.

This section, which consisted of 23 paired questions regarding the five dimensions of service quality as defined by the authors, was discarded after the 'pilot' run. Reasons for this were (i) it was too laborious for the respondent - given the length and complexity of the rest of the questionnaire; (ii) it was not central to the research objectives and (iii) it would constitute an entire study of its own. It is however recommended to conduct a study investigating the applicability of SERVQUAL to Clinical Engineering Services.

4.9 QUEST4: MINISTRIES OF HEALTH / INTERNATIONAL HTM EXPERTS

The fourth and final questionnaire, found in **Appendix C4,** was targeted at representatives of regional/provincial/national Government Departments of Health and international experts in Healthcare Technology Management. The latter included representatives of multilateral organisations and bilateral agencies, as well as technical consultants. The input of this group was considered to be vital because they are closely associated with the major policy- and decision-makers at national and international level. In fact, a significant number of the indicators proposed in the study were sourced from recommendations made by such groups.

4.9.1 Specifying Themes for the Questionnaire

The themes for this questionnaire, as identified in the issue-information matrix, were as follows:

- Demographic (background) information
- Mission, strategy and objectives of CES
- Services provided by the CES and rating of importance
- Services outsourced to alternative service providers (i.e. manufacturers or third-party service providers)
- Business benefit issues (advantages and disadvantages of the in-house CES)
- Quality of service provided by CES
- Performance of CES
- Sustainability of CES

4.9.2 Organisation of the Questionnaire

The questionnaire was organised into the following sections:

1. Demographic data

2. Mission and strategy of CES
3. Services provided by CES
4. Assessment of service provided by CES
5. CES performance and sustainability

4.9.3 Constructing Questions for QUEST4

QUEST4 was basically an adaptation of the questionnaire targeted at institutional management i.e. QUEST1 (see section 4.6.1). The rationale for all the questions have been described previously, so the following section will only address questions briefly.

1. Demographic Data

Sub-section 1.1 was identical to that in the other three questionnaires, i.e. requesting contact details.

Sub-section 1.2 asked respondents whether they were familiar with a Clinical Engineering Service. The question was a simple-dichotomy type, incorporating a conditional branch[9]. Respondents who checked **Yes** were asked to go to Section 2 and respondents who checked **No** were asked to proceed to Section 3.

2. Mission and Strategy of Clinical Engineering Services

For respondents who were familiar with a CES, they were firstly asked questions pertaining to organisational structure, as found in sub-section 3.3 of QUEST1. They were subsequently asked the questions on mission statement and strategy, as described previously.

[9] **Conditional branch:** instructions or "go-to" statements in a questionnaire indicating that the respondent should skip items that do not apply, based on answers to previous questions.

3. Services Provided by Clinical Engineering Service

In this section, the question on service provided by CES asked in all the previous questionnaires was posed. The difference lay in the fact that respondents were only asked to rate the services listed, according to the scale described previously. Given that this group was not necessarily attached to any particular CES, they were not asked to indicate the services provided.

Respondents were subsequently asked their opinion on which of the services listed could/should be outsourced, and then for their opinions on the advantages and disadvantages of in-house Clinical Engineering Services.

4. Assessment of Service Provided by CES

Section 4 was qualitative, as for QUEST1. The target group was asked for their opinions on (a) the impact of CES's on clinical procedures and healthcare service delivery; (b) the implications of outsourcing all equipment maintenance and management functions; and (c) their understanding of the term 'Quality of Service' with respect to a CES.

5. CES Performance and Sustainability

This section focused on the respondent's assessment of performance and sustainability of Clinical Engineering Services.

Sub-section 5.1 asked for suggestions for CES performance indicators, for reasons described earlier.

Sub-section 5.2 focused on sustainability, asking (i) whether the CES service is a 'core' healthcare function, (ii) whether the respondent saw CES's in general surviving in the next 5, 10 or 15 years, and (iii) their perceptions of the institutional, organisational and (socio-political) environmental factors supporting and hindering existence of Clinical Engineering Services.

At this point respondents were asked to proceed to Part 2 of the questionnaire.

4.10 DEVELOPMENT OF PART 2: CES INDICATORS

The main objective of the study was to develop and test a set of comprehensive **key indicators** to describe performance of Clinical Engineering Services, which could then be used in assessing their sustainability. The critical indicators identified should facilitate standardisation of Clinical Engineering Services as well as allowing comparisons of performance, cost-effectiveness and sustainability to be made between CES's in differing environments.

4.10.1 Overview of the Development of Part 2

The development of the final indicator list incorporated into the questionnaire was long and fairly complicated, drawing on the methodologies described at the beginning of Chapter 4, viz. the Management-by-Variance Tool (Hinks and McNay, 1999) and the Performance Measure Record Sheet (Neely *et al*, 1997).

Figure 4.6 illustrates the procedure for the development of the final indicator list. As indicated, the development took place in four stages, namely:

Stage 1: Collection of indicator literature
Stage 2: Questionnaire design of Part 2: intermediate version
Stage 3: Short-listing of indicator list
Stage 4: Final questionnaire design: Part 2

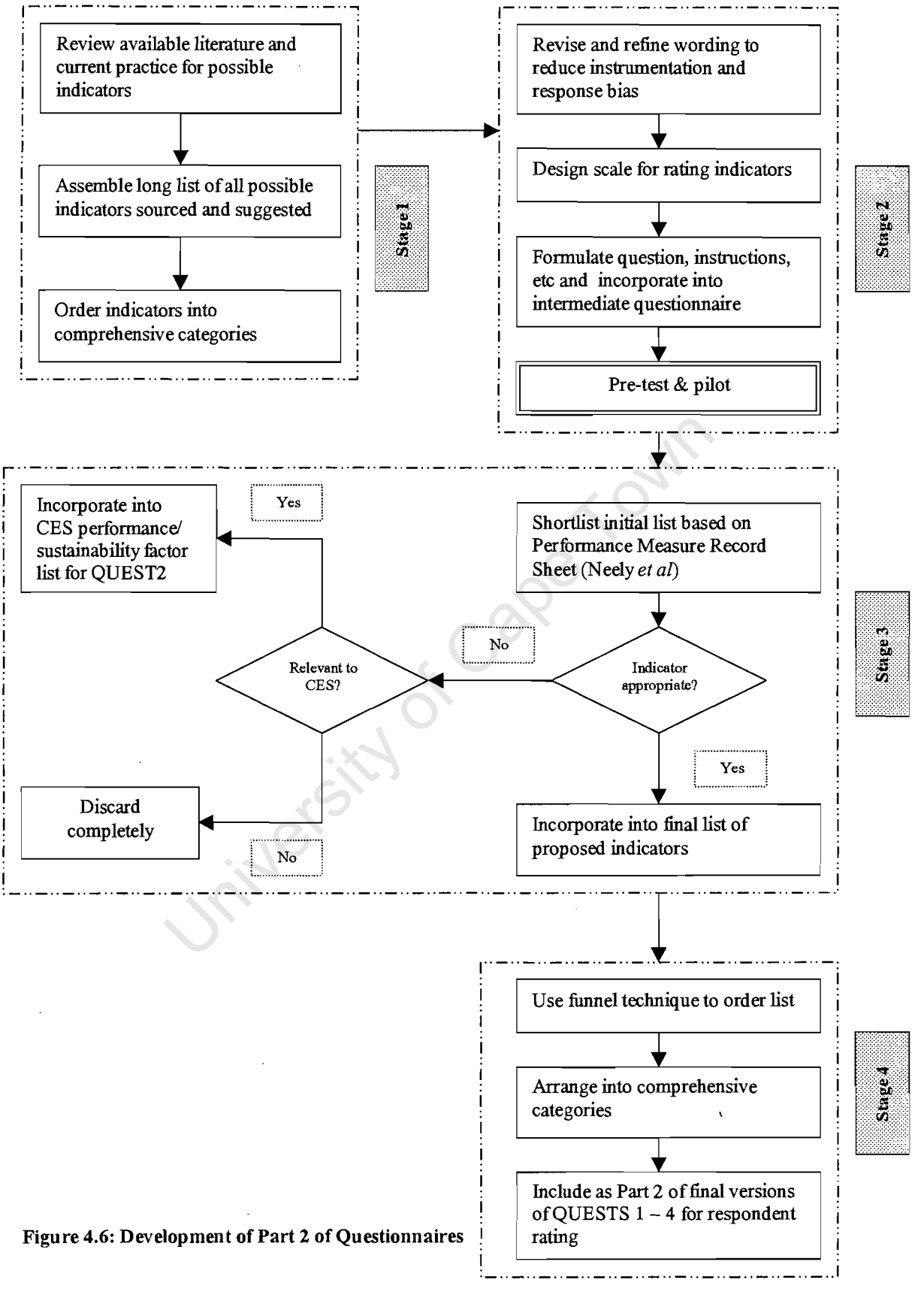


Figure 4.6: Development of Part 2 of Questionnaires

4.10.2 Details of the Development Process

The following section will now describe the different stages briefly.

1. Stage 1: Collection of Indicator Data

The management-by-variance tool suggests that a long list of all possible indicators be prepared and then categorised according to pre-determined parameters. A list of indicators from the available literature and current practice was therefore assembled and then ordered into comprehensive categories according to factors being investigated, namely:

1. Performance
2. General activities performed by CES
3. Inspection and preventive maintenance procedures (IPMs)
4. Corrective maintenance procedures
5. Test equipment available
6. Spare parts
7. Risk-management / safety
8. User-related equipment malfunction
9. Documentation
10. Information systems
11. Technical competence (of CES staff)
12. Patient care
13. Customer service
14. Cost-effectiveness
15. General.

2. Stage 2: Questionnaire Design of Part 2: Intermediate Version

In the second stage, each indicator was checked for wording and general questionnaire considerations, in order to avoid any misunderstandings of terms – given the large range of potential respondents. This was done to

minimise instrumentation and response bias. The initial long list of indicators assembled can be found in **Appendix B.**

The next stage was the construction of an appropriate scale to be used in rating the proposed indicators, in an effort to derive a shortlist of generally important indicators. The same scale used for the rating of CES activities in Part 1 was considered. However, because of the large range of respondents targeted, an "I don't know" response was added. This was considered to be necessary since institutional management and CES clients were likely not to be able to determine the relevance of some of the more specific indicators.

The final scale is illustrated in Table 4.5. The same reasons and concerns raised about the previous scale apply to this scale.

SCALE						
0 Don't know		1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

Table 4.5: Rating Scale for CES Indicators

The list of indicators and the scale were subsequently put into question format and formed part of the numerous pre-tests and the 'pilot' run.

As with the rest of the questionnaire, Part 2 was found to be incredibly onerous and intimidating – requiring respondents to rate 112 proposed indicators, plus add any extras. This caused considerable respondent burden which would affect the validity and reliability of the incoming data. A systematic method for pruning the list therefore had to be determined

3. Stage 3: Shortening the Indicator List

As described in 4.1.3 at the beginning of the chapter, Neely *et al* provide a systematic method for determining whether performance measures are 'well-designed'. They begin by providing recommendations for the design of

performance measures, and then go on to provide a Performance Measure Record Sheet. At this stage of the indicator-development process, the recommendations provided were used to short-list the 112-item indicator list. The most important considerations used in including indicators into the final list were whether they were (i) **quantifiable** (iii) **objective,** i.e. the same measurement could be obtained by different observers, (iii) **relevant** and (iv) **simple to understand**.

This process produced a shortlist containing 33 items as shown in Table 4.6. Indicators not included in this list were either (a) discarded completely or (b) formed part of the performance and sustainability factor list included in QUEST2. The latter group consisted of items that were relevant and simple to understand to CES personnel, but were not quantifiable and objective – a necessary characteristic of a meaningful indicator.

4. Stage 4: Final Questionnaire Design of Part 2

The final design of part 2 is shown in **Appendix C5.** A funnel technique was used to order the indicators, i.e. the more general indicators, likely to be understood by all respondents were placed first, and the specific indicators at the end of the list. The indicator list was further refined by dividing it into comprehensive sections, making it easier for respondents to follow. These sections were:

- Patient/Client related (indicators 1 – 6)
- Performance/personnel (indicators 7 – 17)
- Cost-effectiveness (indicators 18 – 23)
- CES activities (indicators 24 – 33)

	Final Indicator List
1	Inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction
2	Patient (or operator) injury due to medical equipment malfunction or unavailability
3	Patient (or operator) injury due to medical equipment misapplication
4	Number of equipment malfunctions caused by user error/misuse or abuse
5	Type and number of medical equipment supported by CES
6	Percentage of medical equipment supported by CES that is *functional*
7	*Productivity* (ratio of outputs to inputs)
8	Competencies/skills of CES personnel
9	*Certification* and registration of CES personnel/ department with appropriate professional body
10	Evidence of continuing education/ professional development of CES personnel
11	Relative number of different categories of CES personnel (i.e. engineers, technicians, artisans etc.)
12	Absenteeism of CES personnel
13	CES staff levels per number of beds
14	CES staff levels per number of medical devices
15	Working space (m^2) per technical CES staff
16	Salaries and career paths of CES technical staff vs. other healthcare workers
17	Salaries and career paths of CES technical staff vs. similar employees in competing sector (public/private)
18	Allocated CES budget per year (as a percentage of the supported equipment inventory value)
19	Cost *(labour and overhead)* per hour per CES employee
20	Cost of CES service per bed supported
21	Cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type
22	Cost of in-house service vs. cost of outsourced service per equipment type
23	Inventory of spare parts per equipment value supported
24	*Response time* to service requests
25	Percentage of time devoted to IPMs[10] vs. repairs
26	Total number of IPMs/repairs performed per device type per year
27	*Downtime* of equipment due to IPMs/repairs
28	Degree of compliance that has been achieved with the established schedule for routine IPMs/repairs
29	Percentage of IPMs/repairs performed in-house vs. outsourced
30	Percentage and type of outsourced equipment IPMs/repairs checked by in-house CES before returning to clinical environment
31	Percentage of repeat repairs
32	IPMs/repairs conducted in accordance with manufacturer's recommendations, as specified in service manuals
33	Evidence of proper documentation of all work done by CES (e.g. service histories), providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc

Table 4.6: Final Indicator Shortlist

[10] IPMs = *Inspection and Preventive Maintenance procedures*

Respondents were asked to rate the proposed indicators according to the scale provided.

As the list provided was not exhaustive, respondents were asked to suggest any other indicators they considered to be appropriate in measuring CES performance and sustainability. In order to gauge the relative importance of these indicators, they were asked to rate them according to the scale given in Table 4.7. This was an adaptation of the initial scale, where the lower end of the scale was omitted to prevent respondents from suggesting irrelevant indicators.

SCALE		
Neutral	Important	Essential

Table 4.7: Rating Scale for Additional Indicators Suggested by Respondents

Finally, respondents were asked if they had any further comments relating to clinical engineering services generally or on the questionnaire specifically.

Respondents were thanked for their time and effort in completing the questionnaire and the return address (postal, fax, email) was provided.

4.11 ADMINISTRATION OF THE FINAL QUESTIONNAIRES

The accessories to the questionnaire, namely the cover letter and glossary of terms used in the questionnaire were designed in parallel with the questionnaires. The cover letter requested respondents to participate in the study, giving details about the survey, its purpose and importance, the respondent's role and assured confidentiality and access to results. In addition, a general background to the study plus the status quo of medical equipment maintenance and management were provided. Given the range of terminology with respect to clinical engineering services, several definitions were also provided in the cover letter.

Three versions of each of the questionnaires were designed, namely a standard laser-printed mail (paper) version, an email (electronic) version and a web-based version. Due to technical problems the last-mentioned was not used. The sampling procedure was described in chapter 3. Figure 4.7 summarises the administration procedure.

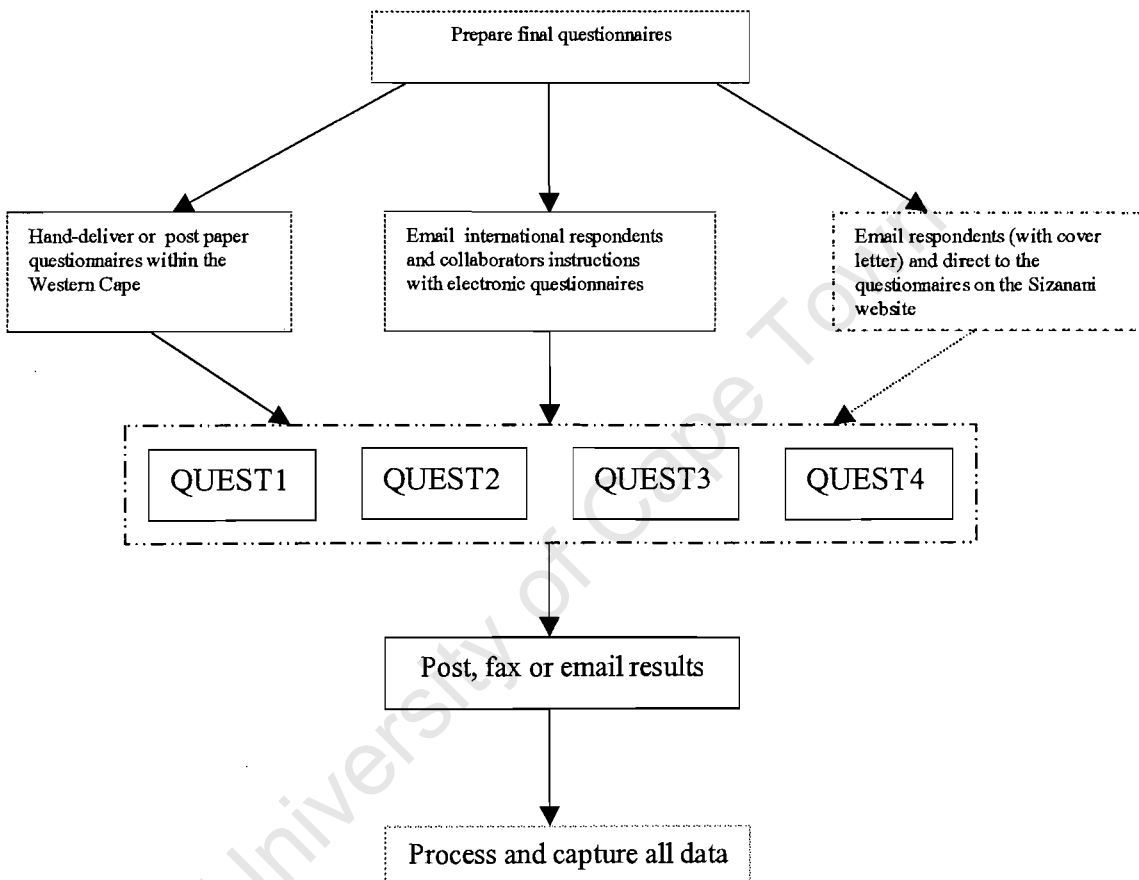


Figure 4.7: Administration of Final Questionnaires

5 RESULTS

Phase Three, as illustrated in the overview of the methodology (Chapter 3.1), consisted of an analysis of the data collected from the completed questionnaires, as well as an analysis of the questionnaires themselves, in order to determine the applicability and effectiveness of the developed instrument. The results from the study – which are **not** conclusive results, i.e. are preliminary results of the ongoing project – will be presented in this chapter, while the following chapter focuses on the analysis of the instrument.

5.1 OVERVIEW OF DATA ANALYSIS METHODS

As described in the previous chapter the four questionnaires were divided into two parts:

Part 1 - comprising mostly of open-ended questions, which would be analysed qualitatively, and a few structured questions that could be analysed statistically.
Part 2 – which was completely structured, thus facilitating statistical analysis of the data.

The two methods used in this study, i.e. (i) the qualitative analysis and (ii) the quantitative analysis will be briefly described in this section.

5.1.1 Qualitative Data Analysis

Dey (1993) describes qualitative data analysis in terms of a logical succession of steps, starting from the first encounter with the data through to the production of an account. Figure 5.1, adapted from Dey, illustrates these steps.

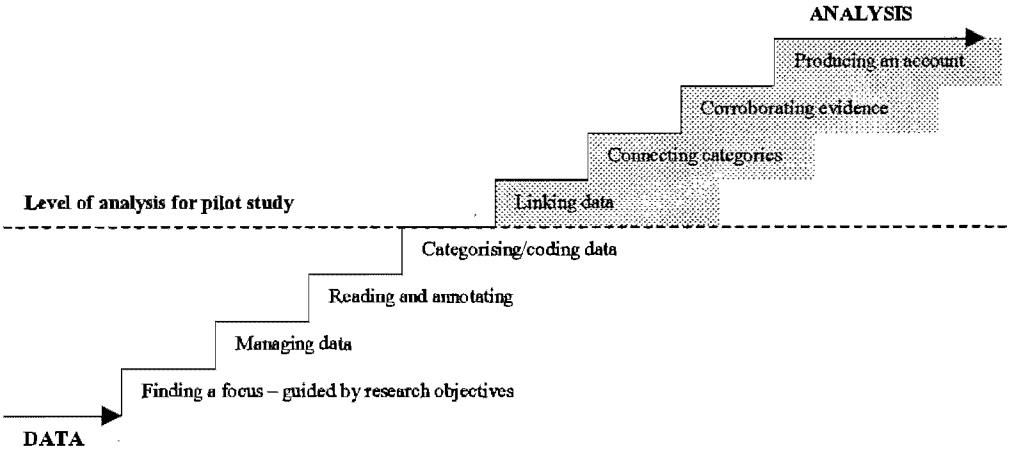


Figure 5.1: Steps involved in qualitative data analysis (Dey, 1993)

As indicted in Figure 5.1, the qualitative analysis for this study ended at the level of categorising the data collected. This was due to certain limitations, including time constraints and low response rate; conclusive results could therefore not be reported. However, dominant themes and trends emerged from the categorisation of the data, which provided considerable insights into the research objectives. The process is illustrated in Figure 5.2.

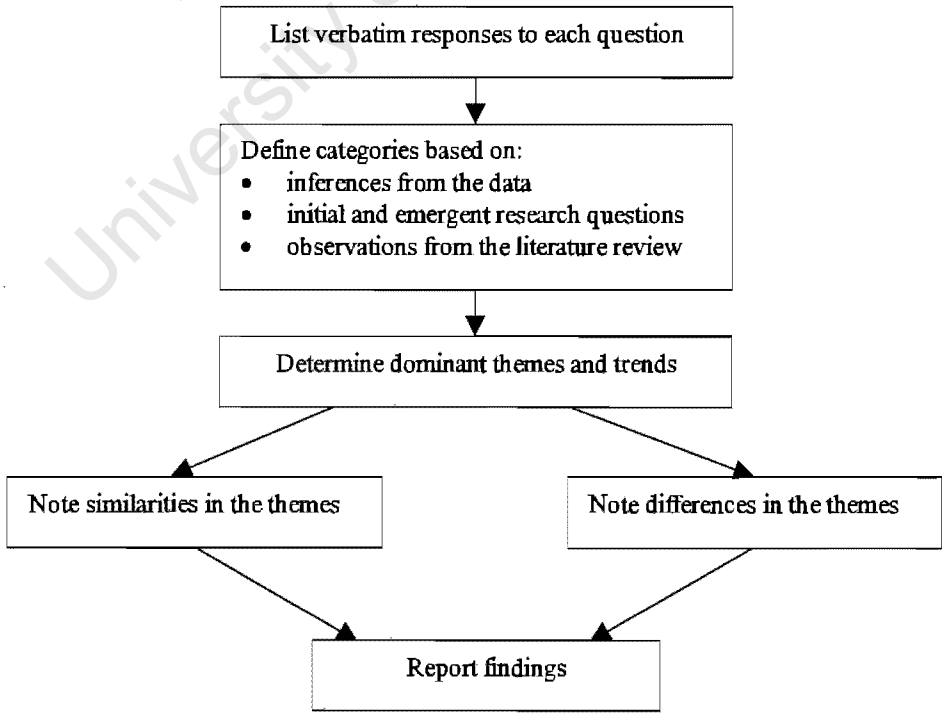


Figure 5.2: Qualitative analysis – categorisation of data

5.1.2 Quantitative Data Analysis

Analysis of Single Variables

Due to the exploratory nature of the study, descriptive statistics[1] were used to determine and describe patterns in the quantitative data. The structured questions in the questionnaire either provided nominal data or ordinal data, which limited the types of analytical tools that were permissible.

Figure 5.3 illustrates the tools permissible with the different types of measurements, as described by Alreck & Settle (1995) and Zikmund (2000).

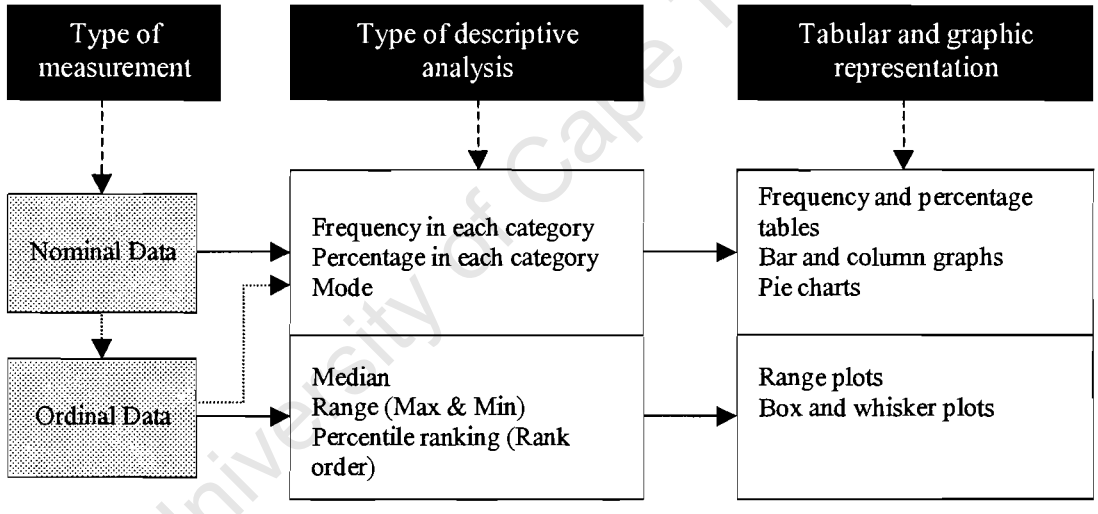


Figure 5.3: Tool selection for descriptive analysis

As shown in Figure 5.3, the descriptive statistics appropriate for the nominal data are also appropriate for the ordinal data.

It should be noted that the arithmetic **mean,** as a measure of central tendency, would not be appropriate for both the nominal and the ordinal data. Firstly, it is not valid to measure the mean of nominal data, as the values are merely names.

[1] **Descriptive statistics:** Statistics such as averages and measures of spread, used to condense and summarise the data to make facts more visible, as well as to indicate the degree to which the sample data is likely to represent the entire population (Alreck & Settle, 1995)

Secondly, for ordinal data, the intervals between code values are not necessarily equal, therefore fractional values have little meaning.

Relationship Between Variables

An additional tool relevant to the study would be to determine the relationship between different variables. As the study provided nominal and ordinal data, **cross-tabulation**[2] - which indicates the relationship between two categorical variables - would be the appropriate measure of association to use. This would entail defining the different variables as either independent[3] or dependent[4] (although this is not an absolute requirement) and subsequently determining the relationship between them. The causative relationship (i.e. which variable is causing or determining the other) is inferred from the research objectives, and the direction of causality is from the independent variable to the dependent variable.

For this study, the independent and dependent variables are defined as:

Independent variables

- Target group*
- Health facility type and size (no. beds, no. equipment)
- Country (region)
- Sector type

Dependent variables

- Service provided*
- Service rating*
- Outsourced services
- Sustainability factors (QUEST2 only)
- Trends affecting CES (QUEST2 only)

[2] **Cross-tabulation:** A technique organising data by groups, categories or classes, thus facilitating comparisons: a joint frequency distribution of observations on two or more sets of variables – presented as a matrix with values of one variable defining the rows and values of a second variable the columns

[3] **Independent variable:** Variable that is causing the other to vary (also called explanatory/predictor variables i.e. used to explain or predict a response, outcome or result – the dependent variable)

[4] **Dependent variable:** Variable that is being affected/varies by independent variable

- Indicator ratings*.

Variables in **boldface** can be defined as **primary** independent and dependent variables which are directly related to the objectives of the study, while those marked with an asterisk (*) indicate the variables that could be cross-tabulated for this study, given the range of responses received.

The three basic requirements for cross-tabulation include:

- data should be in categories
- there should be a limited number of categories for each variable
- the total *n*-size or *number of cases* should be large enough to provide a sufficient minimum cell frequency.

Due to the limited number of cases (low response rate), this method could not be used, as any results produced would not be statistically valid.

All data entry and management was performed using **Microsoft Excel 2000** spreadsheets; and the statistical package **STATISTICA 5.5** used for the data analysis outlined in this section. The results from the analysis of the four questionnaires will now be presented section-by-section, as they appeared in the final questionnaires.

5.2 DEMOGRAPHIC DATA

As indicated in the methodology chapter, two versions of the questionnaires were distributed to potential respondents, namely (i) a paper version for local respondents and (ii) an electronic version (a locked form created in MS Word 2000) e-mailed to international respondents.

The total number of paper questionnaires distributed locally and the subsequent response rates are shown in Table 5.1.

Questionnaire	No. Distributed	No. Received	Response Rate
QUEST1	35	11	31%
QUEST2	35	8	23%
QUEST3	30	8	27%
Total	**100**	**27**	**27%**

Table 5.1: Response Rates of the Questionnaires Distributed within South Africa

The total response rate of 27% is considered to be important, because Part 2 of all the questionnaires was identical, and could therefore be analysed together.

The total number of electronic questionnaires distributed to international respondents cannot be determined due to the 'snowball' sampling technique employed, i.e. potential (known) respondents in Europe, USA and Australia were assigned the task of further distributing the questionnaires in their respective regions. Questionnaires were also distributed via the INFRATECH and IFMBE list-servers, requesting interested parties to participate in the study.

At the time of writing this report, only three responses had been received from the international community, namely one (1) response to QUEST2 and two (2) responses to QUEST4, bringing the total responses to **thirty (30)**. This was considered to be an acceptable number for presenting the preliminary findings of the pilot study. Further responses will form part of continuing research beyond the scope of this study.

The following sub-sections illustrate the results of the demographic information collected.

5.2.1 Distribution of Responses by Target Group

The **target group** was identified as a primary independent variable, allowing comparisons to be made between opinions of CES personnel, their clients, institutional management and experts/decision-makers at regional, national and international levels. Table 5.2 shows the frequency and percentage of responses

from each of the four target groups, while Figure 5.4 illustrates the relative proportion of responses.

Target Group	Frequency	Percentage
QUEST1 (Institutional Management)	11	36%
QUEST2 (CES Management & Personnel)	9	30%
QUEST3 (CES Clients)	8	27%
QUEST4 (International Experts/ MoH	2	7%
Total	**30**	**100%**

Table 5.2: Distribution of Responses by Target Group

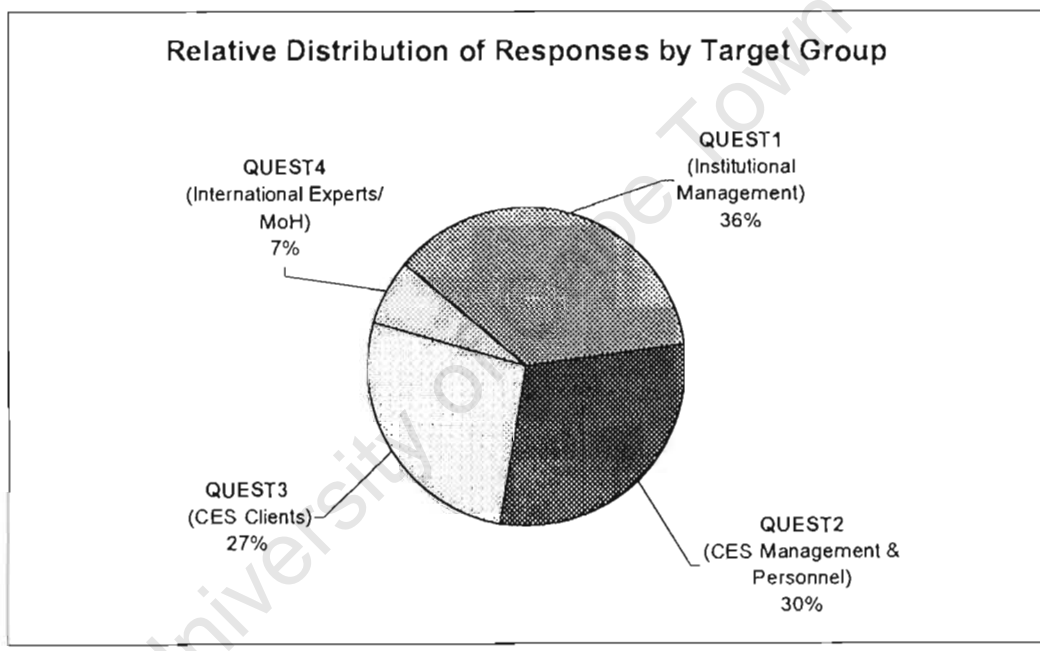


Figure 5.4: Relative distribution of responses by target group

The relative percentages of responses from the first three target groups were roughly similar, therefore facilitating valid comparisons between them. It was interesting to note that not only were there more responses from institutional management than the other groups, but they also contributed the most in the qualitative sections of the questionnaires.

5.2.2 Distribution of Responses by Country

One of the objectives of the project as a whole is to compare functions, services and opinions of CES's in differing regions. The **country** in which each CES was based was therefore defined as a primary independent variable. Table 5.3 and Figure 5.5 respectively, show the distribution of responses by country.

Country	Frequency	Percent
Mozambique	1	3%
Namibia	3	10%
UK	1	3%
South Africa	23	77%
USA	2	7%
Total	**30**	**100%**

Table 5.3: Distribution of Responses by Country

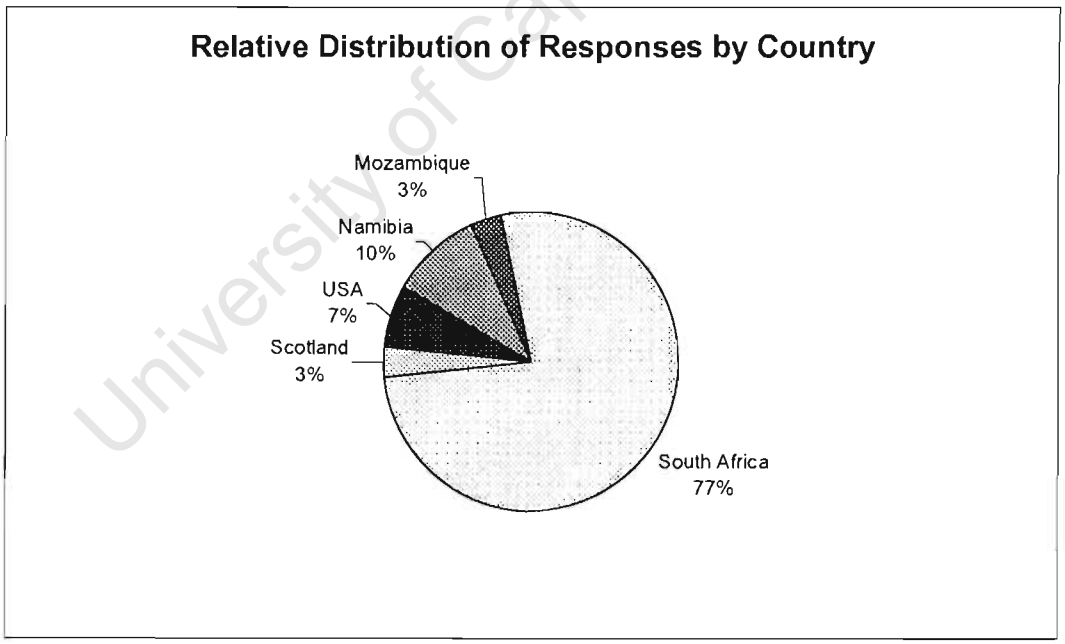


Figure 5.5: Relative Distribution of Responses by Country

With 77% of responses from South Africa (specifically the Western Cape), and all others constituting only 23% of the total, comparative analyses of country- or region-specific variables could not be conducted.

5.2.3 Distribution of Responses by Health Facility Type

The needs and functions of CES's could be found to differ across health facility types and sizes. These were identified as being **secondary** independent variables relative to this study. The proportion of responses from the differing health facility types specified in the questionnaire, plus those suggested by respondents in the 'Other' category of question 1.2 in questionnaires 1 - 3, are summarised in Table 5.4 and Figure 5.6 respectively.

Health Facility Type	Frequency	Percent
Tertiary/Academic health facility	24	85%
Secondary/Referral/Regional	1	4%
National Department of Health (other)	2	7%
All levels of healthcare (other)	1	4%
Total	**28**	**100%**

Table 5.4: Distribution of Responses by Health Facility Type

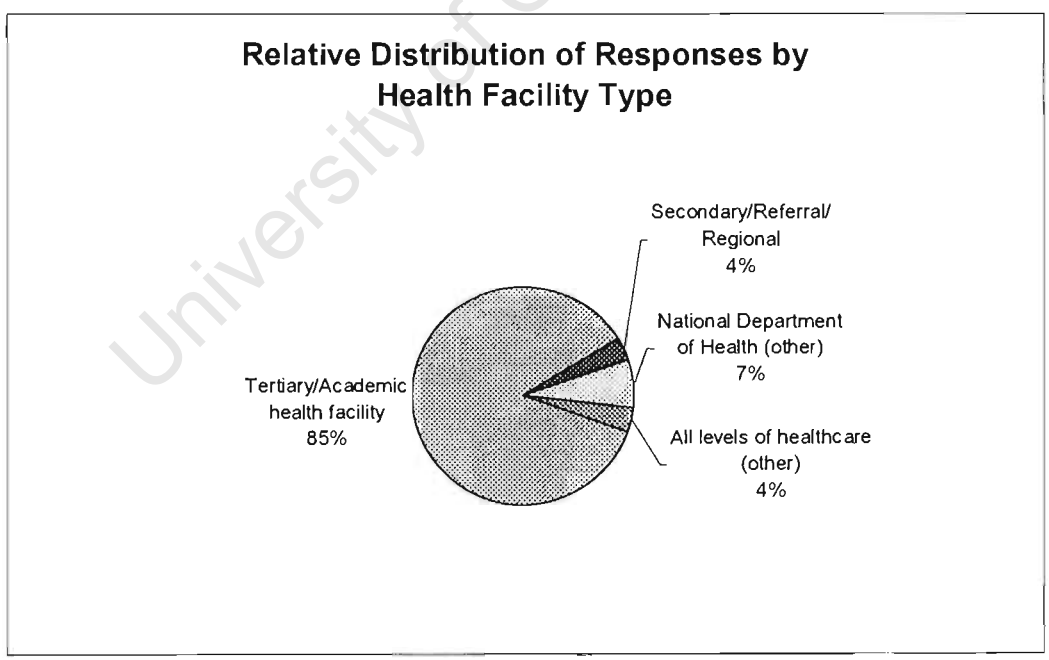


Figure 5.6: Relative Distribution of Responses by Health Facility Type

As illustrated in Figure 5.6 the vast majority of responses were from tertiary or academic health facilities and therefore comparisons between different health facility types could not be conducted.

5.2.4 Summary of Distribution of Responses

In summary, analysis of the demographic data illustrated that the opinions expressed in the study would primarily be from CES's at tertiary institutions in the South African public sector. However, comparisons between the different target groups could be conducted, due to their relative proportions.

5.3 MISSION AND STRATEGY OF CLINICAL ENGINEERING SERVICES

5.3.1 Identifying an Appropriate Mission Statement for a CES

The question of an appropriate mission statement was posed to institutional management, CES personnel and international HTM experts. In most cases, both institutional management and CES personnel were not aware of an existing mission statement specific to the Clinical Engineering Service. Table 5.5 collates the dominant themes that emerged from the three groups.

Suggested Elements in a CES Mission Statement
1. To provide an appropriate technical service to **support** improvement in healthcare delivery.
2. To provide a **professional** and **quality service** in supporting both the provision and effective use of medical equipment from conception/procurement to disposal.
3. To (innovatively) maintain **optimum performance** of all medical equipment.
4. To provide an **efficient** and **cost-effective** clinical engineering service.
5. To promote **safety** of healthcare delivery, with respect to medical equipment.
6. To deliver an **effective** and **sustainable** healthcare support service.
7. To establish **operating policies** and **procedures** for MEM&M.

Table 5.5: Suggested Elements in a CES Mission

Opinions of institutional management were centred around the delivery of quality healthcare delivery support services, while those of the CES personnel were more specific to the functions of a clinical engineering service. The fourth target group, international HTM experts, introduced the need for working policies and procedures for Medical Equipment Maintenance and Management. All three areas are important in contributing to the sustainability of CES's.

5.3.2 Identifying Appropriate Strategic Elements for a CES

The three groups were subsequently asked to suggest appropriate elements in a strategic plan for a CES, in order to achieve its mission. A composite list of suggested strategic elements is presented in Table 5.6. Very similar themes emerged from all three groups.

Suggested Strategic Elements for a CES
1. Improve service delivery.
2. Financial management.
3. Ensure sufficient physical infrastructure (test equipment, space, etc.).
4. Improve human resources.
5. Training and continuous education of users and technical staff.
6. Improve collaboration with stakeholders (clients and management) as well as private companies and other CES's.
7. Implement programmes for maintenance, inspections, replacements, etc.
8. Procedures for corrective maintenance, specifications and procurement of medical equipment.
9. Quality control and improvement.

Table 5.6: Suggested Strategic Elements for a CES

5.4 SERVICES PROVIDED BY CLINICAL ENGINEERING SERVICES

One of the main objectives of the study was to compare the functions and services of CES's in their respective environments (socio-political, regional, institutional). Of particular interest was the relative importance of the CES to the institution it supported, as seen by all four target groups. The services provided by the respective CES's and their subsequent ratings were thus defined as **primary**

dependent variables. The following sub-sections summarise the results of this quantitative section.

5.4.1 Services Provided

Institutional management, CES personnel and CES clients were asked to indicate which medical equipment management and maintenance services, as listed in the questionnaires were (to the best of their knowledge) provided by their respective CES's. Table 5.7 summarises the relative percentages of each service provided. Figure 5.7 illustrates the relative percentages by way of a column chart. Services listed in *italics* were additional services indicated by respondents as being offered by their CES's.

SERVICE	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
% Service Provided	32	32	60	36	57	21	71	18	21	43	14	50
% Service Not Provided	68	68	40	64	43	79	29	82	79	57	86	50
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100

SERVICE	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24
% Service Provided	54	46	71	32	43	36	18	25	39	0	4	0
% Service Not Provided	46	54	29	68	57	64	82	75	61	100	96	100
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100

where:

S1 Strategic technology needs assessment and planning
S2 Technology assessment
S3 Specification, evaluation and procurement of equipment
S4 Asset/inventory management
S5 Review of equipment replacement needs
S6 Cost of ownership monitoring
S7 Management of service contracts
S8 Project management
S9 Facilities and plant management and maintenance
S10 Training equipment users
S11 Risk management
S12 Safety checks
S13 Acceptance testing (incoming inspections)
S14 Inspection and preventive maintenance (IPM)
S15 Corrective maintenance (repair)
S16 Equipment performance monitoring
S17 Functional or calibration checks
S18 Quality assurance and improvement
S19 Research and development/modification of equipment
S20 IT/Computer hardware and networks
S21 Telecommunications
S22 Financial management of CES
S23 Configuration of medical equipment
S24 Incident evaluation and reporting

Table 5.7: Relative Percentages of CES Services Provided

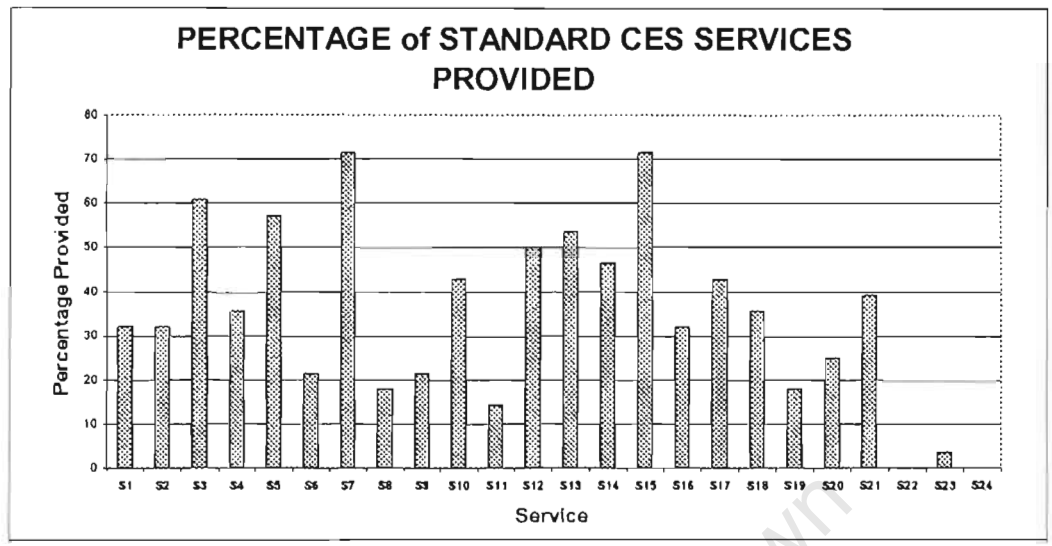
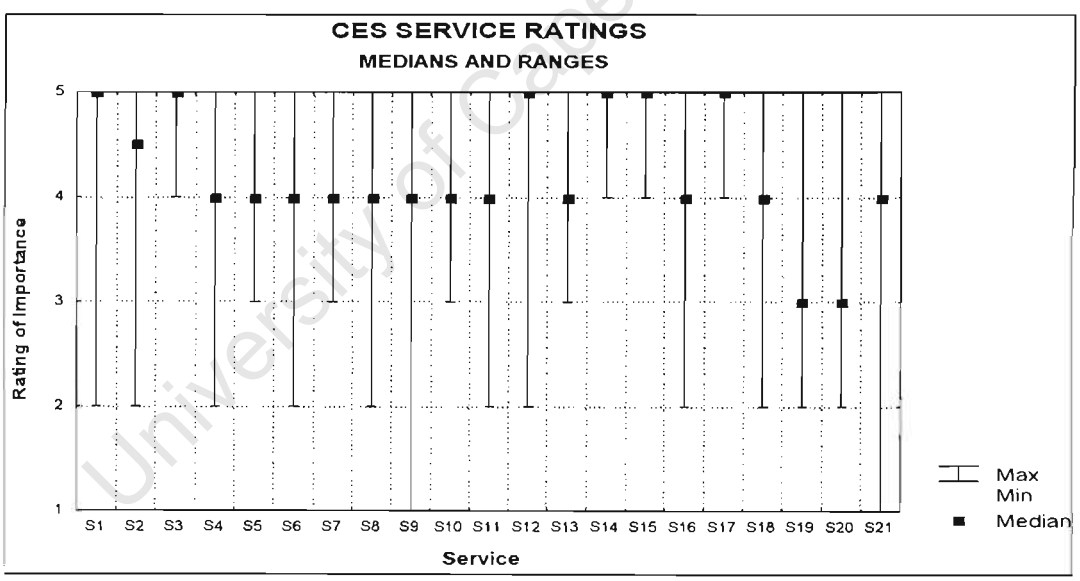


Figure 5.7: Relative Percentages of CES Services provided

Figure 5.7 indicates that the major CES services provided and familiar to all three groups were corrective maintenance (repairs) and management of service contracts, followed by specification, evaluation and procurement of equipment and review of equipment replacement needs, respectively. Acceptance testing of incoming equipment and safety checks were provided by just over 50% of the CES's. Inspection and preventive maintenance (IPM), which the literature review showed to be one of the basic and most important functions of a CES, was checked by just under 50% of respondents. However, a review of the data showed that 82% of CES personnel specified this as a service provided by their departments. This suggests that institutional management and CES clients were unaware of this basic function. Finally, **user training** and **functional/calibration checks** were indicated by 43% of the sample. This distribution, plus the low frequencies of such services as project management and facilities management, suggests that the general functions of the CES's surveyed corroborate with observations from the literature review.

