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Progress Report

Benefit of Legal Metrology for the Economy and Society

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A study for the
International Committee of Legal Metrology

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FOREWORD

In November 2001 the International Bureau of Legal Metrology contracted the author to undertake a study on The Benefit of Legal Metrology for the Economy and Society with the following terms of reference

Terms of Reference

The Consultant will review previous studies of the economics of metrology and particularly legal metrology and provide a summary report and analysis in accordance with the following schedule.

1 BIML will contact all CIML members and Corresponding members to obtain copies of studies relevant to the topic of this study.

2 The Consultant will review these studies and provide a draft report to BIML by 31 March 2002

3 The Consultant will visit appropriate authorities to discuss previous studies and the draft review and provide a report to BIML BY 31 May 2002

4 The Consultant will prepare an analysis of the material obtained with the aim of developing

a) Economic and social analysis criteria to assist legal metrology authorities to determine priorities for resource allocation

b) A rudimentary cost/benefit analysis of the main components of legal metrology

c) An analysis of the costs and benefits of State operated versus privatised legal metrology systems.

and provide the final report and analysis to BIML by 31 July 2002

Mr Magana the Director of BIML contacted all CIML members and corresponding members in December requesting copies of any studies conducted in their nation on the topic.With a few notable exceptions, very few studies were received and as a result the author then drew upon studies over the past forty years which comprise the bibliography of this study.

The publications were then reviewed for their relevance to the topic of the study and Attachment 2 provides a summary of the ideas and concepts that were seen as relevant, particularly to the central issue of quantifying the economic and social benefits of legal metrology.

In June this year the author visited a number of the institutions which have been active in the field of economic analysis of metrology, in particular N.I.S.T.(USA), Measurement Canada and the Measurement Policy Unit of the Department of Trade and Industry in UK. These discussions were valuable in focussing the study.

Whilst there has been little analysis of the economics of legal metrology there has in the past few years been a number of studies on the economic and social benefits of scientific metrology. In particular studies by K.P.M.G. for the Institute of Measurement Standards(Canada) and the International Bureau of Weights and Measures and studies undertaken by the European Measurement Project. These studies have been particularly considered as to whether their methodologies could be applied to legal metrology.

Whilst it was intended to finalise this study by 31 July the delays in obtaining the material to be reviewed has extended this time frame. This Progress Report provides the analysis up to the end of August and it is hoped that discussion at the CIML meetings in October will provide further material that will allow the early completion of the study

BENEFIT of LEGAL METROLOGY
for the ECONOMY and SOCIETY

1 INTRODUCTION

Legal metrology developed over 5000 years ago with the development of civilizations which required consistency of a wide range of measurements used in everyday life. These included;

Time and the calendar

Distance and area

Weights and measures

The relationship between the State and metrology was symbiotic. The State needed measurements to provide the information necessary to organise, plan, defend and tax with efficiency. Such accounting depended on uniform measurements across wide geographical areas and across a broad spectrum of farming and manufacturing practices and work organisation. Metrology on the other hand required the mandate of the State to ensure conformity to measurement requirements.

As well as being a user of metrology the State was also required to provide the necessary trust and confidence in measurement by mandatory standards and requirements. This ensured the integrity of commerce and was realised by the State decreeing and enforcing measurement standards and requirements and controlling fraud to underpin market transactions.

The fundamental requirement, to ensure consistency, was that all measurement be derived from (royal) standards, what we now define as traceability. In addition moral precepts to ensure the integrity of the measurements were contained within the holy books-e.g. the Torah, Bible and Koran. Trust and confidence inherent in the measurement system is a significant component of the social capital of all societies and contributes to the maintenance of a civil society.

Kenneth Arrow the Nobel laureate in Economics commented (122);

> *" Virtually every commercial transaction has within itself an element of trust, certainly any transaction conducted over a period of time. It can be plausibly argued that much of the economic backwardness in the world can be explained by the lack of mutual confidence;"*

China (1) well illustrates this traditional relationship between the State and metrology. During the Shang Dynasty some 3500 years ago a system of standard measuring instruments for length, mass and capacity was established. A State organisation with special officials was assigned responsibility for checking the accuracy of these instruments twice a year. As well as trade in commodities these standards were also mandatory for the production of weapons, vehicles, a wide range of handicrafts and the construction of buildings.