5.4.2 Ratings of Services Provided by CES

In order to evaluate the relative importance of CES services in general, respondents were required to rate all the possible clinical engineering services listed according to their perceived importance to their respective institutions. The rationale behind the scale used was described in the methodology. Although a scale of 1 to 5 was provided, a significant number of respondents rated only those services provided by their institutions, and not the others. Services that were not rated were thus regarded as **missing data**, and not included in the analysis. The significance of this will be discussed in the analysis of the questionnaires. The data produced was ordinal, therefore the medians and ranges of the respective services were computed. The composite descriptive statistics are given in Appendix D2 and Figure 5.8 illustrates the results.



where:

1 = Irrelevant, 2 = Unimportant, 3 = Neutral, 4 = Important, 5 = Essential

Figure 5.8: CES Service Ratings: Medians and Ranges

Figure 5.8 indicates that the following were considered to be **essential** CES services:

i. Specification, evaluation and procurement of equipment (S3)
ii. Inspection and preventive maintenance (IPMs) (S14)
iii. Corrective maintenance (repair) (S15)
iv. Functional or calibration checks (S17).

These services all scored a median rating of **5**, with a minimum rating of 4. Also considered to be essential CES services, scoring a median of **5** but minimum ratings of 2, were:

v. Strategic technology needs assessment and planning (S1)
vi. Safety checks (S12).

The more traditional equipment management and maintenance activities, such as technology assessment, review of equipment replacement needs, training equipment users and management of service contracts were deemed important, even though Figure 5.7 showed that some of them were not sufficiently provided by CES's. Non-traditional services, such as (i) facilities and plant management and maintenance and (ii) telecommunications - usually offered by other departments or outsourced – although scoring a median of 4, had minimum scores of 1, indicating that some respondents considered them irrelevant to the CES function.

Cross-tabulation – or quadrant analysis[5], which has grown increasingly popular as a component of Total Quality Management programmes (Zikmund, 2000) – would have been useful in establishing the relationships between the independent variables identified (specifically target group) and service rating. This would give insight into expectations and perceptions of the different groups. Due to the limited number of cases (*n*-size), this analysis could not be performed. However, descriptive statistics of the ratings from the individual target groups gives an indication of the differing opinions of each group. These are illustrated in Figures 5.9 – 5.11.

[5] **Quadrant Analysis:** A variation of the cross-tabulation table that plots two rating scale questions into four quadrants of a two-dimensional table. Sometimes referred to as **importance-performance analysis** (Zikmund, 2000)

Apart from the similarities indicated by the composite scores shown in Figure 5.8, comparisons of the three graphs shows certain differences between the individual groups. Differences occurred between CES personnel versus institutional management and CES clients, respectively, who both considered **technology assessment** to be an essential service; while CES personnel indicated that **asset/inventory management** was essential. Also, institutional management considered (i) **strategic technology needs assessment and planning,** (ii) **review of equipment replacement needs,** (iii) **acceptance testing** and (iv) **quality assurance** to be essential services, unlike the other two groups. These are issues that would be particularly relevant to institutional management, who would be the main decision-makers, especially with regards to budget allocation.

5.5 EXPECTATIONS AND PERCEPTIONS OF STAKEHOLDERS

The following section describes the expectations and perceptions of both CES direct clients (nurses, doctors etc) and institutional management - who are both stakeholders and the top decision-makers at an institutional level.

The themes emerging from this qualitative section are collated from **QUEST1: Sections 4.1.1** and **4.1.2; QUEST2: Section 3.3.3** and **QUEST3: Sections 2.2.1** and **2.2.2,** which essentially asked the same questions, although phrased differently.

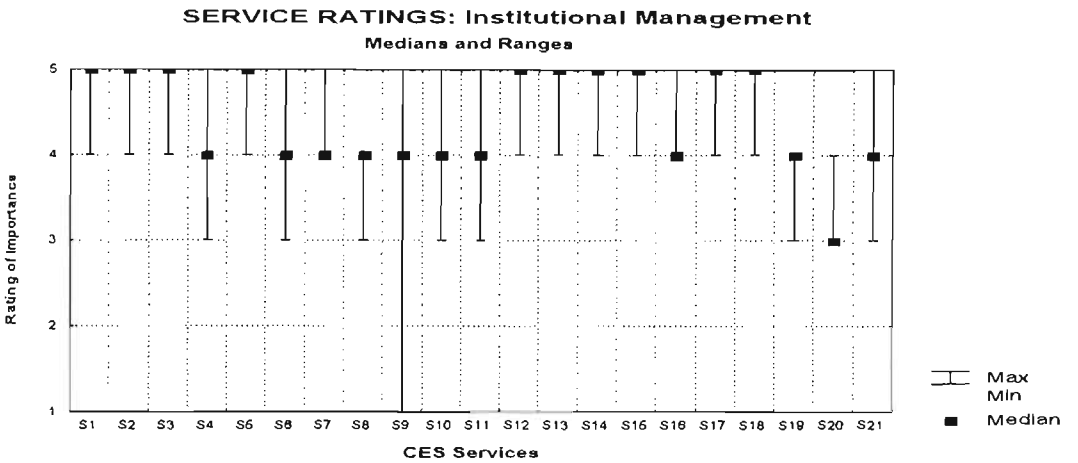


Figure 5.9: Service Ratings: Institutional Management

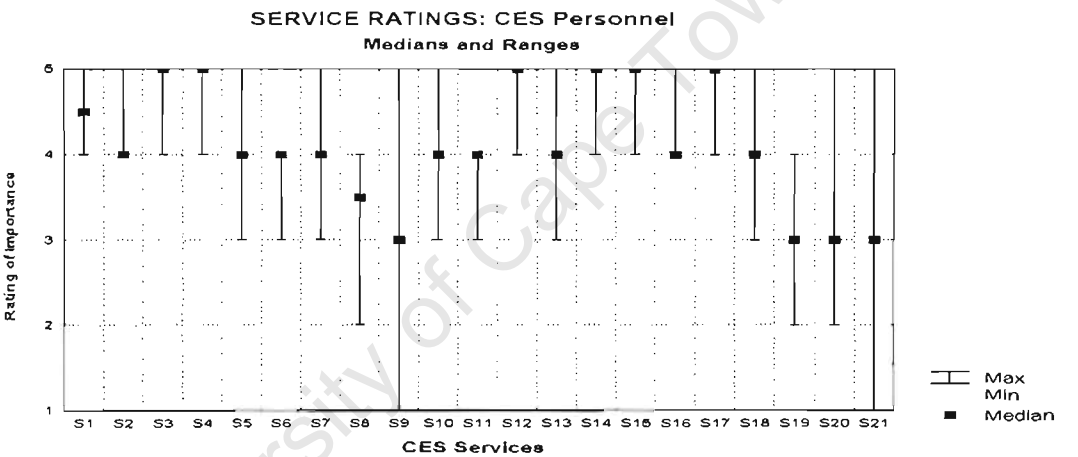


Figure 5.10: Service Ratings: CES Personnel

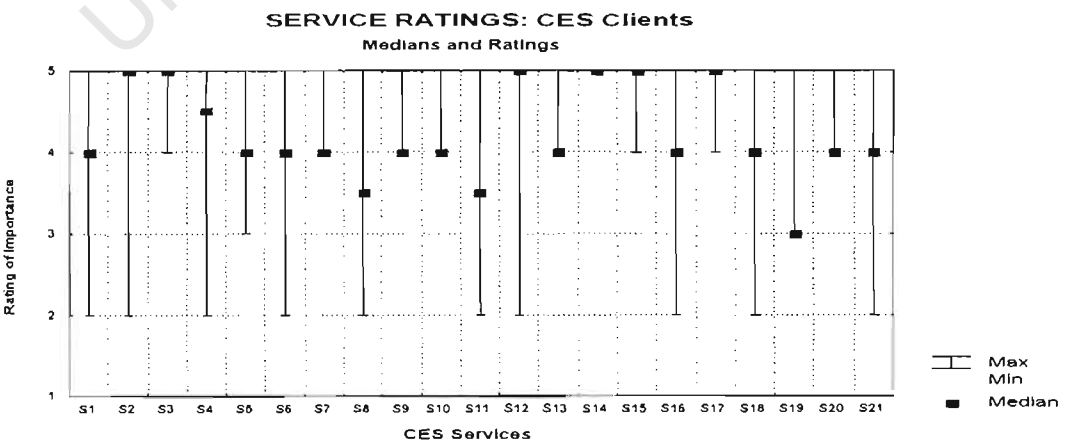


Figure 5.11: Service Ratings: CES Clients

5.5.1 Client and Institutional Management Expectations of CES

In this section, institutional management and clients were asked to indicate what their expectations of a CES were; while CES personnel were asked if they knew the expectations of their clients. The composite themes are presented in Table 5.8.

Client and Institutional Management Expectations of CES's
1. Effective (and timely) management of general CES activities viz. IPM, repairs, inventory management, equipment evaluation & procurement.
2. Prompt, efficient, safe and quality service.
3. Support for institutional management with specification and procurement/replacement of medical equipment; new tenders.
4. Client/user and technical staff training and re-training.
5. Up-to-date knowledge, innovative ideas and ability to adapt.
6. Cost-effectiveness.
7. Strategic planning and needs assessment.
8. Management of service contracts, liaison with outsourced groups, good referral system
9. Quality assurance and control.
10. Minimal downtime of critical equipment.
11. Availability and user-driven service.

Table 5.8: Client and Institutional Management Expectations of CES

5.5.2 Reasons Expectations Are Not Met

In an effort to identify the factors preventing CES from delivering service expected of them, institutional management and clients were asked their opinions on why, if at all, their expectations of the CES were not met. Table 5.9 summarises the themes emerging from this section.

Reasons Expectations Not Met
1. Lack of financial resources.
2. Lack of infrastructure (organisational, physical) and logistics support (e.g. transport).
3. Lack of human resources and technical expertise.
4. Poor staff motivation due to lack of staffing norms, lack of incentives and poor career structure.
5. Poor management and planning of CES functions.
6. Excessive downtime due to old and obsolete equipment, lack of spares.
7. Lack of ownership/discipline regarding handling of equipment.

Table 5.9: Reason Institutional Management/Client Expectations Not Met

5.6 IMPORTANCE OF CES AND IMPACT ON HEALTHCARE DELIVERY

Observations from the literature review showed that medical equipment maintenance and management is often considered **not** to be a 'core' function of healthcare institutions, thus threatening the existence of in-house CES's. The **impact** of CES's on healthcare delivery - as perceived by all four target groups - was considered to be an important factor as a means of qualifying the existence of this service.

5.6.1 Advantages and Disadvantages of Clinical Engineering Services

In an effort **not** to lead respondents in either a positive or negative direction with regards to the importance of CES, institutional management and HTM experts were asked to state both the **advantages** and **disadvantages** of in-house CES's, as opposed to outsourcing all medical equipment maintenance and management. **QUEST1: Section 3.3** and **QUEST4: Section 3.3** address this issue directly. Themes emanating from this question are described in Table 5.10 and Table 5.11.

Advantages of In-House CES's
1. Cost-effective (for repairs, re-distribution of low-tech equipment, etc.) – *provided the CES is well-equipped, staffed and properly managed* .
2. Quick response time.
3. Knowledge of institution's strategic direction and unique requirements, concerning medical equipment (e.g. know when parts can be taken from unused equipment).
4. Good communication channels and working relationship with institutional management and clients.
5. Easily accessible/available - therefore able to re-prioritise (e.g. for emergencies).
6. Loyalty and accountability – therefore quality of workmanship better than outsourced service.
7. Lower cost opportunity for in-house technical training, research, innovation.
8. Better control over inventory - maintenance history data readily available.

Table 5.10: Advantages of In-House CES

An interesting observation was that responses to **QUEST2: Section 4.1,** in which CES personnel were required to state their opinions on the impact of their service

on the **performance** of the healthcare delivery system, corresponded to the advantages of CES's as given in Table 5.10.

Disadvantages of In-House CES
1. Lack of resources (financial, human, material) results in ineffective service (e.g. poor management, long waiting times). 2. High capital cost (medical equipment, test equipment, training, space etc.). 3. Human resource management complex (especially in public sector) – difficult to acquire and retain specialised talent. 4. Lack of knowledge in specialised or complex equipment. 5. Low morale of CES personnel due to lack of incentives. 6. Liability for medical equipment-related injuries/deaths.

Table 5.11: Disadvantages of In-House CES

In **QUEST2: Section 3.3.4,** CES personnel were asked if there would be any advantages of outsourcing CES activities. Table 5.12 describes the results from this question.

Advantages of Outsourcing CE Activities
1. Contractors provide the human resources and training needed to complete MEM&M. 2. Some equipment too specialised/complex to be serviced in-house. 3. Transfer risk to external agent. 4. No requirements to hold stocks of spare parts. 5. Regular software upgrades.

Table 5.12: Advantages of Outsourcing CE Activities

These results correspond with the themes described in Table 5.11, where institutional management and HTM experts were asked for the disadvantages of in-house CES as opposed to outsourcing.

5.6.2 Impact of CES on Healthcare Service Delivery

In this section institutional management, CES clients and HTM experts were asked for their opinions on the impact of CES's on healthcare facilities. Responses to this question were collated from **QUEST1: Section 4.13** and

QUEST4: Section 4a, which ask this directly, while CE clients (**QUEST3: Section 2.2.3**) were asked how the service provided by CES's influence their ability to carry out their own jobs. Table 5.13 summarises the themes emerging from the responses to these questions.

Impact of CES on Healthcare Service Delivery
1. Enhances healthcare service delivery, which is highly dependent on functional medical equipment.
2. Effective CES increases productivity, morale and satisfaction of clinical staff through user-training and by ensuring availability of medical equipment.
3. Improves safety and efficiency of essential medical equipment (in-spite of old age and unavailability of parts).
4. Reduces operational costs and downtime of equipment.
5. Lack of maintenance and non-availability of life support equipment could impact negatively on mortality and morbidity, resulting in medico-legal problems.
6. Limitations of CES (e.g. lack of resources) results in ineffective service - negative impact on healthcare delivery.

Table 5.13: Impact of CES on Healthcare Service Delivery

5.6.3 Implications of No In-House CES

The literature review revealed that outsourcing medical equipment maintenance and management is a trend that has affected CES's globally. In order to establish perceptions on the effect of outsourcing versus in-house CES's, respondents were asked to state what, in their opinion, were the implications of **not** having an in-house CES. This was essentially a rephrasing of Section 6.6.1, in which respondents were asked to state the advantages and disadvantages of CES's over outsourced services. The responses presented in Table 5.14 are collated from **QUEST1: Section 4.1.4, QUEST3: Section 2.2.4** and **QUEST4: Section 4b.**

Themes from Table 5.14 were found to correspond with the advantages of an in-house CES, as described in Table 5.10, thus indicating stability in responses.

Implications of No In-House CES
1. Very costly – especially for day-to-day minor repairs. 2. Less control and lack of accountability on MEM&M from outsourced service . 3. Rigorous supervision is a critical factor. 4. Lack of knowledge of specific institutional needs and strategic plans – therefore less opportunities for integrated project management plans. 5. Slower response times and greater turnaround times. 6. Unavailability of staff for immediate on-site emergencies. 7. External service providers more knowledgeable about specialised equipment.

Table 5.14: Implications of No In-house CES

5.7 'QUALITY OF SERVICE' WITH RESPECT TO CES

A major theme that came up in the expectations of institutional management and clients was that of **quality service.** Business management literature and recent trends in CES management stress the importance of quality, resulting in certain buzzwords such as **Quality Assurance, Total Quality Management, Quantum Quality,** to name a few. However, the literature review also showed that quality has several meanings depending on the customer's needs and expectations.

This section aimed to establish what 'quality of service' means, with respect to Clinical Engineering Services. This question was posed to institutional management and HTM experts, but was found to be difficult to conceptualise. One respondent indicated that not only is it a complex concept – but it is also difficult to transmit to lower academic-level personnel. However, where an attempt was given to define this concept, the themes described in Table 5.15 emerged. Answers were derived from **QUEST1: Section 4.2.1** and **QUEST4: Section 4c.**

Quality of Service with Respect to CES
1. Professional, predictable, reliable and readily available service. 2. Providing safe patient care through effective and efficient service delivery, integrated with the goals of the institution. 3. Ensuring safety, efficient repair, availability and optimum lifespan of medical equipment. 4. Prompt service – minimal response times and minimal equipment downtime. 5. Compliance to standards defined for measuring output and quality.

Table 5.15: Quality of Service with Respect to CES

5.8 PERFORMANCE OF CLINICAL ENGINEERING SERVICES

The implementation of standardised performance indicators would be less costly if integrated with existing performance measurement systems. Autio & Morris (1995) also suggest that indicators could be derived from an existing database, consisting of standard elements. This section sought to determine what, if any, methods were currently used to measure CES performance.

5.8.1 Current Assessment of CES Performance

Institutional management and CES personnel were asked to describe how CES performance was assessed at their respective institutions. Trends resulting from the responses are summarised in Table 5.16. These were collated from **QUEST1: Section 5.1a** and **QUEST2: Section 4.3c.**

Current Assessments of CES Performance
1. Budget vs. cost control / cost-saving benefits. 2. Client complaints. 3. Annual report (e.g. no. of tasks performed annually, records etc.). 4. Observation (e.g. repair requisition monitoring). 5. Average time from service call (from clinical staff) to completion of repair. 6. Service requirements. 7. Ad hoc or no performance assessment system.

Table 5.16: Current Assessment of CES Performance

5.8.2 Suggested CES Performance Indicators

Respondents were subsequently asked to suggest important indicators that could be used to measure CES performance. This question was asked **before** Part 2 of the questionnaire so as to determine general trends, which were not influenced by the indicators proposed later in the questionnaire. Table 5.17 describes dominant themes arising from this section, roughly in the order of frequency of occurrence. These were collected from **QUEST1: Section 5.1b, QUEST2: Section 4.3b** and **QUEST4: Section 5.1a.**

Suggested CES Performance Indicators
1. % reduction in costs per total budget per equipment type (all other factors being constant) e.g. total hourly cost.
2. Downtime (especially critical equipment).
3. No. of functional testing/safety checks – resulting in improved safety (e.g. less injuries).
4. No. of customer complaints - customer satisfaction.
5. Keeping within targeted IPM schedules.
6. Repairs: time to repair; % time devoted to repairs; normalised no. repairs; no. repeat repairs.
7. Response time to service requests.
8. % equipment in good working order / with lifetime within range.
9. Turnaround time per type of equipment.
10. Amount of user-training.
11. No. of jobs in-house vs. outsourced / % equipment sent to agents.
12. No. of equipment per staff member / No. of tasks per staff member.
13. Productivity (single factor, multifactor).
14. Availability of CES and professional conduct.
15. New projects taken, research papers etc.
16. Fraction of institution's insurance cost for covering equipment-related lawsuits.

Table 5.17: Suggested CES Performance Indicators

5.9 SUSTAINABILITY OF CLINICAL ENGINEERING SERVICES

Observations from the literature review stated that Clinical Engineering Services, both in the developing and developing countries, have been (or are currently) threatened with closure. WHO (1999) indicate that inappropriate physical infrastructure and technology (both of which form part of the function of CES's) in turn affect the sustainability of **health systems**. It is therefore imperative to

identify factors that impact on the survival of CES's, in an effort to develop relevant sustainability indicators. This section sought to identify these factors.

5.9.1 Are Clinical Engineering Services a 'Core' Function of Healthcare Service Delivery?

Budget cuts, economic rationalisation, downsizing and outsourcing are trends affecting CES's because the CES function is not considered to be a 'core' function of healthcare service delivery. Of the 22 respondents, 77% considered CES's to be a core function of healthcare delivery. In an effort to establish the rationale behind this reasoning institutional management, CES personnel and HTM experts/ representatives of Departments of Health were asked to elaborate on why they considered CES's to be (or not be) a core healthcare function. Responses to this question are collated from **QUEST1: Section 5.2.1, QUEST2: Section 5.2a** and **QUEST4: Section 5.2.1.** Table 5.18 summarises general opinions of the three groups.

Are CES's a Core Function of Healthcare?
Yes
1. Healthcare technology is a vital component of the healthcare delivery package.
2. Clinical functions - consisting of diagnostic, life support and surgical procedures - are a core function of health service delivery – all of which highly dependent on functional medical equipment/ healthcare technology.
3. Clinical functions are increasingly dependent on expertise that understands this technology.
4. MEM&M ensures availability , safety and understanding of medical equipment to users which is essential to healthcare provision.
5. CES is a supportive function that delivers an essential service for acute emergency care.
6. Without CES, costs of healthcare service would be huge.
No
7. Patient care is the core function of healthcare service delivery.
8. There is a need to define 'core'.
9. 'Core' service is restricted to clinical service.

Table 5.18: Are CES's a Core Function of Healthcare Service Delivery?

5.9.2 Factors Supporting (or Hindering) the Existence of CES

Having established whether the CES function is (or is not) indeed central to healthcare service delivery, this section sought to determine what factors – whether institutional, organisational or (socio-political) environmental – support or hinder the existence of CES's. Tables 5.19 and 5.20, derived from **QUEST1: Section 5.2.2, QUEST2: Section 5.1** and **QUEST4: Section 5.2.2,** summarise the verbatim responses to this question.

Factors Supporting the Existence of CES's
1. Institutional / DoH understanding, commitment and support of CES function.
2. Adequate resources (e.g. physical infrastructure, human resources, financial).
3. Effectiveness of CES in all equipment management and maintenance activities.
4. Organisational structure and strategic direction of institution.
5. Cost-effectiveness of CES vs. external service providers.
6. A need for the service (i.e. disease, leading to a need for healthcare delivery, therefore a need for healthcare technology and subsequently a need for technology support).
7. Adequate budget allocation.
8. Policy development (especially at MoH level).
9. Capacity building, staffing norms and career pathing.
10. Mission statement.

Table 5.19: Factors Supporting the Existence of CES's

Factors Hindering the Existence of CES's
1. Lack of human resources – particularly trained and qualified technical personnel.
2. Lack of financial resources / budget constraints.
3. Trends in outsourcing / private market expansion.
4. Low salary packages.
5. Lack of knowledge / direction in MEM&M.
6. Lack of awareness / political will of decision makers.
7. Lack of initiative and creativity of CES professionals.
8. Institution type (e.g. rural facility / day clinic vs. academic health facility).

Table 5.20: Factors Hindering the Existence of CES's

5.9.3 Sustainability Factors

The Report of the December 1998 WHO Consultation on Physical Infrastructure proposed certain key factors that ensure sustainability of **health systems**. In order to ascertain whether the same factors have an impact on the sustainability of **CES's** - which are a function of health systems and directly linked to physical infrastructure and technology - clinical engineering personnel were requested to indicate which of the proposed factors had a significant impact on CES sustainability. Table 5.21 summarises results of the relative frequency of each factor, while Figure 5.12 illustrates the results graphically. Detailed frequency tables can be found in Appendix D3.

FACTOR	SF1	SF2	SF3	SF4	SF5	SF6	SF7	SF8	SF9	SF10
% Significant	78	8	67	78	67	56	78	78	56	67
% Not Significant	22	22	33	22	33	44	22	22	44	33
TOTAL	100	100	100	100	100	100	100	100	100	100

where :

SF1: Adequate physical infrastructure
SF 2: Adequate financial resources
SF 3: Adequate human resources
SF 4: Management/strategic commitment
SF 5: Conducive environment
SF 6: Legal framework
SF 7: Logistics support
SF 8: Performance of technical staff
SF 9: Stakeholder participation
SF 10: Recognition of acceptance by clients

Table 5.21: Factors With Significant Impact on CES Sustainability

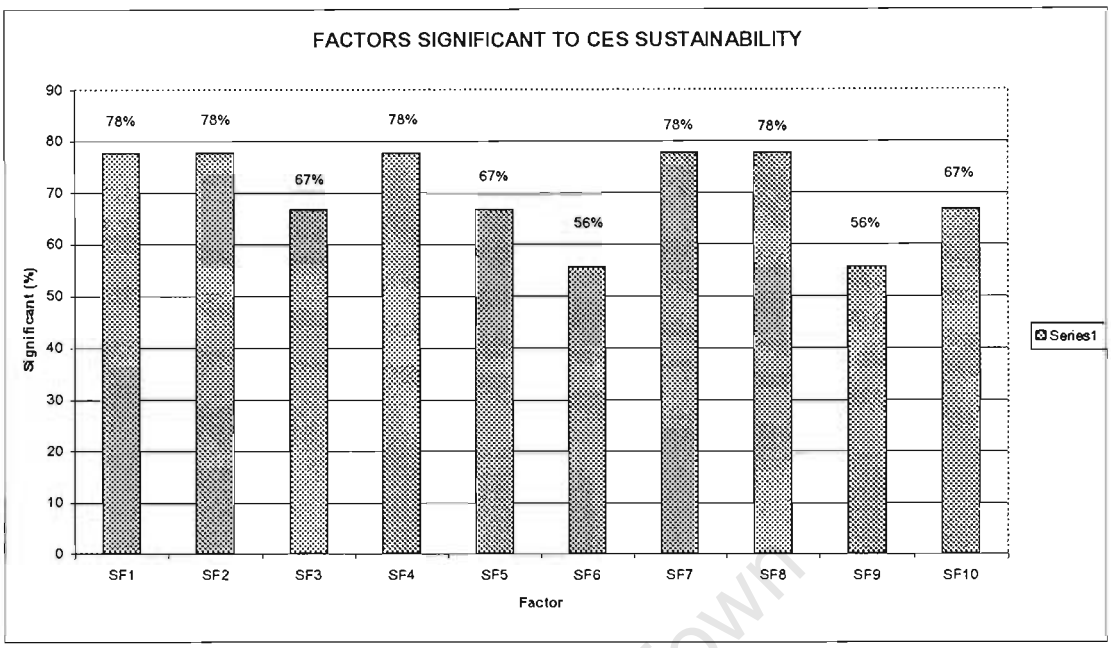


Figure 5.12: Factors Considered Significant to CES Sustainability

In order to evaluate the relative impact of each factor, CES personnel were requested to rate the proposed factors according to their perceived significance on CES sustainability. As with the rating of CES services described in Section 5.4.2, unanswered questions were regarded as missing data. The question produced ordinal data, therefore the medians and ranges of the respective services were computed. The descriptive statistics are given in Appendix D4, and the results illustrated in Figure 5.13.

It should be taken into account that these results are not conclusive, as the sample size consisted of only nine cases. Figure 5.13 indicates that all the proposed factors were generally considered to have a significant impact on CES sustainability. A comparison of Figures 5.12 and 5.13 shows a correspondence between adequate financial resources (**SF2**), management/strategic commitment (**SF4**) and performance of technical staff (**SF8**), as being highly significant to CES sustainability.

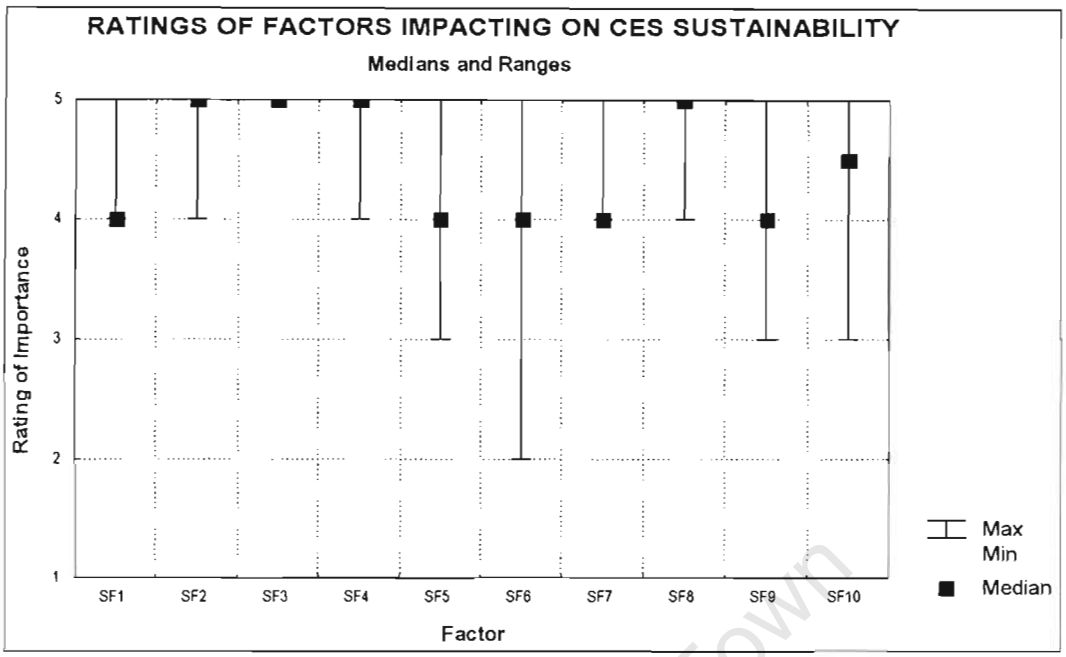


Figure 5.13: Ratings of Factors with Significant Impact on CES Sustainability

A further comparison can be made between Figures 5.12 and 5.13 and the themes emerging from the open-ended responses of institutional management, CES personnel and HTM experts in Tables 5.19 and 5.20. With the exception of the factors (i) legal framework (**SF6**) and (ii) logistic support (**SF7**), all the factors suggested by respondents in this section also are mentioned, thus signifying a stability of results.

5.9.4 Suggested Sustainability Indicators

Having identified CES sustainability factors, CES personnel were requested to suggest **indicators** of sustainability. Table 5.22 gives a list of indicators proposed by respondents.

Of the 'indicators' proposed in Table 5.22, most were a repetition of the sustainability factors mentioned in the previous question. Only indicators 9 – 11 were **quantifiable** but were essentially indicators that had been suggested for measuring **performance.**

Suggested Sustainability Indicators
1. Adequate financial support. 2. Sustainable, reliable management strategy. 3. Sufficient human resources. 4. Physical infrastructure. 5. Recognition and support of management/stakeholders. 6. Updated training programmes. 7. Policies to govern in-house CES's. 8. Logistics support (admin system or asset management system). 9. Cost of maintenance as % of replacement cost. 10. Turnaround time. 11. Up-to-date scheduled inspections.

Table 5.22: Suggested Sustainability Indicators

This indicated that either:

- the previous question had led respondents into giving those responses (response bias),
- the definition of an indicator was misunderstood,
- it is difficult to define or quantify sustainability indicators or
- it is difficult to differentiate between performance indicators and sustainability indicators.

5.10 MANAGEMENT TRENDS AFFECTING CES'S

Observations from the literature review indicated that CES's in recent years have been affected by international business management trends. One of the objectives of the questionnaire was to challenge these observations and to determine the extent to which these trends have affected CES's. Table 5.23 and Figure 5.14 illustrate the results from **QUEST2: Section 6.** Detailed frequency tables are given in Appendix D5. It should be noted that responses shown are not only from a small sample, but are also predominantly from CES's in South Africa at tertiary healthcare facilities in the public sector, and therefore not conclusive.

Figure 5.14 illustrates that, from the sample studied, CES's have been affected by Trends 1 – 4, with downsizing and outsourcing being the predominant themes.

Respondents were further asked to elaborate on **how** these trends have affected their CES's. This question was left open-ended and the responses given are summarised in Table 5.24.

TREND	Trend1	Trend2	Trend3	Trend4	Trend5	Trend6	Trend7
% CES not affected by trend	33	56	44	78	100	100	100
% CES affected by trend	67	44	56	22	0	0	0
TOTAL	100	100	100	100	100	100	100

where :

Trend1: Downsizing
Trend2: Economic rationalisation
Trend3: Outsourcing
Trend4: Total quality management
Trend5: Benchmarking
Trend6: Re-engineering
Trend7: Globalisation

Table 5.23: Management Trends Affecting CES's

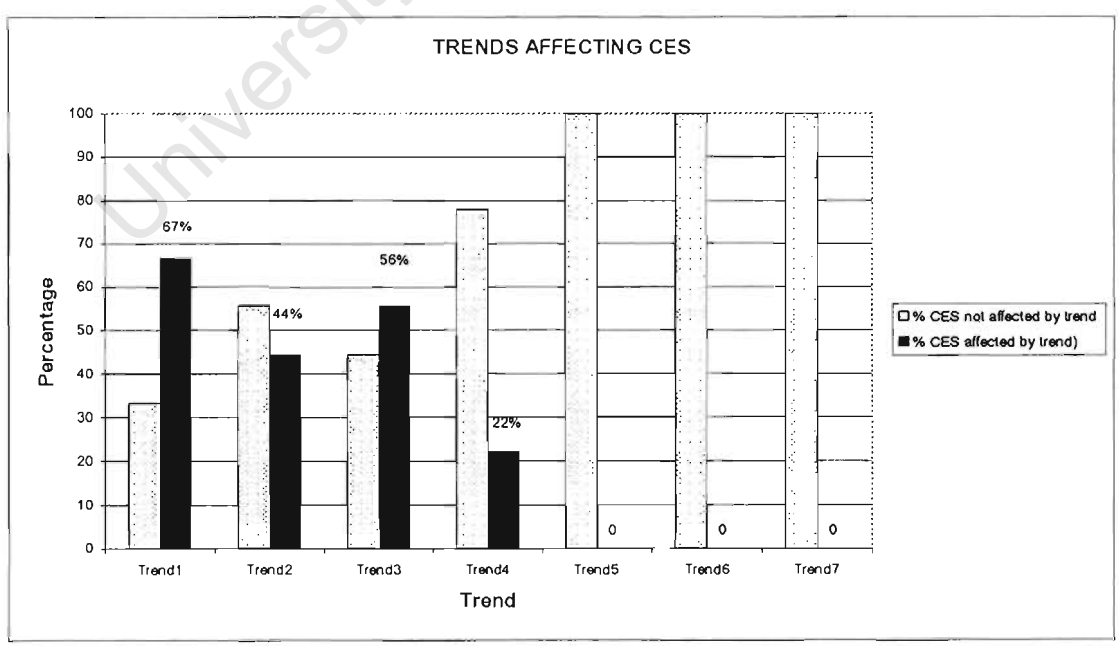


Figure 5.14: Trends Affecting CES's (Perceptions of CES Personnel)

Effect of Management Trends on CES's
Downsizing 1. Staff that resigned/retrenched not replaced - posts frozen and subsequently abolished . 2. Need for staff restructuring. 3. Negative impact on CES's ability to provide prompt, efficient and quality service. **Economic Rationalisation** 4. Inadequate financial resources for IPM and repair. 5. Inadequate equipment replacement budget – obsolete/old/non-functional equipment not replaced. 6. Mismanagement of finances. 7. Resignation of technical staff – joined private companies offering better packages. 8. Poor service from CES, poor performance of medical equipment. **Outsourcing** 9. All MEM&M and staff transferred to private companies. 10. Makes up for lack of in-house service.

Table 5.24: Effect of Management Trends on CES

5.11 FACTORS IMPACTING ON CES PERFORMANCE/SUSTAINABILITY

In Chapter 4, sections 4.1.3 and 4.10.2, the editing and short-listing of the initial long list of indicators was described. Many of the items that did not meet the requirements of a valid indicator (e.g. not quantitative) were still considered to have an impact on the performance and sustainability of CES's. In order to test this, items removed from the list of indicators were grouped under the heading of general **factors specific to CES function** and CES personnel were asked to indicate whether the items had a significant impact on performance or sustainability. These items are described in Table 5.25 and results of the survey illustrated in Table 5.26 and Figure 5.15. Detailed frequency tables can be found in Appendix D6.

General CES Performance/Sustainability Factors	
F1.	Presence of hospital-wide risk and safety management programme, specific to medical equipment
F2.	Presence of hospital-wide quality assurance programme, specific to medical equipment
F3.	Presence of a *hazard notification* system
F4.	Presence of *incident investigation* and reporting system
F5.	Adequate number of *test equipment* properly calibrated and functional per test equipment type
F6.	Adequate spare parts on site for common repairs

F7.	Availability of regular medical equipment training/re-training programmes
F8.	Availability of service manuals (from manufacturers) for all equipment serviced/maintained/repaired
F9.	Availability of operator/user manuals or instructions for all medical equipment
F10.	Availability of hospital-wide equipment inventory/asset register using consistent nomenclature
F11.	Availability of computerised and updated CES medical equipment inventory (including supported medical equipment, test equipment and spares) based on inventory of equipment supported (service, maintenance, user-related malfunctions, incidents) using consistent nomenclature
F12.	Management decisions (relating to needs assessment, procurement, decommissioning and replacement planning) based on inventory and CES equipment service histories
F13.	Client satisfaction surveys performed
F14.	Level of participation and communication by CES with stakeholders (i.e. hospital management, clinical staff, manufacturers/suppliers)
F15.	Accessibility of CES personnel outside normal working hours
F16.	Presence of criteria for inclusion or exclusion of medical devices/equipment into equip management programme
F17.	Presence of continuous quality improvement programme

Table 5.25: General CES Performance and Sustainability Factors

FACTOR	F1	F2	F3	F4	F5	F6	F7	F8	F9
% No	22	11	22	22	11	11	11	11	11
% Yes	56	78	44	44	67	89	78	89	78
% No Answer	22	11	33	33	22	0	11	0	11
TOTAL	100	100	100	100	100	100	100	100	100

FACTOR	F10	F11	F12	F13	F14	F15	F16	F17
% No	11	11	22	22	0	11	11	11
% Yes	67	78	56	44	78	67	44	56
% No Answer	22	11	22	33	22	22	44	33
TOTAL	100	100	100	100	100	100	100	100

Table 5.26: Percentages of Responses on Factors Impacting on Performance / Sustainability

Figure 5.15 illustrates that, while all these factors are considered to have an impact on CES performance and sustainability, certain factors have a more significant impact than others. Of particular significance are (i) **adequate spare parts** and (ii) **availability of service manuals**, followed by (iii) **presence of a Quality Assurance programme,** (iv) **regular medical equipment training (and re-training),** (v) **availability of user manuals,** (vi) **availability of computerised and updated CES medical equipment inventory** and (vii) **stakeholder participation**, which has been mentioned under sustainability factors.

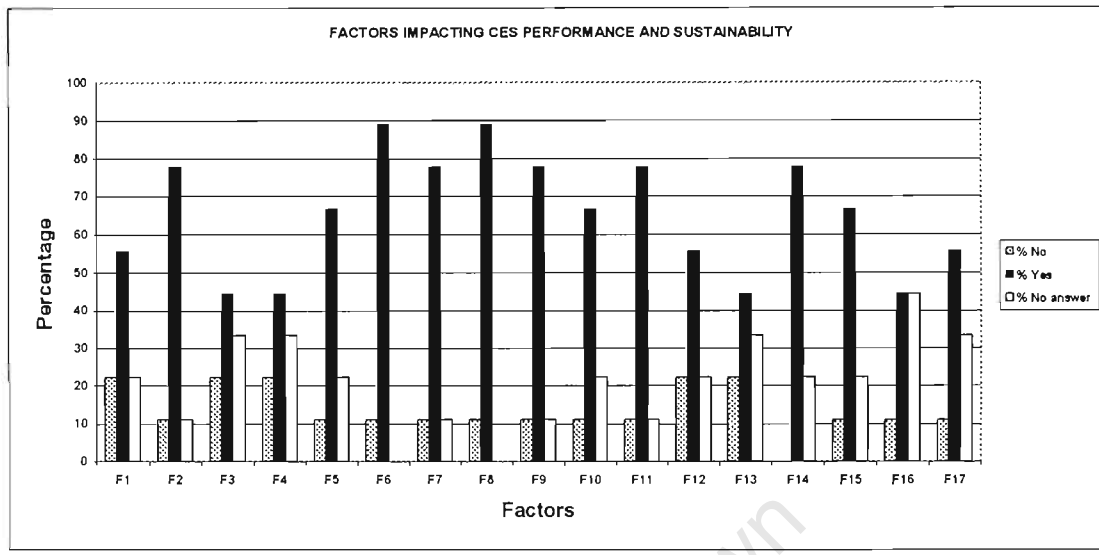


Figure 5.15: Percentages of Responses on Factors Impacting on Performance/Sustainability

5.12 PART 2: CLINICAL ENGINEERING SERVICE INDICATORS

The main objective of the study was to develop a set of comprehensive **key indicators** to describe the performance of clinical engineering, which can be used in assessing their sustainability. The methodology chapter describes the process involved in constructing a list of CES indicators, which respondents were required to rate (on a scale of **1– 5)** according to their perceived importance, or **0** if uncertain. Table 5.27 lists the proposed indicators, as described in the section 4.10.2 of the methodology.

	Final Indicator List
	Patient/Client-Related
1	Inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction
2	Patient (or operator) injury due to medical equipment malfunction or unavailability
3	Patient (or operator) injury due to medical equipment misapplication
4	Number of equipment malfunctions caused by user error/misuse or abuse
5	Type and number of medical equipment supported by CES
6	Percentage of medical equipment supported by CES that is *functional*
	Performance/Personnel
7	*Productivity* (ratio of outputs to inputs)

8	Competencies/skills of CES personnel
9	*Certification* and registration of CES personnel/ department with appropriate professional body
10	Evidence of continuing education/ professional development of CES personnel
11	Relative number of different categories of CES personnel (i.e. engineers, technicians, artisans etc.)
12	Absenteeism of CES personnel
13	CES staff levels per number of beds
14	CES staff levels per number of medical devices
15	Working space (m^2) per technical CES staff
16	Salaries and career paths of CES technical staff vs. other healthcare workers
17	Salaries and career paths of CES technical staff vs. similar employees in competing sector (public/private)
	Cost-effectiveness
18	Allocated CES budget per year (as a percentage of the supported equipment inventory value)
19	Cost (*labour and overhead)* per hour per CES employee
20	Cost of CES service per bed supported
21	Cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type
22	Cost of in-house service vs. cost of outsourced service per equipment type
23	Inventory of spare parts per equipment value supported
	CES Activities
24	*Response time* to service requests
25	Percentage of time devoted to IPMs vs. repairs
26	Total number of IPMs/repairs performed per device type per year
27	*Downtime* of equipment due to IPMs/repairs
28	Degree of compliance that has been achieved with the established schedule for routine IPMs/repairs
29	Percentage of IPMs/repairs performed in-house vs. outsourced
30	Percentage and type of outsourced equipment IPMs/repairs checked by in-house CES before returning to clinical environment
31	Percentage of repeat repairs
32	IPMs/repairs conducted in accordance with manufacturer's recommendations, as specified in service manuals
33	Evidence of proper documentation of all work done by CES (e.g. service histories), providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc

Table 5.27: Final Indicator Shortlist

As the data produced was ordinal, medians and ranges were computed. Indicators rated as **0** were excluded from the analysis. Detailed descriptive statistics from all four groups can be found in Appendix D7 and the results illustrated in Figure 5.16.

The graph shows that most of the indicators proposed were considered to be important as they tended to be rated in the upper two extremes (or else **0** if respondents were uncertain). This can be explained by the fact that the list had already been short-listed according to the criteria described in the methodology. An added factor, of course, was the relatively small sample size of $n = 30$.

Seven indicators, however, were found to be **essential** to the clinical engineering function, all scoring a median of **5**. These are listed in order of increasing range (i.e. maximum rating – minimum rating) shown in Appendix D7, as follows:

i. cost of in-house service vs. cost of outsourced service per equipment type (indic_22);
ii. response time to service requests (indic_24)
iii. inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction (indic_1);
iv. competencies/skills of CES personnel (indic_8);
v. patient (or operator) injury due to medical equipment malfunction or unavailability (indic_2);
vi. patient (or) operator injury due to medical equipment misapplication (indic_3);
vii. allocated CES budget per year as a percentage of supported equipment inventory value (indic_18).

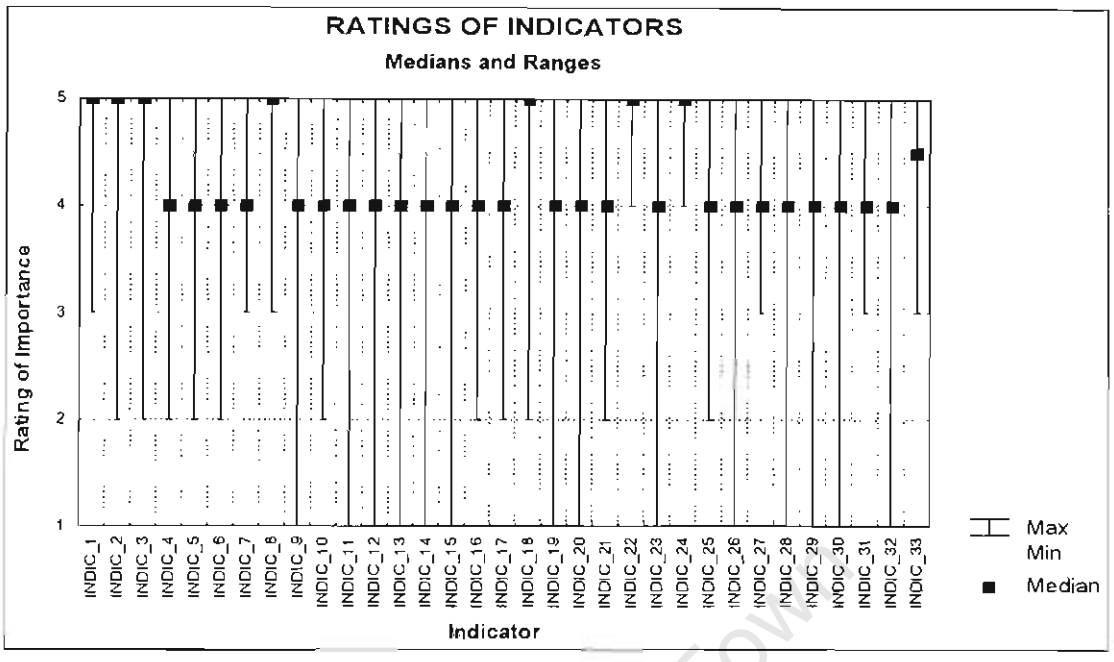


Figure 5.16: Composite Indicator Ratings: Medians and Ranges (indicators as listed in Table 5.27)

Also considered to be of very high importance, with a median of **4.5**, was:

viii. evidence of proper documentation of all work done by CES, providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs, etc (indic_33).

Three more indicators that were considered important, scoring a median rating of **4** with a relatively low range of 2, were:

ix. productivity (indic_7)

x. downtime of equipment due to IPMs or repairs (indic_27)

xi. percentage of repeat repairs (indic_31).

A comparison of the rated indicators against Table 5.17, shows a correspondence between performance indicators suggested by respondents and indic_7, indic_18, indic_24, indic_27 and indic_31, respectively.

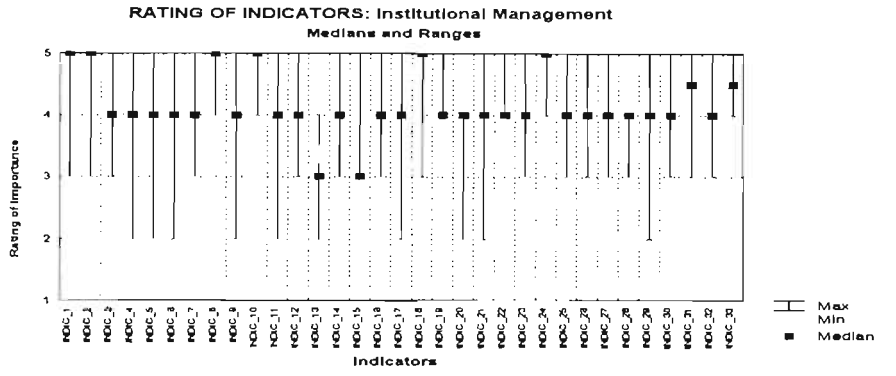
As with the ratings of CES services, the number of cases (*n*) was too small to compute cross-tabulations between target groups and indicator ratings. However, Figure 5.17 gives a graphical illustration of these differences. Detailed descriptive statistics can be found in Appendix D8.

A comparison between the first three target groups shows that institutional management's and CES client's opinions on **essential** indicators were basically those identified from the combined analysis. Differences can be seen between institutional management and CES personnel respectively, versus CES clients, who considered **degree of compliance that has been achieved with the established schedule for routine IPMs/repairs** (indic_28) to be an essential indicator. CES personnel and clients also considered **IPMs/repairs conducted in accordance with manufacturer's recommendations** (indic_32) to be essential. This can be explained that the two groups have direct contact with the medical equipment, unlike institutional management.

Further differences in opinion can be seen between CES personnel and the other two groups. CES personnel considered the following indicators to be essential:

i. number of equipment malfunctions caused by user error/misuse or abuse (indic_4)
ii. salaries and career paths of CES technical staff vs. other healthcare workers (indic_16)
iii. salaries and career paths of CES technical staff vs. similar employees in competing sector (public/private) (indic_17)
iv. cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type (indic_21).

These results correspond with earlier results indicating the factors hindering CES sustainability.



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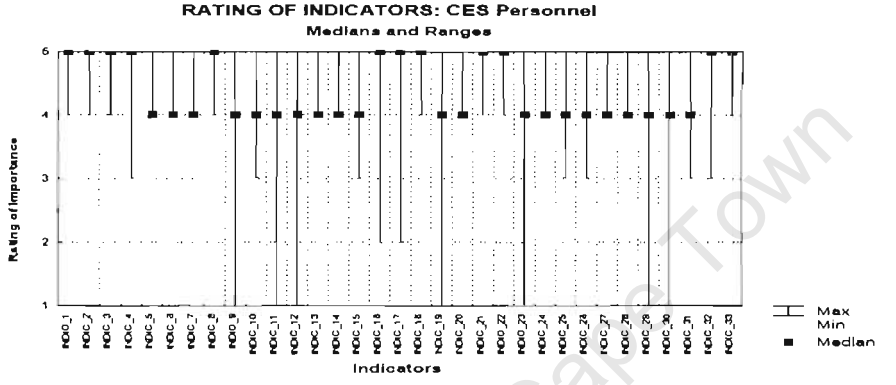

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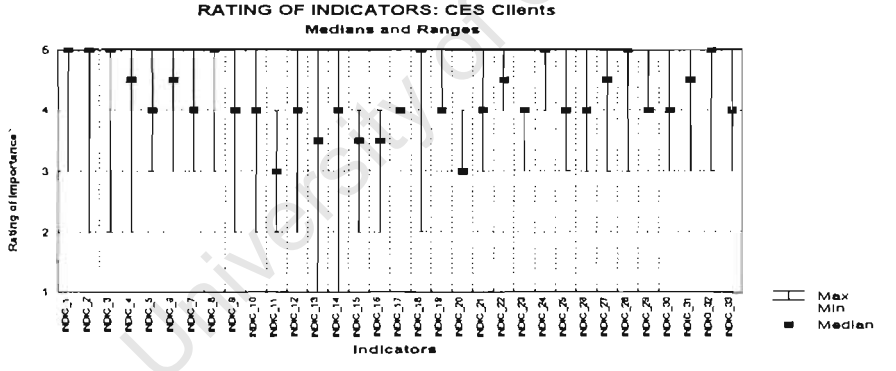

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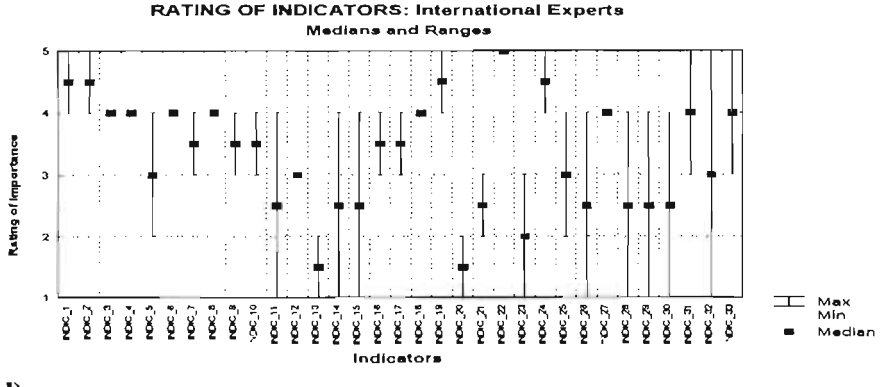

d)

Figure 5.17: Indicator Ratings for the Separate Groups (see Appendix D8)

Chapter 5 presented results from the questionnaires distributed to the target groups. The following chapter collates these results and discusses them in context of the objectives of the research and the relevant literature.

6 GENERAL DISCUSSION

The questionnaires designed for this study produced a substantial amount of information regarding the Clinical Engineering Service function and general opinions of relevant stakeholders. An examination of the results presented in the preceding chapter reveals a fair number of recurring themes emerging from the different questions. This chapter draws these themes together and thus illustrates the significant findings of the study – particularly in the context of the literature review. The chapter subsequently evaluates the questionnaires themselves and discusses their effectiveness in meeting the research objectives. Finally, the limitations and delimitations of the study are presented.

6.1 REVISITING THE OBJECTIVES OF THE QUESTIONNAIRES

Phase One of the methodology (Section 3.5) defined objectives for the questionnaires, which were to be used in developing suitable measures for the performance and sustainability of clinical engineering departments.

It should be noted that it was not an objective of the questionnaire(s) to measure the performance and sustainability of clinical engineering departments. The aim was to develop the measures to be used, by drawing on the professional opinions of clinical engineering personnel, their clients, employers, international HTM experts and representatives of Departments of Health.

6.2 SIGNIFICANT FINDINGS FROM THE SURVEY

Specific findings from each section of the questionnaires were presented in the preceding chapter. The following section draws together common themes arising from the analysis of the questionnaire and discusses them in light of the research objectives and literature.

6.2.1 Links between CES Mission and Function, Expectations of Stakeholders and the Impact of CES's on Healthcare Service Delivery

Figure 6.1 shows how an appropriate mission statement and knowledge of client expectations, achieved via the provision of essential CES services, impact positively on the performance of healthcare institutions.

Although more than 50% of the respondents were not aware of the existence of a documented CES mission statement, analysis of various sections of the questionnaires revealed a common thread between proposed mission statements, expectations of stakeholders and perceived CES 'quality of service'. Six dominant themes emerged, which are illustrated in Figure 6.1. Through a set of structured questions, the four target groups rated CES services according to their perceived importance to healthcare institutions. Six services - also illustrated in Figure 6.1 - were found to be essential to the CES function.

A comparison of the essential services against the aforementioned themes shows a definite correlation. For example, the first requirement, viz. playing a supportive role (to clinical staff and institutional management) in improving healthcare delivery, can be achieved through two CES services, namely (i) strategic technology assessment and planning and (ii) specification, evaluation and procurement. Similarly, IPMs, corrective maintenance and functional/calibration and safety checks help to ensure optimum performance of medical equipment.

Further questioning on the impact of CES's on healthcare service delivery revealed that - provided CES's have sufficient resources and are well-managed - they play an important role by enhancing service delivery, which is highly dependent on functional medical equipment. In order to successfully enhance the healthcare function, CES's have to fulfil the requirements laid out by the mission statement and client expectations.

Although 23% of the respondents felt that 'core' functions of healthcare are restricted to clinical service and patient care, 77% cited that medical equipment is

a vital component of the healthcare delivery package and thus the CES function can be considered as a 'core' health care service.

A review of the literature shows that the conclusions derived from these questions support the views of Issakov (1994) and David (1993) on the role of clinical engineering in healthcare. According to Issakov, medical equipment represents an important investment for healthcare systems in any country. He further adds that the appropriate introduction and proper service, maintenance and use of this equipment are vital for efficient and cost-effective healthcare delivery – at all levels of the health system. David lists objectives of a well-managed clinical engineering programme, which include reducing operating costs, reducing risk exposure and meeting or exceeding standards of care. These correspond with the themes illustrated in Figure 6.1.

In defining the inputs of an effective performance system, Chang and Morgan (2000) state that measures (or indicators) should be aligned with customer's needs and expectations, mission and strategy and the processes for achieving objectives and serving customers. These requirements are further supported by Brinkerhoff & Dressler (1990) and Christopher & Thor (1993). This first step to developing effective performance measures for the clinical engineering function is addressed by the first four objectives of the questionnaires, as listed in Section 6.1. These objectives are fulfilled by the results illustrated in Figure 6.1.

6.2.2 Advantages of an In-house CES

The literature review states that there have traditionally been three methods for providing medical equipment service, namely: (i) in-house or shared CES, (ii) suppliers/manufacturers and (iii) third-party operators. Institutional managements are constantly faced with the task of deciding upon the most appropriate service option for their healthcare facility. According to ECRI (1989) each service modality has particular advantages and disadvantages, all of which must be considered.

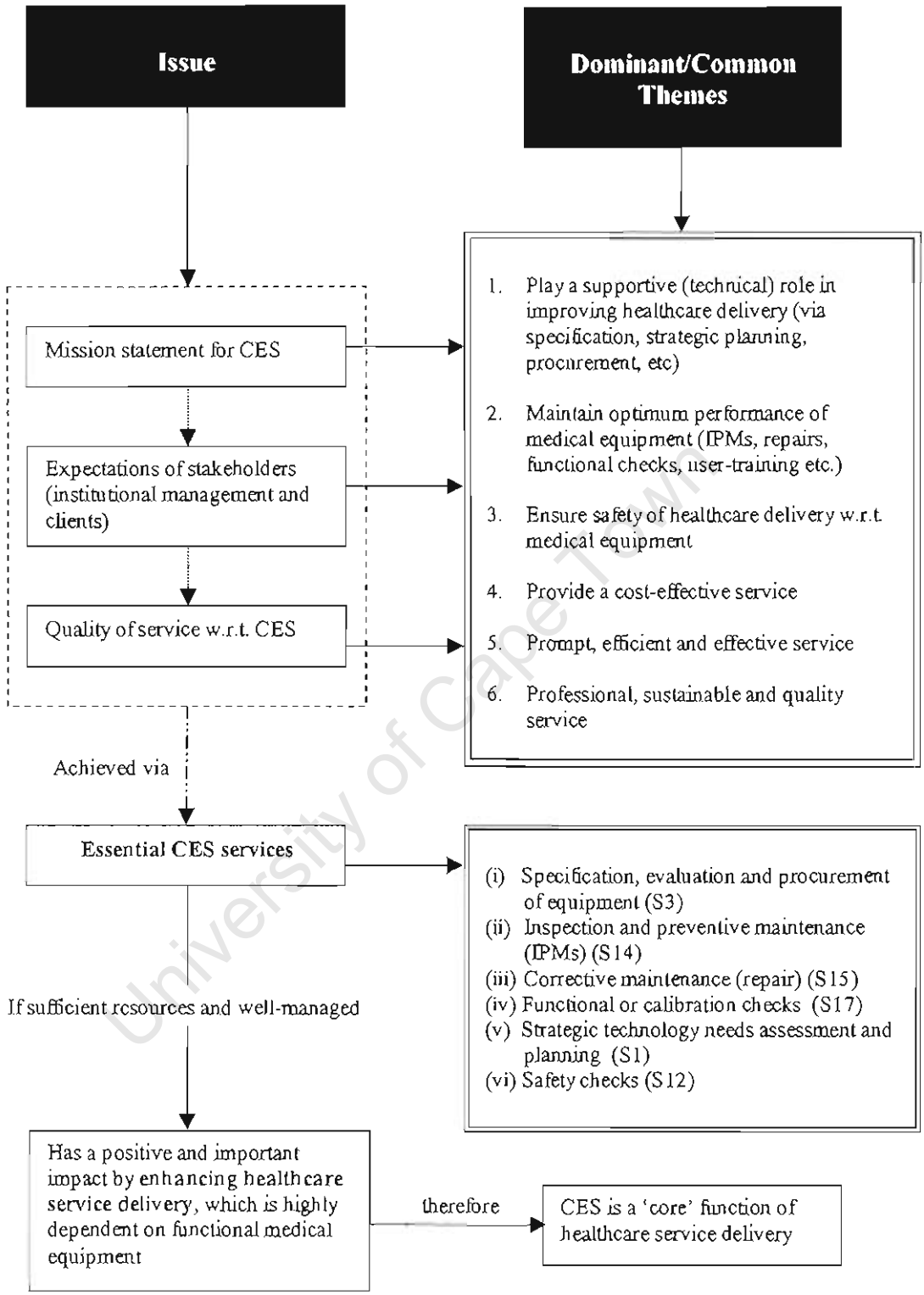

Figure 6.1: Links between CES Mission and Function, Expectations of Stakeholders and Impact on Healthcare Service Delivery

With the recent trends in outsourcing threatening the existence of in-house CES's, the questionnaires sought to determine the perceptions of all the target groups on the advantages and disadvantages of in-house CES's. This issue was addressed by two questions, (i) specifically for the advantages and disadvantages of in-house CES's over outsourcing and (ii) more subtly, the implications of not having an in-house CES. Similar themes emerged from both questions, thus indicating a stability of results. These themes are summarised in Figure 6.2.

These results corroborate with the advantages of in-house CES's specified by ECRI (1989). These are, as stated in the literature review: (i) the immediate availability of the service, (ii) cost containment, (iii) the facilitation of other aspects of equipment support (e.g. user training) and (iv) the fact that in-house personnel can provide expertise on a broad range of equipment and technology management issues.

CES personnel were also asked what impact their CES had on the performance of their respective healthcare facilities and cited similar elements to those listed in Figure 6.2. The literature review states that while many CES's in the developed world were being closed in the mid- to late- 1990's, this situation is now reversing (Locke, 1998). The advantages of in-house CES's identified from this survey support reasons for the reversal of this trend. These results fulfil Objective 4 of the questionnaires, which sought to establish a general consensus on the importance of in-house CES's to healthcare institutions.

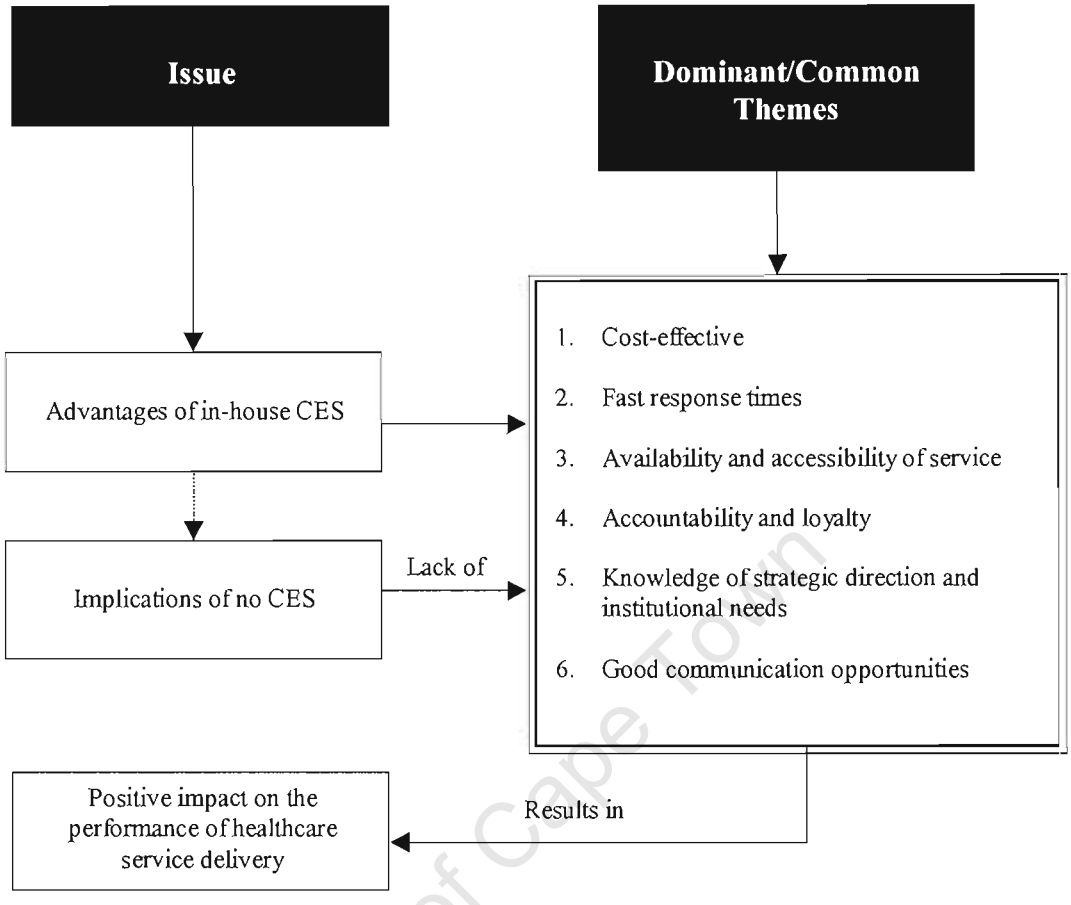

Figure 6.2: Advantages of In-house CES

6.2.3 Sustainability of Clinical Engineering Services

Having established that the function of an in-house clinical engineering service is important in supporting healthcare service delivery - with significant advantages over outsourced services - the questionnaires sought to identify institutional, organisational and socio-political factors that contribute to the **sustainability** of CES's. A comparison between (a) open-ended questions posed to institutional management, CES personnel and HTM experts against (b) a structured question posed only to CES personnel, listing health systems sustainability factors proposed by WHO (1998), yielded similar results. These are illustrated in Figure 6.3.

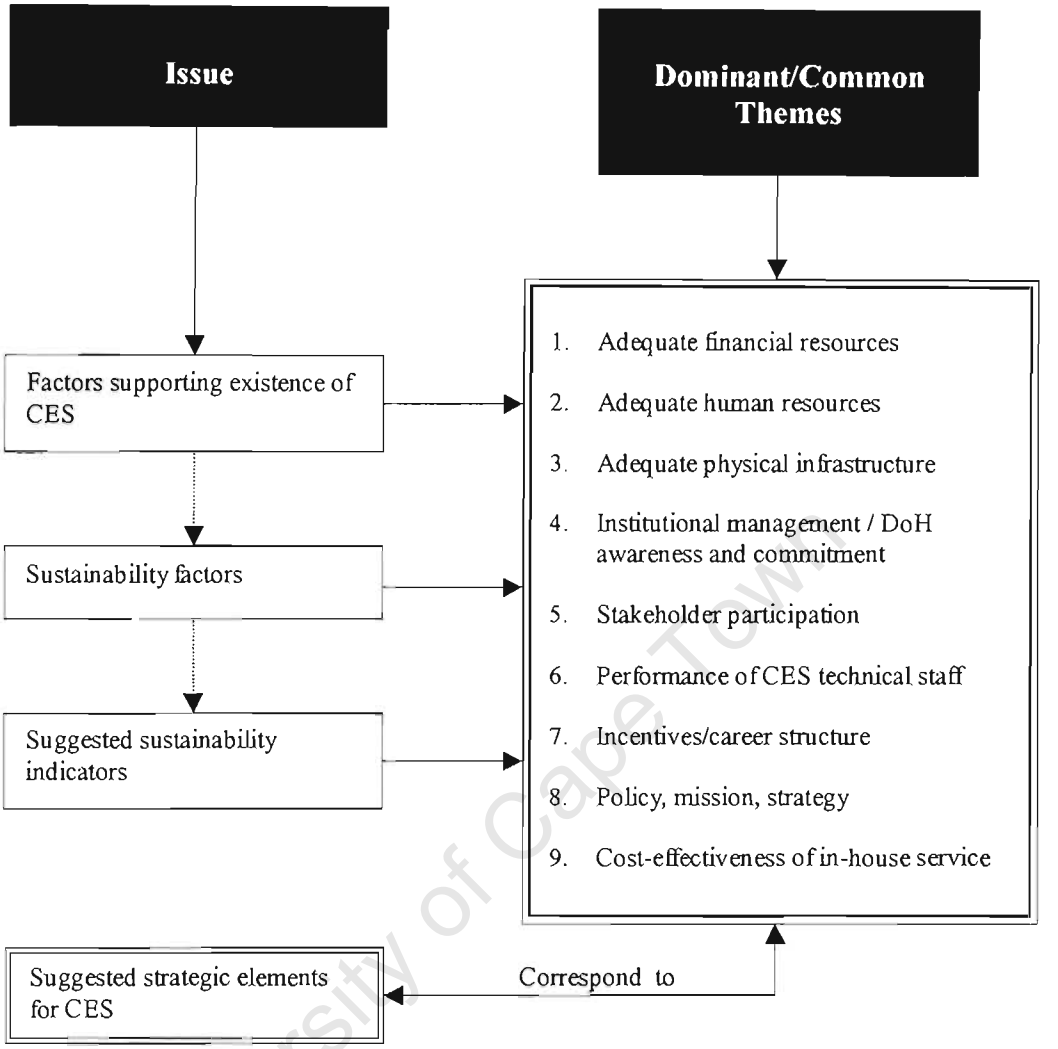

Figure 6.3: Sustainability of Clinical Engineering Services

While the majority of the 22 respondents (64%) were not aware of the existence of a strategic plan for their respective CES's, they were able to suggest suitable elements in such a plan. A comparison of these strategic elements with the sustainability factors indicated in Figure 6.3 shows a strong correlation between them. This suggests that the existence of an appropriate CES strategy, communicated to all relevant stakeholders, is an essential step in ensuring the sustainability of CES's. Once again this corresponds with the views of Chang & Morgan (2000) and Christopher (1993) concerning effective measurement systems, as described in Section 6.2.1.

6.2.4 Factors Hindering CES Sustainability

While both the literature and this survey have shown that there are definite advantages of in-house CES's, many are still under the threat of closure. The questionnaires sought to determine the factors that contribute to this threat. The previous sub-section identified factors supporting the sustainability of CES's. The various questions on both (a) factors hindering CES sustainability and (b) the disadvantages of in-house CES's, yielded results that were basically a negation of the support factors, which is to be expected.

A further link was established between these hindering factors and reasons, cited by institutional management and CES clients, as to why their expectations of CES's were not met. This is illustrated in Figure 6.4 and indicates that the failings of in-house CES's, more often than not, originate at an institutional level or even at the level of policy makers and Departments of Health. This could simply be due to lack of awareness and understanding of the CES function, or due to lack of commitment and political will.

These disadvantages and hindering factors were thus found to pull decision-makers in the direction of certain management trends – and in particular **outsourcing.** While this study does not purport to establish the effects (whether positive or negative) of outsourcing CES functions, reasons given by CES personnel about the advantages of outsourcing were found to correspond with the themes presented in Figure 6.4.

Gay (2000) lists benefits derived from outsourcing, which include: less need for capital investment, focus on core services, reduction in the headcount of the organisation and access to expertise – all of which are applicable to healthcare facilities and correspond to findings from this study. However, citing from the results of a major international study, the author subsequently states that outsourcing does not always achieve the anticipated benefits. Reasons for this vary, but include: an overall reduction in the quality of a function previously

managed in-house, failure to achieve expected cost reductions and failure to develop a true collaborative relationship with the service provider(s).

Apart from outsourcing, the study revealed that CES's, from this sample, had been affected by downsizing and economic rationalisation – both of which were included in the list of management trends affecting CES's in recent years. It can be concluded that these trends were inflicted as a result of hindering factors identified in Figure 6.4. Equally, the introduction of these trends exacerbates the problems faced by CES's – resulting in a catch-22 situation. This suggests that cost-benefit analyses, as part of formal option appraisal, would be useful in identifying those options that are beneficial to the healthcare system in the long-run. As indicated in the literature review, long-term consequences of eradicating CES activities are often not taken into consideration.

While data representative of the international situation was not realised, a review of sub-sections 6.2.3 and 6.2.4 indicates that Objectives 5 and 6 of the questionnaires have been met.

6.2.5 CES Performance/Sustainability 'Enabling' Factors

Sub-sections 6.2.1 to 6.2.4 discuss the major findings of Part One – the qualitative section – of the questionnaires. Although there are significant advantages of in-house CES's, and the results indicate that they are generally perceived as playing an important role in healthcare service delivery – the sustainability of CES's is still being threatened.

The development of Part Two of the survey, as described in the methodology chapter, describes the criteria for including proposed indicators into the final list presented in the questionnaires. It further mentions that suggested indicators, collated from the literature review and current practice, that did not fulfil the requirements of valid indicators (Neely *et al.*) were either discarded, or if considered relevant to CES performance and sustainability, incorporated into a

list of 'enabling' factors. The term 'enabling' is used to describe factors, specific to the CES function, that support the indicators identified

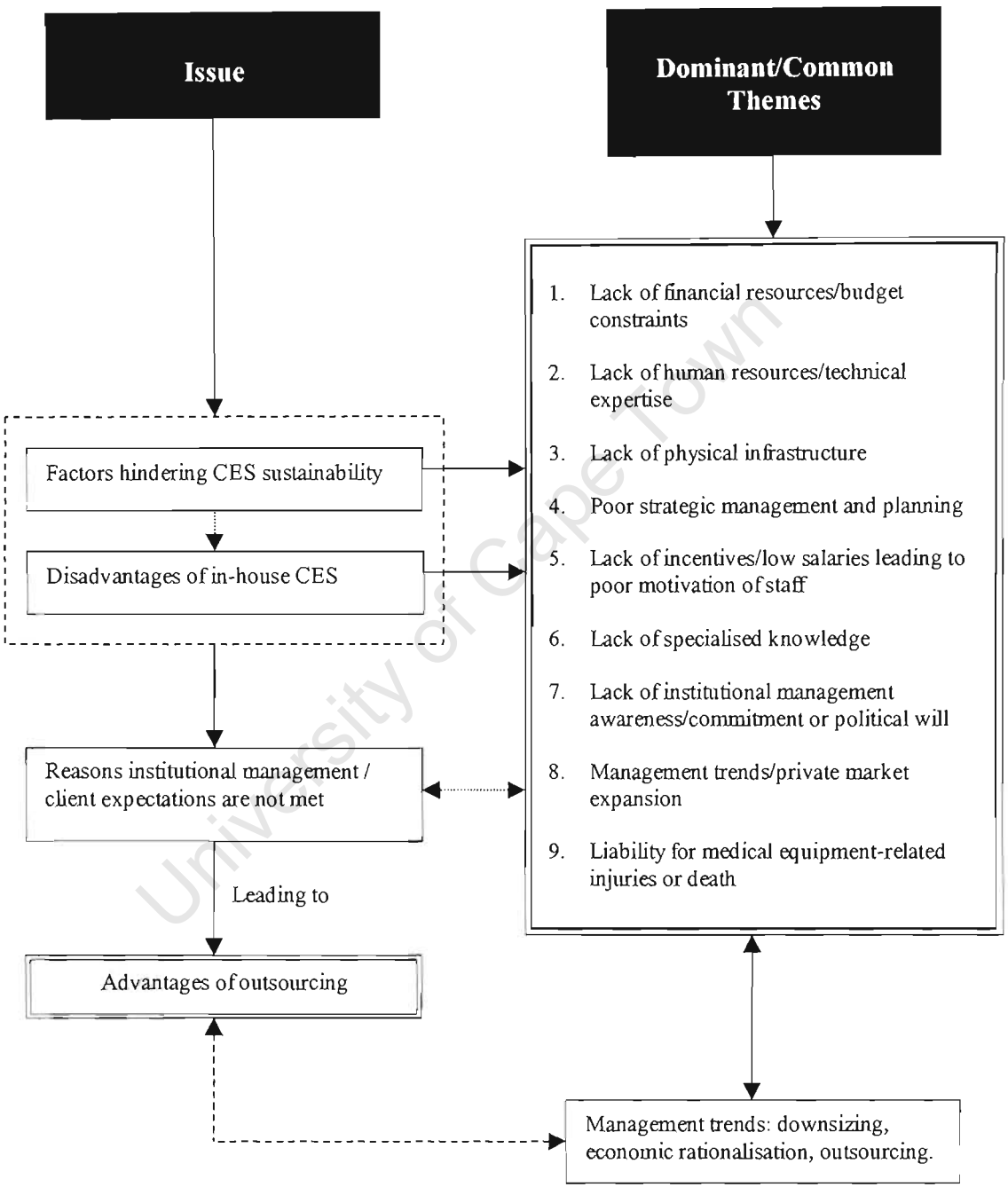

Figure 6.4: Factors Hindering CES Sustainability

Factors found to have a significant impact on CES performance and sustainability were:

i. Adequate spare parts on site for common repairs.
ii. Availability of service manuals (from manufacturers) for all equipment serviced/maintained/repaired.
iii. Presence of a hospital-wide Quality Assurance programme, specific to medical equipment.
iv. Availability of regular medical equipment training and re-training programmes (both to users and technical staff).
v. Availability of operator/user manuals or instructions for all medical equipment.
vi. Availability of computerised and updated CES medical equipment inventory.
vii. Level of participation and communication by CES with stakeholders.

Although the above factors do not fulfil the definition of an indicator *per se*, their presence or absence could have a profound effect on the performance or sustainability of an in-house clinical engineering service.

6.2.6 CES Performance Indicators

According to WHO (1998) there is a need to define the role of physical infrastructure and technology – closely related to the CES function – in the development of **sustainable** health systems. This entails providing **quantitative evidence** of CES's impact on performance of health systems and services in terms of **access, quality, cost-effectiveness, organisational effectiveness** and **health outcomes.** Drawing on the literature and results of the survey, there is thus a need to identify critical and universal performance indicators for CES's in order to:

- develop measures to assess performance and enhance internal quality improvement efforts;

- generate performance information to assist client and institutional management decision-making;
- benchmark performance or quality against other CES's and competition, and
- justify the existence of in-house clinical engineering services.

The development of a methodology to identify CES performance indicators should be translated into a practical guide for decision-making.

The literature review (section 2.9) describes the criteria and components required to develop an effective performance measurement system. These have been tried and tested in various disciplines and are considered essential for the survival of organisations. They are also of great benefit in effective management of change. According to Autio & Morris (1995), clinical engineering services are no exception to this rule. Although quality assurance/performance indicators have been suggested for CES's, a systematic methodology for identifying **essential** and **standardised** indicators has not been developed.

Such a framework – drawing on the various methods described in the literature – has been developed and is illustrated in Figure 6.5. The various components of this framework have been addressed in the preceding sections. The methodology entails (i) identifying basic mission and strategic elements of CES's; (ii) establishing client expectations and perceptions; and (iii) identifying the major functions of the CES, plus the services that fulfil the mission and client expectations. These are integrated and used to identify/develop essential CES performance indicators, taking into account the various factors that impact on them. The indicators identified can be used to assess CES performance, contribute to major decision-making, and thus point towards CES sustainability.

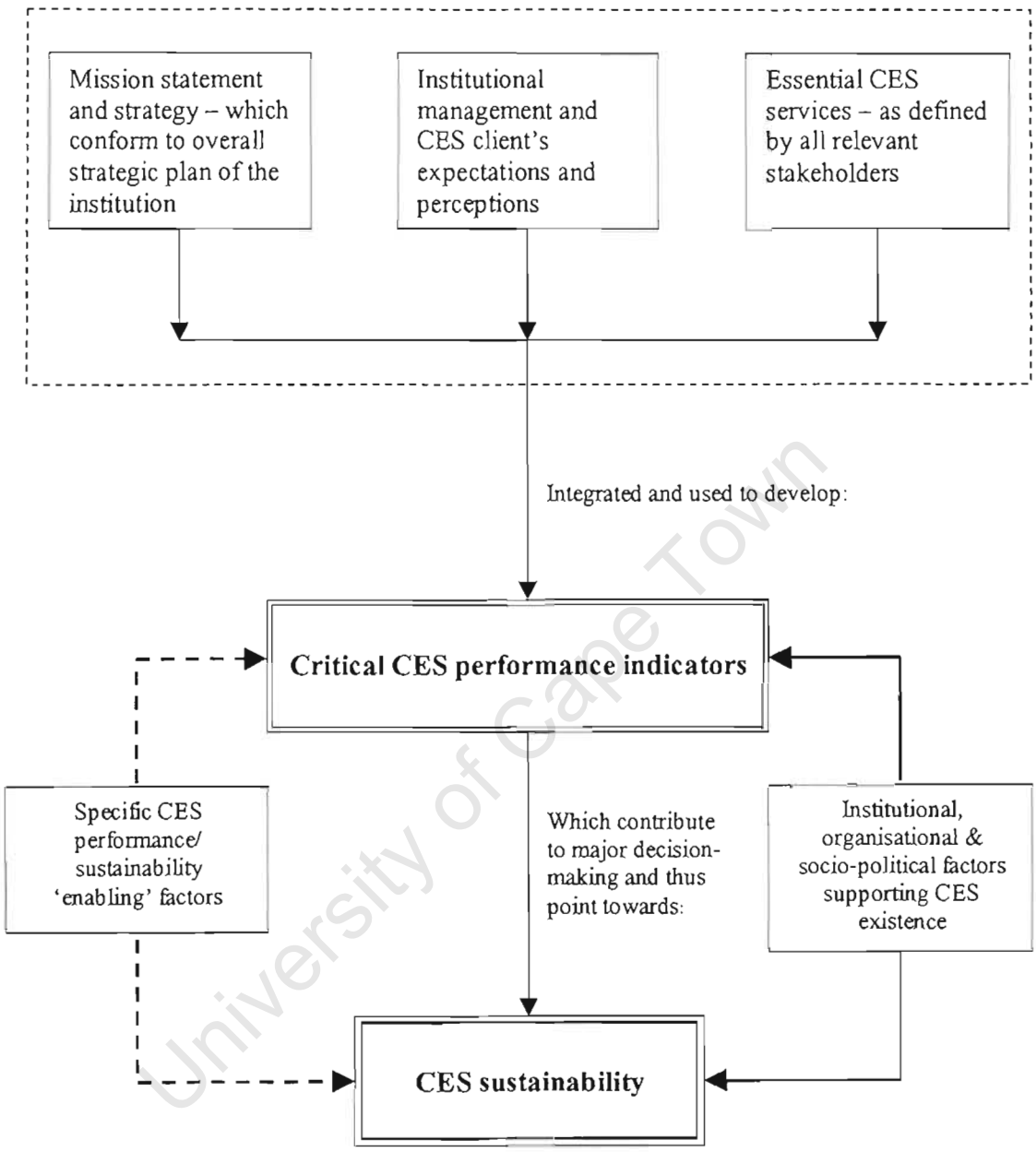

Figure 6.5: Framework for Developing CES Performance and Sustainability Indicators

The methodology chapter describes the process involved in short-listing the final list of indicators presented to respondents in the questionnaires. Analysis of Part Two of the survey revealed that the sample considered most of the proposed indicators to be important. However a group of **7 essential** indicators was identified, plus **4** indicators of **very high importance**.

The essential indicators identified by all four target groups were:

i. cost of in-house service vs. cost of outsourced service per equipment type
ii. response time to service requests
iii. inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction (% of total no. clinical procedures)
iv. competencies/skills of CES personnel (assessed via level of education & evidence of continuing education)
v. patient (or operator) injury due to medical equipment malfunction or unavailability (number of incidents)
vi. patient (or) operator injury due to medical equipment misapplication
vii. allocated CES budget per year as a percentage of supported equipment inventory value

plus the following very important indicator:

viii. evidence of proper documentation of all work done by CES, providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs, etc.

Three more indicators that were considered important, scoring a median rating of **4** with a relatively low range of 2, were:

ix. productivity
x. downtime of equipment due to PMs or repairs

xi. percentage of repeat repairs.

These three indicators, plus the essential indicator 'response time to service requests', formed part of the list of indicators suggested by respondents in Part One of the questionnaires.

Determining the correlation between the listed indicators and the various components of the framework, illustrated in Figure 6.5, is beyond the scope of this study. However, a comparison of each of the eleven indicators against the themes identified in Figure 6.1 and Figure 6.2 shows a correspondence between them. Two examples illustrate this:

1. The indicator 'cost of in-house service vs. cost of outsourced service, per equipment type' is a measure of the 'cost-effectiveness' of the essential services, specified by the suggested mission statement elements and the expectations of stakeholders. These are supported by factors such as 'adequate financial resources' and 'adequate spare parts'.
2. The indicator 'inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction' measures the CES's ability to 'play a supportive (technical) role in improving healthcare delivery', by such services as 'IPMs and functional/calibration checks'. Factors supporting this include: 'stakeholder participation/ communication', 'adequate human resources' and 'availability of user manuals'.

Comparisons between the ratings of the individual groups showed some differences in opinion. Of particular interest were indicators that CES personnel found to be essential. These were:

i. number of equipment malfunctions caused by user error/misuse or abuse
ii. salaries and career paths of CES technical staff vs. other healthcare workers

iii. salaries and career paths of CES technical staff vs. similar employees in competing sector (public/private)

iv. cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type.

These indicators correspond with earlier results (section 5.9) indicating the factors supporting/hindering CES sustainability (e.g. lack of incentives/low salaries leading to poor motivation of staff).

Objective 7 of the questionnaire was to develop a set of standardised key indicators to be used in assessing Clinical Engineering Services. Although results from this section are not universal, they reflect the needs of the sample and health facilities studied. The framework can thus be extended to the international community to establish standardised indicators and thus fulfil this objective.

6.3 EVALUATION OF THE QUESTIONNAIRES

Phase One of the methodology describes the rationale behind using a survey – specifically self-administered questionnaires - to answer the research question. Specific objectives for the questionnaire(s) were defined and target respondents identified, namely, (i) institutional management, (ii) CES personnel, (iii) CES clients and (iv) HTM experts and representatives of Departments of Health. A preliminary questionnaire was developed and administered to a small sample of respondents, consisting of all groups except CES clients. Although the topics addressed in this questionnaire were found to be relevant, the instrument was found to be ineffective.

Phase Two of the methodology describes the process of developing the final instrument, which consisted of four different questionnaires, targeted at each of the respondent categories. The previous chapter describes the results obtained from these questionnaires, while the preceding section discusses them in the context of the objectives and the literature review. While the questionnaires were successful in meeting their objectives, their effectiveness as a valid instrument needs to be assessed.

6.3.1 Length of the Questionnaires

While all efforts were made to reduce the length of the questionnaires - following comments from the preliminary questionnaire and analysis of responses from the trial 'pilot' run – all the questionnaires were considerably long. This was probably a major contributor towards the – especially from respondents outside South Africa. A contributing factor to the length of Part One was the repetition of some questions (by rephrasing), in an effort to test the reliability and validity of responses. Having established general stability in the answers provided by respondents, redundant questions could be eliminated from the questionnaires.

The cover letter (as well as instructions at the beginning of each section) specified that respondents had the option of omitting questions that they were unable to

answer in the qualitative section. This resulted in a fair amount of item non-response in Part One. However – as requested in the cover letter and instructions to Part Two – generally respondents rated all the indicators listed. This was supported by the fact that there was an 'I don't know' option included. The inclusion of this option was deemed necessary because some indicators were more specific to one target group and not the others.

Expert consultation suggested that the 2-page cover letter in itself was too long, as respondents were forced to read through a substantial amount of background text, before specific reference to the questionnaires was given. The cover letter was subsequently reduced to a single page, with the contextual background being added as an Appendix. The revised letter can be found in Appendix E.

CES personnel were found to be the most reluctant to answer questionnaires or to provide answers to the open-ended questions. Whether this was a function of questionnaire length (the CES personnel questionnaire was the longest) or lack of motivation due to factors hindering CES sustainability as indicated earlier (e.g. lack of human resources, lack of incentives and institutional management commitment) should be established.

Specific methods for increasing the response rate, e.g. providing incentives or constant reminders, were not used due to logistical reasons and time constraints. However, the thirty responses received were considered to be sufficient for a pilot study and testing the framework.

6.3.2 Instrumentation Bias

A fair amount of item non-response from the structured questions in Part One revealed some patterns, which suggested some level of instrumentation bias[1]. The following problems were encountered:

[1] **Instrumentation bias:** Errors in the instrument due to instructions, questions, scales or response options.

a. Service Provided by Clinical Engineering Service

This topic was addressed in **QUEST1: Section 3.1, QUEST2: Section 3.1** and **QUEST3: Section 2.1.**

In sub-section **3.1 a)** respondents were asked, to the best of their knowledge, which medical equipment maintenance and management services their CES's provided. A 29% item non-response, specifically from institutional management and CES clients, suggested that these two groups were not fully aware of the services provided by their respective CES's, and therefore could not answer the question. Thus, the results obtained from this question did not reflect a true picture of the spectrum of CES services provided, but perceptions of the services provided. This could have been rectified only by analysing the results of CES personnel. However, lack of stakeholder awareness/ commitment was cited as being an important factor hindering CES sustainability, suggesting that in-house CES's have to market their services more effectively.

Sub-section **3.1 b)** required respondents to rate **all** the CES services listed, according to their perceived importance to their healthcare facility. 39% of respondents – particularly CES personnel – only rated services that were offered by their CES's. This suggested that either the instructions were misunderstood, or it was an onerous task to answer two separate questions on the same table. Services not rated were treated as missing data in the analysis, using the STATISTICA (version 5.5) option of 'pairwise deletion of missing data'[2], as opposed to excluding all cases with missing data ('casewise deletion of missing data'). To rectify this, all the services could have been listed again for part **b)** of this section, or the layout could be modified – as shown in the revised electronic version of the questionnaires (Appendix E).

[2] **Pairwise deletion of missing data:** When this option is selected, cases are excluded from any calculations involving variables for which they have missing data. All valid data points are included in the analyses for the respective variables (resulting possibly in unequal *valid n* per variable).

b. General CES Performance/Sustainability Factors

This question, asked of CES personnel in **QUEST2: Section 7,** required respondents to indicate whether **a)** the factors listed were available at their institution and **b)** they believed each factor had a significant impact on the performance and sustainability of their CES. For each sub-section, respondents were required to tick either **Yes** or **No**. A 21% item non-response indicated the need for an **'I don't know'** option.

c. Part 2: Rating of CES Performance and Sustainability Indicators

This section, asked of all respondents, was generally answered correctly, with 20% of respondents (particularly institutional management and CES clients) selecting the **'I don't know' (0)** option for indicators they were not sure of. This was to be expected, as some indicators were more relevant to some groups and not the others.

A comment made by one of the respondents specified the need to redefine some of the indicators, as it was unclear how they were to be quantified. An example of this would be to state that 'inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction' is expressed as a normalised percentage of total clinical procedures per equipment type.

d. Wording of Qualitative Questions

While most of the open-ended questions were basically understood and relevant answers were provided, three questions were amended, following expert consultation. All amendments can be found in the revised questionnaires (Appendix E).

1. Section 2 in **QUEST1, QUEST2 and QUEST4**, requested respondents to suggest 'appropriate elements in a CES strategic plan'. This was changed to appropriate **objectives,** for clarity.
2. **QUEST1: Section 4.1.3, QUEST2: Section 4.1, QUEST3: Section 2.2.3** and **QUEST4: Section 4a** asked respondents about their opinions on the impact of CES services on clinical procedures specifically, or on healthcare service delivery generally, in their respective institutions. This was identified as a double-barrelled question i.e. it addressed more than one issue. This was amended by splitting it into two sections i.e. the impact of CES services on **a)** clinical procedures and **b)** healthcare service delivery in the respective institutions.
3. Institutional management, CES personnel and HTM experts/ representatives of DoH were asked for the institutional, organisational and environmental factors that support/hinder CES sustainability. There was a need to define the specific type of 'environmental' factors being addressed. This was amended to 'socio-political environmental' factors.

6.3.3 Response Bias

Apart from the forms of bias specified in the preceding section, one question in **QUEST2** showed evidence of response bias[3]. Section 5.3c) requested respondents to suggest indicators of sustainability. As indicated in the results chapter, most of the suggested 'indicators' were a repetition of the sustainability **factors** mentioned in the previous section. The remaining indicators had been suggested in an earlier question on performance measures. This indicates that either

- the previous question had led respondents into responding in a certain way (**mental set**[4] response bias)
- it is difficult to define or quantify sustainability indicators
- it is difficult to differentiate performance indicators and sustainability indicators.

[3] **Response bias:** Error due to mentality or predispositions of the respondents (Alreck & Settle, 1995).
[4] **Mental set bias:** Cognitions or perceptions based on previous items influence response to later ones (Alreck & Settle, 1995)

While the first option is definitely a valid reason for responses to this question, the latter two options support the framework presented in Figure 6.5 which indicates that the development of **performance indicators** can be used to **assess CES sustainability.**

6.3.4 Reliability and Validity

Due to the exploratory and qualitative nature of the questionnaires, statistical measures (e.g. correlation coefficient) of reliability[5] and validity[6] could not be performed. However, the questionnaires were assessed according to the 'qualitative' definitions of reliability and validity.

a. Reliability

There are various methods for evaluating the reliability of an instrument. These include the test-retest method[7] and the equivalent/alternate-form method[8]. Due to time constraints and expected respondent burden (associated with having to fill in the same questionnaire twice), the test-retest method could not be used for this study. The equivalent-form method was therefore used as a measure of reliability.

As mentioned previously, certain questions were designed to measure the same concept, but were phrased differently. Examples of this are 'advantages of in-house CES over outsourcing' vs. 'implications of no in-house CES, i.e. outsourcing all equipment maintenance and management'. As illustrated in Figure 2, similar themes emerged from both questions. Similarly, results from the question on 'institutional, organisational and environmental factors

[5] **Reliability:** The degree to which measures are free from error and therefore yield consistent results, i.e. consistency through repeatability (Zikmund, 2000)
[6] **Validity:** The ability of a scale or measuring instrument to measure what is intended to be measured.
[7] **Test-retest method:** The administering of the same scale or measure to the same respondents at two separate points in time in order to test for reproducibility.
[8] **Equivalent-form method:** A method that measures the correlation between alternative instruments, designed to be a equivalent as possible, administered to the same group.

supporting CES sustainability' in **QUEST1, QUEST2** and **QUEST4** were found to be consistent with the sustainability factors listed in a later section in **QUEST2** (Figure 3). Responses to these questions were also found to be the converse of 'factors hindering CES sustainability, indicating a stability of responses (Figure 4).

b. Validity

Reliability is a necessary condition for validity, but a reliable instrument may not be valid (Zikmund, 2000). The accuracy of the questionnaires, i.e. did they measure what they intended, needs to be assessed. As statistical measures of validity were beyond the scope of this study and there were no 'gold standards' to measure results against (concurrent[9] validity), methods not quantified by statistics had to be used. The 'face' or 'content'[10] validity of the instrument was therefore evaluated.

Two sets of experts were consulted for their evaluation of the questionnaires viz. (i) research methodology / questionnaire design experts, from different fields (social science and engineering management) and (ii) experts in Healthcare Technology Management. Respondents were also invited to provide comments on the questionnaires. With the exception of the various forms of instrumentation and response bias mentioned previously, the questionnaires were generally found to be relevant to the challenges facing CES's and easily understood. Analysis of the different questions showed that they not only provided relevant answers, but answers that were consistent with observations in the literature. Also, the similarities in answers provided by the different target groups (give or take their differences in perspective) showed stability of results.

[9] **Concurrent validity:** A classification of criterion validity whereby a new measure correlates with a criterion measure taken at the same time (Zikmund, 2000).

[10] **Content validity:** Professional agreement that a scale logically appears to be accurately reflecting what was intended to be measured.

The validity of the scale used to rate CES services and indicators would have to be evaluated statistically against the widely used 5-point scale of importance (*very unimportant, unimportant, neutral, important, very important*). However as mentioned in the summary of significant findings (section 6.2.6), results of these ratings were consistent with results from the qualitative sections of the questionnaires.

Given the distribution of responses received, the preliminary results presented are not representative of the situation at an international level. However the instrument has been found to produce consistent results, with a significant level of validity, and can thus be applied in differing situations.

6.4 LIMITATIONS AND DELIMITATIONS OF THE STUDY

6.4.1 Limitations

Certain limitations were imposed on the study. Due to time constraints, lack of participation of collaborators and potential respondents from the international community and low response rates from local health facilities, the focus and scope of the study had to change.

The objectives of the ongoing study include (i) comparing the functions of specific CES's in differing regions and (ii) developing and testing indicators to describe performance and sustainability of CES's. Due to these limitations mentioned, the study thus became the development of a **framework** to fulfil the objectives of the larger project. A pilot study, using a small sample of respondents, was used to test this framework.

The lack of participation from the international community further restricted the geographical scope of the study. Responses obtained were mostly from tertiary institutions within the Western Cape in South Africa – where questionnaires were hand-delivered and collected. As a result, comparisons between CES's in

differing regions or differing health facility types and sizes could not be performed.

The particularly low response rate from CES personnel limited the validity and ability to generalise questions probing into the current situation or functions of the CES's in the region. Most of the responses given by institutional management or CES clients were based on their perceptions or knowledge (which could be limited) of the CES function.

6.4.2 Delimitations

Certain delimitations were imposed – given the abovementioned factors and the fact that the study was highly qualitative in nature.