With the development of the modern State royal decrees and moral precepts were replaced by Weights and Measures legislation which provided the foundation for what we now describe as legal metrology.

What is clear from the history of metrology is that its development was driven by a need of the State for information. Where the State was strong the need, particularly by the bureaucracy, was greatest and there was a strong commitment to the metrology system. As the State declined metrology declined

with it and over the centuries the national metrology systems have ebbed and flowed with the power of the State.

2 METROLOGY IN THE 20TH CENTURY

2.1 Scientific Metrology.

The late 19th century saw a marked increase in international trade and Metrology responded to this with initiatives to enhance the global consistency of measurements. The 1875 Treaty of the Metre with its aim of "international uniformity and precision in standards of weights and measures" was the most significant of these metrological initiatives and it resulted in the establishment of the International Committee of Weights and Measures (CIPM) and the establishment of National Measurement Institutes (NMI's) in the developed nations to maintain national standards of measurement and provide traceability to these standards. This was to provide a necessary infrastructure for the development of science and technology throughout the century.

In this regard the National Academy of Sciences (US) commented;(125)

> *"precise measurement is the hallmark of the remarkable advancement in understanding the physical universe in modern times"*

2.2 Legal Metrology.

One institutional aspect of these developments was the division of metrology into scientific metrology, led by the NMI's, and practical or legal metrology which continued to provided a legislative basis for measurements and measuring instruments when used for legal purposes, and supported the development of domestic and international trade and a wide range of government regulations.

Technological change also facilitated the development of a wide range of new measuring instruments and processes and a massive expansion in the scope of metrology. Metrology responded to these changes with the development of a range of new control mechanism that complemented traceability and were designed to maintain confidence in the integrity of the measurement system. These included

1 Introduction from the late nineteenth century of national pattern approval requirements and certification of trade measurement instruments to ensure fitness for purpose.

2 Introduction from 1947 of accreditation of calibration and testing facilities to ensure confidence in measurement capability.

3 Development of national and international standards for measuring instruments and processes which ensured greater consistency of measurement

4 Development of the SI system of units of measurement, which replaced a multiplicity of national, craft and industry units.

The need to ensure international consistency of trade and regulatory measurements, and to "resolve internationally the technical and administrative problems raised by the use of measuring instruments", led to the establishment in 1955 of a second metrology Treaty organization, the International Organisation of Legal Metrology (OIML). Originally focussed on trade metrology, the rapid expansion in the use by governments of regulatory measurements has seen OIML become increasingly involved in establishing international requirements for a wide range of environmental, health and safety and medical measurements

3 THE NATIONAL MEASUREMENT SYSTEM

The wide application of measurement after World War 11, promoted by the development of electronic technologies, created concerns that the lack of centralisation of control of these measurements could be effecting the quality of these measurements. The societal costs of these poor measurements was seen as large (8, 11). In 1967 a paper by Huntoon (8) put forward the Concept of a National Measurement System and the concept was further developed at NBS in the early 1970's(9, 10, 11) and was defined as comprising

> *"All of the activities and mechanisms- intellectual, operational, technical and institutional- used by the country to produce the physical measurement data needed to create the objective quantitative knowledge required by our society."(9)*

More recently Birkeland has proposed an equivalent definition for the global measurement system (76)

Studies conducted by NBS(8,9,10,11) indicated that the expenditure on measurement was between 3 and 6% of GNP and sectoral measurement intensity varied between 20% and less than I% of sector expenditure. Major users were Government, trade, electric gas and water utilities all of which are legal metrology and highlights the central economic role of legal metrology in the national measurement system.

4 BENEFITS OF LEGAL METROLOGY TO THE ECONOMY

4.1 Trade Metrology

In trade based on measurements Trade Metrology is generally perceived as providing the following benefits

1 Reduced disputation and transaction costs;

From it's beginning measurement was recognised as a provider of objective information. However when used in trade transactions where the measurement process lacked transparency, and there was asymmetry of information between the trader providing the measurements and the trader accepting these measurements (usually the purchaser in retail transactions, the producer in farm produce transactions and the smaller business in commercial transactions) then there was considerable scope for uncertainty, disputation, transaction costs and market inefficiency. (119, 120, 124).

These transaction costs can result from concerns about the accuracy of the measurement e.g. short measure, and the consistency of the measurement e.g. paying more than other customers.