- As mentioned in Phase One of the Methodology, due to the highly specialised nature of the CES function, random (probability) sampling procedures could not be carried out, thus limiting the level of statistical analyses that could be performed.
- Descriptive statistics only were used for evaluation of the preliminary results
- Measures of association between variables could not be carried out due to the limited number of cases. However, comparisons between the ratings and opinions of the different target groups were carried out.
- **QUEST4** was developed, but not widely distributed, as this group were least likely to know of **specific** institutional requirements.
- The scope of research did not include non-traditional models of in-house service vs. outsourced services, e.g. rental companies and shared services.

The final objective of the larger project is to test the indicators developed to determine to what extent common indicators can be used in comparing and assessing the performance and sustainability of CES's in differing environments. Valid conclusions to this question could only be assessed using a longitudinal study – over a substantial amount of time.

6.5 APPLICABILITY OF THE FRAMEWORK

Figure 6.5 illustrates a framework designed to develop a standardised set of performance indicators for in-house Clinical Engineering Services, which can be used by decision- and policy-makers to assess the performance, quality and sustainability of these services. The framework was developed using performance measurement techniques found in the management literature and which have been applied in various fields, including other engineering disciplines.

Due to certain limitations, including time constraints and lack of participation of targeted respondents, the framework was tested primarily in the Western Cape, South Africa. However, a few responses from Namibia, Mozambique, the UK and the USA revealed a common thread of themes. Although advanced statistical techniques could not be used on this relatively small and regionally unrepresentative sample, simple comparisons between the different components - i.e. CES mission and strategy, institutional management and client expectations, and essential CES services - not only revealed similarities in themes, but also corresponded with the essential performance indicators established. These were further supported by various factors pertinent to CES performance and sustainability.

Qualitative reliability and validity tests identified a few problems, however the stability of results and correspondence of the different components, coupled with their consistency with international literature, suggests the framework can be applied at an international level.

The study concentrated specifically on developing a framework for in-house clinical engineering services. Although the delimitations state that the scope of research did not include non-traditional models of in-house services vs. outsourced services e.g. rental companies and shared / regional resource centres, the framework could be extended to monitoring the performance of these services

– thus assisting decision-makers to establish the most appropriate CES service for their institutions.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

In-house Clinical Engineering Services globally are under threat of downsizing or even closure and outsourcing to external service providers. There is therefore an ever-increasing need for in-house CES's to justify their existence by providing institutional management and policy-makers with quantitative evidence of their performance and value.

Performance and quality indicators are frequently used in other fields as quantitative measures pointing towards sustainability. The business management literature provides a variety of methods for developing performance and quality indicators. However, despite the differing approaches to performance measurement, most state the importance of integrating three basic components into an effective performance measurement system, namely (i) mission and strategy of the business unit, (ii) expectations and perceptions of clients/stakeholders and (iii) processes/functions for achieving the objectives and serving clients.

Clinical engineering literature reveals that few, if any, performance measurement systems exist and that there are presently no universally accepted standards for the field. A framework is thus needed to develop performance measurement systems specifically for clinical engineering.

Such a framework was developed in this study, incorporating the methods suggested by the literature review. Four target groups were identified as being able to provide information relating to CES mission and strategy, client expectations and essential CES services. These groups were: (i) institutional management (including nursing management), (ii) CES management and personnel, (iii) CES clients and (iv) international healthcare technology management experts and representatives of national and provincial Ministries of

Health. They were also identified as having a direct impact on the existence of in-house CES's – as well as most likely to benefit from the improvement of clinical engineering services in general.

The use of self-administered questionnaires – specific to each target group – was found to be the most appropriate method of data collection, and four questionnaires were subsequently developed. Each consisted of a qualitative section containing primarily open-ended questions, establishing opinions on certain aspects of the CES function; as well as a uniform quantitative section, requiring all respondents to rate a set of proposed indicators. The questionnaires followed a cycle of testing and revision. They incorporated (in Part Ones) three elements described in the management literature, plus questions pertaining to perceptions on performance, sustainability, management trends affecting CES's and the importance of CES's to healthcare service delivery – specific to each target group. The indicators included in Part Two of all the questionnaires were derived from the healthcare technology management literature and current clinical engineering practice, and subsequently short-listed according to criteria derived from management literature.

A pilot study was conducted by distributing questionnaires to the first three target groups, i.e. institutional management, CES personnel and CES clients. A high level of non-response led to data mostly being collated from the Western Cape in South Africa. Analysis of the responses yielded results that were consistent with the literature. The questionnaires provided basic elements of a CES mission and strategic plan, which correlated with both institutional management and client expectations and with perceptions of CES 'quality of service'. Essential CES services, specific to the sample, were established and included (i) **specification, evaluation and procurement,** (ii) **inspection and preventive maintenance,** (iii) **corrective maintenance** and (iv) **safety checks.** These were consistent with 'core' CES functions described in the literature. Factors supporting and hindering CES sustainability were identified, which corresponded to factors proposed by the WHO and included adequate resources (financial, human, infrastructure) and institutional management/DoH awareness and commitment. General factors such

as adequate spare parts, availability of service manuals and presence of a Quality Assurance programme, were also found to impact on the performance and sustainability of CES's. A general consensus was established that a well-managed in-house CES - with sufficient resources - has an important role to play in healthcare service delivery. Reasons for this included cost-effectiveness, fast response time and CES awareness of the strategic direction and needs of their institutions. Finally a group of essential indicators was established, which included: (i) **cost of in-house service vs. cost of outsourced service per equipment type**, (ii) **response time to service requests** and (iii) **inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction.** Once again, these indicators corresponded to requirements specified in the literature. Of particular importance was the fact that simple comparisons between the indicators identified and dominant themes emerging from analysis of data showed a definite level of correspondence. This supported the validity of the proposed framework.

Reliability and validity tests on the questionnaires revealed some shortcomings; however general correspondence between different issues and consistency of results suggested that reliability and validity of this instrument could be increased with a few minor changes to the questionnaires.

If extended to the international community and covering a larger sample, this methodology could therefore be used to establish standardised measures of performance which could subsequently be used to guide decision-makers into assessing the sustainability of in-house Clinical Engineering Services.

7.2 RECOMMENDATIONS FOR FURTHER WORK

As mentioned in the introduction, the present study forms part of a larger project, the objectives of which are described in Chapter 1. Figure 7.1 gives a diagrammatic overview of the methodology required to fulfil the objectives of the project.

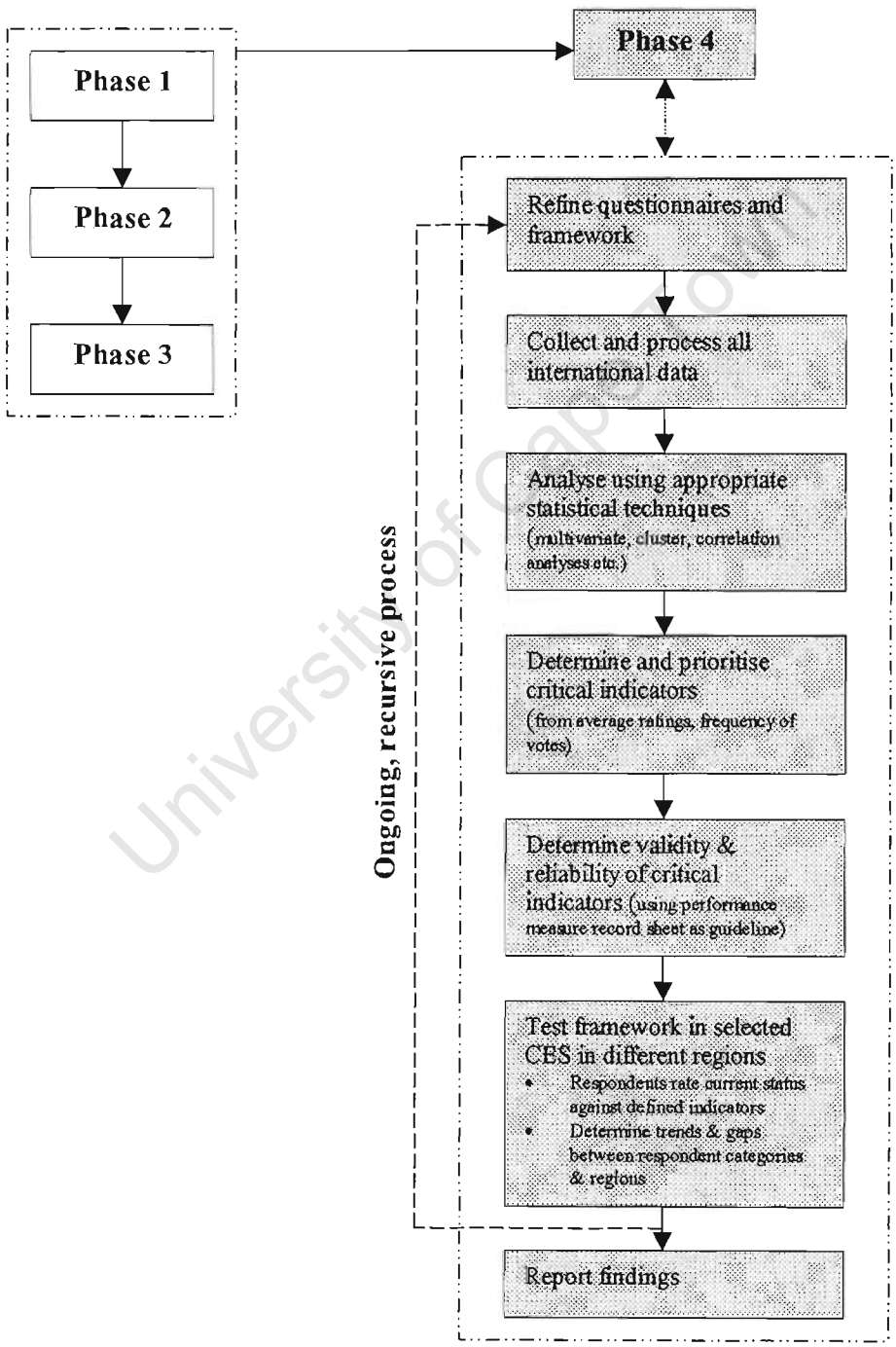

Figure 7.1: Recommendations for further work

It is aimed to let the project run as a self-sustaining, on-going process, reviewed periodically – e.g. every 6 months and lasting a further 3 years.

The process includes:

- Refining the questionnaires to eliminate all bias, and if possible, reduce the length. This could be done by discarding questions that were included to determine stability of responses and thus reliability and validity of responses. Also, once recurring themes appear, open-ended questions could be converted to structured questions, thus reducing respondent (and analysis) burden.
- Putting the revised questionnaires on the Sizanani[1] website as an alternative method of distributing the questionnaires. Paper and electronic versions would still be distributed to the international community and subsequent responses collated.
- Analysing the data using appropriate statistical techniques, e.g. establishing correlation coefficients for measures of association.
- Analysing data for region-specific, target-group-specific, health facility type and size, and sector-specific differences to establish whether global standardised indicators can be defined.
- Developing, refining and validating (by making indicators available for critical analysis) indicators based on the analyses of data,
- Testing and maintaining the indicators in differing environments over a specific period of time, to determine their applicability.

In addition an in-depth study carried out in the CES's selected as case studies would be needed to fulfil the objectives of the project as a whole.

It is hoped that this should provide pertinent information to decision-makers, allowing them to assess performance of in-house CES's, allow CES management to compare their performance against other CES's and lead towards justifying the sustainability of Clinical Engineering Services. Ultimately, however, the aim is to

[1] Website of the Healthcare Technology Management Programme at the University of Cape Town

make a positive contribution to improved quality, efficiency and effectiveness of healthcare service delivery, leading towards improved health status of the populations served.

8. REFERENCES

1. AAMI (1990), *Design of Clinical Engineering Quality Assurance and Risk Management Programmes*, Management Information Reports, AAMI, Arlington.

2. AAMI (1993), *Guideline for Establishing and Administering Medical Instrumentation Maintenance Programmes*, Management Information Report, AAMI, Arlington.

3. ACCE (1995), 'Guidelines for Medical Equipment Donation', *http://www.accenet.org/secure/donationguidelines.html.*

4. Al-Fadel HO (1986), 'Clinical Engineering Productivity and Improvement', *Journal of Clinical Engineering*, Vol. 11, No 5, pp 355–359.

5. Alreck PL & Settle RB (1995), *The Survey Research Handbook, 2nd ed,* Irwin/McGraw-Hill, Massachusetts.

6. American College of Clinical Engineering (ACCE) (2002), ' ACCE Information', *http://www.accenet.org/acceinfo.html.*

7. Anker M, Guidotti RJ, Orzeszyna S, Sapirie SA, Thuriaux MC (1993), 'Rapid Evaluation Methods (REM) of Health Services Performance: Methodological Observations', *WHO Bulletin OMS,* Vol. 71, pp 15–21.

8. Autio DP, Morris RL (1995), *Clinical Engineering Program Indicators,* pp 2556-2565 in: Bronzino JD (ed), The Biomedical Engineering Handbook, CRC Press Inc, Florida.

9. Bauld JT (1991), 'The Definition of a Clinical Engineer', *Journal of Clinical Engineering*, Vol.16, No.5, pp 403–405.

10. Bauld TJ (1987), 'Productivity: Standard Terminology and Definitions', *Journal of Clinical Engineering*, Vol. 12, No 2, pp 139–145.

11. Bostrom U et al (1993), 'Clinical Engineering Worldwide', *IEEE Engineering in Medicine and Biology,* September, pp 34–45.

12. Bourque LB & Fielder EP (1995), *How to Conduct Self-Administered and Mail Surveys,* The Survey Kit, Vol. 3, Sage Publications, Thousand Oaks.

13. Brinkerhoff RO & Dressler DE (1990), *Productivity Measurement: A Guide for Managers and Evaluators,* Applied Social Research Methods Series, Vol. 19, Sage Publications, London.

14. Bronzino JD (1992), *Management of Medical Technology: A Primer for Clinical Engineers,* pp 13–17, Butterworth-Heinemann, Stoneham MA.

15. Brown LD, Franco LM, Rafeh N, Hatzell T (1999), 'Quality Assurance of Healthcare in Developing Countries', *Quality Assurance Methodology Refinement Series*, Quality Assurance Project, Bethesda.

16. Caceres CA (ed) (1977), *The Practice of Clinical Engineering*, Academic Press, New York

17. Chang RY & Morgan MW (2000), *Performance Scorecards: Measuring the Right Things in the Real World*, Jossey-Bass, San Francisco.

18. Christopher WF & Thor CG (eds) (1993), *Handbook for Productivity Measurement and Improvement,* Productivity Press, Portland.

19. Clinical Engineering Q & A (1996), 'Exploring the International Role of Clinical Engineers', *Journal of Clinical Engineering, Vol. 21, No.4, p 287*

20. COHSASA (1997), *Draft Standard on Healthcare Technology Management*, Poluta MA (ed), Council for Health Service Accreditation for Southern Africa, Cape Town.

21. COHSASA (1997), *Quality Assurance/Improvement and Accreditation – What are the Benefits?*

22. Crainer S (1996), *Key Management Ideas: Thinkers that changed the management world,* Pearson Professional, Great Britain.

23. Czaja R & Blair J (1996), *Designing Surveys: A Guide to Decisions and Procedures*, Pine Forge Press, California.

24. David Y (1993), 'The Role of US Clinical Engineering in Supporting International CE', *Journal of Clinical Engineering,* Vol. 18, No 1, pp 39-40.

25. David YD & Judd JM (1993), *Medical Technology Management*, SpaceLabs Medical, Redmond, Washington.

26. David Y & Rohe D (1986), 'Clinical Engineering Program Productivity and Measurements', *Journal of Clinical Engineering,* Vol.11, No 6, pp 435-443.

27. De Cock C & Hipkin I (1997), 'TQM and BPR: Beyond the Myth', *Journal of Management Studies*, Vol. 34, No 5, pp 659–675.

28. Dence R (1995), 'Best Practices Benchmarking' , pp 124–152 in: Holloway J, Lewis J, Mallory G (eds), *Performance Measurement and Evaluation*, SAGE Publications Ltd, London.

29. De Villiers G (1998) 'An Investigation into Consulting Engineering Service Quality Perceptions and Expectations', Master of Science in Engineering Dissertation, University of Cape Town.

30. Dey I (1993), *Qualitative Data Analysis: A User-Friendly Guide for Social Scientists,* Routledge, London.

31. Dickey DM (1996), 'Clinical Engineering Helps Reduce Equipment Costs' http://www.accenet.org/clinengrweek/page3.html, from *Healthcare Financial Management,* Sept 1995.

32. ECRI (1989), 'Special Report on Managing Service Contracts', *Health Technology*, Vol. 3, No. 4, :pp 2–56.

33. Franco LM, Newman J, Murphy G, Mariani E (1999), ' Achieving Quality Through Problem Solving and Process Improvement', 2nd Ed, *Quality Assurance Methodology Refinement Series*, Quality Assurance Project, Bethesda.

34. Frize M (1990), 'Results of an International Survey of Clinical Engineering Departments: Part 1: Role, Functional Involvement and Recognition', *Medical and Biological Engineering and Computing*, Vol. 28, pp 153–159.

35. Frize M (1990), 'Results of an International Survey of Clinical Engineering Departments: Part 2 – Budgets, Staffing, Resources and Financial Strategies', *Medical and Biological Engineering and Computing*, Vol. 28, pp 160–165.

36. Frize M (1994), 'Longitudinal Study of Clinical Engineering Departments in Industrialised Countries 1988 to 1991', *Medical & Biological Engineering & Computing*, Vol. 32, pp331–335.

37. Frize M & Cheng M (1994), 'Technical Services for Healthcare Facilities: A Model for Developing Countries', *Medical & Biological Engineering & Computing*, Vol. 32, pp 335–337.

38. Furst E (1986), 'Productivity and Cost-Effectiveness of Clinical Engineering', *Journal of Clinical Engineering*, Vol.11, No 2, pp 105-113.

39. Gay CL & Essinger J (2000), *Inside Outsourcing: An Insider's Guide to Managing Strategic Sourcing*, Nicolas Brealey Publishing, London.

40. Glouhova M, Kolitsi Z, Pallikarakis N (1999) 'International Survey of Clinical Engineering Departments', *Proceedings Part 1 of the EMBEC '99*, Vienna, Austria, November 4-7, pp 632–633.

41. Glouhova M, Kolitsi Z, Pallikarakis N (1999) 'International Survey of Clinical Engineering Departments: Part 2 – Practices', *IFMBE Proceedings, MEDICON 2001*, June 12 – 15, Pula, Croatia, pp 190-193.

42. Goodman G (1989), 'The Profession of Clinical Engineering', *Journal of Clinical Engineering*, Vol. 14, No 1, pp 27-37.

43. Gordon G (1995), *Breakthrough Management: A New Model for Hospital Technical Services*, AAMI, Arlington.

44. Harbour JL (1997), *The Basics of Performance Measurement*, Quality Resources, New York.

45. Heimann PA (2000), 'Report of the Clinical Engineering Division', *IFMBE News*, No. 43, July 2000, pp N1–N2.

46. Heimann PA, Poluta MA (1997), 'Case Studies on the Organisation of Maintenance in South Africa', *Technologie Sante*, No. 31 (Nov), pp 87-9.

47. Hinks J & McNay P (1999) 'The Creation of a Management-by-Variance tool for Facilities Management Performance Assessment', *Facilities,* Vol. 17 No1/2, pp 31–53.

48. Ibrahim HA & Kirsch AD (1989), ' An Empirical Study of Selected Cost Measures of Clinical Engineering Service Effectiveness', *Journal of Clinical Engineering,* Vol. 14, No 1, pp 43-48.

49. Issakov A (1994), 'Health Care Equipment: A WHO Perspective' in van Gruting (ed), *Medical Devices: International Perspectives on Health and Safety,* Elsevier Science B.V.

50. Issakov A (1994), 'Service and Maintenance in Developing Countries', pp 21- 8 in: van Gruntig CWD (Ed), *Medical Devices: International Perspectives on Health and Safety,* Elsevier Science, Amsterdam.

51. JCAHO (1997), *National Library of Healthcare Indicators,* Health Plan and Network Edition, Joint Commission on Accreditation of Healthcare Organisations, Illinois.

52. JCAHO (1990), *Primer on Indicator Development and Application: Measuring Quality in Health Care,* Joint Commission on Accreditation of Healthcare Organisations, Illinois.

53. Johnston GI (1987), 'Are Productivity and Cost-Effectiveness Comparisons Between In-House Clinical Engineering Departments Possible or Useful?', *Journal of Clinical Engineering*, Vol. 12, No 2, pp 147–152.

54. Johnston GI (1993), 'A Basic Clinical Engineering Model for Developing Nations', *Journal of Clinical Engineering*, Vol. 18, No.1, pp 41-46.

55. Journal of Clinical Engineering eds (1996), 'Exploring the International Role of Clinical Engineers', (editorial), *Journal of Clinical Engineering*, Vol. 21, No.4, p 287.

56. Journal of Clinical Engineering (1987), 'Special Issue on Productivity and Cost Effectiveness', *Journal of Clinical Engineering.,* Vol. 12, No 2.

57. Judd T (2000), *Quality Improvement,* Dominican Republic Advanced Health Technology Management Workshop, March 16.

58. Judd T & Painter F (2000), *The Linkage of Quality Management and Technology Management in Healthcare*, Health Tech 2000.

59. Kaydos W (1991), *Measuring, Managing and Maximising Performance*, Productivity Press, Inc, Massachusetts.

60. Locke GP (1996), 'Clinical Engineering in South Africa', (guest editorial), *Journal of Clinical Engineering*, Vol. 21, No.1, pp 37-40.

61. Locke GP (1998), 'Clinical Engineering - A Vital Element of Health Care Technology Management', *South African Health Technology Monitor*, Vol. 2, No. 6, pp 1-4.

62. Lodge DA (1991), 'Productivity, Efficiency and Effectiveness in the Management of Healthcare Technology: An Incentive Pay Proposal', *Journal of Clinical Engineering*, Vol. 16, No 1, pp 29–33.

63. Mahachek AR (1987), 'Management and Control of Clinical Engineering Productivity: A Case Study', *Journal of Clinical Engineering*, Vol. 12, No 2, pp 127-132.

64. Mehta JC (1983), 'Engineering and Maintenance Services in Developing Countries', in Kleczkowski BM & Pibouleau (Eds), *Approaches to Planning and Design of Health Care Facilities in Developing Areas,* Vol. 4, World Health Organisation, Geneva.

65. Neely A, Richards H, Mills J, Platts K, Bourne M (1997), 'Designing Performance Measures: A Structured Approach', *International Journal of Operations and Production Management,* Vol. 17, No. 1, pp 1131–1152.

66. Neuhausel DJ (1985), 'Productivity in Clinical Engineering', *Journal of Clinical Engineering*, Vol. 10, No 4, pp 289–300.

67. Newshouse VL, Bell DS, Tackel IS, BEn-Zvi MS, Freedman W, Aston R (1989), 'The Future of Clinical Engineering in the 1990s', *Journal of Clinical Engineering,* Vol. 14, No 5, pp 417-420

68. Öberg PA (1991), 'Clinical Engineering: Past, Present, Future', in Abe H *et al* (eds), *A New Horizon on Medical Physics and Biomedical Engineering,* Elsevier, Amsterdam.

69. Ovretveit J (1992), *Health Service Quality: An Introduction to Quality Methods for Health Services,* Blackwell Scientific Publications, Oxford.

70. Panerai RB (1998), 'Validation of Indicators for Health Policy Research', *World Health Forum*, Vol. 19, pp 6–11.

71. Poluta MA (2001), 'Healthcare Technology Management', HTM Overview for Sizanani Postgraduate Diploma in Healthcare Technology Management, UCT.

72. Poluta MA, Heimann PA (undated), 'Clinical Engineering in South Africa: Current Challenges and Initiatives', ...

73. QA Brief (1999), 'Using Accreditation to Improve Quality', *Quality Assurance Project,* Bethesda.

74. Rakich JS, Longest BB and Darr K (1992), *Managing Health Services Organizations*, 3rd Ed., Health Professions Press, Baltimore.

75. Roy Oz (1982), 'The Canadian Medical & Biological Engineering Society's Clinical Engineering Policy and Procedures', *Journal of Medical Engineering & Technology,* Vol. 6, No 2, pp 70-72

76. Smith M (1982), 'Clinical Engineers: The New Hospital Decision Makers', (guest editorial) *Medical Device and Diagnostic Industry (MD&DI),* July: pp10–11.

77. Statham RT (1990), 'An Assessment of Training Requirements for Health Care Technology in the Developing World', *11th IFHE Congress 1990,* pp 52-54.

78. Swanevelder AG (1997), 'Critical Aspects of Technology Management of Medical Equipment in the Healthcare Environment', *Planning for More Affordable Healthcare,* Proceedings, Sun City.

79. Taylor K, Frize M, Iverson N, Paponnet-Cantat C (1999) 'The Need for the Integration of Clinical Engineering and Social Perspectives in the Management of Medical Equipment Within Developing Countries', *http://www.sce.carleton.ca/faculty/frize/old/devcount.htm*

80. Thor CG, Jarrett JR (1999), 'Benchmarking and Reengineering: Alternatives or Partners?', *International Journal of Technology Management*, Vol. 17, No 7/8, pp 786-96.

81. Wang B (1999), 'What is the Purpose of Clinical Engineering Certification?', *Journal of Clinical Engineering*, Vol. 24, No. 5.

82. World Health Organisation (WHO) (1999), *WHO Consultation on Physical Infrastructure and Technology*, Draft Final Report.

83. World Health Organisation (WHO) (2000), *The World Health Report 2000 – Health Systems: Improving Performance*, Geneva.

84. Zairi M (1996), *Effective Benchmarking: Learning from the Best*, Chapman & Hall, London.

85. Zikmund WG (2000), *Business Research Methods, 6th Edition,* Harcourt College Publishers, Orlando.

9. BIBLIOGRAPHY

BOOKS

Christopher WF & Thor CG (eds) (1993), *Handbook for Productivity Measurement and Improvement,* Productivity Press, Portland. Specific Chapters:

- Christopher WF, 'The Starting Point: Company Mission'
- Thor CG, 'Ten Rules for Building a Measurement System'
- Scheuing EE, 'Measuring Customer Expectations and Competitive Position'
- Thor CG, 'Measuring the Maintenance Department'
- Parasuraman A, Berry LL, Zeithaml VA, 'Guidelines for Measuring Service Industry Quality'
- Packer MB, 'Measuring Productivity and Organisational Effectiveness in Technical Organisations'
- Christopher WF, 'The Cost of Non-Quality'
- Miller JA, 'The Best Way to Implement an Activity-Based Cost Management System'

Collier DA (1994), *The Service Quality Solution: Using Service Management to Gain Competitive Advantage*, Irwin Inc, Illinois.

Cooper HM (1989), *Integrating Research: A Guide for Literature Reviews, 2nd Ed*, Sage Publications, London.

Fries BE (1981), *Applications of Operations Research to Health Care Delivery Systems: A Complete Review* of *Periodical Literature*, Springer-Verlag, Berlin.

Gattiker UE (1990), *Technology Management in Organisations*, Sage Publications, London.

Gaynor GH (ed) (1996), *Handbook of Technology Management*, McGraw Hill Companies Inc, New York.

Handy C (1999), *Understanding Organisations*, 4th Ed, Penguin Books, London.

Heizer J, Render B, (1996), *Production and Operations Management: Strategic and Tactical Decisions,* 4th Ed, Prentice Hall, New Jersey.

Herzberg F (1991), 'One More Time: How do you Motivated Employees?', pp 13-22 in *Harvard Business Review: Business Classics: Fifteen Key Concepts for Managerial Success*, Harvard Business School Publishing, Boston.

Kanji GK & Asher M (1996), *100 Methods for Total Quality Management,* Sage Publications, London.

Kelada JN (1996), *Integrating Reengineering with Total Quality*, ASQC Quality Press, Wisconsin.

Kennedy C (1998), *Guide to the Management Gurus: Shortcuts to the Ideas of Leading Management Thinkers,* Century Ltd, London.

Lascelles D & Peackock R (1996), *Self-Assessment for Business Excellence,* Quality In Action Series, Mcgraw-Hill International, New York.

Lock D (1996), *Project Management,* 6th Ed, Gower Publishing Ltd, Hampshire.

Mahachek AR (ed), (1992), *Selected Management Topics for Clinical Engineering: Tools for Technical Managers*, Association for the Advancement of Medical Instrumentation (AAMI), Arlington.

McNair CJ, Leibfried KHJ (1994), *Benchmarking: A Tool for Continuous Improvement*, The Cooppers & Lybrand Performance Solutions Series, Harper Collins Publishers, London.

Rainey HG (1991), *Understanding and Managing Public Organisations,* Jossey-Bass Publishers, San Francisco.

Spendolini MJ (1992), *The Benchmarking Book*, American Management Association, New York.

Webster JG, Cook AM (eds) (1979), *Clinical Engineering Principles and Practices,* pp 121–127, Prentice-Hall, Englewood Cliffs, NJ.

Wolcott HF (1990), *Writing Up Qualitative Research,* Sage Publications, London.

Research Methodology Books

Fink A (1995), *How to Analyse Survey Data,* The Survey Kit, Vol. 8, Sage Publications, Thousand Oaks.

Greenfield T, (ed) (1996), *Research Methods: Guidance for Postgraduates,* Arnold, London

Litwin MS (1995), *How to Measure Survey Reliability and Validity,* The Survey Kit, Vol. 7, Sage Publications, Thousand Oaks

Professional Communication Unit, UCT (1996), *Handbook: A Guide to Effective Spoken and Written Communication*, Juta & Co, Kenwyn

Rudestam KE & Newton RR (1992), *Surviving Your Dissertation: A Comprehensive Guide to Content and Process,* SAGE Publications, London.

Silverman D (1993), *Interpreting Qualitative Data: Methods for Analysing Talk, Text and Interaction,* Sage Publications, Thousand Oaks.

JOURNAL ARTICLES

Aggarwal S (1997), 'Re-engineering: a Breakthrough or Little New', *International Journal of Technology Management*, Vol. 13, No. 3, pp 326-344.

Amoore JN, Stay DG, Mather J (1995), 'Scheduled Inspection of Electromedical Equipment. Planning and Assessment', *Journal of Medical Engineering and Technology*, Vol. 19, No 6, pp 211–218.

Andrade JD (1993), 'Improved Delivery and Reduced Costs of Health Care Through Engineering', Discussion Meeting April 1992, Washington, *IEEE Engineering in Medicine and Biology,* June 1993, pp 38-41.

Ben-Zvi S (1984), 'Development of Preventive Maintenance Procedures', *Journal of Clinical Engineering*, Vol. 9, No 2, pp 103-12.

Betts WF (1987), 'Cost-Effective Clinical Engineering Programs: An Expanding Role in Hospitals', *Journal of Clinical Engineering*, Vol. 12, No 2, pp 119-125.

Boddendijk H (2000), 'Value People, Stay Competitive: Next Century's Demands', *Int. Journal of Technology Management*, Vol. 19, No 6, pp 571-575.

Bridger R (1996), 'Kill Two Birds with One Stone', *Productivity SA,* (May/June), pp 26-29.

Bronzino JD (1990), 'Education of Clinical Engineers in the 1990s', *Journal of Clinical Engineering,* Vol. 15, No 3, pp 185-189.

Brush LC (1992), 'Becoming an Effective Clinical Engineering or Biomedical Technology Manager, *Journal of Clinical Engineering,* Vol. 17, No 4, pp 313-316.

Brush LC (1993), 'Creating an Effective Clinical Engineering Team', *Journal of Clinical Engineering*, Vol. 18, No 2, pp 139-47.

Brush LC (1993), 'The BMET Career', *Journal of Clinical Engineering,* Vol. 18, No 4, pp 327-333.

Caceres CA (1980), 'Skills Required for Clinical Engineering Practice', *Clinical Engineering,* Vol. 8, No 5, pp 49-60.

Cheese J & Whelan B (1996), 'A Process View of Technology Management - Implications for R&D', *International Journal of Technology Management*, Vol. 11, No. 3/4, pp 315-328.

Cooper C, Seswaali A, Jackson D (1998), 'Track Service Productivity', *Productivity SA,* Jul/Aug, pp 25-28.

Crol JB (2000), 'Creating Support for a Change in Strategy', *Int. Journal of Technology Management*, Vol. 19, No 6, pp 586-596.

DeNovellis R (1992) 'Technical People, Technical management and Successful management - What are the Challenges?), *Journal of Clinical Engineering,* Vol. 17, No 6 pp 481-485.

Dermer J (1992), 'Traps in Technology Management', Technical Management Note, *IEEE Transactions on Engineering Management*, Vol. 39, No 4, pp 412-416.

ECRI (1989), 'Special Report on Managing Service Contracts', *Health Technology*, Vol. 3, No. 4, pp 2-56.

Efrat Z (1997), 'Outsourcing DOES Improve Productivity', *Productivity SA,* Sept/Oct, pp 43-45.

Goba N (1998), 'How to Improve Productivity', *Productivity SA,* May/June, pp 14–16.

Goodman G (1989), 'The Profession of Clinical Engineering', *Journal of Clinical Engineering,* Vol. 14, No 1, pp 27-37.

Gordon GJ (1990), 'Hospital Technology Management: The Tao of Clinical Engineering', *Journal of Clinical Engineering*, Vol. 15, No 2, pp 111-117.

Hahn HA, Houghton FK, Youngblood A (1995), 'Job-Task Analysis: Which Way?', *Ergonomics in Design*, Oct, pp 22-28.

Harrington DP (1991), 'The Developing World and Biomedical Equipment' (guest editorial), *Journal of Clinical Engineering*, Vol. 16, No 6, pp 448, 477-478.

Harrington JH, (1997), 'The New Model for Improvement - Total Improvement Management', *Journal of Cost Management*, (Jan/Feb), pp 32-39.

Hill D (1992), 'Evolving Practices of Medical Equipment Management Following FDA Inspections', *Journal of Clinical Engineering*, Vol. 17, No 1, pp 49-57.

Hughes JD (1993), 'Strategies for Technology Management in Clinical Engineering', *Journal of Clinical Engineering,* Vol. 18, No 2, pp 149-153.

Husain Z & Sushil (1997), 'Strategic Management of Technology - a Glimpse of Literature' *Int. Journal of Technology Management,* Vol. 14, No 5, pp 539-578.

Ilori MO & Irefin IA (1997), ' Technology Decision Making in Oganisations', *Technovation*, Vol. 17, No 3, pp153-160.

Irnich W (1989), ' Structuring of Service Centres for Economic and Equipment Efficiency', *Medical & Biological Engineering & Computing*, Vol. 27, pp 69-74.

Jackson PM, ' Productivity and Performance of Public Sector Organisations', *Int. Journal of Technology Management*, Vol. 17, Nos. 7/8, pp 753-766.

Jarzembski WB (1984), 'Managerial & Technical Skill Balance Needed in Engineering Management', *Journal of Clinical Engineering*, Vol. 9, No 1/2, pp 3, 78-79.

Jewkes RK (1995), 'Quality Improvement in Health Services - Time for Appropriate Managerial Technology', *SAMJ*, Vol. 85, No 10, pp 985-986.

Keil OR (1987), 'Quality Assurance', *Journal of Clinical Engineering*, Vol. 12, No 2, pp 153-158.

Keil OR (1999), 'How Much do you Really Know About "Your" Hospital?', *Journal of Clinical Engineering*, Vol. 24, No 5, pp

Kotter JP (1997), 'Leading Change: Why Transformation Efforts Fail', *IEEE Engineering Management Review*, (Spring), pp 34-40.

Kraats van de AH (2000), 'Introduction: People Management as the Key to Successful Integrated Business and Technology Management', *Int. Journal of Technology Management* Vol. 19, No 6, pp 557-558.

Leifer R & Burke WJ (1994), 'Organizational Activity Analysis: A Methodology for Analyzing and Improving Technical Organisations', *IEEE Transactions on Engineering Management,* Vol. 41, No 3, pp 234-235.

Lodge DA (1991), 'Productivity, Efficiency and Effectiveness in the Management of Healthcare Technology: An Incentive Pay Proposal', *Journal of Clinical Engineering*, Vol. 16, No 1, pp 29-33.

Ludwig B (1998), 'Quality for Quality's Sake', *Productivity SA,* Jul/Aug, p 14-15.

Martino JP (1999), 'The Environment for Technological Change', *Int. Journal of Technology Management*, Vol. 18, Nos. 1/2, pp 4-10.

Mbigi L (1995), 'Ubuntu in the Workplace: An Open Door for Managers', *Productivity SA*, July/Aug, pp 10-13.

McKinley W, Sanchez CM, Schick AG (1997), 'Organisational Downsizing: Constraining, Cloning, Learning', *IEEE Engineering Management Review*, Spring, pp 16-23.

Metzemaekers DAMM (2000), 'Critical Success Factors in Technology Management', *Int. Journal of Technology Management*, Vol. 19, No 6, pp 583 – 585.

Ndala R (1998), 'Teams', *Productivity SA,* Sept/Oct, p 24.

Oberg PA (1983), 'Comment: International Certification of Clinical Engineers', *Journal of Medical Engineering and Technology*, Vol. 7, No 3, pp 147–148.

Panerai RB (1998), 'Validation of Indicators for Health Policy Research', *World Health Forum*, Vol. 19, pp 6-11.

Piepenbrink JC (1991), 'Focus On: Boston City Hospital Department of Clinical Engineering', *Journal of Clinical Engineering,* Vol. 16, No 2, pp 123-128.

Popson MJ (1989), 'Clinical Engineering Department Staffing: Analysis of Two Surveys', *Journal of Clinical Engineering,* Vol. 14, No 6, pp 505-512.

Rafii F & Carr LP (1997), ' Cost Management: Why Major Change Programs Fail: An Integrative Analysis', *Journal of Cost Management*, Jan/Feb '97, pp 41-45.

Rennie M (1999), 'Accounting for Knowledge Assets: Do We Need a New Financial Statement?', *Int. Journal of Technology Management*, Vol.. 18, Nos. 5/6/7/8, pp 648-659.

Russell D (1992), 'Preventive Maintenance Quality Assurance', *Journal of Clinical Engineering*, Vol. 17, No 4, pp 321-323.

Sahay KB & Saxena RK (1993), 'The Importance of a Database in Developing and Implementing a Cost-Effective BME System in India', *Journal of Clinical Engineering*, Vol. 18, No 1, pp 47-51.

Schewefel D & Pons MC (994), 'Winners Show the Way to Good Management in Health Care' , *World Health Forum,* Vol. 15, pp 348-352.

Shaffer MJ (1983), 'Applicability of Personnel Management Concepts to Clinical Engineering

Practice', *Medical Instrumentation*, Vol. 17, No 1, pp 34-37.

Sherwood MK (1991), 'Quality Assurance in Biomedical or Clinical Engineering', *Journal of Clinical Engineering*, Vol. 16, No 6, pp 479-483.

Smith C (1998), 'Personal Productivity - do-it-yourself', *Productivity SA,* Sept/Oct, pp 22-23.

Stern SM (1989), 'Emergence of a New Bioengineering Infrastructure and a "College of Clinical Engineering" ', *Journal of Clinical Engineering*, Vol. 14, No 6, pp 513-519.

Swartz D (1998), 'Unlock the Potential', *Productivity SA,* Jul/Aug, pp 19-21.

Topham WS (1976), 'The Cost of a Clinical Engineering Department', *Journal of Clinical Engineering*, Vol. 1, No 1, pp 24-27.

Tuijl van HFJM & Kraats van de AH (2000), ' Value People, the Missing Link in Creating High Performance Organisations', *Int. Journal of Technology Management*, Vol. 19, No 6, pp 559-570.

Wang B (1990), 'Clinical Engineering and Equipment Policy for Sao Paulo State, Brazil', *Journal of Clinical Engineering*, Vol. 15, No 4, pp 287-293.

Wilcox M, Dale BG, Boaden RJ, McQuater RE (1996), 'Managing for Quality: the Strategic Issues', *Int. Journal of Technology Management,* Vol. 17, No 1, pp 59-74.

de Winter ER (1996), 'Material Resources Are Not Enough: Good Management is the Key to Effectiveness', *World Health Forum,* Vol. 17, pp 49-51.

REPORTS, PROCEEDINGS, PRESENTATIONS

AAMI (1994), *Computerized Maintenance Management Systems for Clinical Engineering,* (Management Information Report), Association for the Advancement of Medical Instrumentation (AAMI), Arlington.

Adam HA (1997), 'Cost Control Measures in Private Sector Hospitals', Proceedings, *Planning for More Affordable Health Care* Conference, Sun City.

Aid S & Golubjatnikov O (1999), *Healthcare Technology Management and Continuous Improvement*, Proceedings: 11th Nordic-Baltic Conference on Biomedical Engineering, Tallin, Estonia.

Alliance for Health Systems and Policy Research (2000), 'About the Alliance', *www.who.int/evidence/alliance/about_the_alliance_english.htm.*

Amoore JN (1999), *Annual Report: 1998/1999*, Equipment Management Section, Department of Medical Physics and Medical Engineering, Royal Infirmary of Edinburgh NHS Trust.

Bothma B (1997), 'Facilities Maintenance Management: Reducing the Life-Cycle Cost of Fixed Health Assets', Proceedings, *Planning for More Affordable Health Care* Conference, Sun City.

CMBES (1996), *Clinical Engineering Standards of Practice in Canada* (voting document),

Canadian Medical and Biological Engineering Society.

CMBES (undated), *Peer Review Mechanism for Clinical Engineering Services in Canada* (proposal), Canadian Medical and Biological Engineering Society.

Cronje T (1997), 'Clinical Engineering Education at Technikons: Implications on Affordable Health Care', Proceedings, *Planning for More Affordable Health Care* Conference, Sun City.

Freidberg S (undated), *Productivity: Mind over Matter?* (Ergonomics report), Dept. of Biomedical Engineering, University of Cape Town.

Gaamangwe T (1997), 'Determining Human Resource Requirements for Clinical Engineering Service', Proceedings, *Planning for More Affordable Health Care* Conference, Sun City.

Gajjar N (2000), *Activities at BEHTS Herston, Australia,* Presentation at UCT Department of Biomedical Engineering, Jan 2000.

Gould W (1997), 'Medical Equipment Maintenance Methodology', Proceedings, *Planning for More Affordable Health Care* Conference, Sun City.

Halbwachs H, Korte R (eds) (1989), *Maintenance Strategies for Public Health Facilities in Developing Countries*, (workshop proceedings), GTZ & WHO, Harare.

Labuschagne J-P, 'Public Private Partnerships in the Health Industry', Proceedings, *Planning for More Affordable Health Care* Conference, Sun City.

Malloupas A, Porter D, Issakov A (1990), *Guideline for Country Situation Analysis on Management, Maintenance and Repair of Health Care Equipment*, Report, WHO.

Malloupas A (1988), *Maintenance of Medical Equipment,* WHO Mission Report.

Mariani E, Klaus D (1999), 'Training Manager's Guide', *Quality Assurance Methodology Refinement Series*, Quality Assurance Project, Bethseda

Medical Research Council (1995), *Health Care Technical Services in the Sub-Saharan Region,* AFTH/MRC Regional Workshop Proceedings

Methven JY (1990), *Hospital Design and Planning,* WHO Mission Report

Nyamu JM (undated), *Biomedical Engineering and Maintenance Services in Kenya*, Medical Engineering Services Division, Ministry of Health, Kenya

QA Brief (1999), 'Using Accreditation to Improve Quality', *Quality Assurance Project,* Bethesda.

Wickham T (1997), 'Are International Standards Appropriate for South Africa?', Proceedings, *Planning for More Affordable Health Care* Conference, Sun City.

WHO (1999), 'Investment in Hospitals: Dilemmas Facing Ministers', *Fifty-Second World Health Assembly*, Geneva, Switzerland.

World Health Organisation (1987), *Interregional Meeting on the Maintenance and Repair of Health Care Equipment*, Proceedings.

World Health Organisation (1990), *Manpower Development for a Health Care Technical Service,* Report of the WHO Interregional Meeting on Manpower Development and Training for Health Care Equipment Management, Maintenance and Repair.

COURSE NOTES

Hoffman M (2001), 'Research Methods: Methods of Data Collection', Research Methodology Module, Dept. of Public Health, UCT.

Human L (1997), 'Managing People', Course Module, Diploma in Health Management, Dept. of Community Health, UCT.

Lister G (1999), 'How to Manage for Performance Improvement in Quality and Productivity' Course notes, School of Engineering Management, UCT.

Sayed RA (2001), 'Introductory Manual for Biostatistics', Dept of Public Health, UCT.

School of Engineering Management, UCT (undated), 'Industrial Engineering', course Reader.

DISSERTATIONS

Muller JH (1988), *A Clinical Engineering Decision Support System,* , Master of Philosophy Dissertation, University of Cape Town

Frize M (1989) , *Evaluating the Effectiveness of Clinical Engineering Departments in Canadian Hospitals,* Ph.D, Erasmus University, Rotterdam.

WEB SITES / ELECTRONIC PUBLICATIONS

Association for Services Management (AFSM) International Research and Studies, *www.afsmi.org.*

Kirakowski J (2001), 'Questionnaires in Usability Engineering: A list of Frequently Asked Questions (3rd Ed.) *www.ucc.ie/hfrg/resources/qfaq1.html.*

Guidstar Communications (2001), 'Online Surveys – Frequently Asked Questions', *www.guidestaco.com/e-survey-faq-page.htm.*

APPENDIX A: PRELIMINARY QUESTIONNAIRE

Dear

This questionnaire forms part of an MSc research project looking at **Global Sustainability Indicators for Clinical Engineering Departments.** In recognising new challenges to the field and a changing healthcare environment, it builds on the earlier survey conducted by Monique Frize. In addressing issues of sustainability, it complements the recent survey conducted by Maria Glouhova.

Your time in completing this questionnaire and comments in terms of how it could be improved would be greatly appreciated. Should you wish this questionnaire to be sent to you in electronic form, I would be happy to do so.

Please note that the term *clinical engineering department (CED)* refers to any hospital-linked unit or structure (in either the public or private sector) involved in the management and/or maintenance of healthcare technology.

If you are not head of a clinical engineering department or closely involved/familiar with one, your input would still be greatly appreciated. In this case, please complete the questionnaire to the extent that you can and mark N/A (not applicable) in the relevant places.

Thanking you

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QUESTIONNAIRE (draft) – Pilot Run

1. DEMOGRAPHIC DATA

1.1 Please complete the following:

Name .....
Position.....
Email address.....
Telephone..... Fax.....
Postal address.....
City..... Country.....

1.2 **a)** What is the scope of service covered by your CED? (Please tick)

A. Equipment management support unit at ministry level ❑
B. Provincial hospital with workshop ❑
C. District hospital (50 - 100 beds) with workshop ❑
D. Health unit (no workshop) ❑

b) What is the hospital type? (Please tick)

A. Teaching hospital ❑
B. General hospital ❑
C. Government funded ❑
D. Community hospital ❑
E. Specialised hospital ❑
F. Other (please specify) ❑ .....

c) What is the number of beds supported by the hospital? (Please tick)

< 100 ❑ 100 - 250 ❑ 251 – 500 ❑ 501 – 750 ❑
751 - 1000 ❑ 1001 - 2000 ❑ > 2000 ❑ (Please specify) .....

d) What is the number of devices supported by the CED? (Please tick)

< 500 ❑ 500 – 1000 ❑ 1001 – 1500 ❑
1501 – 2000 ❑ 2001 – 3000 ❑ 3001 – 4000 ❑
4001 – 5000 ❑ > 5001 ❑ (Please specify) .....

2. MISSION AND OBJECTIVES

(Please refer to Appendix A of questionnaire for definitions)

2.1 Does your department have a documented **vision**? Yes ❑ No ❑
If 'Yes' please specify .....
.....
.....
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2.2 Do you have a documented **mission**, defining the dimension and scope of responsibility of the CED? Yes ☐ No ☐
If 'Yes', please specify .....
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2.3 Does your department have documented **strategic goals**? Yes ☐ No ☐
If 'Yes', please specify .....
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2.4 What are the specific management values of the department?
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2.5 Does your department have specific **objectives**? Yes ☐ No ☐
If 'Yes', what are the (management) objectives of your CED for next 5 years?
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2.6 Does the CED's mission and statement conform to the overall strategic plan of the hospital? (Please elaborate)
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3. SERVICE PROVIDED BY CED

3.1 Which of the following CE services does your department provide? (Please tick)

- Specification, evaluation and procurement of equipment ☐
- Technology assessment ☐
- Acceptance testing ☐
- Risk and safety management ☐
- Inspection, preventive maintenance and repair ☐
- Quality assurance and improvement ☐
- Asset/inventory management ☐
- Equipment performance and cost management ☐
- Equipment utilisation ☐
- Training equipment users ☐
- Research and development ☐
- Review of equipment replacement needs ☐
- Project management ☐
- Facilities and plant management and maintenance ☐
- Other (please specify) ..... ☐
  ..... ☐

In evaluating current tasks, questions that can be asked of each activity:

a) *Are there laid down procedures and guidelines for each activity?*
b) *Do these comply with national or institutional policy (if it exists)?*
c) *How does the activity support the hospital's strategy?*
d) *Who is the 'customer'/'client' receiving the service?*
e) *Has the 'customer' (hospital administration, users etc.) specified exactly what is needed?*
f) *Do you feel that the need relating to each activity is being met?*
g) *If not, in what respects is the service lacking?*
h) *Do you have adequate resources for each activity, including appropriately?*
i) *What additional resources would you require to provide an acceptable service?*
j) *Is there another way of accomplishing the same result?*
k) *Would it be more cost-effective to **outsource** any of the CED activities?*

3.2 For each activity performed by your department:

a) Please rank according to performance (i.e. 1 = highest importance, 2 = next highest etc)
b) Estimate the percentage time spent by CED personnel on the activity
c) Estimate the percentage of the allocated budget spent on the activity

Activity	a) Rank	b) % time	c) % budget
Specification, evaluation, procurement			
Technology assessment			
Acceptance testing			
Risk and safety management			
Inspection, preventive maintenance and repair			
Quality assurance and improvement			
Asset/inventory management			
Equipment performance & cost management			
Equipment utilisation			
Training equipment users			
Research and development			
Review of equipment replacement needs			
Project management			
Facilities & plant management & maintenance			
Other (please specify)			

3.3 **a)** What proportion of inspection, preventive maintenance and repair is performed by the following service providers, across all equipment categories?:

A. In-house CED .....
B. Manufacturer .....
C. Third-party (shared service/commercial firm).....
D. Combination of above .....

b) Do you have maintenance insurance (i.e. financial protection against high service costs)? Yes ❑ No ❑

3.4 Do you have any additional comments on the service provided by your CED?

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4. EQUIPMENT MANAGEMENT

4.1 Does your department have a computerised equipment management system?
Yes ❑ No ❑

4.2 Do you have an up-to-date database/documentation containing the following? (please tick):

- Service provided/requested, including ❑
  - equipment maintenance tasks ❑
  - equipment management tasks ❑
  - technology management tasks ❑
  - repairs done ❑
  - inspections performed ❑
- In-house labour, including ❑
  - no of hours spent providing a particular service ❑
  - associated labour rate ❑
  - identification of the individual providing the service ❑
- Vendor labour, including ❑
  - hours spent and rate ❑
  - travel and zone charges ❑
- Parts list, including ❑
  - part number, description and cost ❑
- Budget allocation and use ❑
- Timeliness / time usage ❑
- Problem reported ❑
- Equipment identification and inventory ❑
- Complaints ❑
- User-related problems ❑
- Waste (resource not converted to useful product/output) ❑
- Other (please specify)..... ❑
  ..... ❑
  ..... ❑

5 PERFORMANCE FACTORS

5.1 Does your CED have measures/programmes to evaluate the following:
(Please refer to Appendix A for definitions)

- Productivity Yes ❑ No ❑ .....
- Quality Yes ❑ No ❑ .....
- Timeliness Yes ❑ No ❑ .....
- Resource utilisation Yes ❑ No ❑ .....
- Cycle time Yes ❑ No ❑ .....
- Outcome Yes ❑ No ❑ .....

If 'Yes' please specify.

5.2 Does your CED do any of the following?

- Measure performance against customers' expectations? Yes ❑ No ❑
- Measure performance against competition / other CEDs? Yes ❑ No ❑
- Measure the relative importance of service dimensions and attributes? Yes ❑ No ❑
- Use qualitative methods such as customer focus groups and direct observation? Yes ❑ No ❑
- Conduct employee research Yes ❑ No ❑

5.3 Does your CED experience/document any of the following?:

- Inventory that is not utilised/needed? Yes ❑ No ❑
- Staff without skills to use available resources Yes ❑ No ❑
- Staff with skills that are not being used Yes ❑ No ❑
- Inappropriate management strategy / delegation Yes ❑ No ❑
- More quality than is necessary Yes ❑ No ❑
- Meetings/reports that do not convey useful info Yes ❑ No ❑
- Absenteeism Yes ❑ No ❑
- Lengthy planning, budgeting processes Yes ❑ No ❑
- Lengthy capital appropriation procedures Yes ❑ No ❑

6. BUDGET AND COSTS

6.1 **a)** Is there adequate budget provision within the institution for the following? (Please tick)

- Purchasing costs/ Capital equipment Yes ❑ No ❑
- Operating costs Yes ❑ No ❑
- Maintenance costs Yes ❑ No ❑
- Staff costs (salaries and benefits) Yes ❑ No ❑
- Transport and installation costs Yes ❑ No ❑
- Costs of recording and evaluation data Yes ❑ No ❑
- Training costs Yes ❑ No ❑
- Costs of removal from service Yes ❑ No ❑

- Administrative and supply costs Yes ❑ No ❑
- Parts and materials Yes ❑ No ❑
- Services provided by external service sources Yes ❑ No ❑
- Other (please specify) Yes ❑ No ❑

b) Are there significant differences between the availability of funds for different types of technology? If so, please specify.

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6.2 Cost Analysis

6.2.1 **a)** Does your CED have formal cost analysis procedures for the services provided? Yes ❑ No ❑

b) If 'Yes' please specify? .....
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6.2.2 Do you have documentation of the following:

- Hourly labour rates Yes ❑ No ❑
- Annual available labour hours/Employee Yes ❑ No ❑
- Total fixed costs Yes ❑ No ❑
- Chargeable hours Yes ❑ No ❑
- Variable costs/hour Yes ❑ No ❑
- Profits = Revenue - Expenses Yes ❑ No ❑
- Service contract rates Yes ❑ No ❑

(For evaluating hourly labour costs, cost-volume-profit relationships & pricing options)

6.3 Cost-effectiveness *(adapted from AAMI, 1993)*

6.3.1 **a)** Are there written policies and procedures regarding management of the cost-effectiveness of the clinical engineering program? Yes ❑ No ❑

b) If 'Yes', are these policies and procedures reviewed periodically? Yes ❑ No ❑

6.3.2 Is hospital administration provided with periodic reports on the cost and effectiveness of the department? Yes ❑ No ❑

6.3.3 Are analyses conducted regularly to determine the appropriate balance between services provided by external vendors and the in-house CED ? Yes ❑ No ❑

6.3.4 Is there documentation of the technical qualifications of the CED staff? Yes ❑ No ❑

6.3.5 Is there a documented programme of continuing education for technical staff? Yes ❑ No ❑

6.3.6 Is there a policy requiring authorisation of (estimated) expensive repairs before the repair is made? Yes ❑ No ❑

6.3.7 **a)** Is the in-house CED provided with adequate work and storage space , tools and test equipment, technical staff, office and clerical support, reference materials and financial resources? Yes ❑ No ❑

b) If 'Yes' are these resources adequately utilised by the CED? Yes ❑ No ❑

6.3.8 **a)**Have performance indicators been defined for CED cost-effectiveness? Yes ❑ No ❑

b) If 'Yes', are these indicators routinely monitored? Yes ❑ No ❑

6.3.9 Do you have any further comments on the cost-effectiveness of your/any CED?

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7 SUSTAINABILITY

7.1 **a)** Do you see your CED surviving in the next 5, 10 or 15 years? Yes ❑ No ❑

b) If 'Yes' what are the institutional, organisational or environmental factors that would support its existence?
If 'No' what are the institutional, organisational or environmental factors that would threaten its existence?

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7.2 **a)** Is/has your department (been) under the threat of closure? Yes ❑ No ❑

b) If 'Yes', how could it be / was it avoided ?

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7.3 Would you consider your CED as a 'core' function of your health care institution?
Yes ❑ No ❑
Why? .....
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7.4 In your opinion, is your department well-accepted, recognised by:

a) Medical/nursing staff? Yes ❑ No ❑
b) Hospital management/administration? Yes ❑ No ❑
c) Other technical departments? Yes ❑ No ❑

7.5 What factors enhance the sustainability of CEDs?

- Adequate physical resources ❑
- Adequate financial resources ❑
- Adequate human resources ❑
- Management/strategic commitment ❑
- Conducive environment ❑
- Legal framework (e.g. threat of litigation) ❑
- Logistics support ❑
- Cultural considerations ❑
- Stakeholder participation ❑

Please elaborate

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8 QUALITY ASSURANCE

(Please refer to Appendix A for definitions)

8.1 Does the department have a formal quality assurance (QA) programme? Yes ❑ No ❑

If 'No' are there any plans to establish one in the near future; or are you taking any steps toward improving quality? (Please elaborate)

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8.2 If 'Yes' please answer the following questions:

8.2.1 Does your QA programme address the following dimensions of quality? (Please tick)

A. Technical competence ❑
B. Access to service ❑
C. Effectiveness ❑
D. Interpersonal relations ❑
E. Efficiency ❑
F. Continuity ❑
G. Safety ❑
H. Amenities ❑

8.2.2 Does your programme adhere to the following principles of QA: (Please tick)

A. A focus on client needs? ❑
B. A focus on systems and processes? ❑
C. A focus on data-based decisions? ❑
D. A focus on participation and teamwork in quality improvement? ❑

8.2.3 Does the programme use any of the following analytical tools to analyse problems/processes?

A. System modelling ❑
B. Flowcharting ❑
C. Cause-and-effect analysis ❑
D. Force-field analysis ❑
E. Statistical tools ❑
F. Other (please specify) ❑ .....

8.2.4 Are quality assurance resources available to employees? Yes ❑ No ❑

8.3 a) Is your department accredited with an appropriate accreditation body (e.g. JCAHO?) Yes ❑ No ❑

b) Do you feel that accreditation has a role in improving the quality of healthcare technology services? Yes ❑ No ❑

Please elaborate .....
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c) Is your CED ISO9000 certified? Yes ❑ No ❑

8.4 What steps are you taking or can be taken towards continuous quality improvement in CE? Please elaborate
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9 GENERAL

9.1 Is your department housed in a **public/private** institution? (please circle)

9.2 Are documented policies and procedures reviewed periodically, or as circumstances change? Yes ❑ No ❑

9.3 **a)** Are the majority of your personnel certified/registered with appropriate certification or professional bodies? Yes ❑ No ❑
b) Does your CED provide a personal achievement and growth ladder for the employees? Yes ❑ No ❑

9.4 **a)** Has your department been affected by/experienced any of the following trends? (please tick) (Please refer to Appendix A for definitions)

A.	Downsizing	❑
B.	Economic rationalisation	❑
C.	Outsourcing	❑
D.	Total quality management	❑
E.	Benchmarking	❑
F.	Re-engineering	❑
G.	Accreditation	❑
H.	Globalisation	❑
I.	Other (please specify)	❑ .....

b) If so, how?
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10 PERFORMANCE, COST-EFFECTIVENESS AND SUSTAINABILITY MEASURES

10.1 What measures would you suggest that could be used to assess a) performance b) sustainability c) cost-effectiveness of clinical engineering departments?

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10.2 Which of these measures are currently used in your CED?

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11 COMMENTS

Do you have any additional comments, or suggestions for improvement on the questionnaire?

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APPENDIX A

DEFINITIONS

A1. **Vision:** where you see the department in the present and in the future

A2. **Mission:** a statement defining the dimension and scope of responsibility of the CED i.e. what products and services, for what markets and customers will build the success of the particular department?

A3. **Goals:** specific end results derived from the mission. Goals direct the department towards the future

A4. **Values:** the philosophy of the kind of department that exists or aspires to be

A5. **Objectives:** priorities

A6. **Customer:** an individual/organisation who receives, uses or is impacted by a product. May be internal or external

A7. **Productivity:** relationship between output and input of a given process i.e. productivity is the ability to combine and convert inputs (labour, capital, materials and other resources) into outputs (goods and/or services) which satisfy market needs.

A8. **Quality:** conformance to requirements (stated or implied). This includes internal measurements e.g. number of rejects; and external measures such as customer satisfaction rating. Alternatively, the degree of excellence of a product or service

A9. **Timeliness:** assesses whether process takes place at time intended

A10. **Resource utilisation:** resources used versus resources available (e.g. hospital, equipment, in-house tools)

A11. **Cycle time:** amount of time to proceed from one defined point in process to another i.e. how long a process takes

A12. **Outcome:** measures of the effects of the outputs of the system. Outputs often represent the various objectives of the system and may be used as intermediate indicators of sub-optimal performance by the system

A13. **Quality assurance:** all the planned or systematic actions that are carried out to set standards and to monitor and improve performance so that the service provided is as effective and as safe as possible i.e. providing adequate confidence that a product or service will satisfy requirements for quality

A14. **System modelling:** a means for diagramming how elements of a system relate to one another

A15. **Flowcharting:** a means of graphically representing the flow of a process. Can be used to identify redundancy and unnecessary complexity (among other things)

A16. **Cause-and-effect analysis (Fishbone or Tree diagram):** a display of the factors that are thought to affect a particular output or outcome in a system

A17. **Force-field analysis:** a systematic method for understanding competing forces that increase or decrease the likelihood of successfully implementing change

A18. **Statistical/data presentation tools:** a set of charts to display different types of data (e.g. run charts, control charts, histogram, scatter diagram)

A19. **Continuous Quality Improvement (CQI):** an approach to improving and maintaining quality that emphasizes internally driven and relatively constant assessments of potential causes of quality defects, followed by action aimed either avoiding decrease in quality or else correcting it in an early stage

A20. **Certification**: the procedure and action by a duly body of determining, verifying and allocating in writing to the quality of personnel, processes, procedures or items in accordance with applicable requirements

A21. **Accreditation:** certification by a duly recognised body of the facilities, capability, objectivity, competencies and integrity of an agency, service or operational group

or individual to provide the specific service or operation needed

A22. **Downsizing:** intended reductions of personnel

A23. **Economic rationalisation:**

A24. **Outsourcing:** using the services of a contractor rather than in-house staff to accomplish an activity

A25. **Total Quality Management:** management-led philosophy of continuous improvement in every process of planning, production and service - a way of managing to improve the effectiveness, efficiency, flexibility and competitiveness of the business as a whole

A26. **Benchmarking:** the gathering of quantitative data, either physical or financial, to compare the performance of different organisations in order to identify and understand elements of superior/world-class performance in a particular work process

A27. **Re-engineering:** "...changing processes, organisational structures, management style and behaviour, compensation and reward systems, as well as relationships with shareholders, customers, suppliers and other external partners." (Kelada, 1996)

A28. **Globalisation:** geographical extension of economic activity across national boundaries AND the functional integration of such internationally dispersed activities

REFERENCES

AAMI (1990), *Design of Clinical Engineering Quality Assurance and Risk Management Programmes*, Management Information Reports, AAMI, Arlington, USA

AAMI (1993), *Guideline for Establishing and Administering Medical Instrumentation Maintenance Programmes*, Management Information Report, AAMI, Arlington, USA

Autio DP, Morris RL (1995), *Clinical Engineering Program Indicators*, pp 2556 - 2565 in: Bronzino JD (Ed), The Biomedical Engineering Handbook, CRC Press Inc

Bronzino JD (1992), *Management of Medical Technology: A Primer for Clinical Engineers*, pp 13 – 17, Butterworth-Heinemann, Stoneham MA

Brown LD, Franco LM, Rafeh N, Hatzell T (1999?), 'Quality Assurance of Healthcare in Developing Countries', *Quality Assurance Methodology Refinement Series*, Quality Assurance Project, Bethseda USA

Chang RY & Morgan MW (2000), *Performance Scorecards: Measuring the Right Things in the Real World*, Jossey-Bass, San Fransisco

Christopher WF & Thor CG (eds) (1993), *Handbook for Productivity Measurement and Improvement*, Productivity Press, Portland, Oregon

David YD, Judd JM (1993), *Medical Technology Management*, SpaceLabs Medical, Redmond, Washington, USA

David Y & Rohe D (1986), 'Clinical Engineering Program Productivity and Measurements, *Journal of Clinical Engineering*, Vol 11, No 6, pp 435 - 443

Dicken P (1998), *Global Shift, 3rd Edition*, Paul Chapman Publishing Ltd, London

Franco LM, Newman J, Murphy G, Mariani E (1999), ' Achieving Quality Through Problem Solving and Process Improvement, 2nd Ed', *Quality Assurance Methodology Refinement Series*,

Frize M (1990), *Results of an International Survey of Clinical Engineering Departments: Part 1: Role, Functional Involvement and Recognition,* Medical and Biological Engineering and Computing, 28:pp 153 – 159

Furst E (1986), 'Productivity and Cost-Effectiveness of Clinical Engineering', *Journal of Clinical Engineering,* Vol 11, No 2, pp 105 - 113

Harbour JL (1997), *The Basics of Performance Measurement*, Quality Resources, New York

Ibrahim HA & Kirsch AD (1989), ' An Empirical Study of Selected Cost Measures of Clinical Engineering Service Effectiveness' *Journal of Clinical Engineering,* Vol 14, No 1, pp 43 - 48

Issakov A (1994), 'Service and Maintenance in Developing Countries', pp 21 - 28 in: van Gruntig CWD (Ed) (1994), *Medical Devices: International Perspectives on Health and Safety,* Elsevier Science, Amsterdam

Kaydos W (1991), "*Measuring, Managing and Maximising Performance*", Productivity Press, Inc, Massachusettes, USA

QA Brief (1999), 'Using Accreditation to Improve Quality..etc' , *Quality Assurance Project,* Bethseda, USA

Swanevelder AG (1997), 'Critical Aspects of Technology Management of Medical Equipment in the Healthcare Environment', *Planning for More Affordable Healthcare,* Proceedings, Paper

World Health Organisation (1999), *WHO Consultation on Physical Infrastructure and Technology*, Draft Final Report

(end)

APPENDIX B: COMPLETE LIST OF INDICATORS

COMPLETE LIST OF INDICATORS

The following is a complete list of indicators sourced from the available literature and current best practice, in no particular order. Indicators in *italics* are defined in the glossary.

Factor	Indicator
1. Performance	1. Percentage of medical equipment supported by CED that is functional
	2. *Productivity* 3. (ratio of output to input/resources)
	4. Percentage of service tasks completed within acceptable period
	5. Mean time per job activity
	6. Percentage time spent doing technical work vs. administrative work
	7. Absenteeism/ sick leave
	8. Job satisfaction/ incentives
2. General Activities Carried Out by the CED	1. Type and number of medical devices supported by CED
	2. Presence of hospital-wide safety /risk management programme, specific to medical equipment
	3. Presence of hospital-wide quality assurance programme, specific to medical equipment
	4. *Normalised* number of routine checks of medical equipment (e.g. life support systems) proactively performed by CED, in different clinical departments per unit time
	5. Positive contribution to equipment management activities (as listed in question 3.1 above)
	6. Percentage of time devoted to consultation vs. IPMs[1] vs. repairs vs other
3. Inspection and Preventive Maintenance Procedures (IPMs)	1. Total number of IPMs performed per device type per unit time
	2. IPMs not performed because equipment could not be located (% of total scheduled IPMs)
	3. IPMs not performed because equipment was in use (% of total scheduled IPMs)
	4. *Downtime* of equipment due to IPMs
	5. Degree of compliance that has been achieved with the established schedule for routine performance IPMs

[1] IPMs = inspection and preventive maintenance procedures

	6. Percentage IPMs performed in-house vs. IPMs outsourced
	7. Percentage IPMs performed incorrectly by technical staff
	8. IPMs not performed due to unavailability of staff
4. Corrective Maintenance Procedures (Repairs)	1. Number of repairs completed per device per unit type
	2. Average time per repair per equipment type
	3. Downtime of equipment due to repairs
	4. *Response time* to service requests
	5. Percentage repeat repairs
	6. Percentage repairs delayed due to parts orders
	7. Downtime of equipment due to unavailability of spare parts
	8. Downtime of equipment for which abnormal labour or replacement parts were required
	9. Percentage repairs performed in-house vs. repairs outsourced
	10. Percentage repairs performed incorrectly by technical staff
5. Test Equipment Available	1. Availability of functional test equipment
	2. Adequate number of test equipment available per test equipment type
	3. Monetary value of test equipment
	4. Percentage of test equipment properly calibrated and functional
	5. Adequate training to technical staff on test equipment
6. Spare Parts	1. Adequate spare parts on site for common repairs
	2. Adequate spare parts on site for critical medical equipment (e.g. life support equipment)
	3. Ratio of parts value to equipment value – (total value of inventory divided by total value of equipment being serviced)
	4. Turnover factor - how often the parts kept in the inventory are used
	5. Availability of inventory of spare parts
	6. Mean time it takes to obtain spare parts for uncommon repairs
7. Risk-Management / Safety	1. Percentage and type of outsourced equipment repairs checked by in-house CES before returning to clinical environment
	2. Percentage and type of outsourced IPMs checked by in-house CES
	3. Presence of working *hazard notification* system
	4. Presence of *incident investigation* and reporting system
	5. Number and type of *litigation* cases
	6. Normalised number of incidents

8. User-Related Equipment Malfunction	1. Number of equipment malfunction caused by user errors/misuse or abuse
	2. Frequency of equipment malfunction caused by user errors/misuse or abuse
	3. Frequency of similar user errors on the same shift on the same equipment
	4. Percentage user errors/misuse associated with high risk medical equipment e.g. life support equipment
	5. Percentage user errors/misuse associated with complex equipment i.e. equipment malfunction as a function of equipment complexity
	6. Percentage user errors/misuse before in-house user-training vs. after user-training
	7. Quality of user training and instruction
	8. Percentage user errors/misuse before training by outside agency
	9. Availability of regular training/re-training programmes
	10. Stated confidence of users in terms of correct application of medical equipment
9.Documentation	1. Evidence of proper documentation of all work done by CES
	2. IPMs/repairs conducted in accordance with manufacturer's recommendations, as specified in service manuals
	3. Availability of service manuals (from manufacturers) for all equipment serviced/maintained/repaired
	4. IPMs/repairs not performed due to lack of necessary documentation
	5. Availability of documentation for test equipment
	6. Presence of equipment service histories, providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc.
	7. Availability of operator/user manuals or instructions for all medical equipment
10. Information Systems	1. Availability of hospital-wide equipment inventory / asset register using consistent nomenclature
	2. Availability of updated CES medical equipment inventory (including supported medical equipment, test equipment and spares) based on inventory of equipment supported (service, maintenance, user-related malfunctions, incidents) using consistent nomenclature
	3. Availability of records of equipment service history (IPMs and repairs)
	4. Regular updating and verification of information systems

	5. Management decisions (relating to needs assessment, procurement, decommissioning and replacement planning) based on inventory and CES equipment service histories
	6. Database on service provided by equipment suppliers and third party service providers
11. Technical Competence (of CES staff)	1. Educational background and skills level
	2. *Certification* and registration with appropriate professional body
	3. Continuing education/ professional development
	4. Competency in performing designated equipment maintenance activities (e.g. knowledge of how to use test equipment)
	5. Technical efficiency of work performed (e.g. time spent completing activity)
	6. Quality of work performed per activity
12. Patient Care	1. Interruption of patient care due to failure in technology
	2. Interruption of patient care or extension of patient stay due to failure of user to correctly apply technology
	3. Inability to perform clinical procedures due to medical equipment non-functionality/ unavailability
	4. Risk to patient relating to medical equipment utilisation or functioning
	5. Risk to user/operator relating to medical equipment utilisation or functioning
	6. Number of reported hazards/incidents relating to medical equipment
13. Customer Service	1. Relative number and frequency of different types of complaint: e.g. those related to response time, equipment downtime, courtesy, ability to meet deadlines or other causes
	2. Frequency of complaints per equipment type per department
	3. *Effectiveness* of response to reported malfunction
	4. Client satisfaction surveys performed
	5. Percentage clients satisfied with service provided
14. Cost-Effectiveness	1. *Labour (direct/variable) cost* per hour
	2. *Overhead (fixed) cost* per hour
	3. Labour cost plus overhead cost per repair per equipment type
	4. Cost of CED service per bed supported
	5. Number of medical devices/equipment per bed supported
	6. Cost of CED support as a percentage of capital cost of supported medical equipment per equipment type
	7. Cost of in-house service vs. cost of outsourced service

15. General	1. Availability and use of management tools including guidelines, policies, computer-based decision support systems etc
	2. Regular contact between service provider and client
	3. Level of participation and communication with stakeholders (i.e. hospital management, clinical staff, manufacturers/ suppliers etc)
	4. Level of interaction with equipment suppliers including third party service providers
	5. Proper management of CES budget allocation and disbursement
	6. Salary levels of CES technical staff vs. salary levels of other healthcare employees
	7. Salary levels of CES technical staff vs. similar employees in competing sector (public/private)
	8. Job security, career prospects and incentives for employees
	9. Existence and use of institutional/ 10. organisational policies and guidelines for health care technology management
	11. Awareness and application of institutional/organisational policies and guidelines for medical equipment management

APPENDIX C: FINAL PAPER QUESTIONNAIRES

SIZANANI

UNIVERSITY OF CAPE TOWN / GROOTE SCHUUR HOSPITAL

Participating Centre in MRC/WHO Collaborating Centre for Essential Technologies in Health

16 July 2001

Dear

Questionnaire: PERFORMANCE AND SUSTAINABILITY OF CLINICAL ENGINEERING SERVICES

BACKGROUND

This questionnaire aims to establish indicators for the performance and sustainability of **medical equipment management and maintenance** * services, as part of cost-effective healthcare service delivery. Your time in completing this questionnaire and providing your valuable insights will be greatly appreciated. You will also contribute to improved healthcare technology management internationally by addressing, *inter alia*, the important issue of whether or not MEM&M services are a core function of healthcare delivery.

> * *Units responsible for providing this service are known variously as Clinical Engineering Departments, Health Care Technical Services, Medical Physics Departments, Biomedical Technology / Engineering Services, Medical Apparatus / Equipment Workshops, etc. For the sake of clarity and consistency, we will use the term* ***Clinical Engineering Service*** *or* ***CES****.*

The general function of a Clinical Engineering Service is to provide a supportive role in the planning, needs assessment, evaluation, procurement, installation, utilisation and maintenance of medical equipment, defined as including all medical/surgical devices, equipment and instruments. However, the boundaries of these support roles are not clear and well-defined, as what applies to one country or institution does not necessarily apply to another. Also, a clinical engineering service can range from one isolated but dedicated individual to a fully equipped department with professional and technical/artisan staff, supported by adequate technological and administrative infrastructures, to a shared regional/central resource centre.

Alongside the change in scope and function of Clinical Engineering Services over the years, is the shift from being primarily task-driven to being more business-oriented and cost-justified. A further development has been the adoption (sometimes imposed) of various international trends in business and management, e.g. total quality management, benchmarking, re-engineering, outsourcing (of non-core business activities) and, most recently, ISO9000 standard accreditation. As sustainability is often dependent on issues of cost-effectiveness and relevance, and associated perceptions of institutional/organisational stakeholders, these considerations may threaten otherwise successful departments and/or services with closure.

STATUS QUO

The latest World Health Report[1] suggests four key *functions* of a health system, viz. service delivery, capacity building, financing and stewardship, and three key health system *inputs*, viz. human resources, capital investment (in physical assets such as buildings and equipment) and consumables (including drugs).

Many countries (and notably developing and emerging economies) are under-resourced in terms of what is needed for equitable service delivery of acceptable quality, as well as the management-level skills needed to maximise the impact of healthcare technologies on service delivery. Within this context healthcare technology management (HTM) practitioners and activities are being increasingly recognised for their contribution to health system performance. There is thus an urgent need to (i) build HTM management capacity and (ii) develop effective HTM tools while at the same time (iii) developing indicators for HTM performance and sustainability.

pto...

[1] The World Health Report 2000 - Health Systems: Improving Performance. World Health Organization, Geneva (2000)

This questionnaire, which follows and complements previous work by Frize (1990) and Glouhova (1999), focuses on the last-mentioned and specifically on the development of indicators for Clinical Engineering Services, be they situated within a health facility or a shared / regional resource centre. These indicators will form qualitative and quantitative components of a tool for objective assessment and comparison of Clinical Engineering Services in different settings, as well as identifying pointers to performance, cost-effectiveness and sustainability. This in turn will contribute to improved management of these services, with the overall aim of improving the performance and quality of healthcare delivery.

QUESTIONNAIRE

The questionnaire is being addressed to four key target groups:

- Institutional / health facility management (including nursing management) **[QUEST1]**;
- Personnel (both managerial and technical) of CE Services/Departments **[QUEST2]**;
- CE Service Clients, i.e. health workers in clinical departments providing healthcare services **[QUEST3]** and
- Representatives of national and provincial ministries of health and international HTM experts (including representatives of multilateral organisations and bilateral agencies, as well as technical consultants) **[QUEST4]**.

The questionnaire is split into two parts:

- **Part 1** comprises mostly unstructured questions to gauge your general opinion about the CES in (or serving) your institution. **Please answer as much of this part as you are able to.**
- **Part 2** is structured, requiring you to rate a list of proposed indicators, as well as adding any that you feel would be appropriate. As this part is directly related to the main objective of the study, we would appreciate it if you could answer all the questions.

Please note that all terms appearing in *italics* in the Questionnaire are defined in the **Glossary** (Appendix A). A selected bibliography is given in Appendix B.

Your responses will be kept confidential and general statistics only will be published. Should you wish to remain anonymous, you may do so; however an indication of your **position or job description** and **country** are needed for comparative purposes. We would be happy to provide you with a summary of the findings of this study and these should hopefully be of benefit to you and your institution.

Please return the completed questionnaire to the address (or fax number) indicated below, by Friday 3rd August. Should you wish this questionnaire to be sent to you in electronic form, or should you need any additional information, please let us know.

Thank you for your co-operation.

Yours sincerely

Signatures Removed

Mladen Poluta Rutendo Ngara

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Appendix A: GLOSSARY OF TERMS

A1. ACCREDITATION: certification by a duly recognised body of the facilities, capability, objectivity, competencies and integrity of an agency, operational group or individual to provide a service, usually specified in the form of standards.

A2. ASSET / INVENTORY MANAGEMENT: Management of capital assets, including medical equipment, on the basis of asset registers (inventory).

A3. BENCHMARKING: the gathering of quantitative data, either physical or financial, to compare the performance of different organisations in order to identify and understand elements of best practice / world-class performance in a particular work process.

A4. CERTIFICATION: the procedure and action by a duly appointed body of determining, verifying and documenting the quality of personnel, processes, procedures or items in accordance with applicable requirements.

A5. CES PERSONNEL: technical staff of a clinical engineering service. It is assumed that the CES has administrative and clerical backup.

A6. CLINICAL ENGINEERING SERVICE: a service that provides a supportive role in the planning and development of facilities, technology and technical methods as they relate directly to healthcare delivery. In different environments CES's can fall under different names, e.g. *medical equipment workshop, medical physics department, biomedical technology service, health care technical service, etc.* The service can range in scope from one dedicated but under-resourced individual to an entire department, situated within a health facility or elsewhere as a shared regional/central resource centre.

A7. CORRECTIVE MAINTENANCE / REPAIR: Trouble shooting to isolate the cause of device malfunction and then replacement or subsequent adjustments of components or subsystems to restore normal function, safety, performance and reliability (Bronzino, 1992).

A8. COST OF OWNERSHIP: Cost of ownership encompasses all direct and indirect expenses associated with medical equipment over its lifetime. It includes acquisition costs, operation and maintenance costs (i.e. installation, supplies, training, spare parts, test equipment, transport, etc.) (David, 1993).

A9. COST-EFFECTIVENESS: The cost of a technology or of alternative technologies, compared to the resultant benefits, with costs and benefits not expressed by the same unit. Costs are usually expressed in a currency (or equivalent) while benefits/effectiveness are expressed in terms such as lives saved, disability avoided, quality-adjusted life years saved, etc.

A10. CLIENT / CUSTOMER: an individual/group/organisation receiving, using or impacted by a product or service.

A11. DOWNSIZING: intended reduction of personnel in an organisation, often as a consequence of economic rationalisation.

A12. DOWNTIME: time during which medical equipment is not available for its normal function (e.g. due to IPMs or repairs).

A13. ECONOMIC RATIONALISATION: management decisions based almost purely on the (short-term) "bottom-line" often with little or no regard for the wider (longer term) consequences.

A14. EFFICACY: Benefit of a technology achievable under ideal conditions.

A15. EFFECTIVENESS: Benefit of a technology achievable under average conditions of use.

A16. EQUIPMENT PERFORMANCE MONITORING: Monitoring of equipment utilisation, cost-effectiveness, availability (uptime), etc.

A17. FACILITIES AND PLANT MANAGEMENT: A support programme that provides and maintains the proper environment for the delivery of healthcare services. FPM programmes ensure that buildings and associated utilities, transport and communications systems are acquired, operated and maintained in a

manner that promotes the most efficacious and productive environment for normal hospital operations and the delivery of quality medical care (Bronzino, 1992).

A18. **FUNCTIONAL:** Equipment in good and proper working order, according to specification.

A19. **GLOBALISATION:** extension of economic activity across national and regional boundaries, and the functional integration of such internationally dispersed activities.

A20. **HAZARD NOTIFICATION SYSTEM:** Guidelines, procedures and mechanisms for informing clinical and technical personnel of emerging information on equipment-related risks, usually due to design flaws or production/manufacturing defects.

A21. **HEALTHCARE TECHNOLOGY MANAGEMENT (HTM):** "An accountable, systematic approach to ensuring that cost-effective, safe, efficacious and appropriate equipment is available to meet the demands of quality patient care" (ECRI, 1989). Defined at the **national** level as "the goal of optimising the acquisition and utilisation of technology to achieve maximum beneficial impact on health outcomes" (Rakich, 1992). Such an approach requires that medical equipment resources be managed and that the management strategies have measurable outputs that are monitored and evaluated (COHSASA, 1997).

A22. **HIGH RISK MEDICAL EQUIPMENT:** Equipment associated with a high risk to the patient in terms of either intended function or consequences of failure, such as electrosurgical units or life-support equipment.

A23. **HOSPITAL ENGINEERING:** Management and maintenance of health facility infrastructure, including services, plant, machinery and buildings (synonymous with Facilities and Plant Management)..

A24. **INCIDENT:** An "incident" is defined as an event in which equipment or procedure has caused injury to a patient, and occasionally staff members (users/operators) or even visitors. The incident can be caused by specific equipment malfunction, user error or a combination of the two.

A25. **INCIDENT INVESTIGATION** An incident investigation includes: preservation of evidence and assessment of the overall condition of the equipment; interviews with involved personnel; review of maintenance history and review matters related to training associated with the equipment.

A26. **INDICATORS:** An indicator is an objective, quantitative variable that indicates or shows a given situation, and thus can be used to measure change. It is objective in that the same measurement can be obtained by different observers.

A27. **IN-HOUSE CES**: A clinical engineering service based within or readily accessible to the institution / hospital benefiting from its services (for purposes of this questionnaire this specifically excludes private-sector service providers).

A28. **INSPECTION AND PREVENTIVE MAINTENANCE (IPM):** There are three basic categories: (i) Periodic procedures to minimise the risk of failure and to ensure proper operation (including cleaning, lubricating, adjusting etc.); (ii) Functional testing, performance verification and calibration; (iii) Safety inspection. (Bronzino, 1992). IPMs are seen as lowering the total maintenance cost over the equipment lifetime, partly through extending this lifetime.

A29. **LABOUR COST (VARIABLE COSTS):** Costs that are assumed to vary (linearly) with production volume or service output. They can be viewed as costs that would not exist if there were no labour force. These include salary and wages of active service staff, continuing education expenses, liability insurance costs, repair and service supplies, employee benefits, etc. (Bronzino, 1992).

A30. **LITIGATION:** Legal action taken as a result of patient injury due to neglect of medical/nursing staff or equipment failure.

A31. **LOGISTICS SUPPORT:** includes supply systems, information and communications systems, and transport.

A32. **MEDICAL EQUIPMENT:** defined as including all medical/surgical equipment, devices and instruments used in healthcare delivery; the term is used interchangeably with 'medical devices' or 'medical technology'.

A33. **NEEDS ASSESSMENT:** A formal process for assessing (equipment) needs, usually on the basis of audits of clinical services offered, on the one hand, and an audit of existing (equipment) inventory on the other.

A34. **NORMALISED:** with respect to a specified time period or other appropriate unit.

A35. **OUTSOURCING:** using the services of an outside contractor (private sector service provider) rather than in-house staff to accomplish an activity.

A36. **OVERHEAD COST (FIXED COSTS):** Costs that do not fluctuate with the level of activity. These include effective cost of hospital floor space and utilities, capital depreciation; administrative and clerical labour cost, and costs of carrying a spare parts inventory (Bronzino, 1992).

A37. **PERFORMANCE:** An actual work accomplishment or output (not to be confused with work behaviour). Quality and productivity are dimensions of a higher-level measure called 'performance' or 'effectiveness'.

A38. **PHYSICAL INFRASTRUCTURE:** Includes health facilities (buildings and utilities) and hospital equipment, machinery and plant.

A39. **PRODUCTIVITY:** the ability to combine and convert inputs (labour, capital, materials and other resources) into outputs (goods and/or services) which satisfy market needs. Productivity can also be seen as a relationship between output and input of a given process i.e. *P = Output/Input = (production of some desired result)/(consumption of resources).*

A40. **QUALITY:** conformance to requirements (stated or implied). This includes internal measurements, e.g. number of rejects; and external measures such as customer satisfaction rating. Alternatively, the degree of excellence of a product or service.

A41. **QUALITY ASSURANCE:** all the planned or systematic actions that are carried out to set standards and to monitor and improve performance so that the service provided is as effective and as safe as possible i.e. providing adequate confidence that a product or service will satisfy requirements for quality.

A42. **RE-ENGINEERING:** "...changing processes, organisational structures, management style and behaviour, compensation and reward systems, as well as relationships with shareholders, customers, suppliers and other external partners" (Kelada, 1996).

A43. **RESPONSE TIME:** the time between the receipt of a service call and the time the technician actually arrives at the equipment site (AAMI, 1990).

A44. **RISK AND SAFETY MANAGEMENT:** An organised programme that removes and controls elements that can contribute to the avoidance of exposure to risks and the minimisation of liability exposure (David, 1993), i.e. minimises or prevents the occurrence of undesirable outcomes.

A45. **STRATEGY:** A vision of the position the service is to reach in the market and of how to get there, including financial, personnel and other sub-plans, as well as service strategy and quality strategy.

A46. **STRATEGIC PLAN:** "A continuous process of making present risk-taking decisions systematically and with greatest knowledge of their futurity; organising systematically the efforts needed to carry out these decisions; and measuring the results of these decisions against the expectations through organised systematic feedback" (David, 1993).

A47. **SUSTAINABILITY:** Medium- and/or long-term continuity of a process or service, usually determined on the basis of factors such as cost of delivery, availability of inputs/resources, desirability of the process or service, benefits accrued, opportunity costs, etc.

A48. **TECHNOLOGY ASSESSMENT:** A process used for examining and reporting properties of medical technology used in healthcare, such as safety, efficacy, effectiveness, feasibility and indications for use as well as social, economic and ethical consequences, whether intended or unintended (David, 1993). TA tools include cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA).

A49. **TEST EQUIPMENT:** Any tools and equipment used by CE personnel to perform calibration checks, IPMs and corrective maintenance, e.g. oscilloscopes, digital multimeters, defibrillator testers, physiological simulators, etc.

A50. THIRD-PARTY SERVICE PROVIDER: An independent medical equipment service organisation (i.e. not equipment supplier or in-house service). May be small and only specialise in a few types of equipment, or may be large enough to provide service for most equipment in a hospital.

A51. TOTAL QUALITY MANAGEMENT: management-led philosophy of continuous improvement in every process of planning, production and service - a way of managing to improve the effectiveness, efficiency, flexibility and competitiveness of the business as a whole.

Appendix B: SELECTED BIBLIOGRAPHY

B1. AAMI (1990), *Design of Clinical Engineering Quality Assurance and Risk Management Programmes*, Management Information Reports, AAMI, Arlington.

B2. AAMI (1993), *Guideline for Establishing and Administering Medical Instrumentation Maintenance Programmes*, Management Information Report, AAMI, Arlington.

B3. Autio DP, Morris RL (1995), *Clinical Engineering Program Indicators,* pp 2556-2565 in: Bronzino JD (Ed), The Biomedical Engineering Handbook, CRC Press Inc.

B4. Bronzino JD (1992), *Management of Medical Technology: A Primer for Clinical Engineers,* pp 13–17, Butterworth-Heinemann, Stoneham MA.

B5. Brown LD, Franco LM, Rafeh N, Hatzell T (1999?), 'Quality Assurance of Healthcare in Developing Countries', *Quality Assurance Methodology Refinement Series*, Quality Assurance Project, Bethesda.

B6. Chang RY & Morgan MW (2000), *Performance Scorecards: Measuring the Right Things in the Real World*, Jossey-Bass, San Francisco.

B7. Christopher WF & Thor CG (eds) (1993), *Handbook for Productivity Measurement and Improvement,* Productivity Press, Portland.

B8. David YD, Judd JM (1993), *Medical Technology Management*, SpaceLabs Medical, Redmond, Washington.

B9. David Y & Rohe D (1986), 'Clinical Engineering Program Productivity and Measurements, *Journal of Clinical Engineering,* Vol. 11, No 6, pp 435-443.

B10. De Villiers G (1998) 'An Investigation into Consulting Engineering Service Quality Perceptions and Expectations' Dissertation, Master of Science in Engineering, University of Cape Town.

B11. Franco LM, Newman J, Murphy G, Mariani E (1999), ' Achieving Quality Through Problem Solving and Process Improvement, 2nd Ed', *Quality Assurance Methodology Refinement Series*, Quality Assurance Project, Bethesda.

B12. Frize M (1990), 'Results of an International Survey of Clinical Engineering Departments: Part 1: Role, Functional Involvement and Recognition', *Medical and Biological Engineering and Computing*, 28:pp 153–159.

B13. Frize M (1990), 'Results of an International Survey of Clinical Engineering Departments: Part 2 – Budgets, Staffing, Resources and Financial Strategies', *Medical and Biological Engineering and Computing*, 28:pp 160 – 165.

B14. Furst E (1986), 'Productivity and Cost-Effectiveness of Clinical Engineering', *Journal of Clinical Engineering,* Vol. 11, No 2, pp 105-113.

B15. Glouhova M, Kolitsi Z, Pallikarakis N (1999) 'International Survey of Clinical Engineering Departments', *Proceedings Part 1 of the EMBEC '99,* Vienna, Austria, November 4-7, pp 632 – 633.

B16. Glouhova M, Kolitsi Z, Pallikarakis N (1999) 'International Survey of Clinical Engineering Departments: Part 2 – Practices, *IFMBE Proceedings, MEDICON 2001,* June 12 – 15, Pula, Croatia, pp 190 – 193.

B17. Harbour JL (1997), *The Basics of Performance Measurement*, Quality Resources, New York.

B18. Hinks J & McNay P (1999) 'The Creation of a Management-by-Variance tool for Facilities Management Performance Assessment, *Facilities,* Vol. 17 No1/2, pp 31 – 53.

B19. Ibrahim HA & Kirsch AD (1989), ' An Empirical Study of Selected Cost Measures of Clinical Engineering Service Effectiveness' *Journal of Clinical Engineering,* Vol. 14, No 1, pp 43-48.

B20. Issakov A (1994), 'Service and Maintenance in Developing Countries', pp 21 - 28 in: van Gruntig CWD (Ed), *Medical Devices: International Perspectives on Health and Safety,* Elsevier Science, Amsterdam.

B21. Kaydos W (1991), "*Measuring, Managing and Maximising Performance*", Productivity Press, Inc, Massachusetts.

B22. Neely A, Richards H, Mills J, Platts K, Bourne M (1997), 'Designing Performance Measures: A Structured Approach', *International Journal of Operations and Production Management,* vol. 17, No. 1, pp 1131 –1152.

B23. QA Brief (1999), 'Using Accreditation to Improve Quality', *Quality Assurance Project,* Bethesda.

B24. Rakich JS, Longest BB and Darr K (1992), "*Managing health services organizations*", 3rd ed., Health Professions Press, Baltimore.

B25. Swanevelder AG (1997), 'Critical Aspects of Technology Management of Medical Equipment in the Healthcare Environment', *Planning for More Affordable Healthcare,* Proceedings, Planning for More Affordable Health Care Conference, Sun City, South Africa.

B26. World Health Organisation (1999), *WHO Consultation on Physical Infrastructure and Technology*, Draft Final Report.

(end)

TARGET GROUP: INSTITUTIONAL MANAGEMENT **(including Nursing Management)**

Part 1 *(pages 1 to 6)*

1. DEMOGRAPHIC DATA

The following set of questions focuses on general information about your institution and the *Clinical Engineering Service* supporting it.

1.1 Please complete the following:
(If you prefer to remain anonymous, please indicate your position or job description and country in the space provided)

Surname ..... First Name/Initial .... Title .....
or ❑ Anonymous
Position/Job Description .....
Country .....

(The following information is optional)

Institution/Hospital .....
Email address .....
Telephone ..... Fax .....
Postal address .....
City ..... Postal Code .....

1.2 a) What type of health facility is your institution?
(Please tick [✓] *one* box only)

1 ❑ Tertiary / Academic health facility
2 ❑ Secondary / Referral / Regional health facility
3 ❑ District hospital
4 ❑ Day clinic / Community health centre
5 ❑ Other (please specify) .....

b) What is the number of beds supported by the health facility? (Please tick [✓] *one* box only)

❑ < 100 ❑ 100 - 250 ❑ 251 - 500 ❑ 501 - 750
❑ 751 - 1000 ❑ 1001 - 2000 ❑ > 2000 (Please specify) .....

c) Is your health facility a public sector or private sector institution? (Please tick [✓] appropriate box)

1 ❑ Public sector institution
2 ❑ Private sector institution
3 ❑ Other (please specify) .....

1.3 a) Is your institution supported by an *in-house* clinical engineering service (CES) or an external* clinical engineering service? (Please tick [✓] appropriate box)

1 ❑ In-house CES
2 ❑ External CES (*regional or centralised workshop/service)
3 ❑ Combination of in-house and external CES
4 ❑ Not supported at all

Please continue Section 1 on Page 2

b) Does the CES exist as a separate unit (e.g. Clinical Engineering Department, Health Care Technical Service, etc.) or part of another department (e.g. Hospital Engineering)?
(Please tick [✓]appropriate box)

❑ Separate unit, called .....

❑ Part of another department (Please specify) .....

c) To whom does the CES report?

.....

2. MISSION AND STRATEGY OF CLINICAL ENGINEERING SERVICE

The following set of questions aims to establish general mission statements and basic strategies of Clinical Engineering Services.
If your institution is supported by an in-house CES, please answer as much of this section as you can. If your institution does not have an in-house CES, please move on to Section 3.

2.1 a) Are you aware of the *mission statement* of the Clinical Engineering Service (CES) supporting your institution?

❑ Yes ❑ No ❑ I don't know

b) In your opinion, what would be an appropriate mission statement for a CES?

.....
.....
.....
.....

2.2 a) To your knowledge, does the CES have an appropriate *strategy (*or business plan) to achieve its mission?

❑ Yes ❑ No ❑ I don't know

b) In your opinion, what would be appropriate elements in such a plan?

.....
.....
.....
.....

c) If it exists, does this strategy support the overall strategic plan of your institution?

❑ Yes ❑ No ❑ I don't know

Please proceed to Section 3 on page 3

3. SERVICE PROVIDED BY CLINICAL ENGINEERING SERVICE

The following set of questions focuses on the services provided by the CES and the importance of these services to your institution
Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 4.