Typical examples of trade measurement transactions that may lack transparency are

1 Petroleum sales to service stations and motorists.

2 Billing of telephone calls.

3 Sale of firewood

4 Sale of grain and rice by farmers based on moisture measurements.

5 Sale of alcohol where stamped glasses are not used

6 Utility measurements i.e electricity, water and gas.

The State metrological compliance system was developed to provide, through legislative requirements, pattern approval of the measuring instruments and third party auditing and inspection, trust and confidence in the measurements and minimise disputation and transaction costs.

The World Bank in its 1997 World Development Report on "The State in a Changing World (85) made the point that;

"an effective State is vital for the provision of the rules and institutions that allow markets to flourish. Without it sustainable development both economic and social is impossible".

However in recent years a number of governments in developed countries have reduced their commitment to their metrology system and placed greater reliance on the market to resolve measurement disputes.

2 Consumer protection

Measurement, and goods packed by measure, has generally replaced number and simple measures (bucket, plate etc.) as the basis of transaction for a wide range of consumer commodities and products. The increased consistency of these measurements, when adequately controlled, has significantly reduced disputation, and fraud and increased the efficiency of the marketplace.

3 Level playing field for commerce

Metrological control ensures fair trading by eliminating the use of short measure to obtain commercial advantage over competitors in the market place and through pattern approval of measuring instruments ensures that measuring instruments that are manufactured and sold, are fit-for-purpose and are to internationally recognised standards.

4 Effective stock control

The aggregation of trade measurements by individual businesses provides accurate and effective stock control to facilitate the ordering of new stock

5 Control of fraud

As well as the control of fraud in the marketplace by State inspection, stock control by measurements can also provide effective fraud control for individual businesses. Pattern approval and certification also ensures that the design of measuring instruments do not facilitate fraud.

6 Full collection of government excise and taxes based on measurement

Governments of both developed and developing nations collect significant amounts of revenue through excise and resource rent taxes based on measurement. Papua New Guinea revenue well illustrates this point (68),viz.

- Mineral products contribute 70%of PNG export income and 17% of government revenue
- PNG has recently changed its taxes on alcohol and tobacco from an ad valorem tax to taxes based on weight and volume
- There is a proposal to develop the PNG natural gas deposits and export the gas to Australia by a high pressure gas pipeline

All of these sources of government revenue and national income rely on accurate and consistent measurement."

7 Full national benefit for commodity exports

Export income from the sale by measure of bulk and pre packed commodities is a significant component of both export and national income for many nations. Often for reasons of jurisdiction or lack of technical capability these measurements are not metrologically controlled by the State with a consequent risk of loss of national income.

Recent concerns by the European Commission on the accuracy of the quantitity of grain exported from Europe led to the development of the UNISTOCK Charter for grain measurements, based on OIML international Recommendations

Developing countries have even greater concerns. In trade contracts to meet the short measure requirement of trade contracts, commodity export countries give away value to the extent of the uncertainty of the measurement(95). The The Asia Pacific Legal Metrology Forum (APLMF) have also expressed concern about the use of draft surveys for commodity exports rather than the more accurate weighing and measurement systems. UNCTAD has noted (83) the importance for commodity dependent countries to develop an adequate measurement system for accurate valuation of goods.

8 Support of global trade in measuring instruments

The development of International Recommendations for the Pattern approval of measuring instruments supports the global market for measuring instruments to internationally recognised standards.

4.2 Regulatory Metrology

Governments now use measurements in a wide range of government regulations, particularly for the environment, health and safety, traffic control and medicine. The benefits of legal metrology in these applications include

1 Increased compliance.

Legal measuring instruments are able to provide continuous monitoring and greatly increase the probability of apprehension. The objectivity of the measurements also provides enhanced acceptance by industry and the community

2 Sound evidential basis for the measurements.

The legal metrology authority can provide a sound evidential basis for regulatory measurements by providing for certification of standards, measuring instruments, measurements and reference materials under National Measurement Legislation. Without such certification the measurements may be incorrectly interpreted by the courts using such rules as the English common law rule of the “presumption of accuracy of scientific instruments” (138). In addition the certification enhances community confidence in the measurements.

3 Benefit/cost of metrology regulation can be greater than other policy options.

Regulation by legal metrology can provide cost effective solutions to a wide range of community issues by “social engineering” e.g. the application of radar speed devices and breathalysers have had a marked impact in changing the behaviour of car drivers and markedly reduced the road toll (59). An alternative policy option of road construction to avoid accidents would be much more costly

4 International Recommendations provide level playing field for sale of appropriate measuring instruments.

OIML International Recommendations provide confidence in the instrument being fit for purpose and establish a level playing field for the manufacture and sale of these instruments.