3.1 a) To your knowledge, which of the following medical equipment management and maintenance services does the CES provide? (Please tick [✓] boxes on left, as appropriate, in table below)

b) Please pick a number from the scale, to indicate how important you believe all possible CE services (as listed below) to be to your healthcare institution.
Please also rate those services that are not currently provided by the CES.
(Please circle [e.g.⑤] appropriate number on the right in the table below)

SCALE				
1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

NB: The following terms are defined in the Glossary on page 10: technology assessment, needs assessment, asset/inventory management, cost of ownership, facilities and plant management, risk and safety management, inspection and preventive maintenance, corrective maintenance, equipment performance monitoring, and quality assurance.

	a) Provided?	SERVICE	b) Rating of Importance (Please circle appropriate number for all services)				
1	❑	Strategic technology needs assessment and planning	1	2	3	4	5
2	❑	Technology assessment	1	2	3	4	5
3	❑	Specification, evaluation and procurement of equipment	1	2	3	4	5
4	❑	Asset/inventory management	1	2	3	4	5
5	❑	Review of equipment replacement needs	1	2	3	4	5
6	❑	Cost of ownership monitoring	1	2	3	4	5
7	❑	Management of service contracts	1	2	3	4	5
8	❑	Project management	1	2	3	4	5
9	❑	Facilities and plant management and maintenance	1	2	3	4	5
10	❑	Training equipment users	1	2	3	4	5
11	❑	Risk management	1	2	3	4	5
12	❑	Safety checks	1	2	3	4	5
13	❑	Acceptance testing (incoming inspections)	1	2	3	4	5
14	❑	Inspection and preventive maintenance (IPM)	1	2	3	4	5
15	❑	Corrective maintenance (repair)	1	2	3	4	5
16	❑	Equipment performance monitoring	1	2	3	4	5
17	❑	Functional or calibration checks	1	2	3	4	5
18	❑	Quality assurance and improvement	1	2	3	4	5
19	❑	Research and development/modification of equipment	1	2	3	4	5
20	❑	IT/Computer hardware and networks	1	2	3	4	5
21	❑	Telecommunications	1	2	3	4	5
22	❑	Other (please specify)	1	2	3	4	5
23	❑	.....	1	2	3	4	5
24	❑	.....	1	2	3	4	5

REMINDER: Have you rated **all** of the services listed above?

Please continue Section 3 on page 4

3.2 a) To your knowledge, are any of the following services *outsourced* to equipment suppliers/ agents or *third party service* providers (e.g. commercial firm/shared service) ?
(Please tick [✓] appropriate box in table below)

	Service Provided	Outsourced? *Please tick [✓] appropriate box*		
1	Training equipment users	❑ Yes	❑ No	❑ Both / mixed
2	Acceptance testing (incoming inspections).....	❑ Yes	❑ No	❑ Both / mixed
3	Inspection and preventive maintenance (IPM	❑ Yes	❑ No	❑ Both / mixed
4	Corrective maintenance (repair).....	❑ Yes	❑ No	❑ Both / mixed
5	Other (please specify)	❑ Yes	❑ No	❑ Both / mixed
6	....	❑ Yes	❑ No	❑ Both / mixed
7	....	❑ Yes	❑ No	❑ Both / mixed

3.3 In your opinion, what are the advantages and the disadvantages of having an in-house CES, as opposed to outsourcing all equipment management and maintenance, as listed above?

Advantages of in-house CES

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.....
.....
.....

Disadvantages of in-house CES

.....
.....
.....
.....

4. ASSESSMENT OF SERVICE PROVIDED BY CLINICAL ENGINEERING SERVICE

The following set of questions focuses on your assessment of the service provided by the CES. Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 5.

4.1 Institutional Expectations of the Clinical Engineering Service

4.1.1 Please list, in order of preference, what you as institutional management, expects from a CES.

1 .....
2 .....
3 .....
4 .....
5 .....

4.1.2 In your opinion, what major factors contribute to your expectations of the CES **not** being met (e.g. redoing work, excessive equipment *downtime*, poor *response time*, unprofessional conduct etc)

1 .....
2 .....
3 .....
4 .....
5 .....

4.1.3 In your opinion, what impact does the service provided by the CES have on clinical procedures specifically, or on health care service delivery generally, in your institution, as a whole?

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.....
.....
.....

4.1.4 In your opinion, what would be the implications of **not** having an in-house CES at all (e.g. outsourcing all medical equipment management and maintenance functions)?

.....
.....
.....
.....

4.2 Quality of Service Provided

4.2.1 What you believe to be understood by the term "*Quality* of Service" with respect to a CES?

.....
.....
.....
.....

4.2.2 Are other services within the healthcare institution assessed in terms of quality (e.g. through *accreditation*)?

.....
.....
.....
.....

Please proceed to Section 5 on page 6

5. CES PERFORMANCE AND SUSTAINABILITY

The following set of questions focuses on your assessment of the performance and *sustainability* of the CES supporting your institution
Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Part 2.

5.1 Performance

a) How is *performance* of the CES currently assessed at your institution?

.....
.....
.....
.....

b) What would you suggest as 5 important *indicators* of performance?

1 .....
2 .....
3 .....
4 .....
5 .....

5.2 Sustainability

5.2.1 Would you consider the CES service to be a 'core' function of your health care institution?

❑ Yes ❑ No

Please elaborate on your answer.

.....
.....
.....

5.2.2 a) Do you see the CES supporting your institution surviving in the next 5, 10 or 15 years?
(Please tick [✓] most appropriate box)

❑ Yes, 5 years ❑ Yes, 10 years ❑ Yes, 15 years ❑ Not at all

b) What are the institutional, organisational or environmental factors that would **support** the existence of your CES?

.....
.....
.....

c) What are the institutional, organisational or environmental factors that would **hinder** the existence of your CES?

.....
.....
.....

Part 2 *(pages 7 to 9)*

CLINICAL ENGINEERING SERVICE INDICATORS

The main objective of the study is to develop and test a set of comprehensive **key indicators** to describe the performance of clinical engineering services which can be used in assessing their sustainability.
(An indicator is an objective, quantitative variable that indicates or shows a given situation, and thus can be used to measure change. It is objective in that the same measurement can be obtained by different observers).
The critical indicators identified should facilitate standardisation of clinical engineering services; as well as allowing comparisons of performance, cost-effectiveness and sustainability to be made between clinical engineering services in differing environments.

The following is a list of proposed indicators derived from the available literature and current best practice, in no particular order. For **each** of the proposed indicators please do the following:

- Please pick a number from the scale to indicate how important you believe the measure to be and circle it [e.g.(5)] next to the statement. If you are uncertain of the relevance of the indicator please select the 'Don't know' i.e. (0) option.

SCALE					
0 Don't know	1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

	Indicators	Rating *Please circle appropriate number*					
	Patient/Client-Related						
1	Inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction	0	1	2	3	4	5
2	Patient (or operator) injury due to medical equipment malfunction or unavailability	0	1	2	3	4	5
3	Patient (or operator) injury due to medical equipment misapplication	0	1	2	3	4	5
4	Number of equipment malfunctions caused by user error/misuse or abuse	0	1	2	3	4	5
5	Type and number of medical equipment supported by CES	0	1	2	3	4	5
6	Percentage of medical equipment supported by CES that is *functional*	0	1	2	3	4	5
	Performance/Personnel						
7	*Productivity* (ratio of outputs to inputs)	0	1	2	3	4	5
8	Competencies/skills of CES personnel	0	1	2	3	4	5
9	*Certification* and registration of CES personnel/ department with appropriate professional body	0	1	2	3	4	5
10	Evidence of continuing education/ professional development of CES personnel	0	1	2	3	4	5

11	Relative number of different categories of CES personnel (i.e. engineers, technicians, artisans etc.)	0	1	2	3	4	5
12	Absenteeism of CES personnel	0	1	2	3	4	5
13	CES staff levels per number of beds	0	1	2	3	4	5
14	CES staff levels per number of medical devices	0	1	2	3	4	5
15	Working space (m^2) per technical CES staff	0	1	2	3	4	5
16	Salaries and career paths of CES technical staff vs. other healthcare workers	0	1	2	3	4	5
17	Salaries and career paths of CES technical staff vs. similar employees in competing sector (public/private)	0	1	2	3	4	5
	Cost-effectiveness						
18	Allocated CES budget per year (as a percentage of the supported equipment inventory value)	0	1	2	3	4	5
19	Cost (*labour and overhead)* per hour per CES employee	0	1	2	3	4	5
20	Cost of CES service per bed supported	0	1	2	3	4	5
21	Cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type	0	1	2	3	4	5
22	Cost of in-house service vs. cost of outsourced service per equipment type	0	1	2	3	4	5
23	Inventory of spare parts per equipment value supported	0	1	2	3	4	5
	CES Activities						
24	*Response time* to service requests	0	1	2	3	4	5
25	Percentage of time devoted to IPMs[1] vs. repairs	0	1	2	3	4	5
26	Total number of IPMs/repairs performed per device type per year	0	1	2	3	4	5
27	*Downtime* of equipment due to IPMs/repairs	0	1	2	3	4	5
28	Degree of compliance that has been achieved with the established schedule for routine IPMs/repairs	0	1	2	3	4	5
29	Percentage of IPMs/repairs performed in-house vs. outsourced	0	1	2	3	4	5
30	Percentage and type of outsourced equipment IPMs/repairs checked by in-house CES before returning to clinical environment	0	1	2	3	4	5
31	Percentage of repeat repairs	0	1	2	3	4	5
32	IPMs/repairs conducted in accordance with manufacturer's recommendations, as specified in service manuals	0	1	2	3	4	5
33	Evidence of proper documentation of all work done by CES (e.g. service histories), providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc	0	1	2	3	4	5

SCALE						
0 Don't know		1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

[1] IPMs = *Inspection and Preventive Maintenance procedures*

- The above list is by no means exhaustive. Please add any other indicators you believe to be appropriate, in the empty numbered spaces and rate them according to the scale below. (Please tick [✓] *one* box only next to each indicator you suggest)

SCALE		
Neutral	**Important**	**Essential**

100	❑ Neutral	❑ Important	❑ Essential
101	❑ Neutral	❑ Important	❑ Essential
102	❑ Neutral	❑ Important	❑ Essential
103	❑ Neutral	❑ Important	❑ Essential
104	❑ Neutral	❑ Important	❑ Essential
105	❑ Neutral	❑ Important	❑ Essential
106	❑ Neutral	❑ Important	❑ Essential
107	❑ Neutral	❑ Important	❑ Essential
108	❑ Neutral	❑ Important	❑ Essential
109	❑ Neutral	❑ Important	❑ Essential

Do you have any additional comments, relating to clinical engineering services generally, or on this questionnaire specifically?

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.....

Thank you for your time and effort in answering the questionnaire.

Please return the completed questionnaire to the address (or fax number) indicated below, by Friday 3rd August.

Healthcare Technology Management (HTM) Programme
Dept. of Human Biology
UCT Health Sciences Faculty
Anzio Road, Observatory 7925
South Africa

Fax: **+27 21 448 7226**

Tel: +27 21 406-6549 or 406 6545
E-mail: rutendo@cormack.uct.ac.za

TARGET GROUP: CLINICAL ENGINEERING SERVICE MANAGERS & PERSONNEL

Part 1 *(pages 1 to 8)*

1. DEMOGRAPHIC DATA

The following set of questions focuses on general information about your institution and the *Clinical Engineering Service* supporting it.

1.1 Please complete the following:
(If you prefer to remain anonymous, please indicate your **position or job description** and your **country** in the spaces provided)

Surname ..... First Name/Initial .... Title .....
or ❑ Anonymous
Position/Job Description .....
Country .....

(The following information is optional)

Institution/Hospital .....
Email address .....
Telephone ..... Fax .....
Postal address .....
City ..... Postal Code .....

1.2 a) What type of health facility is your institution?
(Please tick [✓] *one* box only)

1 ❑ Tertiary / Academic health facility
2 ❑ Secondary / Referral / Regional health facility
3 ❑ District hospital
4 ❑ Day clinic / Community health centre
5 ❑ Other (please specify) .....

b) Is your health facility a public sector or private sector institution? (Please tick [✓] appropriate box)

1 ❑ Public sector institution
2 ❑ Private sector institution
3 ❑ Other (please specify) .....

c) What is the number of beds supported by the health facility? (Please tick [✓] *one* box only)

❑ < 100 ❑ 100 - 250 ❑ 251 - 500 ❑ 501 - 750
❑ 751 - 1000 ❑ 1001 - 2000 ❑ > 2000 (Please specify) .....

1.3 a) What is the number of devices supported by your CES? (Please tick [✓] *one* box only)

❑ < 500 ❑ 500 - 1000 ❑ 1001 – 1500 ❑ 1501 - 2000
❑ 2001 – 3000 ❑ 3001 – 4000 ❑ 4001 – 5000
❑ > 5001 (Please specify)..... ❑ Don't Know

Please continue Section 1 on page 2

b) What is the scope of service covered by your CES, in terms of types/range of equipment supported by your CES?

.....

.....

c) What is the scope of service covered by your CES, in terms of service provided to other institutions?

.....

.....

2. MISSION AND OBJECTIVES OF CLINICAL ENGINEERING SERVICE

The following set of questions aims to establish general mission statements and basic strategies of Clinical Engineering Services.
Please answer as much of this section as you can. If you are unable to answer any questions please move on to Section 3

2.1 a) Does your department bave a documented *mission statement*?

❑ Yes ❑ No ❑ I don't know

b) If '*Yes*', please specify.
If *'No'*, what in your opinion, would be an appropriate mission statement for the CES?

.....

.....

.....

.....

2.2 a) Does your CES have a documented *strategy* (or business plan) to achieve your mission?

❑ Yes ❑ No ❑ I don't know

b) If '*Yes*', please specify
If *'No'*, what in your opinion, would be appropriate elements in such a plan?

.....

.....

.....

.....

2.3 Do the CES' mission statement and strategy conform to the overall strategic plan of the hospital? (Please elaborate)

.....

.....

.....

.....

Please proceed to Section 3 on page 3

3. SERVICE PROVIDED BY CLINICAL ENGINEERING SERVICE

The following set of questions focuses on the services provided by the CES and the importance of these services to your institution
Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 4.

3.1 a) Which of the following medical equipment management and maintenance services does your CES provide? (Please tick [✓] boxes on left, as appropriate, in table below)

b) Please pick a number from the scale, to indicate how important you believe all possible CE services (as listed below) to be to your healthcare institution
Please also rate those services that are not currently provided by the CES.
(Please circle [e.g. ⑤] appropriate number on the **right** in the table below)

SCALE				
1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

NB: The following terms are defined in the Glossary on page iii: technology assessment, needs assessment, asset/inventory management, cost of ownership facilities and plant management, risk and safety management, inspection and preventive maintenance, corrective maintenance, equipment performance monitoring, and quality assurance.

	a) Provided?	Service	b) Rating of Importance (Please circle appropriate number for all services)				
1	❑	Strategic technology needs assessment and planning	1	2	3	4	5
2	❑	Technology assessment	1	2	3	4	5
3	❑	Specification, evaluation and procurement of equipment	1	2	3	4	5
4	❑	Asset/inventory management	1	2	3	4	5
5	❑	Review of equipment replacement needs	1	2	3	4	5
6	❑	Cost of ownership monitoring	1	2	3	4	5
7	❑	Management of service contracts	1	2	3	4	5
8	❑	Project management	1	2	3	4	5
9	❑	Facilities and plant management and maintenance	1	2	3	4	5
10	❑	Training equipment users	1	2	3	4	5
11	❑	Risk management	1	2	3	4	5
12	❑	Safety checks	1	2	3	4	5
13	❑	Acceptance testing (incoming inspections)	1	2	3	4	5
14	❑	Inspection and preventive maintenance (IPM)	1	2	3	4	5
15	❑	Corrective maintenance (repair)	1	2	3	4	5
16	❑	Equipment performance monitoring	1	2	3	4	5
17	❑	Functional or calibration checks	1	2	3	4	5
18	❑	Quality assurance and improvement	1	2	3	4	5
19	❑	Research and development/modification of equipment	1	2	3	4	5
20	❑	IT/Computer hardware and networks	1	2	3	4	5
21	❑	Telecommunications	1	2	3	4	5
22	❑	Other (please specify)	1	2	3	4	5
23	❑		1	2	3	4	5
24	❑		1	2	3	4	5

REMINDER: Have you rated **all** of the services listed above?

Please continue Section 3 on page 4

3.2 To your knowledge, are any of the following services *outsourced* to (i) equipment suppliers/agents or (ii) *third party service* providers (e.g. commercial firm/shared service)?
(Please tick [✓] appropriate box in table below)

	Service Provided	Outsourced? *Please tick [✓] appropriate box*		
1	Training equipment users	❑ Yes	❑ No	❑ Both / mixed
2	Acceptance testing (incoming inspections).....	❑ Yes	❑ No	❑ Both / mixed
3	Inspection and preventive maintenance (IPM	❑ Yes	❑ No	❑ Both / mixed
4	Corrective maintenance (repair).....	❑ Yes	❑ No	❑ Both / mixed
5	Other (please specify)	❑ Yes	❑ No	❑ Both / mixed
6	....	❑ Yes	❑ No	❑ Both / mixed
7	....	❑ Yes	❑ No	❑ Both / mixed

3.3 Please answer the following questions regarding the service provided by your CES.

3.3.1 Are there laid down procedures and guidelines for each activity?

❑ Yes ❑ No ❑ I don't know

3.3.2 Who are the *clients/customers* receiving the service you provide?

.....
.....

3.3.3 Do you know what your clients expect from the CES?

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.....
.....
.....

3.3.4 Would there be any advantages of *outsourcing* any CES activities?

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.....
.....

Please proceed to Section 4 on page 5

4. PERFORMANCE OF CLINICAL ENGINEERING SERVICE

The following set of questions focuses on your assessment of the performance of your CES
Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 5

4.1 In your opinion, what impact does your CES have on the *performance* of the health care service delivery system or clinical procedures in your institution/environment as a whole?

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4.2 To what extent is your service supported (or hindered) by external service providers (i.e. equipment suppliers or *third party service* providers)?

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.....
.....

4.3 **a)** How is performance currently assessed in your CES?

.....
.....
.....

b) What, if any, *indicators* are used to assess performance in your CES?

1 .....
2 .....
3 .....
4 .....
5 .....

5. SUSTAINABILITY OF CLINICAL ENGINEERING SERVICE

The following set of questions focuses on your assessment of the *sustainability* of your CES.
Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 6.

5.1 **a)** Do you see your CES surviving in the next 5, 10 or 15 years? (Please tick [✓] appropriate box)

❑ Yes, 5 years ❑ Yes, 10 years ❑ Yes, 15 years ❑ Not at all

b) What are the institutional, organisational or environmental factors that would **support** the existence of your CES?

.....
.....
.....

c) What are the institutional, organisational or environmental factors that would **hinder** the existence of your CES?

.....
.....
.....

5.2 Would you consider your CES to be a 'core' function of your health care institution?

❑ Yes ❑ No

Please elaborate on your answer

.....
.....
.....

5.3 a) Which of the following general factors do you feel have a significant impact on the *sustainability* of CESs? (Please tick [✓] as appropriate in the boxes on the left)

b) Please pick a number from the scale, to indicate how significant the factor is to the sustainability of CES'. (Please circle [e.g.⑤] appropriate number on the right in the table below)

SCALE				
1 Irrelevant	2 Insignificant	3 Neutral	4 Significant	5 Highly Significant

a) Significant?		Factor	b) Rating of Significance *Please circle appropriate number for all factors*				
1	❑	Adequate *physical infrastructure*	1	2	3	4	5
2	❑	Adequate financial resources.....	1	2	3	4	5
3	❑	Adequate human resources.....	1	2	3	4	5
4	❑	Management/strategic commitment.....	1	2	3	4	5
5	❑	Conducive environment.....	1	2	3	4	5
6	❑	Legal framework (e.g. threat of *litigation*).....	1	2	3	4	5
7	❑	*Logistics* support.....	1	2	3	4	5
8	❑	Performance of technical staff.....	1	2	3	4	5
9	❑	Stakeholder participation.....	1	2	3	4	5
10	❑	Recognition or acceptance by clients.....	1	2	3	4	5
11	❑	Other (Please specify)	1	2	3	4	5
	❑	.....	1	2	3	4	5
	❑	.....	1	2	3	4	5
	❑	.....	1	2	3	4	5
	❑	.....	1	2	3	4	5

Please continue Section 5 on page 7

b) Please suggest a maximum of 5 important indicators of sustainability.

1 .....
2 .....
3 .....
4 .....
5 .....

6. TRENDS AFFECTING CLINICAL ENGINEERING SERVICES

The following set of questions focuses on trends that may have been affecting CESs in recent years. Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 7.

6 a) Has your department been affected by/experienced any of the following trends?
(Please refer to the glossary for definitions and tick [✓] as appropriate))

1 ❑ *Downsizing*
2 ❑ *Economic rationalisation*
3 ❑ *Outsourcing*
4 ❑ *Total quality management*
5 ❑ *Benchmarking*
6 ❑ *Re-engineering*
7 ❑ *Globalisation*
8 ❑ Other (please specify) .....
.....
.....
.....

b) If so, how?

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Please proceed to Section 7 on page 8

7. CES PERFORMANCE / SUSTAINABILITY FACTORS

The following section focuses on more specific factors that may or may not impact on the performance or sustainability of your CES.
Please answer as much of this section as you can. If you are unable to answer any questions, please proceed to Part 2 of the questionnaire.

For each of the factors in the table below, please indicate:

a) Whether it is available at your institution (please tick [✓] appropriate box)

b) Whether you believe it has a significant impact on the performance or sustainability of your CES (Please tick [✓] appropriate box)

Factors	a) Available at your institution?	b) Has significant impact on performance or sustainability?
1. Presence of hospital-wide risk and safety management programme, specific to medical equipment	❑ Yes ❑ No	❑ Yes ❑ No
2. Presence of hospital-wide quality assurance programme, specific to medical equipment	❑ Yes ❑ No	❑ Yes ❑ No
3. Presence of a *hazard notification* system	❑ Yes ❑ No	❑ Yes ❑ No
4. Presence of *incident investigation* and reporting system	❑ Yes ❑ No	❑ Yes ❑ No
5. Adequate number of *test equipment* properly calibrated and functional per test equipment type	❑ Yes ❑ No	❑ Yes ❑ No
6. Adequate spare parts on site for common repairs	❑ Yes ❑ No	❑ Yes ❑ No
7. Availability of regular medical equipment training/re-training programmes	❑ Yes ❑ No	❑ Yes ❑ No
8. Availability of service manuals (from manufacturers) for all equipment serviced/maintained/repaired	❑ Yes ❑ No	❑ Yes ❑ No
9. Availability of operator/user manuals or instructions for all medical equipment	❑ Yes ❑ No	❑ Yes ❑ No
10. Availability of hospital-wide equipment inventory/asset register using consistent nomenclature	❑ Yes ❑ No	❑ Yes ❑ No
11. Availability of computerised and updated CES medical equipment inventory (including supported medical equipment, test equipment and spares) based on inventory of equipment supported (service, maintenance, user-related malfunctions, incidents) using consistent nomenclature	❑ Yes ❑ No	❑ Yes ❑ No
12. Management decisions (relating to needs assessment, procurement, decommissioning and replacement planning) based on inventory and CES equipment service histories	❑ Yes ❑ No	❑ Yes ❑ No
13. Client satisfaction surveys performed	❑ Yes ❑ No	❑ Yes ❑ No
14. Level of participation and communication by CES with stakeholders (i.e. hospital management, clinical staff, manufacturers/suppliers)	❑ Yes ❑ No	❑ Yes ❑ No
15. Accessibility of CES personnel outside normal working hours	❑ Yes ❑ No	❑ Yes ❑ No
16. Presence of criteria for inclusion or exclusion of medical devices/equipment into equip management programme	❑ Yes ❑ No	❑ Yes ❑ No
17. Presence of continuous quality improvement programme	❑ Yes ❑ No	❑ Yes ❑ No

Please proceed to Part 2 of the questionnaire

Part 2 *(pages 9 to 11)*

CLINICAL ENGINEERING SERVICE INDICATORS

The main objective of the study is to develop and test a set of comprehensive **key indicators** to describe the performance of clinical engineering services which can be used in assessing their sustainability.

(An indicator is an objective, quantitative variable that indicates or shows a given situation, and thus can be used to measure change. It is objective in that the same measurement can be obtained by different observers). The critical indicators identified should facilitate standardisation of clinical engineering services; as well as allowing comparisons of performance, cost-effectiveness and sustainability to be made between clinical engineering services in differing environments.

The following is a list of proposed indicators derived from the available literature and current best practice, in no particular order. For **each** of the proposed indicators please do the following:

- Please pick a number from the scale to indicate how important you believe the measure to be and circle it [e.g.⑤] next to the statement. If you are uncertain of the relevance of the indicator please select the 'Don't know' i.e. (0) option.

SCALE						
0 Don't know		1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

	Indicators	Rating *Please circle appropriate number*					
	Patient/Client Related						
1	Inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction	0	1	2	3	4	5
2	Patient (or operator) injury due to medical equipment malfunction or unavailability	0	1	2	3	4	5
3	Patient (or operator) injury due to medical equipment misapplication	0	1	2	3	4	5
4	Number of equipment malfunctions caused by user error/misuse or abuse	0	1	2	3	4	5
5	Type and number of medical equipment supported by CES	0	1	2	3	4	5
6	Percentage of medical equipment supported by CES that is *functional*	0	1	2	3	4	5
	Performance/Personnel						
7	*Productivity* (ratio of outputs to inputs)	0	1	2	3	4	5
8	Competencies/skills of CES personnel	0	1	2	3	4	5
9	*Certification* and registration of CES personnel/ department with appropriate professional body	0	1	2	3	4	5
10	Evidence of continuing education/ professional development of CES personnel	0	1	2	3	4	5

11	Relative number of different categories of CES personnel (i.e. engineers, technicians, artisans etc.)	0	1	2	3	4	5
12	Absenteeism of CES personnel	0	1	2	3	4	5
13	CES staff levels per number of beds	0	1	2	3	4	5
14	CES staff levels per number of medical devices	0	1	2	3	4	5
15	Working space (m^2) per technical CES staff	0	1	2	3	4	5
16	Salaries and career paths of CES technical staff vs. other healthcare workers	0	1	2	3	4	5
17	Salaries and career paths of CES technical staff vs. similar employees in competing sector (public/private)	0	1	2	3	4	5
	Cost-effectiveness						
18	Allocated CES budget per year (as a percentage of the supported equipment inventory value)	0	1	2	3	4	5
19	Cost (*labour and overhead)* per hour per CES employee	0	1	2	3	4	5
20	Cost of CES service per bed supported	0	1	2	3	4	5
21	Cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type	0	1	2	3	4	5
22	Cost of in-house service vs. cost of outsourced service per equipment type	0	1	2	3	4	5
23	Inventory of spare parts per equipment value supported	0	1	2	3	4	5
	CES Activities						
24	*Response time* to service requests	0	1	2	3	4	5
25	Percentage of time devoted to IPMs[1] vs. repairs	0	1	2	3	4	5
26	Total number of IPMs/repairs performed per device type per year	0	1	2	3	4	5
27	*Downtime* of equipment due to IPMs/repairs	0	1	2	3	4	5
28	Degree of compliance that has been achieved with the established schedule for routine IPMs/repairs	0	1	2	3	4	5
29	Percentage of IPMs/repairs performed in-house vs. outsourced	0	1	2	3	4	5
30	Percentage and type of outsourced equipment IPMs/repairs checked by in-house CES before returning to clinical environment	0	1	2	3	4	5
31	Percentage of repeat repairs	0	1	2	3	4	5
32	IPMs/repairs conducted in accordance with manufacturer's recommendations, as specified in service manuals	0	1	2	3	4	5
33	Evidence of proper documentation of all work done by CES (e.g. service histories), providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc	0	1	2	3	4	5

SCALE						
0		1	2	3	4	5
Don't know		Irrelevant	Unimportant	Neutral	Important	Essential

[1] IPMs = *Inspection and Preventive Maintenance procedures*

- The above list is by no means exhaustive. Please add any other indicators you believe to be appropriate, in the empty numbered spaces and rate them according to the scale below. (Please tick [✓] *one* box only next to each indicator you suggest)

SCALE		
Neutral	Important	Essential

101	❑ Neutral	❑ Important	❑ Essential
102	❑ Neutral	❑ Important	❑ Essential
103	❑ Neutral	❑ Important	❑ Essential
104	❑ Neutral	❑ Important	❑ Essential
105	❑ Neutral	❑ Important	❑ Essential
106	❑ Neutral	❑ Important	❑ Essential
107	❑ Neutral	❑ Important	❑ Essential
108	❑ Neutral	❑ Important	❑ Essential
109	❑ Neutral	❑ Important	❑ Essential
110	❑ Neutral	❑ Important	❑ Essential

Do you have any additional comments, relating to clinical engineering services generally, or on this questionnaire specifically?

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Thank you for your time and effort in answering the questionnaire.

Please return the completed questionnaire to the address (or fax number) indicated below, by Friday 3rd August.

Healthcare Technology Management (HTM) Programme
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E-mail: rutendo@cormack.uct.ac.za

TARGET GROUP: CLINICAL ENGINEERING SERVICE CLIENTS

Part 1 *(pages 1 to 3)*

1. DEMOGRAPHIC DATA

The following set of questions focuses on general information about your institution and the *Clinical Engineering Service* supporting it.

1.1 Please complete the following:
(If you prefer to remain anonymous, please indicate your position or job description and country in the space provided)

Surname ..... First Name/Initial ..... Title .....
or ❑ Anonymous
Position/Job Description .....
Country.....
(The following information is optional)
Institution/Hospital .....
Email address.....
Telephone ..... Fax .....
Postal address.....
City..... Postal Code.....

1.2 a) What type of health facility is your institution?
(Please tick [✓] *one* box only)

1 ❑ Tertiary / Academic health facility
2 ❑ Secondary / Referral / Regional health facility
3 ❑ District hospital
4 ❑ Day clinic / Community health centre
5 ❑ Other (please specify) .....

b) What is the number of beds supported by the health facility? (Please tick [✓] *one* box only)

❑ < 100 ❑ 100 - 250 ❑ 251 - 500 ❑ 501 - 750
❑ 751 - 1000 ❑ 1001 - 2000 ❑ > 2000 (Please specify) .....

c) Is your health facility a public sector or private sector institution? (Please tick [✓] appropriate box)

1 ❑ Public sector institution
2 ❑ Private sector institution
3 ❑ Other (please specify) .....

1.3 a) Is your institution supported by an *in-house* clinical engineering service (CES) or an external* clinical engineering service (CES)? (Please tick [✓] appropriate box)

1 ❑ In-house CED
2 ❑ External CES (*regional or centralised workshop/service)
3 ❑ Combination of in-house and external CES
4 ❑ Not supported at all

b) If you *are* supported by a clinical engineering service, what is it called (e.g. Clinical Engineering Department, Health Care Technical Service, etc.)?

.....

2. ASSESSMENT OF SERVICE

The following set of questions focuses on the services provided by the CES and your assessment of the importance of these services to your institution. Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Part 2.

2.1 a) To your knowledge, which of the following medical equipment management and maintenance services does the CES provide? (Please tick [✓] boxes on left, as appropriate, in the table below)

b) Please pick a number from the scale, to indicate how important you believe all possible CE services (as listed below) to be to your healthcare institution
(Please circle [e.g. ⑤] appropriate number on the right in the table below)

SCALE				
1	2	3	4	5
Irrelevant	Unimportant	Neutral	Important	Essential

NB: The following terms are defined in the Glossary on page 7: technology assessment, needs assessment, asset/inventory management, cost of ownership, facilities and plant management, risk and safety management, inspection and preventive maintenance, corrective maintenance, equipment performance monitoring, and quality assurance.

	a) Provided?	Service	b) Rating of Importance (Please circle appropriate number)				
1	❑	Strategic technology needs assessment and planning	1	2	3	4	5
2	❑	Technology assessment	1	2	3	4	5
3	❑	Specification, evaluation and procurement of equipment	1	2	3	4	5
4	❑	Asset/inventory management	1	2	3	4	5
5	❑	Review of equipment replacement needs	1	2	3	4	5
6	❑	Cost of ownership monitoring	1	2	3	4	5
7	❑	Management of service contracts	1	2	3	4	5
8	❑	Project management	1	2	3	4	5
9	❑	Facilities and plant management and maintenance	1	2	3	4	5
10	❑	Training equipment users	1	2	3	4	5
11	❑	Risk management	1	2	3	4	5
12	❑	Safety checks	1	2	3	4	5
13	❑	Acceptance testing (incoming inspections)	1	2	3	4	5
14	❑	Inspection and preventive maintenance (IPM)	1	2	3	4	5
15	❑	Corrective maintenance (repair)	1	2	3	4	5
16	❑	Equipment performance monitoring	1	2	3	4	5
17	❑	Functional or calibration checks	1	2	3	4	5
18	❑	Quality assurance and improvement	1	2	3	4	5
19	❑	Research and development/modification of equipment	1	2	3	4	5
20	❑	IT/Computer hardware and networks	1	2	3	4	5
21	❑	Telecommunications	1	2	3	4	5
22	❑	Other (please specify)	1	2	3	4	5
23	❑	.....	1	2	3	4	5
24	❑	.....	1	2	3	4	5

REMINDER: Have you rated **all** of the services listed above?

Please continue Section 2 on page 3

2.2 Client Requirements and Views of Clinical Engineering Services

2.2.1 Please list in order of preference, your requirements from a CES, as the client receiving their service.

1 .....
2 .....
3 .....
4 .....
5 .....

2.2.2 In your opinion, what factors contribute to your requirements of the CES **not** being met (e.g. redoing work, excessive equipment *downtime,* poor *response time*, unprofessional conduct etc.)

1 .....
2 .....
3 .....
4 .....
5 .....

2.2.3 How does the service offered by the CES influence your ability to carry out your own job in providing clinical procedures specifically or health care services in general?

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2.2.4 In your opinion, what would be the implications of **not** having an in-house CES at all (e.g. outsourcing medical equipment management and maintenance, as listed above)?

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.....
.....

Please proceed to Part 2 of the questionnaire

Part 2 *(pages 4 to 6)*

CLINICAL ENGINEERING SERVICE INDICATORS

The main objective of the study is to develop and test a set of comprehensive **key indicators** to describe the performance of clinical engineering services which can be used in assessing their sustainability.

(An indicator is an objective, quantitative variable that indicates or shows a given situation, and thus can be used to measure change. It is objective in that the same measurement can be obtained by different observers). The critical indicators identified should facilitate standardisation of clinical engineering services; as well as allowing comparisons of performance, cost-effectiveness and sustainability to be made between clinical engineering services in differing environments.

The following is a list of proposed indicators derived from the available literature and current best practice, in no particular order. For **each** of the proposed indicators please do the following:

- Please pick a number from the scale to indicate how important you believe the measure to be and circle it [e.g.⑤] next to the statement. If you are uncertain of the relevance of the indicator- please select the 'Don't know' i.e. (0) option.

SCALE						
0 Don't know		1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

	Indicators	Rating *Please circle appropriate number*					
	Patient/Client-Related						
1	Inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction	0	1	2	3	4	5
2	Patient (or operator) injury due to medical equipment malfunction or unavailability	0	1	2	3	4	5
3	Patient (or operator) injury due to medical equipment misapplication	0	1	2	3	4	5
4	Number of equipment malfunctions caused by user error/misuse or abuse	0	1	2	3	4	5
5	Type and number of medical equipment supported by CES	0	1	2	3	4	5
6	Percentage of medical equipment supported by CES that is *functional*	0	1	2	3	4	5
	Performance/Personnel						
7	*Productivity* (ratio of outputs to inputs)	0	1	2	3	4	5
8	Competencies/skills of CES personnel	0	1	2	3	4	5
9	*Certification* and registration of CES personnel/ department with appropriate professional body	0	1	2	3	4	5
10	Evidence of continuing education/ professional development of CES personnel	0	1	2	3	4	5

11	Relative number of different categories of CES personnel (i.e. engineers, technicians, artisans etc.)	0	1	2	3	4	5
12	Absenteeism of CES personnel	0	1	2	3	4	5
13	CES staff levels per number of beds	0	1	2	3	4	5
14	CES staff levels per number of medical devices	0	1	2	3	4	5
15	Working space (m^2) per technical CES staff	0	1	2	3	4	5
16	Salaries and career paths of CES technical staff vs. other healthcare workers	0	1	2	3	4	5
17	Salaries and career paths of CES technical staff vs. similar employees in competing sector (public/private)	0	1	2	3	4	5
	Cost-effectiveness						
18	Allocated CES budget per year (as a percentage of the supported equipment inventory value)	0	1	2	3	4	5
19	Cost (*labour and overhead)* per hour per CES employee	0	1	2	3	4	5
20	Cost of CES service per bed supported	0	1	2	3	4	5
21	Cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type	0	1	2	3	4	5
22	Cost of in-house service vs. cost of outsourced service per equipment type	0	1	2	3	4	5
23	Inventory of spare parts per equipment value supported	0	1	2	3	4	5
	CES Activities						
24	*Response time* to service requests	0	1	2	3	4	5
25	Percentage of time devoted to IPMs[1] vs. repairs	0	1	2	3	4	5
26	Total number of IPMs/repairs performed per device type per year	0	1	2	3	4	5
27	*Downtime* of equipment due to IPMs/repairs	0	1	2	3	4	5
28	Degree of compliance that has been achieved with the established schedule for routine IPMs/repairs	0	1	2	3	4	5
29	Percentage of IPMs/repairs performed in-house vs. outsourced	0	1	2	3	4	5
30	Percentage and type of outsourced equipment IPMs/repairs checked by in-house CES before returning to clinical environment	0	1	2	3	4	5
31	Percentage of repeat repairs	0	1	2	3	4	5
32	IPMs/repairs conducted in accordance with manufacturer's recommendations, as specified in service manuals	0	1	2	3	4	5
33	Evidence of proper documentation of all work done by CES (e.g. service histories), providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc	0	1	2	3	4	5

SCALE						
0		1	2	3	4	5
Don't know		Irrelevant	Unimportant	Neutral	Important	Essential

[1] IPMs = *Inspection and Preventive Maintenance procedures*

- The above list is by no means exhaustive. Please add any other indicators you believe to be appropriate, in the empty numbered spaces and rate them according to the scale below. (Please tick [✓] *one* box only next to each indicator you suggest)

SCALE		
Neutral	Important	Essential

100	❑ Neutral	❑ Important	❑ Essential
101	❑ Neutral	❑ Important	❑ Essential
102	❑ Neutral	❑ Important	❑ Essential
103	❑ Neutral	❑ Important	❑ Essential
104	❑ Neutral	❑ Important	❑ Essential
105	❑ Neutral	❑ Important	❑ Essential
106	❑ Neutral	❑ Important	❑ Essential
107	❑ Neutral	❑ Important	❑ Essential
108	❑ Neutral	❑ Important	❑ Essential
109	❑ Neutral	❑ Important	❑ Essential

Do you have any additional comments, relating to clinical engineering services generally, or on this questionnaire specifically?

.....

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.....

.....

Thank you for your time and effort in answering the questionnaire.

Please return the completed questionnaire to the address (or fax number) indicated below, by Friday 3rd August.

Healthcare Technology Management (HTM) Programme
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E-mail: rutendo@cormack.uct.ac.za

TARGET GROUP: MINISTRIES OF HEALTH / HTM EXPERTS

Part 1 *(pages 1 to 5)*

1. DEMOGRAPHIC DATA

The following set of questions focuses on general information.

1.1 Please complete the following:
(If you prefer to remain anonymous, please indicate your **position or job description** and **country** in the space provided)

Surname ..... First Name/Initial .... Title .....
or ❑ Anonymous
Position/Job Description .....
Country .....

(The following information is optional)

Institution/Organisation.....
Email address.....
Telephone ..... Fax .....
Postal address.....
City..... Postal Code.....

1.2 a) Are you familiar with a Clinical Engineering Service ?

❑ Yes ❑ No

If "Yes", please proceed to Section 2 below. If "No", please go to Section 3 on the next page.

2. MISSION AND STRATEGY OF CLINICAL ENGINEERING SERVICE

The following set of questions aims to establish general mission statements and basic strategies of Clinical Engineering Services.

2.1 a) Does the CES exist as a separate unit (e.g. Clinical Engineering Department, Health Care Technical Service, etc.) or part of another department (e.g. Hospital Engineering)?
(Please tick [✓]appropriate box)

❑ Separate unit, called .....
❑ Part of another department (Please specify) .....

b) To whom does the CES report? .....

c) Are you aware of the *mission statement* of the Clinical Engineering Service (CES) ?

❑ Yes ❑ No ❑ I don't know

d) In your opinion, what would be an appropriate mission statement for a CES?

.....
.....
.....
.....

2.2 **a)** To your knowledge, does the CES have an appropriate *strategy* (or business plan) to achieve its mission?

❑ Yes ❑ No ❑ I don't know

b) In your opinion, what would be appropriate elements in such a plan?

.....
.....
.....
.....

c) If it exists, does this strategy support the overall strategic plan of the institution/s it serves?

❑ Yes ❑ No ❑ I don't know

3. SERVICES PROVIDED BY CLINICAL ENGINEERING SERVICE

The following set of questions focuses on the services typically provided by a CES and the importance of these services to the institution/s it serves.

3.1 **a)** Please pick a number, from the scale, to indicate how important you believe the service to be.

(Please circle [e.g.⑤] appropriate number on the **right** in the table below)

SCALE				
1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

NB: The following terms are defined in the Glossary on page 10: *technology assessment, needs assessment, asset/inventory management, cost of ownership, facilities and plant management, risk and safety management, inspection and preventive maintenance, corrective maintenance, equipment performance monitoring, and quality assurance.*

	SERVICE	Rating of Importance *Please circle appropriate number for all services*				
1	Strategic technology needs assessment and planning.....	1	2	3	4	5
2	Technology assessment.....	1	2	3	4	5
3	Specification, evaluation and procurement of equipment.....	1	2	3	4	5
4	Asset/inventory management	1	2	3	4	5
5	Review of equipment replacement needs.....	1	2	3	4	5

6	Cost of ownership monitoring.....	1	2	3	4	5
7	Management of service contracts.....	1	2	3	4	5
8	Project management.....	1	2	3	4	5
9	Facilities and plant management and maintenance.....	1	2	3	4	5
10	Training equipment users.....	1	2	3	4	5
11	Risk management.....	1	2	3	4	5
12	Safety checks.....	1	2	3	4	5
13	Acceptance testing (incoming inspections).....	1	2	3	4	5
14	Inspection and preventive maintenance (IPM).....	1	2	3	4	5
15	Corrective maintenance (repair).....	1	2	3	4	5
16	Equipment performance monitoring.....	1	2	3	4	5
17	Functional or calibration checks.....	1	2	3	4	5
18	Quality assurance and improvement	1	2	3	4	5
19	Research and development/modification of equipment.....	1	2	3	4	5
20	IT/Computer hardware and networks.....	1	2	3	4	5
21	Telecommunications.....	1	2	3	4	5
22	Other (please specify)	1	2	3	4	5
23	.....	1	2	3	4	5
24	.....	1	2	3	4	5

3.2 **a)** In your opinion, which of the following services could/should be *outsourced* to equipment suppliers/agents or *third party service* providers (e.g. commercial firm/shared service) ?

(Please tick [✓] appropriate box in table below)

	Service	Outsource ? *Please tick [✓] appropriate box*		
1	Training equipment users	❑ Yes	❑ No	❑ Both/mixed
2	Acceptance testing (incoming inspections).....	❑ Yes	❑ No	❑ Both/mixed
3	Inspection and preventive maintenance (IPM).....	❑ Yes	❑ No	❑ Both/mixed
4	Corrective maintenance (repair).....	❑ Yes	❑ No	❑ Both/mixed
5	Other (please specify)	❑ Yes	❑ No	❑ Both/mixed
6	.....	❑ Yes	❑ No	❑ Both/mixed
7	.....	❑ Yes	❑ No	❑ Both/mixed

pto

3.3 In your opinion, what are the advantages and the disadvantages of having an in-house CES, as opposed to outsourcing equipment management and maintenance services ?

Advantages of in-house CES

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Disadvantages of in-house CES

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4. ASSESSMENT OF SERVICE PROVIDED BY CLINICAL ENGINEERING SERVICE

The following set of questions focuses on your assessment of the service provided by a CES. Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 5.

a). In your opinion, what impact does the service provided by a CES have on clinical procedures specifically, or on health care service delivery generally, at a health facility as a whole?

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b) In your opinion, what would be the implications of **not** having an in-house CES at all (e.g. outsourcing all medical equipment management and maintenance functions)?

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c) What you believe to be understood by the term "Quality of Service" with respect to a CES?

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5. CES PERFORMANCE AND SUSTAINABILITY

The following set of questions focuses on your assessment of the performance and *sustainability* of CES's.

5.1 Performance

a) What would you suggest as 5 important *indicators* of performance?

1 .....
2 .....
3 .....
4 .....
5 .....

5.2 Sustainability

5.2.1 Would you consider the CES service to be a 'core' healthcare function ?

❑ Yes ❑ No

Please elaborate on your answer.

.....
.....
.....

5.2.2 a) Do you see the CES's surviving in the next 5, 10 or 15 years ?
(Please tick [✓] most appropriate box)

❑ Yes, 5 years ❑ Yes, 10 years ❑ Yes, 15 years ❑ Not at all

b) What institutional, organisational or environmental factors would **support** the existence of CES's ?

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.....

What institutional, organisational or environmental factors would **hinder** the existence of CES's?

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.....
.....
.....
.....

Part 2 *(pages 6 to 8)*

CLINICAL ENGINEERING SERVICE INDICATORS

The main objective of the study is to develop and test a set of comprehensive **key indicators** to describe the performance of clinical engineering services which can be used in assessing their sustainability. (*An indicator is an objective, quantitative variable that indicates or shows a given situation, and thus can be used to measure change. It is objective in that the same measurement can be obtained by different observers).* The critical indicators identified should facilitate standardisation of clinical engineering services; as well as allowing comparisons of performance, cost-effectiveness and sustainability to be made between clinical engineering services in differing environments.

The following is a list of proposed indicators derived from the available literature and current best practice, in no particular order. For **each** of the proposed indicators please do the following:

- Please pick a number from the scale to indicate how important you believe the measure to be and circle it [e.g.⑤] next to the statement. If you are uncertain of the relevance of the indicator- please select the 'Don't know' i.e. (0) option.

SCALE						
0 Don't know		1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

	Indicators	Rating *Please circle appropriate number*					
	Patient/Client-Related						
1	Inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction	0	1	2	3	4	5
2	Patient (or operator) injury due to medical equipment malfunction or unavailability	0	1	2	3	4	5
3	Patient (or operator) injury due to medical equipment misapplication	0	1	2	3	4	5
4	Number of equipment malfunctions caused by user error/misuse or abuse	0	1	2	3	4	5
5	Type and number of medical equipment supported by CES	0	1	2	3	4	5
6	Percentage of medical equipment supported by CES that is *functional*	0	1	2	3	4	5
	Performance/Personnel						
7	*Productivity* (ratio of outputs to inputs)	0	1	2	3	4	5
8	Competencies/skills of CES personnel	0	1	2	3	4	5
9	*Certification* and registration of CES personnel/ department with appropriate professional body	0	1	2	3	4	5
10	Evidence of continuing education/ professional development of CES personnel	0	1	2	3	4	5

11	Relative number of different categories of CES personnel (i.e. engineers, technicians, artisans etc.)	0	1	2	3	4	5
12	Absenteeism of CES personnel	0	1	2	3	4	5
13	CES staff levels per number of beds	0	1	2	3	4	5
14	CES staff levels per number of medical devices	0	1	2	3	4	5
15	Working space (m^2) per technical CES staff	0	1	2	3	4	5
16	Salaries and career paths of CES technical staff vs. other healthcare workers	0	1	2	3	4	5
17	Salaries and career paths of CES technical staff vs. similar employees in competing sector (public/private)	0	1	2	3	4	5
	Cost-effectiveness						
18	Allocated CES budget per year (as a percentage of the supported equipment inventory value)	0	1	2	3	4	5
19	Cost *(labour and overhead)* per hour per CES employee	0	1	2	3	4	5
20	Cost of CES service per bed supported	0	1	2	3	4	5
21	Cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type	0	1	2	3	4	5
22	Cost of in-house service vs. cost of outsourced service per equipment type	0	1	2	3	4	5
23	Inventory of spare parts per equipment value supported	0	1	2	3	4	5
	CES Activities						
24	*Response time* to service requests	0	1	2	3	4	5
25	Percentage of time devoted to IPMs[1] vs. repairs	0	1	2	3	4	5
26	Total number of IPMs/repairs performed per device type per year	0	1	2	3	4	5
27	*Downtime* of equipment due to IPMs/repairs	0	1	2	3	4	5
28	Degree of compliance that has been achieved with the established schedule for routine IPMs/repairs	0	1	2	3	4	5
29	Percentage of IPMs/repairs performed in-house vs. outsourced	0	1	2	3	4	5
30	Percentage and type of outsourced equipment IPMs/repairs checked by in-house CES before returning to clinical environment	0	1	2	3	4	5
31	Percentage of repeat repairs	0	1	2	3	4	5
32	IPMs/repairs conducted in accordance with manufacturer's recommendations, as specified in service manuals	0	1	2	3	4	5
33	Evidence of proper documentation of all work done by CES (e.g. service histories), providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc	0	1	2	3	4	5

SCALE						
0		1	2	3	4	5
Don't know		Irrelevant	Unimportant	Neutral	Important	Essential

[1] IPMs = *Inspection and Preventive Maintenance procedures*

- The above list is by no means exhaustive. Please add any other indicators you believe to be appropriate, in the empty numbered spaces and rate them according to the scale below. (Please tick [✓] *one* box only next to each indicator you suggest)

SCALE		
Neutral	Important	Essential

100	❑ Neutral	❑ Important	❑ Essential
101	❑ Neutral	❑ Important	❑ Essential
102	❑ Neutral	❑ Important	❑ Essential
103	❑ Neutral	❑ Important	❑ Essential
104	❑ Neutral	❑ Important	❑ Essential
105	❑ Neutral	❑ Important	❑ Essential
106	❑ Neutral	❑ Important	❑ Essential
107	❑ Neutral	❑ Important	❑ Essential
108	❑ Neutral	❑ Important	❑ Essential
109	❑ Neutral	❑ Important	❑ Essential

Do you have any additional comments, relating to clinical engineering services generally, or on this questionnaire specifically?