5 International Recommendations support global regulatory agreements.

OIML International Recommendations provide confidence in the global consistency of a wide range of environmental and health and safety measurements that are referenced in International Treaties, e.g. Greenhouse Gas Emissions.

Arrow (137) has proposed eight principles for Benefit –Cost Analysis in Environment, Health and Safety Regulation that could be applied to legal metrology.

5 BENEFITS OF LEGAL METROLOGY TO SOCIETY

Legal Metrology provides considerable benefits to society including;

1 Support of a Civil Society

As mentioned above measurement has been an important component of the culture of all civilisations. However when measurements are used in trade transactions or government regulation there is a lack of transparency and imperfect information about the measurements. This is overcome by government legislation that establishes the rules of the measurement system and by Government enforcement of these rules This system reduces disputation over trade transaction and government regulation and is an important component of the social capital of a society. As such an effective measurement system supports a civil society

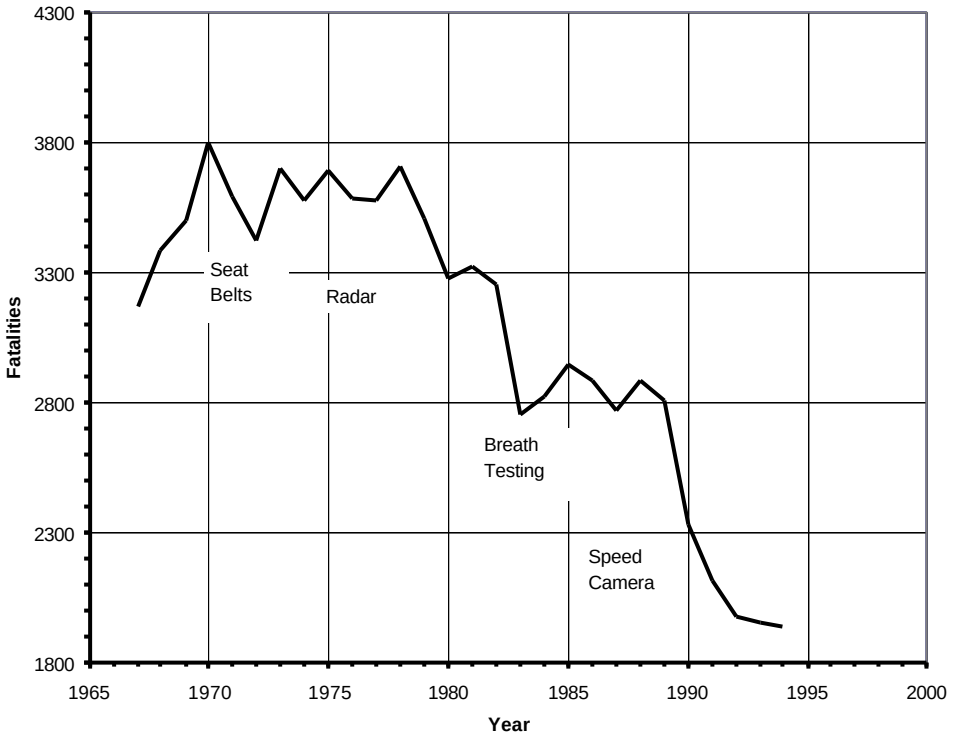
2 Technological Education

The systematic structure of the measurement system provides an important but largely unrecognised educational tool for industry and the community.The regular use of measurements in everyday life transfers simple but important technological concepts to the community.The effectiveness of this education is particularly demonstrated by shoppers detecting fraud in the marketplace

3 Reduction of deaths and injuries from accidents

Application of legal metrology in health and safety applications can significantly reduce accidents by changing peoples behaviour, providing early warning signals and providing effective enforcement of safety requirements. Birch (59) provides an example of the impact of the use of radar speed devices and breathalysers on the Australian road toll, (see figure below).

The economic impact of such reduction in fatalities can be very high. Stiglitz(7) provides a discussion on the economic value of a life with numbers of between $US2million and $US8million (in 1997 dollars).A study in Victoria, Australia estimated the saving to the community from a reduction in road fatalities of 380 was approximately $A1.6 billion.