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Thank you for your time and effort in answering the questionnaire.

Please return the completed questionnaire to the address (or fax number) indicated below, by Friday 3rd August.

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APPENDIX D: DETAILED STATISTICS

TABLE OF CONTENTS

D1 Frequency Tables of Services Provided by CES's 2

D2 Descriptive Statistics: Ratings of CES Services 5

D3 Factors With Significant Impact to CES Sustainability (QUEST2 Section 5.3a) 6

D4 Descriptive Statistics: Rating of Sustainability Factors 7

D5 Trends Affecting CES: Frequency Tables 8

D6 General CES Performance/Sustainability Factors: Frequency Tables 9

D7 Descriptive Statistics: CES Indicators (Part 2: QUEST 1 - 4) 12

D8 Descriptive Statistics for Individual Target Groups 13

D8.1 Descriptive Statistics: Institutional Management Indicator Ratings 13

D8.2 Descriptive Statistics: CES Personnel Indicator Ratings 14

D8.3 Descriptive Statistics: CES Clients Indicator Ratings 15

D8.4 Descriptive Statistics: International Experts Ratings 16

D1 Frequency Tables of Services Provided by CES's

SERVIC1: Strategic technology needs assessment and planning

	Frequency	Percent
0 (Not provided by CES)	19	67.85714
1 (Provided by CES)	9	32.14286
Total	28	100

SERVIC2: Technology assessment

	Frequency	Percent
0 (Not provided by CES)	19	67.9
1 (Provided by CES)	9	32.1
Total	28	100

SERVIC3: Specification, evaluation and procurement of equipment

	Frequency	Percent
0 (Not provided by CES)	11	39.3
1 (Provided by CES)	17	60.7
Total	28	100

SERVIC4: Asset/inventory management

	Frequency	Percent
0 (Not provided by CES)	18	64.3
1 (Provided by CES)	10	35.7
Total	28	100

SERVIC5: Review of equipment replacement needs

	Frequency	Percent
0 (Not provided by CES)	12	42.9
1 (Provided by CES)	16	57.1
Total	28	100

SERVIC6: Cost of ownership monitoring

	Frequency	Percent
0 (Not provided by CES)	22	78.6
1 (Provided by CES)	6	21.4
Total	28	100

SERVIC7: Management of service contracts

	Frequency	Percent
0 (Not provided by CES)	8	28.6
1 (Provided by CES)	20	71.4
Total	28	100

SERVIC8: Project management

	Frequency	Percent
0 (Not provided by CES)	23	82.1
1 (Provided by CES)	5	17.9
Total	28	100

SERVIC9: Facilities and plant management and maintenance

	Frequency	Percent
0 (Not provided by CES)	22	78.6
1 (Provided by CES)	6	21.4
Total	28	100

SERVIC10: Training equipment users

	Frequency	Percent
0 (Not provided by CES)	16	57.1
1 (Provided by CES)	12	42.9
Total	28	100

SERVIC11: Risk management

	Frequency	Percent
0 (Not provided by CES)	24	85.7
1 (Provided by CES)	4	14.3
Total	28	100

SERVIC12: Safety checks

	Frequency	Percent
0 (Not provided by CES)	14	50.0
1 (Provided by CES)	14	50.0
Total	28	100

SERVIC13: Acceptance testing (incoming inspections)

	Frequency	Percent
0 (Not provided by CES)	13	46.4
1 (Provided by CES)	15	53.6
Total	28	100

SERVIC14: Inspection and preventive maintenance (IPM)

	Frequency	Percent
0 (Not provided by CES)	15	53.6
1 (Provided by CES)	13	46.4
Total	28	100

SERVIC15: Corrective maintenance (repair)

	Frequency	Percent
0 (Not provided by CES)	8	28.6
1 (Provided by CES)	20	71.4
Total	28	100

SERVIC16: Equipment performance monitoring

	Frequency	Percent
0 (Not provided by CES)	19	67.9
1 (Provided by CES)	9	32.1
Total	28	100

SERVIC17: Functional or calibration checks

	Frequency	Percent
0 (Not provided by CES)	16	57.1
1 (Provided by CES)	12	42.9
Total	28	100

SERVIC18: Quality assurance and improvement

	Frequency	Percent
0 (Not provided by CES)	18	64.3
1 (Provided by CES)	10	35.7
Total	28	100

SERVIC19: Research and development/modification of equipment

	Frequency	Percent
0 (Not provided by CES)	23	82.1
1 (Provided by CES)	5	17.9
Total	28	100

SERVIC20: IT/Computer hardware and networks

	Frequency	Percent
0 (Not provided by CES)	21	75.0
1 (Provided by CES)	7	25.0
Total	28	100

SERVIC21: Telecommunications

	Frequency	Percent
0 (Not provided by CES)	17	60.7
1 (Provided by CES)	11	39.3
Total	28	100

SERVIC22: Financial management of CES

	Frequency	Percent
0 (Not provided by CES)	28	100
1 (Provided by CES)	0	0
Total	28	100

SERVIC23: Configuration of medical equipment

	Frequency	Percent
0 (Not provided by CES)	27	96.4
1 (Provided by CES)	1	3.6
Total	28	100

SERVIC24: Incident evaluation and reporting

	Frequency	Percent
0 (Not provided by CES)	28	100
1 (Provided by CES)	0	0
Total	28	100

D2 Descriptive Statistics: Ratings of CES Services

	Valid N	Median	Minimum	Maximum	Range	Std.Dev.
SERVIC1	28	4.0	0	5	5	2.24
SERVIC2	28	4.0	0	5	5	2.23
SERVIC3	28	4.0	0	5	5	1.84
SERVIC4	28	4.0	0	5	5	2.09
SERVIC5	28	4.0	0	5	5	1.91
SERVIC6	28	3.0	0	5	5	2.02
SERVIC7	28	4.0	0	5	5	1.47
SERVIC8	28	2.0	0	5	5	1.89
SERVIC9	28	2.5	0	5	5	2.08
SERVIC10	28	4.0	0	5	5	1.94
SERVIC11	28	2.5	0	5	5	2.05
SERVIC12	28	5.0	0	5	5	2.25
SERVIC13	28	4.0	0	5	5	2.15
SERVIC14	28	4.5	0	5	5	2.28
SERVIC15	28	5.0	0	5	5	1.73
SERVIC16	28	4.0	0	5	5	2.09
SERVIC17	28	4.5	0	5	5	2.19
SERVIC18	28	4.0	0	5	5	2.20
SERVIC19	28	3.0	0	5	5	1.81
SERVIC20	28	3.0	0	5	5	1.81
SERVIC21	28	3.0	0	5	5	2.01
SERVIC22	28	0.0	0	5	5	.94
SERVIC23	28	0.0	0	1	1	.19
SERVIC24	28	0.0	0	0	0	0.00

D3 Factors With Significant Impact to CES Sustainability (QUEST2 Section 5.3a)

SFACT1: Adequate physical infrastructure

	Frequency	Percent
0 (no significant impact)	2	22.2
1 (significant impact)	7	77.8
Total	9	100

SFACT2: Adequate financial resources

	Frequency	Percent
0 (no significant impact)	2	22.2
1 (significant impact)	7	77.8
Total	9	100

SFACT3: Adequate human resources

	Frequency	Percent
0 (no significant impact)	3	33.3
1 (significant impact)	6	66.7
Total	9	100

SFACT4: Management/strategic commitment

	Frequency	Percent
0 (no significant impact)	2	22.2
1 (significant impact)	7	77.8
Total	9	100

SFACT5: Conducive environment

		Percent
0 (no significant impact)	3	33.3
1 (significant impact)	6	66.7
Total	9	100

SFACT6: Legal framework

	Frequency	Percent
0 (no significant impact)	4	44.4
1 (significant impact)	5	55.6
Total	9	100

SFACT7: Logistics support

	Frequency	Percent
0 (no significant impact)	2	22.2
1 (significant impact)	7	77.8
Total	9	100

SFACT8: Performance of technical staff

	Frequency	Percent
0 (no significant impact)	2	22.2
1 (significant impact)	7	77.8
Total	9	100

SFACT9: Stakeholder participation

	Frequency	Percent
0 (no significant impact)	4	44.4
1 (significant impact)	5	55.6
Total	9	100

SFACT10 :Recognition of acceptance by clients

	Frequency	Percent
0 (no significant impact)	3	33.3
1 (significant impact)	6	66.7
Total	9	100

D4 Descriptive Statistics: Rating of Sustainability Factors

Factor	Valid N	Median	Minimum	Maximum	Range	Std.Dev.
SFACT1	9	4.0	4	5	1	.44
SFACT2	9	5.0	4	5	1	.33
SFACT3	9	5.0	5	5	0	0.00
SFACT4	9	5.0	4	5	1	.53
SFACT5	9	4.0	3	5	2	.50
SFACT6	9	4.0	2	5	3	1.05
SFACT7	9	4.0	4	5	1	.44
SFACT8	9	5.0	0	5	5	1.61
SFACT9	9	4.0	0	5	5	1.56
SFACT10	9	4.0	0	5	5	1.61

D5 Trends Affecting CES: Frequency Tables

TREND1: Downsizing

	Frequency	Percent
0 (CES not affected by trend)	3	33.3
1 (CES affected by trend)	6	66.7
Total	9	100

TREND2: Economic rationalisation

	Frequency	Percent
0 (CES not affected by trend)	5	55.6
1 (CES affected by trend)	4	44.4
Total	9	100

TREND3: Outsourcing

	Frequency	Percent
0 (CES not affected by trend)	4	44.4
1 (CES affected by trend)	5	55.6
Total	9	100

TREND4: Total Quality Management

	Frequency	Percent
0 (CES not affected by trend)	7	77.8
1 (CES affected by trend)	2	22.2
Total	9	100

TREND5: Benchmarking

	Frequency	Percent
0 (CES not affected by trend)	9	100
1 (CES affected by trend)	0	0
Total	9	100

TREND6: Re-engineering

	Frequency	Percent
0 (CES not affected by trend)	9	100
1 (CES affected by trend)	0	0
Total	9	100

TREND7: Globalisation

	Frequency	Percent
0 (CES not affected by trend)	9	100
1 (CES affected by trend)	0	0
Total	9	100

D6 General CES Performance/Sustainability Factors: Frequency Tables

FACTOR1: Risk and safety management programme

Significant Impact?	Frequency	Percent
No	2	22.2
Yes	5	55.6
No answer	2	22.2
Total	9	100

FACTOR2: Quality assurance programme

Significant Impact?	Frequency	Percent
No	1	11.1
Yes	7	77.8
No answer	1	11.1
Total	9	100

FACTOR3: Hazard notification system

Significant Impact?	Frequency	Percent
No	2	22.2
Yes	4	44.4
No answer	3	33.3
Total	9	100

FACTOR4: Incident investigation system

Significant Impact?	Frequency	Percent
No	2	22.2
Yes	4	44.4
No answer	3	33.3
Total	9	100

FACTOR5: Adequate functional test equipment

Significant Impact?	Frequency	Percent
No	1	11.1
Yes	6	66.7
No answer	2	22.2
Total	9	100

FACTOR6: Spare parts for common repairs

Significant Impact?	Frequency	Percent
No	1	11.1
Yes	8	88.9
Total	9	100

FACTOR7: Medical equipment training/re-training programmes

Significant Impact?	Frequency	Percent
No	1	11.1
Yes	7	77.8
No answer	1	11.1
Total	9	100

FACTOR8: Service manuals for all med equip

Significant Impact?	Frequency	Percent
No	1	11.1
Yes	8	88.9
Total	9	100

FACTOR9: Operator/user manuals for all med equip

Significant Impact?	Frequency	Percent
No	1	11.1
Yes	7	77.8
No answer	1	11.1
Total	9	100

FACTOR10: Inventory asset register

Significant Impact?	Frequency	Percent
No	1	11.1
Yes	6	66.7
No answer	2	22.2
Total	9	100

FACTOR11: Computerised & updated med equip inventory

Significant Impact?	Frequency	Percent
No	1	11.1
Yes	7	77.8
No answer	1	11.1
Total	9	100

FACTOR12: Management decisions based on inventory and service histories

Significant Impact?	Frequency	Percent
No	2	22.2
Yes	5	55.6
No answer	2	22.2
Total	9	100

FACTOR13: Client satisfaction surveys performed

Significant Impact?	Frequency	Percent
No	2	22.2
Yes	4	44.4
No answer	3	33.3
Total	9	100

FACTOR14: Participation and communication with stakeholders

Significant Impact?	Frequency	Percent
No	0	0
Yes	7	77.8
No answer	2	22.2
Total	9	100

FACTOR15: Accessibility of CES personnel after hours

Significant Impact?	Frequency	Percent
No	1	11.1
Yes	6	66.7
No answer	2	22.2
Total	9	100

FACTOR16: Criteria for incl/excl med equipment into MEM&M programme

Significant Impact?	Frequency	Percent
No	1	11.1
Yes	4	44.4
No answer	4	44.4
Total	9	100

FACTOR17: Continuous Quality Improvement programme

Significant Impact?	Frequency	Percent
No	1	11.1
Yes	5	55.6
No answer	3	33.3
Total	9	100

D7 Descriptive Statistics: CES Indicators (Part 2: QUEST 1 - 4)

	Valid N	Median	Minimum	Maximum	Range	Std.Dev.
INDIC_1	30	5.0	0	5	5	1.32
INDIC_2	30	5.0	0	5	5	1.58
INDIC_3	30	4.5	0	5	5	1.74
INDIC_4	30	4.0	0	5	5	1.78
INDIC_5	30	4.0	0	5	5	1.59
INDIC_6	30	4.0	0	5	5	1.61
INDIC_7	30	4.0	0	5	5	1.50
INDIC_8	30	5.0	0	5	5	1.32
INDIC_9	30	4.0	0	5	5	1.54
INDIC_10	30	4.0	0	5	5	1.47
INDIC_11	30	4.0	0	5	5	1.46
INDIC_12	30	4.0	0	5	5	1.54
INDIC_13	30	3.5	0	5	5	1.63
INDIC_14	30	4.0	0	5	5	1.67
INDIC_15	30	3.5	0	5	5	1.53
INDIC_16	30	4.0	0	5	5	1.63
INDIC_17	30	4.0	0	5	5	1.75
INDIC_18	30	5.0	0	5	5	1.35
INDIC_19	30	4.0	0	5	5	1.72
INDIC_20	30	4.0	0	5	5	1.59
INDIC_21	30	4.0	0	5	5	1.74
INDIC_22	30	5.0	0	5	5	1.67
INDIC_23	30	4.0	0	5	5	1.56
INDIC_24	30	5.0	0	5	5	.97
INDIC_25	30	4.0	0	5	5	1.38
INDIC_26	30	4.0	0	5	5	1.41
INDIC_27	30	4.0	0	5	5	1.46
INDIC_28	30	4.0	0	5	5	1.59
INDIC_29	30	4.0	0	5	5	1.67
INDIC_30	30	4.0	0	5	5	1.67
INDIC_31	30	4.0	0	5	5	1.48
INDIC_32	30	4.0	0	5	5	1.42
INDIC_33	30	4.0	0	5	5	1.28

D8 Descriptive Statistics for Individual Target Groups

D8.1 Descriptive Statistics: Institutional Management Indicator Ratings

	Valid N	Median	Minimum	Maximum	Range	Std.Dev.
INDIC_1	11	5.0	0	5	5	1.56
INDIC_2	11	5.0	0	5	5	1.95
INDIC_3	11	4.0	0	5	5	1.86
INDIC_4	11	4.0	0	5	5	1.70
INDIC_5	11	4.0	0	5	5	1.78
INDIC_6	11	4.0	0	5	5	1.78
INDIC_7	11	4.0	0	5	5	2.00
INDIC_8	11	5.0	0	5	5	1.49
INDIC_9	11	4.0	0	5	5	1.90
INDIC_10	11	4.0	0	5	5	1.90
INDIC_11	11	4.0	0	5	5	1.76
INDIC_12	11	4.0	0	5	5	1.64
INDIC_13	11	3.0	0	4	4	1.43
INDIC_14	11	4.0	0	5	5	1.64
INDIC_15	11	3.0	0	5	5	1.58
INDIC_16	11	4.0	0	5	5	1.72
INDIC_17	11	4.0	0	5	5	1.79
INDIC_18	11	5.0	0	5	5	1.54
INDIC_19	11	4.0	0	5	5	1.81
INDIC_20	11	3.0	0	4	4	1.54
INDIC_21	11	3.0	0	5	5	1.73
INDIC_22	11	4.0	0	5	5	1.86
INDIC_23	11	3.0	0	5	5	1.61
INDIC_24	11	5.0	4	5	1	.40
INDIC_25	11	4.0	0	5	5	1.81
INDIC_26	11	4.0	0	5	5	1.35
INDIC_27	11	4.0	0	5	5	1.47
INDIC_28	11	4.0	0	4	4	1.55
INDIC_29	11	4.0	0	5	5	1.44
INDIC_30	11	4.0	0	5	5	1.72
INDIC_31	11	4.0	0	5	5	1.48
INDIC_32	11	4.0	0	5	5	1.35
INDIC_33	11	4.0	0	5	5	1.45

D8.2 Descriptive Statistics: CES Personnel Indicator Ratings

	Valid N	Median	Minimum	Maximum	Range	Std.Dev.
INDIC_1	9	5.0	4	5	1	.50
INDIC_2	9	5.0	4	5	1	.50
INDIC_3	9	5.0	4	5	1	.44
INDIC_4	9	5.0	0	5	5	1.69
INDIC_5	9	4.0	4	5	1	.53
INDIC_6	9	4.0	4	5	1	.53
INDIC_7	9	4.0	4	5	1	.44
INDIC_8	9	5.0	4	5	1	.44
INDIC_9	9	4.0	1	5	4	1.32
INDIC_10	9	4.0	3	5	2	.67
INDIC_11	9	4.0	1	5	4	1.12
INDIC_12	9	4.0	1	5	4	1.20
INDIC_13	9	4.0	4	5	1	.53
INDIC_14	9	4.0	4	5	1	.53
INDIC_15	9	4.0	3	5	2	.78
INDIC_16	9	5.0	2	5	3	1.01
INDIC_17	9	5.0	2	5	3	1.01
INDIC_18	9	5.0	4	5	1	.50
INDIC_19	9	4.0	1	5	4	1.09
INDIC_20	9	4.0	4	5	1	.44
INDIC_21	9	5.0	4	5	1	.50
INDIC_22	9	5.0	4	5	1	.33
INDIC_23	9	4.0	1	5	4	1.17
INDIC_24	9	4.0	4	5	1	.53
INDIC_25	9	4.0	3	5	2	.60
INDIC_26	9	4.0	3	5	2	.50
INDIC_27	9	4.0	4	5	1	.53
INDIC_28	9	4.0	4	5	1	.44
INDIC_29	9	4.0	1	5	4	1.22
INDIC_30	9	4.0	1	5	4	1.27
INDIC_31	9	4.0	3	5	2	.67
INDIC_32	9	5.0	3	5	2	.87
INDIC_33	9	5.0	4	5	1	.53

D8.3 Descriptive Statistics: CES Clients Indicator Ratings

	Valid N	Median	Minimum	Maximum	Range	Std.Dev.
INDIC_1	8	5.0	0	5	5	1.77
INDIC_2	8	4.0	0	5	5	1.85
INDIC_3	8	4.5	0	5	5	1.93
INDIC_4	8	4.0	0	5	5	2.17
INDIC_5	8	3.5	0	5	5	1.89
INDIC_6	8	4.0	0	5	5	2.12
INDIC_7	8	4.0	0	5	5	1.51
INDIC_8	8	5.0	0	5	5	1.82
INDIC_9	8	3.5	0	5	5	1.55
INDIC_10	8	4.0	0	5	5	1.69
INDIC_11	8	3.0	0	4	4	1.28
INDIC_12	8	3.5	0	5	5	1.55
INDIC_13	8	2.5	0	5	5	1.92
INDIC_14	8	3.5	0	5	5	2.12
INDIC_15	8	3.0	0	4	4	1.69
INDIC_16	8	3.0	0	4	4	1.69
INDIC_17	8	4.0	0	4	4	2.07
INDIC_18	8	4.5	0	5	5	1.83
INDIC_19	8	4.0	0	5	5	2.19
INDIC_20	8	3.0	0	4	4	1.81
INDIC_21	8	3.0	0	5	5	2.07
INDIC_22	8	4.0	0	5	5	2.13
INDIC_23	8	4.0	0	4	4	1.81
INDIC_24	8	5.0	0	5	5	1.73
INDIC_25	8	3.5	0	5	5	1.49
INDIC_26	8	3.5	0	5	5	1.89
INDIC_27	8	4.0	0	5	5	2.12
INDIC_28	8	4.0	0	5	5	2.19
INDIC_29	8	4.0	0	5	5	2.19
INDIC_30	8	3.5	0	5	5	1.89
INDIC_31	8	4.0	0	5	5	2.12
INDIC_32	8	5.0	0	5	5	1.81
INDIC_33	8	4.0	0	5	5	1.67

D8.4 Descriptive Statistics: International Experts Ratings

	Valid N	Median	Minimum	Maximum	Range	Std.Dev.
INDIC_1	2	4.5	4	5	1	.71
INDIC_2	2	4.5	4	5	1	.71
INDIC_3	2	2.0	0	4	4	2.82
INDIC_4	2	4.0	4	4	0	0.00
INDIC_5	2	3.0	2	4	2	1.41
INDIC_6	2	4.0	4	4	0	0.00
INDIC_7	2	3.5	3	4	1	.71
INDIC_8	2	4.0	4	4	0	0.00
INDIC_9	2	3.5	3	4	1	.71
INDIC_10	2	3.5	3	4	1	.71
INDIC_11	2	2.5	1	4	3	2.12
INDIC_12	2	1.5	0	3	3	2.12
INDIC_13	2	1.5	1	2	1	.71
INDIC_14	2	2.5	1	4	3	2.12
INDIC_15	2	2.5	1	4	3	2.12
INDIC_16	2	3.5	3	4	1	.71
INDIC_17	2	3.5	3	4	1	.71
INDIC_18	2	4.0	4	4	0	0.00
INDIC_19	2	4.5	4	5	1	.71
INDIC_20	2	1.5	1	2	1	.71
INDIC_21	2	2.5	2	3	1	.71
INDIC_22	2	5.0	5	5	0	0.00
INDIC_23	2	2.0	1	3	2	1.41
INDIC_24	2	4.5	4	5	1	.71
INDIC_25	2	3.0	2	4	2	1.41
INDIC_26	2	2.5	1	4	3	2.12
INDIC_27	2	4.0	4	4	0	0.00
INDIC_28	2	2.5	1	4	3	2.12
INDIC_29	2	2.5	1	4	3	2.12
INDIC_30	2	2.5	1	4	3	2.12
INDIC_31	2	4.0	3	5	2	1.41
INDIC_32	2	3.0	1	5	4	2.83
INDIC_33	2	4.0	3	5	2	1.41

APPENDIX E: REVISED ELECTRONIC QUESTIONNAIRES

Questionnaire: PERFORMANCE AND SUSTAINABILITY OF CLINICAL ENGINEERING SERVICES

As part of the focus on improved performance of health systems (WHO World Health Report, 2000), we wish to establish indicators for the performance and sustainability of Clinical Engineering Services[†] as an integral part of cost-effective service delivery. These indicators will form one component of a tool for assessment and comparison of Clinical Engineering Services in different settings, with the overall aim of improving the performance and quality of healthcare delivery. This study follows and complements earlier work by Frize (1990) and Glouhova *et al* (1999).

The main data gathering instrument is a set of 4 questionnaires, directed at four key target groups:

- Institutional / health facility management (including nursing management);
- Personnel (both managerial and technical) of Clinical Engineering Services;
- Clinical Engineering Service Clients, i.e. clinical departments providing healthcare services, and
- Representatives of national/provincial ministries of health and international HTM experts (including representatives of multilateral organisations and bilateral agencies, as well as technical consultants).

This is an open invitation to all interested parties to participate in this study. We look forward to receiving your valued input and insights.

Signatures Removed

Mladen Poluta and Rutendo Ngara

Healthcare Technology Management (HTM) Programme
Groote Schuur Hospital / University of Cape Town &
MRC/WHO Collaborating Centre for Essential Technologies in Health

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[†] Units responsible for providing medical equipment and maintenance services are known variously as Clinical Engineering Departments, Health Care Technical Services, Medical Physics Departments, Biomedical Technology/Engineering Services, Medical Equipment Workshops, etc., and may be located within a health facility or outside as a shared / regional resource centre.

Instructions for completing the questionnaires

1. Save the attached covering letter as '**covlet.doc**'. You may wish to print this document as it contains a Glossary of Terms, useful to refer to while completing the questionnaire.

2. Open the attached questionnaires (created in MS Word 2000 and saved as Templates).

3. For each:

    - On the **File** menu, click **Save As**.

    - In the **File name** box, save the questionnaires, where applicable, as:

        1. **'Q1e_MAN.doc'** for Institutional Management [Quest1]
        2. **'Q2e_CED.doc'** for CES Management & Personnel [Quest2]
        3. **'Q3e_CLI.doc'** for CES Clients [Quest3]
        4. **'Q4e_EXP.doc'** for Ministries of Health/HTM Experts [Quest4]

4. Fill in the questionnaire by entering information in each grey-shaded form field. (A **form field** is a location where a particular type of data is stored. Form fields include *text boxes* to fill in, *check boxes* to select or clear, and *dropdown list boxes,* from which to select items. In this questionnaire all three types are used).

5. You can move from field to field by positioning your mouse cursor and clicking at the required field. You can also use the TAB (to move forward) and SHIFT+TAB (to move backwards), or the arrow keys to move between fields.

6. Please read the instructions given with each question carefully. You can go back and change answers if you so wish. You may, of course, also save the file, and return to the questionnaire at a later time.

7. Please note that the check boxes in this questionnaire are not mutually exclusive. If you wish to change an answer for a question where the instruction says (Please check [i.e. ☒] *one* box only), you will need to **clear** the incorrect answer first, by clicking it with your mouse.

8. Once you have completed the questionnaire, on the **File** menu, click **Save**.

9. Please **email** the completed questionnaires – preferably zipped - as an attachment to rutendo@cormack.uct.ac.za. Please include the filename/s in the subject box.

Note1: If you do not know what to enter in a form field, click the form field, and then check the status bar or press F1. The designer of the form may have added text to assist you.

Note2: You can also print out the form and complete it by hand. In this case please **fax** the completed form to +27 21 448 7226. Please mark it 'Attention: Rutendo'.

Thank you !

TARGET GROUP: INSTITUTIONAL MANAGEMENT **(including Nursing Management)**

Part 1 *(pages 1 to 6)*

In order to answer the questionnaire, please click in the grey-shaded answer fields

1. DEMOGRAPHIC DATA

The following set of questions focuses on general information about your institution and the *Clinical Engineering Service* supporting it.

1.1 Please complete the following:
(If you prefer to remain anonymous, please indicate your **position or job description** and **country** in the spaces provided)

Surname | First Name/Initial | Title

or ☐ Anonymous

Position/Job Description

Country

(The following information is optional)

Institution/Hospital

Email address

Telephone | Fax

Postal address

City | Postal Code

1.2 a) What type of health facility is your institution?
(Please select *one* option from drop-down menu or fill in 'Other' field)

(Please select one option)
Other (please specify)

b) What is the number of beds supported by the health facility? (Please check [i.e. ☒] *one* box only)

☐ < 100 ☐ 100 - 250 ☐ 251 - 500 ☐ 501 - 750
☐ 751 - 1000 ☐ 1001 - 2000 ☐ > 2000 (Please specify)

c) Is your health facility a public sector or private sector institution? (Please check [i.e. ☒] *one* box only)

1 ☐ Public sector institution
2 ☐ Private sector institution
3 ☐ Other (please specify)

1.3 a) Is your institution supported by an *in-house* clinical engineering service (CES) or an external* clinical engineering service? (Please check [i.e. ☒] *one* box only)

1 ☐ In-house CES
2 ☐ External CES (*regional or centralised workshop/service)
3 ☐ Combination of in-house and external CES
4 ☐ Not supported at all

Please continue Section 1 on Page 2

b) Does the CES exist as a separate unit (e.g. Clinical Engineering Department, Health Care Technical Service, etc.) or part of another department (e.g. Hospital Engineering)?
(Please check [i.e. ☒] *one* box only, and fill in text field)

☐ Separate unit, called

☐ Part of another department (Please specify)

c) To whom does the CES report?

2. MISSION AND STRATEGY OF CLINICAL ENGINEERING SERVICE

- **The following set of questions aims to establish general mission statements and basic strategies of Clinical Engineering Services.**
- **If your institution is supported by an in-house CES, please answer as much of this section as you can.**
- **If your institution does not have an in-house CES, please move on to Section 3.**

2.1 **a)** Are you aware of the *mission statement* of the Clinical Engineering Service (CES) supporting your institution?

☐ Yes ☐ No ☐ I don't know

b) In your opinion, what would be an appropriate mission statement for a CES?

2.2 **a)** To the best of your knowledge, does the CES have an appropriate *strategy (*or business plan) to achieve its mission?

☐ Yes ☐ No ☐ I don't know

b) In your opinion, what would be appropriate objectives in such a plan?

c) If it exists, does this strategy support the overall strategic plan of your institution?

☐ Yes ☐ No ☐ I don't know

Please proceed to Section 3 on page 3

3. SERVICE PROVIDED BY CLINICAL ENGINEERING SERVICE

- **The following set of questions focuses on the services provided by the CES and the importance of these services to your institution**
- **Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 4.**

3.1 a) To the best of your knowledge, which of the following medical equipment management and maintenance services does the CES provide? (Please check [i.e. ☒] relevant boxes on the left in the table below)

NB: The following terms are defined in the Glossary on page iii: technology assessment, needs assessment, asset/inventory management, cost of ownership, facilities and plant management, risk and safety management, inspection and preventive maintenance, corrective maintenance, equipment performance monitoring, and quality assurance.

	a) Provided?	Service	b) Rating of Importance
1	☐	Strategic technology needs assessment and planning.....	Please select one option
2	☐	Technology assessment.....	Please select one option
3	☐	Specification, evaluation and procurement of equipment.....	Please select one option
4	☐	Asset/inventory management.....	Please select one option
5	☐	Review of equipment replacement needs.....	Please select one option
6	☐	Cost of ownership monitoring.....	Please select one option
7	☐	Management of service contracts.....	Please select one option
8	☐	Project management.....	Please select one option
9	☐	Facilities and plant management and maintenance.....	Please select one option
10	☐	Training equipment users.....	Please select one option
11	☐	Risk management.....	Please select one option
12	☐	Safety checks.....	Please select one option
13	☐	Acceptance testing (incoming inspections).....	Please select one option
14	☐	Inspection and preventive maintenance (IPM).....	Please select one option
15	☐	Corrective maintenance (repair).....	Please select one option
16	☐	Equipment performance monitoring.....	Please select one option
17	☐	Functional or calibration checks.....	Please select one option
18	☐	Quality assurance and improvement.....	Please select one option
19	☐	Research and development/modification of equipment.....	Please select one option
20	☐	IT/Computer hardware and networks	Please select one option
21	☐	Telecommunications.....	Please select one option
22	☐	Other (please specify)	Please select one option
23	☐		Please select one option
24	☐		Please select one option

b) Please pick a number from the scale below, to indicate how important you believe **all** the CE services listed in the table above would be to your healthcare institution.
Please also rate those services that are not currently provided by the CES.
(Please select *one* option from drop-down menu on the right in the table above)

SCALE				
1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

REMINDER: Have you rated **all** of the services as listed above?

3.2 a) To the best of your knowledge, are any of the following services *outsourced* to equipment suppliers/agents or *third party service* providers (e.g. commercial firm/shared service) ?
(Please check [i.e. ☒] the relevant box in table below)

	Service Provided	Outsourced? *Please check [i.e. ☒] relevant box*		
1	Training equipment users	☐ Yes	☐ No	☐ Both/mixed
2	Acceptance testing (incoming inspections).....	☐ Yes	☐ No	☐ Both/mixed
3	Inspection and preventive maintenance (IPM).....	☐ Yes	☐ No	☐ Both/mixed
4	Corrective maintenance (repair).....	☐ Yes	☐ No	☐ Both/mixed
5	Other (please specify)	☐ Yes	☐ No	☐ Both/mixed
6		☐ Yes	☐ No	☐ Both/mixed
7		☐ Yes	☐ No	☐ Both/mixed

3.3 In your opinion, what are the advantages and the disadvantages of having an in-house CES, as opposed to outsourcing all equipment management and maintenance, as listed in Section 3.1?

Advantages of in-house CES

Disadvantages of in-house CES

4. ASSESSMENT OF SERVICE PROVIDED BY CLINICAL ENGINEERING SERVICE

- **The following set of questions focuses on your assessment of the service provided by the CES.**
- **Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 5.**

4.1 Institutional Expectations of the Clinical Engineering Service

4.1.1 Please list, in order of preference, what you as institutional management, expect from a CES.

1
2
3
4
5

4.1.2 In your opinion, what major factors contribute to your expectations of the CES **not** being met (e.g. redoing work, excessive equipment *downtime*, poor *response time*, unprofessional conduct etc)

1
2
3
4
5

4.1.3 In your opinion, what impact does the service provided by the CES have on (**a**) clinical procedures specifically, or on (**b**) health care service delivery generally, in your institution?

a)

b)

4.1.4 In your opinion, what would be the implications of **not** having an in-house CES at all (e.g. outsourcing all medical equipment management and maintenance functions)?

4.2 Quality of Service Provided

4.2.1 What do you understand by the term "*Quality* of Service" with respect to a CES?

4.2.2 Is the quality of other services within the healthcare institution assessed (e.g. through *accreditation*)?

Please proceed to Section 5 on page 6

5. CES PERFORMANCE AND SUSTAINABILITY

- **The following set of questions focuses on your assessment of the performance and *sustainability* of the CES supporting your institution**
- **Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Part 2.**

5.1 Performance

a) How is *performance* of the CES currently assessed at your institution, if at all?

b) What would you suggest as 5 important *indicators* of performance?

1
2
3
4
5

5.2 Sustainability

5.2.1 Would you consider the CES service to be a 'core' function of your health care institution?

☐ Yes ☐ No

Please elaborate on your answer.

5.2.2 a) Do you see the CES supporting your institution surviving in the next 5, 10 or 15 years?
(Please check [i.e. ☒] the relevant box)

☐ Yes, 5 years ☐ Yes, 10 years ☐ Yes, 15 years ☐ Not at all

b) What are the institutional, organisational or socio-political environment factors that would **support** the existence of your CES?

c) What are the institutional, organisational or socio-political environment factors that would **hinder** the existence of your CES?

Part 2 *(pages 7 to 9)*

CLINICAL ENGINEERING SERVICE INDICATORS

- The main objective of the study is to develop and test a set of comprehensive **key indicators** to describe the performance, *cost-effectiveness* and sustainability of clinical engineering services.
- *(An indicator is an objective, quantitative variable that indicates or shows a given situation, and thus can be used to measure change. It is objective in that different observers can obtain the same measurement).*
- The critical indicators identified should facilitate standardisation of clinical engineering services; as well as allowing comparisons of performance, cost-effectiveness and sustainability to be made between clinical engineering services in differing environments.

The following is a list of proposed indicators (derived from the available literature and current best practice), in no particular order. For **each** of the proposed indicators please do the following:

- Please pick a number from the scale to indicate how important you believe the measure to be and select it from the drop-down menu. If you are uncertain of the relevance of the indicator please select the 'Don't know' i.e. (0) option.

SCALE						
0 Don't know		1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

	Indicators	Rating Please select rating from drop-down menu
	Patient/Client-Related	
1	Inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction	Please select one option
2	Patient (or operator) injury due to medical equipment malfunction or unavailability	Please select one option
3	Patient (or operator) injury due to medical equipment misapplication	Please select one option
4	Number of equipment malfunctions caused by user error/misuse or abuse	Please select one option
5	Type and number of medical equipment supported by CES	Please select one option
6	Percentage of medical equipment supported by CES that is *functional*	Please select one option
	Performance/Personnel	
7	*Productivity* (Ratio of outputs to inputs)	Please select one option
8	Competencies/skills of CES personnel	Please select one option
9	*Certification* and registration of CES personnel/ department with appropriate professional body	Please select one option
10	Evidence of continuing education/ professional development of CES personnel	Please select one option
11	Relative number of different categories of CES personnel (i.e. engineers, technicians, artisans etc.)	Please select one option

12	Absenteeism of CES personnel	Please select one option
13	CES staff levels per number of beds	Please select one option
14	CES staff levels per number of medical devices	Please select one option
15	Working space (m^2) per technical CES staff	Please select one option
16	Salaries and career paths of CES technical staff vs. other healthcare workers	Please select one option
17	Salaries and career paths of CES technical staff vs. similar employees in competing sector (public/private)	Please select one option
	Cost-effectiveness	
18	Allocated CES budget per year (as a percentage of the supported equipment inventory value)	Please select one option
19	Cost (*labour and overhead)* per hour per CES employee	Please select one option
20	Cost of CES service per bed supported	Please select one option
21	Cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type	Please select one option
22	Cost of in-house service vs. cost of outsourced service per equipment type	Please select one option
23	Inventory of spare parts per equipment value supported	Please select one option
	CES Activities	
24	*Response time* to service requests	Please select one option
25	Percentage of time devoted to IPMs[1] vs. repairs	Please select one option
26	Total number of IPMs/repairs performed per device type per year	Please select one option
27	*Downtime* of equipment due to IPMs/repairs	Please select one option
28	Degree of compliance that has been achieved with the established schedule for routine IPMs/repairs	Please select one option
29	Percentage of IPMs/repairs performed in-house vs. outsourced	Please select one option
30	Percentage and type of outsourced equipment IPMs/repairs checked by in-house CES before returning to clinical environment	Please select one option
31	Percentage of repeat repairs	Please select one option
32	IPMs/repairs conducted in accordance with manufacturer's recommendations, as specified in service manuals	Please select one option
33	Evidence of proper documentation of all work done by CES (e.g. service histories), providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc	Please select one option

[1] IPMs = *Inspection and Preventive Maintenance procedures*

- The above list is by no means exhaustive. Please add any other indicators you believe to be appropriate, in the empty numbered spaces and rate them according to the scale below. (Please check [i.e. ☒] *one* box only next to each indicator you suggest)

SCALE		
Neutral	**Important**	**Essential**

100	☐ Neutral ☐ Important ☐ Essential
101	☐ Neutral ☐ Important ☐ Essential
102	☐ Neutral ☐ Important ☐ Essential
103	☐ Neutral ☐ Important ☐ Essential
104	☐ Neutral ☐ Important ☐ Essential
105	☐ Neutral ☐ Important ☐ Essential
106	☐ Neutral ☐ Important ☐ Essential
107	☐ Neutral ☐ Important ☐ Essential
108	☐ Neutral ☐ Important ☐ Essential
109	☐ Neutral ☐ Important ☐ Essential

Do you have any additional comments, relating to clinical engineering services generally, or on this questionnaire specifically?

Thank you for your time and effort in answering the questionnaire.

Please save the file as 'Q1e_MAN.doc' and email the completed questionnaire to rutendo@cormack.uct.ac.za **at your earliest convenience.**

Healthcare Technology Management (HTM) Programme
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TARGET GROUP: CLINICAL ENGINEERING SERVICE MANAGERS/PERSONNEL

Part 1 *(pages 1 to 8)*

In order to answer the questionnaire, please click in the grey-shaded answer fields

1. DEMOGRAPHIC DATA

The following set of questions focuses on general information about your institution and the *Clinical Engineering Service* supporting it.

1.1 Please complete the following:
(If you prefer to remain anonymous, please indicate your position or job description and country in the spaces provided)

Surname | First Name/Initial | Title

or ☐ Anonymous

Position/Job Description

Country

(The following information is optional)

Institution/Hospital

Email address

Telephone | Fax

Postal address

City | Postal Code

1.2 a) What type of health facility is your institution?
(Please select *one* option from drop-down menu or fill in 'Other' field)

(Please select one option)
Other (please specify)

b) Is your health facility a public sector or private sector institution? (Please check [i.e. ☒] *one* box only)

1 ☐ Public sector institution
2 ☐ Private sector institution
3 ☐ Other (please specify)

c) What is the number of beds supported by the health facility? (Please check [i.e. ☒] *one* box only)

☐ < 100 ☐ 100 - 250 ☐ 251 - 500 ☐ 501 - 750
☐ 751 - 1000 ☐ 1001 - 2000 ☐ > 2000 (Please specify)

1.3 a) What is the number of devices supported by your CES? (Please check [i.e. ☒] *one* box only)

☐ < 500 ☐ 500 - 1000 ☐ 1001 - 1500 ☐ 1501 - 2000
☐ 2001 - 3000 ☐ 3001 - 4000 ☐ 4001 – 5000
☐ > 5001 (Please specify) ☐ Don't Know

Please continue Section 1 on page 2

b) What is the scope of service covered by your CES, in terms of types/range of equipment supported by your CES?

c) What is the scope of service covered by your CES, in terms of service provided to other institutions?

2. MISSION AND OBJECTIVES OF CLINICAL ENGINEERING SERVICE

- **The following set of questions aims to establish general mission statements and basic strategies of Clinical Engineering Services.**
- **Please answer as much of this section as you can. If you are unable to answer any questions please move on to Section 3**

2.1 a) Does your department have a documented *mission statement*?

☐ Yes ☐ No ☐ I don't know

b) If '*Yes*', please specify.
If *'No'*, what in your opinion, would be an appropriate mission statement for the CES?

2.2 a) Does your CES have a documented *strategy* (or business plan) to achieve your mission?

☐ Yes ☐ No ☐ I don't know

b) If '*Yes*', please specify
If *'No'*, what, in your opinion, would be appropriate objectives in such a plan?

2.3 Do the CES' mission statement and strategy conform to the overall strategic plan of the hospital? (Please elaborate)

Please proceed to Section 3 on page 3

3. SERVICE PROVIDED BY CLINICAL ENGINEERING SERVICE

- **The following set of questions focuses on the services provided by the CES and the importance of these services to your institution**
- **Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 4.**

3.1 a) To the best of your knowledge, which of the following medical equipment management and maintenance services does the CES provide? (Please check [i.e. ☒] relevant boxes on the **left** in the table below)

NB: The following terms are defined in the Glossary on page iii: technology assessment, needs assessment, asset/inventory management, cost of ownership, facilities and plant management, risk and safety management, inspection and preventive maintenance, corrective maintenance, equipment performance monitoring, and quality assurance.

	a) Provided?	Service	b) Rating of Importance
1	☐	Strategic technology needs assessment and planning.....	Please select one option
2	☐	Technology assessment.....	Please select one option
3	☐	Specification, evaluation and procurement of equipment.....	Please select one option
4	☐	Asset/inventory management.....	Please select one option
5	☐	Review of equipment replacement needs.....	Please select one option
6	☐	Cost of ownership monitoring.....	Please select one option
7	☐	Management of service contracts.....	Please select one option
8	☐	Project management.....	Please select one option
9	☐	Facilities and plant management and maintenance.....	Please select one option
10	☐	Training equipment users.....	Please select one option
11	☐	Risk management.....	Please select one option
12	☐	Safety checks.....	Please select one option
13	☐	Acceptance testing (incoming inspections).....	Please select one option
14	☐	Inspection and preventive maintenance (IPM).....	Please select one option
15	☐	Corrective maintenance (repair).....	Please select one option
16	☐	Equipment performance monitoring.....	Please select one option
17	☐	Functional or calibration checks.....	Please select one option
18	☐	Quality assurance and improvement.....	Please select one option
19	☐	Research and development/modification of equipment.....	Please select one option
20	☐	IT/Computer hardware and networks	Please select one option
21	☐	Telecommunications.....	Please select one option
22	☐	Other (please specify)	Please select one option
23	☐		Please select one option
24	☐		Please select one option

b) Please pick a number from the scale below, to indicate how important you believe **all** the CE services listed in the table above would be to your healthcare institution.
Please also rate those services that are not currently provided by the CES.
(Please select *one* option from drop-down menu on the **right** in the table above)

SCALE				
1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

REMINDER: Have you rated **all** of the services listed above?

Please continue Section 3 on page 4

3.2 To the best of your knowledge, are any of the following services *outsourced* to (i) equipment suppliers/agents or (ii) *third party service* providers (e.g. commercial firm/shared service)?
(Please check [i.e. ☒] *one* box only)

	Service Provided	Outsourced? *Please check [i.e. ☒] appropriate box*		
1	Training equipment users	☐ Yes	☐ No	☐ Both/mixed
2	Acceptance testing (incoming inspections).....	☐ Yes	☐ No	☐ Both/mixed
3	Inspection and preventive maintenance (IPM).....	☐ Yes	☐ No	☐ Both/mixed
4	Corrective maintenance (repair).....	☐ Yes	☐ No	☐ Both/mixed
5	Other (please specify)	☐ Yes	☐ No	☐ Both/mixed
6		☐ Yes	☐ No	☐ Both/mixed
7		☐ Yes	☐ No	☐ Both/mixed

3.3 Please answer the following questions regarding the service provided by your CES.

3.3.1 Are there laid down procedures and guidelines for each activity?

☐ Yes ☐ No ☐ I don't know

3.3.2 Who are the *clients/customers* receiving the service you provide?

3.3.3 Do you know what your clients expect from the CES?

3.3.4 Would there be any advantages of *outsourcing* any CES activities?

Please proceed to Section 4 on page 5

4. PERFORMANCE OF CLINICAL ENGINEERING SERVICE

- **The following set of questions focuses on your assessment of the performance of your CES**
- **Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 5**

4.1 In your opinion, what impact does your CES have on the *performance* of the health care service delivery system or clinical procedures in your institution?

4.2 To what extent is your service supported (or hindered) by external service providers (i.e. equipment suppliers or *third party service* providers)?

4.3 a) How is performance currently assessed in your CES, if at all?

b) What, if any, *indicators* are used to assess performance in your CES?

1
2
3
4
5

5 SUSTAINABILITY OF THE CLINICAL ENGINEERING SERVICE

- **The following set of questions focuses on your assessment of the *sustainability* of your CES.**
- **Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 6.**

5.1 a) Do you see your CES surviving in the next 5, 10 or 15 years? (Please check [i.e. ☒] relevant box)

☐ Yes, 5 years ☐ Yes, 10 years ☐ Yes, 15 years ☐ Not at all

b) What are the institutional, organisational or socio-political environment factors that would **support** the existence of your CES?

b) What are the institutional, organisational or socio-political environment factors that would **hinder** the existence of your CES?

5.2 Would you consider your CES to be a 'core' function of your health care institution?

☐ Yes ☐ No

Please elaborate on your answer

5.3 a) Which of the following general factors do you feel have a significant impact on the *sustainability* of CESs? (Please check [i.e. ☒] all relevant boxes on **left** in the table below)

b) Please pick a number from the scale, to indicate how significant the factors chosen are to the sustainability of CES'(Please select *one* option from drop-down menu on the **right** in the table below)

SCALE				
1 Irrelevant	2 Insignificant	3 Neutral	4 Significant	5 Highly Significant

a) Significant?		Factor	b) Rating of Significance
1	☐	Adequate *physical infrastructure*	Please select one option
2	☐	Adequate financial resources.....	Please select one option
3	☐	Adequate human resources.....	Please select one option
4	☐	Management/strategic commitment.....	Please select one option
5	☐	Conducive environment.....	Please select one option
6	☐	Legal framework (e.g. threat of *litigation*).....	Please select one option
7	☐	*Logistics* support.....	Please select one option
8	☐	Performance of technical staff.....	Please select one option
9	☐	Stakeholder participation.....	Please select one option
10	☐	Recognition or acceptance by clients.....	Please select one option
11	☐	Other (Please specify)	Please select one option
12.	☐		Please select one option
13.	☐		Please select one option
14.	☐		Please select one option
15.	☐		Please select one option

Please continue Section 5 on page 7

b) Please suggest a maximum of 5 important indicators of sustainability.

1	
2	
3	
4	
5	

6 TRENDS AFFECTING CLINICAL ENGINEERING SERVICES

- **The following set of questions focuses on trends that may have been affecting CESs in recent years.**
- **Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 7.**

6 a) Has your department been affected by/experienced any of the following trends?
(Please refer to the glossary for definitions and check [i.e. ☒] all relevant boxes on left)

1 ☐ *Downsizing*
2 ☐ *Economic rationalisation*
3 ☐ *Outsourcing*
4 ☐ *Total quality management*
5 ☐ *Benchmarking*
6 ☐ *Re-engineering*
7 ☐ *Globalisation*
8 ☐ Other (please specify)

b) If so, how?

Please proceed to Section 7 on page 8

7 PERFORMANCE/SUSTAINABILITY FACTORS FOR CLINICAL ENGINEERING SERVICES

- **The following section focuses on more specific factors that may or may not impact on the performance or sustainability of your CES.**
- **Please answer as much of this section as you can. If you are unable to answer any questions, please proceed to Part 2 of the questionnaire.**

For each of the factors in the table below, please indicate:

a) Whether it is available at your institution (Please check [i.e. ☒] *one* box only, in column **a**)

b) Whether you believe it has a significant impact on the performance or sustainability of your CES (Please check [i.e. ☒] *one* box only, in column **b**)

Factors	a) Available at your institution?	b) Has significant impact on performance or sustainability?
1. Presence of hospital-wide risk and safety management programme, specific to medical equipment	☐ Yes ☐ No	☐ Yes ☐ No
2. Presence of hospital-wide quality assurance programme, specific to medical equipment	☐ Yes ☐ No	☐ Yes ☐ No
3. Presence of a *hazard notification* system	☐ Yes ☐ No	☐ Yes ☐ No
4. Presence of *incident investigation* and reporting system	☐ Yes ☐ No	☐ Yes ☐ No
5. Adequate number of *test equipment* properly calibrated and functional per test equipment type	☐ Yes ☐ No	☐ Yes ☐ No
6. Adequate spare parts on site for common repairs	☐ Yes ☐ No	☐ Yes ☐ No
7. Availability of regular medical equipment training/re-training programmes	☐ Yes ☐ No	☐ Yes ☐ No
8. Availability of service manuals (from manufacturers) for all equipment serviced/maintained/repaired	☐ Yes ☐ No	☐ Yes ☐ No
9. Availability of operator/user manuals or instructions for all medical equipment	☐ Yes ☐ No	☐ Yes ☐ No
10. Availability of hospital-wide equipment inventory/asset register using consistent nomenclature	☐ Yes ☐ No	☐ Yes ☐ No
11. Availability of computerised and updated CES medical equipment inventory (including supported medical equipment, test equipment and spares) based on inventory of equipment supported (service, maintenance, user-related malfunctions, incidents) using consistent nomenclature	☐ Yes ☐ No	☐ Yes ☐ No
12. Management decisions (relating to needs assessment, procurement, decommissioning and replacement planning) based on inventory and CES equipment service histories	☐ Yes ☐ No	☐ Yes ☐ No
13. Client satisfaction surveys performed	☐ Yes ☐ No	☐ Yes ☐ No
14. Level of participation and communication by CES with stakeholders (i.e. hospital management, clinical staff, manufacturers/suppliers)	☐ Yes ☐ No	☐ Yes ☐ No
15. Accessibility of CES personnel outside normal working hours	☐ Yes ☐ No	☐ Yes ☐ No
16. Presence of criteria for inclusion or exclusion of medical devices/equipment into equip management programme	☐ Yes ☐ No	☐ Yes ☐ No
17. Presence of continuous quality improvement programme	☐ Yes ☐ No	☐ Yes ☐ No

Please proceed to Part 2 of the questionnaire

Part 2 *(pages 9 to 11)*

CLINICAL ENGINEERING SERVICE INDICATORS

- The main objective of the study is to develop and test a set of comprehensive **key indicators** to describe the performance, *cost-effectiveness* and sustainability of clinical engineering services.
- *(An indicator is an objective, quantitative variable that indicates or shows a given situation, and thus can be used to measure change. It is objective in that the same measurement can be obtained by different observers).*
- The critical indicators identified should facilitate standardisation of clinical engineering services; as well as allowing comparisons of performance, cost-effectiveness and sustainability to be made between clinical engineering services in differing environments.

The following is a list of proposed indicators (derived from the available literature and current best practice), in no particular order. For **each** of the proposed indicators please do the following:

- Please pick a number from the scale to indicate how important you believe the measure to be and select it from the dropdown menu.. If you are uncertain of the relevance of the indicator please select the 'Don't know' i.e. (0) option.

SCALE						
0 Don't know		1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

	Indicators	Rating Please select from drop-down menu
	Patient/Client-Related	
1	Inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction	Please select one option
2	Patient (or operator) injury due to medical equipment malfunction or unavailability	Please select one option
3	Patient (or operator) injury due to medical equipment misapplication	Please select one option
4	Number of equipment malfunctions caused by user error/misuse or abuse	Please select one option
5	Type and number of medical equipment supported by CES	Please select one option
6	Percentage of medical equipment supported by CES that is *functional*	Please select one option
	Performance/Personnel	
7	*Productivity* (ratio of outputs to inputs)	Please select one option
8	Competencies/skills of CES personnel	Please select one option
9	*Certification* and registration of CES personnel/ department with appropriate professional body	Please select one option
10	Evidence of continuing education/ professional development of CES personnel	Please select one option

11	Relative number of different categories of CES personnel (i.e. engineers, technicians, artisans etc.)	Please select one option
12	Absenteeism of CES personnel	Please select one option
13	CES staff levels per number of beds	Please select one option
14	CES staff levels per number of medical devices	Please select one option
15	Working space (m^2) per technical CES staff	Please select one option
16	Salaries and career paths of CES technical staff vs. other healthcare workers	Please select one option
17	Salaries and career paths of CES technical staff vs. similar employees in competing sector (public/private)	Please select one option
	Cost-effectiveness	
18	Allocated CES budget per year (as a percentage of the supported equipment inventory value)	Please select one option
19	Cost (*labour and overhead)* per hour per CES employee	Please select one option
20	Cost of CES service per bed supported	Please select one option
21	Cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type	Please select one option
22	Cost of in-house service vs. cost of outsourced service per equipment type	Please select one option
23	Inventory of spare parts per equipment value supported	Please select one option
	CES Activities	
24	*Response time* to service requests	Please select one option
25	Percentage of time devoted to IPMs[1] vs. repairs	Please select one option
26	Total number of IPMs/repairs performed per device type per year	Please select one option
27	*Downtime* of equipment due to IPMs/repairs	Please select one option
28	Degree of compliance that has been achieved with the established schedule for routine IPMs/repairs	Please select one option
29	Percentage of IPMs/repairs performed in-house vs. outsourced	Please select one option
30	Percentage and type of outsourced equipment IPMs/repairs checked by in-house CES before returning to clinical environment	Please select one option
31	Percentage of repeat repairs	Please select one option
32	IPMs/repairs conducted in accordance with manufacturer's recommendations, as specified in service manuals	Please select one option
33	Evidence of proper documentation of all work done by CES (e.g. service histories), providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc	Please select one option

[1] IPMs = *Inspection and Preventive Maintenance procedures*

- The above list is by no means exhaustive. Please add any other indicators you believe to be appropriate, in the empty numbered spaces and rate them according to the scale below. ((Please check [i.e. ☒] *one* box only next to each indicator you suggest)

SCALE		
Neutral	**Important**	**Essential**

101	☐ Neutral	☐ Important	☐ Essential
102	☐ Neutral	☐ Important	☐ Essential
103	☐ Neutral	☐ Important	☐ Essential
104	☐ Neutral	☐ Important	☐ Essential
105	☐ Neutral	☐ Important	☐ Essential
106	☐ Neutral	☐ Important	☐ Essential
107	☐ Neutral	☐ Important	☐ Essential
108	☐ Neutral	☐ Important	☐ Essential
109	☐ Neutral	☐ Important	☐ Essential
110	☐ Neutral	☐ Important	☐ Essential

Do you have any additional comments, relating to clinical engineering services generally, or on this questionnaire specifically?

Thank you for your time and effort in answering the questionnaire.

Please save the file as 'Q2e_CED.doc' and email the completed questionnaire to rutendo@cormack.uct.ac.za **, at your earliest convenience.**

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South Africa

Fax: **+27 21 448 7226**
Tel: +27 21 406-6549 or 406 6545
E-mail: rutendo@cormack.uct.ac.za

TARGET GROUP: CLINICAL ENGINEERING SERVICE CLIENTS

Part 1 *(pages 1 to 3)*

1. DEMOGRAPHIC DATA

The following set of questions focuses on general information about your institution and the *Clinical Engineering Service* supporting it.

1.1 Please complete the following:
(If you prefer to remain anonymous, please indicate your position or job description and country in the spaces provided)

Surname | First Name/Initial | Title

or ☐ Anonymous

Position/Job Description

Country

(The following information is optional)

Institution/Hospital

Email address

Telephone | Fax

Postal address

City | Postal Code

1.2 a) What type of health facility is your institution?
(Please select *one* option from drop-down menu or fill in 'Other' field)

(Please select one option)
Other (please specify)

b) What is the number of beds supported by the health facility? (Please check [i.e. ☒] *one* box only)

☐ < 100 ☐ 100 - 250 ☐ 251 - 500 ☐ 501 - 750
☐ 751 - 1000 ☐ 1001 - 2000 ☐ > 2000 (Please specify)

c) Is your health facility a public sector or private sector institution? (Please check [i.e. ☒] *one* box only)

1 ☐ Public sector institution
2 ☐ Private sector institution
3 ☐ Other (please specify)

1.3 a) Is your institution supported by an *in-house* clinical engineering service (CES) or an external* clinical engineering service? (Please check [i.e. ☒] *one* box only)

1 ☐ In-house CES
2 ☐ External CES (*regional or centralised workshop/service)
3 ☐ Combination of in-house and external CES
4 ☐ Not supported at all

b) If you *are* supported by a clinical engineering service, what is it called (e.g. Clinical Engineering Department, Health Care Technical Service, etc.)?

2. ASSESSMENT OF SERVICE

- **The following set of questions focuses on the services provided by the CES and the importance of these services to your institution**
- **Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Part 2.**

2.1 a) To the best of your knowledge, which of the following medical equipment management and maintenance services does the CES provide? (Please check [i.e. ☒] relevant boxes on the left in the table below)

NB: The following terms are defined in the Glossary on page iii: technology assessment, needs assessment, asset/inventory management, cost of ownership, facilities and plant management, risk and safety management, inspection and preventive maintenance, corrective maintenance, equipment performance monitoring, and quality assurance.

	a) Provided?	Service	b) Rating of Importance
1	☐	Strategic technology needs assessment and planning.....	Please select one option
2	☐	Technology assessment.....	Please select one option
3	☐	Specification, evaluation and procurement of equipment.....	Please select one option
4	☐	Asset/inventory management.....	Please select one option
5	☐	Review of equipment replacement needs.....	Please select one option
6	☐	Cost of ownership monitoring.....	Please select one option
7	☐	Management of service contracts.....	Please select one option
8	☐	Project management.....	Please select one option
9	☐	Facilities and plant management and maintenance.....	Please select one option
10	☐	Training equipment users.....	Please select one option
11	☐	Risk management.....	Please select one option
12	☐	Safety checks.....	Please select one option
13	☐	Acceptance testing (incoming inspections).....	Please select one option
14	☐	Inspection and preventive maintenance (IPM).....	Please select one option
15	☐	Corrective maintenance (repair).....	Please select one option
16	☐	Equipment performance monitoring.....	Please select one option
17	☐	Functional or calibration checks.....	Please select one option
18	☐	Quality assurance and improvement.....	Please select one option
19	☐	Research and development/modification of equipment.....	Please select one option
20	☐	IT/Computer hardware and networks	Please select one option
21	☐	Telecommunications.....	Please select one option
22	☐	Other (please specify)	Please select one option
23	☐		Please select one option
24	☐		Please select one option

b) Please pick a number from the scale below, to indicate how important you believe **all** the CE services listed in the table above would be to your healthcare institution.
Please also rate those services that are not currently provided by the CES.
(Please select *one* option from drop-down menu on the right in the table above)

SCALE				
1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

REMINDER: Have you rated **all** of the rated services as listed above?

Please continue Section 2 on page 3

2.2 Client Requirements and Views of Clinical Engineering Services

2.2.1 Please list in order of preference, your requirements from a CES, as the client receiving their service.

1
2
3
4
5

2.2.2 In your opinion, what factors contribute to your requirements of the CES **not** being met (e.g. redoing work, excessive equipment *downtime,* poor *response time,* unprofessional conduct etc.)

1
2
3
4
5

2.2.3 How does the service offered by the CES influence (a) your ability to carry out your own job in providing clinical procedures specifically or (b) health care services in general?

a)

b)

2.2.4 In your opinion, what would be the implications of **not** having an in-house CES at all (e.g. outsourcing medical equipment management and maintenance, as listed above)?

Please proceed to Part 2 of the questionnaire

Part 2 *(pages 4 to 6)*

CLINICAL ENGINEERING SERVICE INDICATORS

- The main objective of the study is to develop and test a set of comprehensive **key indicators** to describe the performance, *cost-effectiveness* and sustainability of clinical engineering services.
- *(An indicator is an objective, quantitative variable that indicates or shows a given situation, and thus can be used to measure change. It is objective in that different observers can obtain the same measurement).*
- The critical indicators identified should facilitate standardisation of clinical engineering services; as well as allowing comparisons of performance, cost-effectiveness and sustainability to be made between clinical engineering services in differing environments.

The following is a list of proposed indicators (derived from the available literature and current best practice), in no particular order. For **each** of the proposed indicators please do the following:

- Please pick a number from the scale to indicate how important you believe the measure to be and select it from the drop-down menu.. If you are uncertain of the relevance of the indicator– please select the 'Don't know' i.e. (0) option.

SCALE						
0 Don't know		1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

	Indicators	Rating Please select rating from drop-down menu
	Patient/Client-Related	
1	Inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction	Please select one option
2	Patient (or operator) injury due to medical equipment malfunction or unavailability	Please select one option
3	Patient (or operator) injury due to medical equipment misapplication	Please select one option
4	Number of equipment malfunctions caused by user error/misuse or abuse	Please select one option
5	Type and number of medical equipment supported by CES	Please select one option
6	Percentage of medical equipment supported by CES that is *functional*	Please select one option
	Performance/Personnel	
7	*Productivity* (ratio of outputs to inputs)	Please select one option
8	Competencies/skills of CES personnel	Please select one option
9	*Certification* and registration of CES personnel/ department with appropriate professional body	Please select one option
10	Evidence of continuing education/ professional development of CES personnel	Please select one option
11	Relative number of different categories of CES personnel (i.e. engineers, technicians, artisans etc.)	Please select one option

12	Absenteeism of CES personnel	Please select one option
13	CES staff levels per number of beds	Please select one option
14	CES staff levels per number of medical devices	Please select one option
15	Working space (m^2) per technical CES staff	Please select one option
16	Salaries and career paths of CES technical staff vs. other healthcare workers	Please select one option
17	Salaries and career paths of CES technical staff vs similar employees in competing sector (public/private)	Please select one option
	Cost-effectiveness	
18	Allocated CES budget per year (as a percentage of the supported equipment inventory value)	Please select one option
19	Cost (*labour and overhead)* per hour per CES employee	Please select one option
20	Cost of CES service per bed supported	Please select one option
21	Cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type	Please select one option
22	Cost of in-house service vs. cost of outsourced service per equipment type	Please select one option
23	Inventory of spare parts per equipment value supported	Please select one option
	CES Activities	
24	*Response time* to service requests	Please select one option
25	Percentage of time devoted to IPMs[1] vs. repairs	Please select one option
26	Total number of IPMs/repairs performed per device type per year	Please select one option
27	*Downtime* of equipment due to IPMs/repairs	Please select one option
28	Degree of compliance that has been achieved with the established schedule for routine IPMs/repairs	Please select one option
29	Percentage of IPMs/repairs performed in-house vs. outsourced	Please select one option
30	Percentage and type of outsourced equipment IPMs/repairs checked by in-house CES before returning to clinical environment	Please select one option
31	Percentage of repeat repairs	Please select one option
32	IPMs/repairs conducted in accordance with manufacturer's recommendations, as specified in service manuals	Please select one option
33	Evidence of proper documentation of all work done by CES (e.g. service histories), providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc	Please select one option

[1] IPMs = *Inspection and Preventive Maintenance procedures*

- The above list is by no means exhaustive. Please add any other indicators you believe to be appropriate, in the empty numbered spaces and rate them according to the scale below. (Please check [i.e. ☒] *one* box only next to each indicator you suggest)

SCALE		
Neutral	Important	Essential

100	☐ Neutral ☐ Important ☐ Essential
101	☐ Neutral ☐ Important ☐ Essential
102	☐ Neutral ☐ Important ☐ Essential
103	☐ Neutral ☐ Important ☐ Essential
104	☐ Neutral ☐ Important ☐ Essential
105	☐ Neutral ☐ Important ☐ Essential
106	☐ Neutral ☐ Important ☐ Essential
107	☐ Neutral ☐ Important ☐ Essential
108	☐ Neutral ☐ Important ☐ Essential
109	☐ Neutral ☐ Important ☐ Essential

Do you have any additional comments, relating to clinical engineering services generally, or on this questionnaire specifically?

Thank you for your time and effort in answering the questionnaire.

Please save the file as 'Q3e_CLI.doc' and email the completed questionnaire to rutendo@cormack.uct.ac.za **, at you earliest convenience**

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E-mail: rutendo@cormack.uct.ac.za

TARGET GROUP: MINISTRIES OF HEALTH / HTM EXPERTS

Part 1 *(pages 1 to 5)*

1. DEMOGRAPHIC DATA

The following set of questions focuses on general information.

1.1 Please complete the following:
(If you prefer to remain anonymous, please indicate your position or job description and country in the spaces provided)

Surname | First Name/Initial | Title

or ☐ Anonymous

Position/Job Description

Country

(The following information is optional)

Institution/Hospital

Email address

Telephone | Fax

Postal address

City | Postal Code

1.2 a) Are you familiar with a Clinical Engineering Service ?

☐ Yes ☐ No

If "Yes", please proceed to Section 2 below. If "No", please go to Section 3 on the next page.

2. MISSION AND STRATEGY OF CLINICAL ENGINEERING SERVICE

The following set of questions aims to establish general mission statements and basic strategies of Clinical Engineering Services.

2.1 a) Does the CES exist as a separate unit (e.g. Clinical Engineering Department, Health Care Technical Service, etc.) or part of another department (e.g. Hospital Engineering)?
(Please check [i.e. ☒] *one* box only, and fill in text field)

☐ Separate unit, called

☐ Part of another department (Please specify)

b) To whom does the CES report?

c) Are you aware of the *mission statement* of the Clinical Engineering Service (CES) ?

☐ Yes ☐ No ☐ I don't know

d) In your opinion, what would be an appropriate mission statement for a CES?

2.2 **a)** To the best of your knowledge, does the CES have an appropriate *strategy* (or business plan) to achieve its mission?

☐ Yes ☐ No ☐ I don't know

b) In your opinion, what would be appropriate objectives in such a plan?

c) If it exists, does this strategy support the overall strategic plan of the institution/s it serves?

☐ Yes ☐ No ☐ I don't know

3. SERVICES PROVIDED BY CLINICAL ENGINEERING SERVICE

The following set of questions focuses on the services typically provided by a CES and the importance of these services to the institution/s it serves.

3.1 **a)** Please pick a number, from the scale, to indicate how important you believe the service to be.

(Please select *one* option from drop-down menu on the **right**)

SCALE				
1 **Irrelevant**	**2** **Unimportant**	**3** **Neutral**	**4** **Important**	**5** **Essential**

NB: The following terms are defined in the Glossary on page iii: *technology assessment, needs assessment, asset/inventory management, cost of ownership, facilities and plant management, risk and safety management, inspection and preventive maintenance, corrective maintenance, equipment performance monitoring, and quality assurance.*

	SERVICE	Rating of Importance *Please select appropriate number for all services*
1	Strategic technology needs assessment and planning.....	Please select one option
2	Technology assessment.....	Please select one option
3	Specification, evaluation and procurement of equipment.....	Please select one option
4	Asset/inventory management	Please select one option

5	Review of equipment replacement needs.....	Please select one option
6	Cost of ownership monitoring.....	Please select one option
7	Management of service contracts.....	Please select one option
8	Project management.....	Please select one option
9	Facilities and plant management and maintenance.....	Please select one option
10	Training equipment users.....	Please select one option
11	Risk management.....	Please select one option
12	Safety checks.....	Please select one option
13	Acceptance testing (incoming inspections).....	Please select one option
14	Inspection and preventive maintenance (IPM).....	Please select one option
15	Corrective maintenance (repair).....	Please select one option
16	Equipment performance monitoring.....	Please select one option
17	Functional or calibration checks.....	Please select one option
18	Quality assurance and improvement	Please select one option
19	Research and development/modification of equipment.....	Please select one option
20	IT/Computer hardware and networks.....	Please select one option
21	Telecommunications.....	Please select one option
22	Other (please	Please select one option
23		Please select one option
24		Please select one option

3.2 **a)** In your opinion, which of the following services could/should be *outsourced* to equipment suppliers/agents or *third party service* providers (e.g. commercial firm/shared service) ?
(Please check [i.e. ☒] appropriate box in table below)

	Service	Outsource ? *Please check [i.e. ☒] appropriate box*		
1	Training equipment users	☐ Yes	☐ No	☐ Both/mixed
2	Acceptance testing (incoming inspections).....	☐ Yes	☐ No	☐ Both/mixed
3	Inspection and preventive maintenance (IPM).....	☐ Yes	☐ No	☐ Both/mixed
4	Corrective maintenance (repair).....	☐ Yes	☐ No	☐ Both/mixed
5	Other (please specify)	☐ Yes	☐ No	☐ Both/mixed
6		☐ Yes	☐ No	☐ Both/mixed
7		☐ Yes	☐ No	☐ Both/mixed

3.3 In your opinion, what are the advantages and the disadvantages of having an in-house CES, as opposed to outsourcing equipment management and maintenance services ?

Advantages of in-house CES

Disadvantages of in-house CES

4. ASSESSMENT OF SERVICE PROVIDED BY CLINICAL ENGINEERING SERVICE

The following set of questions focuses on your assessment of the service provided by a CES. Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 5.

a) In your opinion, what impact does the service provided by a CES have on (i) clinical procedures specifically, or on (ii) health care service delivery generally, at a health facility?

i)

ii)

b) In your opinion, what would be the implications of **not** having an in-house CES at all (e.g. outsourcing all medical equipment management and maintenance functions)?

c) What you believe to be understood by the term "Quality of Service" with respect to a CES?

5. CES PERFORMANCE AND SUSTAINABILITY

The following set of questions focuses on your assessment of the performance and *sustainability* of CES's.

5.1 Performance

a) What would you suggest as 5 important *indicators* of performance?

1
2
3
4
5

5.2 Sustainability

5.2.1 Would you consider the CES service to be a 'core' healthcare function ?

☐ Yes ☐ No

Please elaborate on your answer.

5.2.2 a) Do you see the CES's surviving in the next 5, 10 or 15 years ?
(Please check [i.e. ☒] most relevant box)

☐ Yes, 5 years ☐ Yes, 10 years ☐ Yes, 15 years ☐ Not at all

b) What institutional, organisational or socio-political environment factors would **support** the existence of CES's ?

What institutional, organisational or socio-political environment factors would **hinder** the existence of CES's?

Part 2 *(pages 6 to 8)*

CLINICAL ENGINEERING SERVICE INDICATORS

- The main objective of the study is to develop and test a set of comprehensive **key indicators** to describe the performance, *cost-effectiveness* and sustainability of clinical engineering services.
- *(An indicator is an objective, quantitative variable that indicates or shows a given situation, and thus can be used to measure change. It is objective in that the same measurement can be obtained by different observers).*
- The critical indicators identified should facilitate standardisation of clinical engineering services; as well as allowing comparisons of performance, cost-effectiveness and sustainability to be made between clinical engineering services in differing environments.

The following is a list of proposed indicators (derived from the available literature and current best practice), in no particular order. For **each** of the proposed indicators please do the following:

- Please pick a number from the scale to indicate how important you believe the measure to be and select it from the drop-down menu.. If you are uncertain of the relevance of the indicator please select the 'Don't know' i.e. (0) option.

SCALE						
0 Don't know		1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

	Indicators	Rating Please select rating from drop-down menu
	Patient/Client-Related	
1	Inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction	Please select one option
2	Patient (or operator) injury due to medical equipment malfunction or unavailability	Please select one option
3	Patient (or operator) injury due to medical equipment misapplication	Please select one option
4	Number of equipment malfunctions caused by user error/misuse or abuse	Please select one option
5	Type and number of medical equipment supported by CES	Please select one option
6	Percentage of medical equipment supported by CES that is *functional*	Please select one option
	Performance/Personnel	
7	*Productivity* (ratio of outputs to inputs)	Please select one option
8	Competencies/skills of CES personnel	Please select one option
9	*Certification* and registration of CES personnel/ department with appropriate professional body	Please select one option

10	Evidence of continuing education/ professional development of CES personnel	Please select one option
11	Relative number of different categories of CES personnel (i.e. engineers, technicians, artisans etc.)	Please select one option
12	Absenteeism of CES personnel	Please select one option
13	CES staff levels per number of beds	Please select one option
14	CES staff levels per number of medical devices	Please select one option
15	Working space (m^2) per technical CES staff	Please select one option
16	Salaries and career paths of CES technical staff vs. other healthcare workers	Please select one option
17	Salaries and career paths of CES technical staff vs. similar employees in competing sector (public/private)	Please select one option
	Cost-effectiveness	
18	Allocated CES budget per year (as a percentage of the supported equipment inventory value)	Please select one option
19	Cost *(labour and overhead)* per hour per CES employee	Please select one option
20	Cost of CES service per bed supported	Please select one option
21	Cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type	Please select one option
22	Cost of in-house service vs. cost of outsourced service per equipment type	Please select one option
23	Inventory of spare parts per equipment value supported	Please select one option
	CES Activities	
24	*Response time* to service requests	Please select one option
25	Percentage of time devoted to IPMs[1] vs. repairs	Please select one option
26	Total number of IPMs/repairs performed per device type per year	Please select one option
27	*Downtime* of equipment due to IPMs/repairs	Please select one option
28	Degree of compliance that has been achieved with the established schedule for routine IPMs/repairs	Please select one option
29	Percentage of IPMs/repairs performed in-house vs. outsourced	Please select one option
30	Percentage and type of outsourced equipment IPMs/repairs checked by in-house CES before returning to clinical environment	Please select one option
31	Percentage of repeat repairs	Please select one option
32	IPMs/repairs conducted in accordance with manufacturer's recommendations, as specified in service manuals	Please select one option
33	Evidence of proper documentation of all work done by CES (e.g. service histories), providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc	Please select one option

[1] IPMs = *Inspection and Preventive Maintenance procedures*

- The above list is by no means exhaustive. Please add any other indicators you believe to be appropriate, in the empty numbered spaces and rate them according to the scale below. (Please check [i.e. ☒] *one* box only next to each indicator you suggest)

SCALE		
Neutral	**Important**	**Essential**

100	☐ Neutral ☐ Important ☐ Essential
101	☐ Neutral ☐ Important ☐ Essential
102	☐ Neutral ☐ Important ☐ Essential
103	☐ Neutral ☐ Important ☐ Essential
104	☐ Neutral ☐ Important ☐ Essential
105	☐ Neutral ☐ Important ☐ Essential
106	☐ Neutral ☐ Important ☐ Essential
107	☐ Neutral ☐ Important ☐ Essential
108	☐ Neutral ☐ Important ☐ Essential
109	☐ Neutral ☐ Important ☐ Essential

Do you have any additional comments, relating to clinical engineering services generally, or on this questionnaire specifically?

Thank you for your time and effort in answering the questionnaire.

Please save the file as 'Q4e_EXP.doc' and email the completed questionnaire to rutendo@cormack.uct.ac.za **, at your earliest convenience**

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APPENDIX F: QUESTIONNAIRE DESIGN

TARGET GROUP: MINISTRIES OF HEALTH / HTM EXPERTS

Part 1 *(pages 1 to 5)*

1. DEMOGRAPHIC DATA

The following set of questions focuses on general information.

1.1 Please complete the following:
(If you prefer to remain anonymous, please indicate your position or job description and country in the spaces provided)

Surname _____ First Name/Initial _____ Title _____

or ☐ Anonymous

Position/Job Description _____

Country _____

(The following information is optional)

Institution/Hospital _____

Email address _____

Telephone _____ Fax _____

Postal address _____

City _____ Postal Code _____

1.2 a) Are you familiar with a Clinical Engineering Service ?

☐ Yes ☐ No

If "Yes", please proceed to Section 2 below. If "No", please go to Section 3 on the next page.

2. MISSION AND STRATEGY OF CLINICAL ENGINEERING SERVICE

The following set of questions aims to establish general mission statements and basic strategies of Clinical Engineering Services.

2.1 a) Does the CES exist as a separate unit (e.g. Clinical Engineering Department, Health Care Technical Service, etc.) or part of another department (e.g. Hospital Engineering)?
(Please check [i.e. ☒] *one* box only, and fill in text field)

☐ Separate unit, called _____

☐ Part of another department (Please specify) _____

b) To whom does the CES report? _____

c) Are you aware of the *mission statement* of the Clinical Engineering Service (CES) ?

☐ Yes ☐ No ☐ I don't know

d) In your opinion, what would be an appropriate mission statement for a CES?

2.2 a) To the best of your knowledge, does the CES have an appropriate *strategy* (or business plan) to achieve its mission?

☐ Yes ☐ No ☐ I don't know

b) In your opinion, what would be appropriate objectives in such a plan?

c) If it exists, does this strategy support the overall strategic plan of the institution/s it serves?

☐ Yes ☐ No ☐ I don't know

3. SERVICES PROVIDED BY CLINICAL ENGINEERING SERVICE

The following set of questions focuses on the services typically provided by a CES and the importance of these services to the institution/s it serves.

3.1 a) Please pick a number, from the scale, to indicate how important you believe the service to be.

(Please select *one* option from drop-down menu on the **right**)

SCALE				
1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

NB: The following terms are defined in the Glossary on page iii: *technology assessment, needs assessment, asset/inventory management, cost of ownership, facilities and plant management, risk and safety management, inspection and preventive maintenance, corrective maintenance, equipment performance monitoring, and quality assurance.*

	SERVICE	Rating of Importance *Please select appropriate number for all services*
1	Strategic technology needs assessment and planning.....	Please select one option
2	Technology assessment.....	Please select one option
3	Specification, evaluation and procurement of equipment.....	Please select one option
4	Asset/inventory management	Please select one option

5	Review of equipment replacement needs.....	Please select one option
6	Cost of ownership monitoring.....	Please select one option
7	Management of service contracts.....	Please select one option
8	Project management.....	Please select one option
9	Facilities and plant management and maintenance.....	Please select one option
10	Training equipment users.....	Please select one option
11	Risk management.....	Please select one option
12	Safety checks.....	Please select one option
13	Acceptance testing (incoming inspections).....	Please select one option
14	Inspection and preventive maintenance (IPM).....	Please select one option
15	Corrective maintenance (repair).....	Please select one option
16	Equipment performance monitoring.....	Please select one option
17	Functional or calibration checks.....	Please select one option
18	Quality assurance and improvement	Please select one option
19	Research and development/modification of equipment.....	Please select one option
20	IT/Computer hardware and networks.....	Please select one option
21	Telecommunications.....	Please select one option
22	Other (please	Please select one option
23		Please select one option
24		Please select one option

3.2 **a)** In your opinion, which of the following services could/should be *outsourced* to equipment suppliers/agents or *third party service* providers (e.g. commercial firm/shared service) ?
(Please check [i.e. ☒] appropriate box in table below)

	Service	Outsource ? *Please check [i.e. ☒] appropriate box*		
1	Training equipment users	☐ Yes	☐ No	☐ Both/mixed
2	Acceptance testing (incoming inspections).....	☐ Yes	☐ No	☐ Both/mixed
3	Inspection and preventive maintenance (IPM).....	☐ Yes	☐ No	☐ Both/mixed
4	Corrective maintenance (repair).....	☐ Yes	☐ No	☐ Both/mixed
5	Other (please specify)	☐ Yes	☐ No	☐ Both/mixed
6		☐ Yes	☐ No	☐ Both/mixed
7		☐ Yes	☐ No	☐ Both/mixed

3.3 In your opinion, what are the advantages and the disadvantages of having an in-house CES, as opposed to outsourcing equipment management and maintenance services ?

Advantages of in-house CES

Disadvantages of in-house CES

4. ASSESSMENT OF SERVICE PROVIDED BY CLINICAL ENGINEERING SERVICE

The following set of questions focuses on your assessment of the service provided by a CES. Please answer as much of this section as you can. If you are unable to answer any questions, please move on to Section 5.

a) In your opinion, what impact does the service provided by a CES have on (i) clinical procedures specifically, or on (ii) health care service delivery generally, at a health facility?

i)

ii)

b) In your opinion, what would be the implications of **not** having an in-house CES at all (e.g. outsourcing all medical equipment management and maintenance functions)?

c) What you believe to be understood by the term "Quality of Service" with respect to a CES?

5. CES PERFORMANCE AND SUSTAINABILITY

The following set of questions focuses on your assessment of the performance and *sustainability* of CES's.

5.1 Performance

a) What would you suggest as 5 important *indicators* of performance?

1
2
3
4
5

5.2 Sustainability

5.2.1 Would you consider the CES service to be a 'core' healthcare function ?

☐ Yes ☐ No

Please elaborate on your answer.

5.2.2 **a)** Do you see the CES's surviving in the next 5, 10 or 15 years ?
(Please check [i.e. ☒] most relevant box)

☐ Yes, 5 years ☐ Yes, 10 years ☐ Yes, 15 years ☐ Not at all

b) What institutional, organisational or socio-political environment factors would **support** the existence of CES's ?

What institutional, organisational or socio-political environment factors would **hinder** the existence of CES's?

Part 2 *(pages 6 to 8)*

CLINICAL ENGINEERING SERVICE INDICATORS

- The main objective of the study is to develop and test a set of comprehensive **key indicators** to describe the performance, *cost-effectiveness* and sustainability of clinical engineering services.
- *(An indicator is an objective, quantitative variable that indicates or shows a given situation, and thus can be used to measure change. It is objective in that the same measurement can be obtained by different observers).*
- The critical indicators identified should facilitate standardisation of clinical engineering services; as well as allowing comparisons of performance, cost-effectiveness and sustainability to be made between clinical engineering services in differing environments.

The following is a list of proposed indicators (derived from the available literature and current best practice), in no particular order. For **each** of the proposed indicators please do the following:

- Please pick a number from the scale to indicate how important you believe the measure to be and select it from the drop-down menu.. If you are uncertain of the relevance of the indicator please select the 'Don't know' i.e. (0) option.

SCALE					
0 Don't know		1 Irrelevant	2 Unimportant	3 Neutral	4 Important	5 Essential

	Indicators	Rating Please select rating from drop-down menu
	Patient/Client-Related	
1	Inability to perform clinical procedures or extension of patient stay due to medical equipment malfunction	Please select one option
2	Patient (or operator) injury due to medical equipment malfunction or unavailability	Please select one option
3	Patient (or operator) injury due to medical equipment misapplication	Please select one option
4	Number of equipment malfunctions caused by user error/misuse or abuse	Please select one option
5	Type and number of medical equipment supported by CES	Please select one option
6	Percentage of medical equipment supported by CES that is *functional*	Please select one option
	Performance/Personnel	
7	*Productivity* (ratio of outputs to inputs)	Please select one option
8	Competencies/skills of CES personnel	Please select one option
9	*Certification* and registration of CES personnel/ department with appropriate professional body	Please select one option

10	Evidence of continuing education/ professional development of CES personnel	Please select one option
11	Relative number of different categories of CES personnel (i.e. engineers, technicians, artisans etc.)	Please select one option
12	Absenteeism of CES personnel	Please select one option
13	CES staff levels per number of beds	Please select one option
14	CES staff levels per number of medical devices	Please select one option
15	Working space (m^2) per technical CES staff	Please select one option
16	Salaries and career paths of CES technical staff vs. other healthcare workers	Please select one option
17	Salaries and career paths of CES technical staff vs. similar employees in competing sector (public/private)	Please select one option
	Cost-effectiveness	
18	Allocated CES budget per year (as a percentage of the supported equipment inventory value)	Please select one option
19	Cost (*labour and overhead)* per hour per CES employee	Please select one option
20	Cost of CES service per bed supported	Please select one option
21	Cost of CES support as a percentage of capital cost of supported medical equipment, per equipment type	Please select one option
22	Cost of in-house service vs. cost of outsourced service per equipment type	Please select one option
23	Inventory of spare parts per equipment value supported	Please select one option
	CES Activities	
24	*Response time* to service requests	Please select one option
25	Percentage of time devoted to IPMs[1] vs. repairs	Please select one option
26	Total number of IPMs/repairs performed per device type per year	Please select one option
27	*Downtime* of equipment due to IPMs/repairs	Please select one option
28	Degree of compliance that has been achieved with the established schedule for routine IPMs/repairs	Please select one option
29	Percentage of IPMs/repairs performed in-house vs. outsourced	Please select one option
30	Percentage and type of outsourced equipment IPMs/repairs checked by in-house CES before returning to clinical environment	Please select one option
31	Percentage of repeat repairs	Please select one option
32	IPMs/repairs conducted in accordance with manufacturer's recommendations, as specified in service manuals	Please select one option
33	Evidence of proper documentation of all work done by CES (e.g. service histories), providing strategic and operational evidence relating to safety, cost-effectiveness, replacement needs etc	Please select one option

[1] IPMs = *Inspection and Preventive Maintenance procedures*

- The above list is by no means exhaustive. Please add any other indicators you believe to be appropriate, in the empty numbered spaces and rate them according to the scale below. (Please check [i.e. ☒] *one* box only next to each indicator you suggest)

SCALE		
Neutral	**Important**	**Essential**

100	☐ Neutral ☐ Important ☐ Essential
101	☐ Neutral ☐ Important ☐ Essential
102	☐ Neutral ☐ Important ☐ Essential
103	☐ Neutral ☐ Important ☐ Essential
104	☐ Neutral ☐ Important ☐ Essential
105	☐ Neutral ☐ Important ☐ Essential
106	☐ Neutral ☐ Important ☐ Essential
107	☐ Neutral ☐ Important ☐ Essential
108	☐ Neutral ☐ Important ☐ Essential
109	☐ Neutral ☐ Important ☐ Essential

Do you have any additional comments, relating to clinical engineering services generally, or on this questionnaire specifically?

Thank you for your time and effort in answering the questionnaire.

Please save the file as 'Q4e_EXP.doc' and email the completed questionnaire to rutendo@cormack.uct.ac.za **, at your earliest convenience**

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TABLE OF CONTENTS

F. SUGGESTIONS FOR IMPROVING THE QUESTIONNAIRE.....2

F.1 Format of Survey Questions.....2

F.2 Constructing Questions.....2

F.3 Constructing Instructions.....3

F.4 Guidelines for Reducing Instrumentation Bias.....4

F.5 Sources of Response Bias.....4

F.6 Guidelines for Reducing Response Bias.....5

F.7 Methods of Increasing Respondent Rate.....5

F. SUGGESTIONS FOR IMPROVING THE QUESTIONNAIRE

Several guidelines are provided in the available literature for designing valid, reliable questionnaires. The following sub-section, combining viewpoints of Zikmund (2000), Alreck & Settle (1995) and Bourque & Fielder (1995), outlines guidelines used in the study for constructing the final questionnaires.

F.1 Format of Survey Questions

There are two basic formats for survey questions: unstructured (open-ended) and structured (closed).

a. With **unstructured questions**, respondents are free to answer questions in their own words. These types of questions are usually used in a preliminary qualitative survey to 'get a feel' for the subject, especially when the researcher requires information that is not available. While unstructured questions are relatively easy to ask and offer the opportunity to probe into a subject, major disadvantages include difficulty of processing and analysis, the probability of inappropriate answers and an extra effort for respondents. Particular attention has to be placed on specifying the range of responses to respondents.

b. **Structured questions** provide respondents with a choice of alternative (discrete or categorical) answers, usually requiring them to simply check/tick the most relevant answer. These question types are more difficult to construct, requiring attention to be paid to (i) providing an all-inclusive list of alternatives (ii) ensuring that all alternatives are mutually exclusive (iii) clustering answers into meaningful categories and (iv) using appropriate scales. It is important to allow for the residual 'Other' category in the event that all options are not exhausted. Issues of **reliability** and **validity** of the questions have to be taken into consideration. However, well-designed structured questions are easier for the respondent to answer and data provided is easier to analyse and compare.

While the use of structured questions is often recommended for the reasons given above, a carefully thought-out mix of the two types could be used to reduce respondent boredom and fatigue.

F.2 Constructing Questions

The following should be taken into consideration, with respect to the wording of survey questions:

- Brevity of questions
- Direct focus and clarity
- Avoiding ambiguity
- Avoiding vague qualifiers (e.g. usually, sometimes)

- Avoiding generalisations and over-specifications
- Using core vocabulary and grammar
- Avoiding abstract terms and jargon, using definitions where necessary
- Stating clearly criteria by which respondents must respond to questions
- Avoiding inapplicable questions
- Avoiding requiring demanding recall or thought by respondents
- Avoiding double-barrelled[1] questions
- Avoiding leading[2] and loaded[3] questions.

F.3 Constructing Instructions

Given the complexity of the questionnaire, attention would have to be paid to the design of **instructions** to make the response task clearer for respondents. The following guidelines are suggested by the literature:

- Decide whether general instructions will be given in a cover letter, the questionnaire or both.
- Tell the respondents what the questionnaire is about, what they are asked to do and why (general instructions).
- Identify places where transitional instructions are needed (e.g. change of topic, context for questions that follow) – Describe purpose of each section.
- Determine whether detailed instructions about filling out subsets of questions, are needed.
- Give instructions about what to do once questionnaire is answered (fax? submit?).
- Set instructions slightly apart from questions and highlight them using bulleting, boldface type or uppercase letters.
- Pay attention to the wording of instructions, as outlined for the wording of questions, i.e. keep instructions as clear and simple as possible.
- State how responses are to be reported or recorded, e.g. tick, number, circle etc.
- Clearly indicate which items are to be rated and if only one is to be picked or an answer recorded for all items.
- Describe how the scale is to be used and include an example if the task is complicated.

[1] **Double-barrelled question:** having two questions contained within one item
[2] **Leading question**: questions that lead the respondents to a particular answer
[3] **Loaded questions:** questions that include some wording or phrases that constitute a subtle form of influence

F.4 Guidelines for Reducing Instrumentation Bias

The following guidelines are thus suggested by the authors, when evaluating a questionnaire for **instrumentation bias,** i.e. errors in the instrument due to instructions, questions, scales or response options:

1. Does the question state the criterion for answering?
2. Is the question applicable to all respondents? *Either reword or provide detour.*
3. Does the item contain an example that is also a possible answer? *If so change or discard the example.*
4. Does the question require the respondent to remember too much detail or recall distant events? *Modify or generalise to make recall easier.*
5. Is the question as specific as it can reasonably be? *If too general, state more specifically.*
6. Is the item more specific than the way respondents think? *Make more general*
7. Does the question overemphasize some condition? *State in less dramatic terms.*
8. Are some words ambiguous? *Reword using more commonly used phrasing.*
9. Is the question as free from threat to respondents as possible? *Reduce threat.*
10. Is the question double-barrelled (i.e. addresses more than one issue)?
11. Will yea-sayers or nay-sayers always choose one answer?
12. Does the question lead respondents towards a particular answer?
13. Is the question *loaded* with a reason for responding in a particular way? *Remove reason.*

F.5 Sources of Response Bias

Attention would also have to be paid to reducing **response bias**, which is error due to the mentality or predispositions of the respondents. Ten major types of bias are outlined by Alreck and Settle. These are described in Figure F.1.

1. *Social desirability:* Response based on what's perceived as being socially acceptable or respectable
2. *Acquiescence:* Response based on respondent's perception of what would be desirable to the sponsor
3. *Yea- and Nay-saying:* Response influenced by the global tendency toward positive or negative answers
4. *Prestige:* Response intended to enhance the image of the respondent in the eyes of others
5. *Threat:* Response influenced by anxiety or fear instilled by the nature of the questions
6. *Hostility:* Response arising from feelings of anger or resentment engendered by the response task
7. *Auspices:* Response dictated by the image or opinion of the sponsor rather than the actual question
8. *Mental set:* Cognitions or perceptions based on previous items influence response to later ones
9. *Order:* The sequence in which a series is listed affects the responses to the items
10. *Extremity:* Clarity of extremes and ambiguity of mid-range options encourage extreme responses

Figure F.1: Sources of Response Bias (Alreck & Settle, 1995)

F.6 Guidelines for Reducing Response Bias

1. Is the question subject to any of the 10 sources of response bias listed above? If so:
2. Can the question be reworded to reduce or eliminate bias? *Compose a few alternative versions and compare.*
3. Might the instructions be changed so the item isn't subject to bias? *Examine and substitute instructions for the question, section or scale to reduce bias.*
4. Does the source of bias arise from the choice or form of a scale?
5. Does the structure of the section or questionnaire induce or encourage bias?
6. Do the presence or nature of preceding or following questions make the question subject to bias? *Tentatively rearrange the items in the section or move the question to another section to control the bias.*
7. Do the modifications in the question or questionnaire to reduce one form of bias make it more subject to another? *Go to point 1.*

F.7 Methods of Increasing Respondent Rate

a. Question Sequence: The order of questions may serve several functions for the researcher. Surveys that begin with interesting, simple to comprehend and easy to answer questions usually help with maintaining respondent cooperation and involvement throughout the questionnaire. The use of **funnel technique**[4] within question modules or sections is usually recommended. The use of **filter questions**[5], to avoid asking inapplicable questions to some respondents is also advised. Conditional branching can also be used in such an instance, i.e. respondents can be asked to skip a series of questions and 'go to' another section. However, if more than a few branches are required within the questionnaire, multiple forms of the questionnaire should be considered.

b. Cover Letter: A cover letter providing details about the survey, the purpose and importance, who is responsible for the research, the respondent's role, possible **incentives**, access to results, cut-off date and ensuring confidentiality of the respondent should be included with the administered questionnaire.

c. Sending advance letters to respondents, providing incentives if they complete the questionnaire, sending reminders to return the questionnaire, providing return envelopes have also been found to increase respondent rate.

d. Finally, particular attention would have to be paid to the **layout,** question numbering and general, ergonomic design of the final questionnaires, making them easy to follow, attractive to the eye and professional-looking.

[4] **Funnel technique:** A procedure whereby general questions are asked before specific questions in order to obtain unbiased responses.

[5] **Filter question:** a question that screens out respondents not qualified to answer subsequent questions.