The World Disaster Report (104) highlighted the significance of this issue for developing countries.

4 Improvement in the natural environment

Legal metrology has a wide range of applications in the monitoring and control of the natural environment. Kleppan et al (100) provide an example of resource control in the fishing industry and OIML have developed a number of International Recommendations for instruments measuring organic and metal pollutants, pesticides and toxic substances and automobile emissions

5 Improved health from standardisation of measurement and testing.

Legal metrology through timely and accurate diagnosis provides significant economic and social benefits in medicine and health.The NIST studies (30, 31) on cholesterol standards highlights these benefits and a number of case studies on medical applications of legal metrology are provided in Measuring Man (71).

OIML has developed a range of International Recommendations in the fields of medicine and health.

6 QUANTIFYING THE ECONOMIC BENEFITS OF METROLOGY

6.1 National Bureau of Standards (NBS, USA)

NBS studies of the national measurement system from 1965 to 1977 included a number of micro and macro economic studies of the system (8,9,10,) which identified the labour and equipment costs employed in making measurements in all industry sectors in the US. From these studies it was

estimated that the cost of making measurements was 6% of GNP (9). However it was recognised that weaknesses of these studies were (9,10)

1 That they were conducted from the perspective of the physical scientist and the specific measurement function he was concerned with.

2 Improved measurements may not yield benefits in an economic sense, in particular it will depend on the extent to which it satisfies wants and maximises profits.

3 Costs and benefits of measurement to society may be significantly different from the sum of the costs and benefits to individuals due to complex secondary effects arising from political and humanitarian goals of society

4 An alternative approach would be to focus on the user and in particular consumers which would make it easier to explore secondary impacts of costs and benefits of measurement for the society as a whole. In addition measurement problems for consumers probably encompass most types of physical measurement

In 1984 Don Vito (13) further extended these studies of the national measurement system to estimate the cost of measurement and the value added (defined as the value of goods and services sold less non-labour costs plus certain other items such as profits and indirect business taxes).The cost of labour is typically the largest component of value added.

Using Department of Commerce, Bureau of Economic Analysis figures for value added by each of the 81 industry sectors of the US economy, estimates of value added by measurement were calculated using survey estimates of measurement labour intensity and using the labour component of value added as a surrogate for total value added. From this analysis it was estimated that the average value added from measurement related activities was 3.5% of GNP

The total cost of measurement to industry (capital plus labour expenditures) was estimated to be $US 163 billion in 1984, representing approximately two per cent of sales. Approximately three quarters of the cost of measurement was attributable to labour expenditure.

This analysis by Don Vito was strongly criticised by Klein (50 and 49) on the grounds of “the fallacy of estimating output values from input costs” and qualified by Birch (59).

6.2 Measurement Canada

In the 1980’s Measurement Canada conducted a series of studies (33. 34) to determine the economic impact of the Canadian trade metrology control system. The value of goods measured across trade measurement instruments was determined and when combined with the performance of these instruments provided an estimate of the benefit/cost ratio of the inspection system- found to be 11.4 for periodic inspection and 28.7 for targeted inspection- and the annual inequity corrected by inspectors.

The total economic impact of the Canadian trade metrology system derived from these studies were consistent with estimates made by NSC, Australia (58) and the Office of Weights & Measures, NIST (USA) (22). viz. that the annual aggregrate value of trade measurement transactions was 50-60% of the GNP.

More recently Measurement Canada has developed a Market Place intervention Model for prioritising their degree of intervention in trade sectors based upon their economic significance, dependent vulnerability metrological practices and negotiations with stakeholders.

6.3 Dept. of Trade & Industry (UK)

For over twenty years the UK government has funded the government measurement infrastructure on the basis of a customer contractor principle. This has been administered by the Measurement Policy Unit of the Department of Trade and Industry (DTI) who have established a variety of advisory bodies as proxy customers to determine priorities for the allocation of funds. A number of studies have been conducted for the DTI to provide an economic rationale for this process and key elements of these studies relevant to this study have been highlighted in the Review attachment (46, 47,49,50 and 51).The current methodology is Mapping Measurement Impact (51),however it underemphasizes the pervasive impact of the measurement system and as such has limited application to legal metrology. One alternative being considered by DTI is sectoral measurement intensities as a proxy indicator for the influence of measurement

6.4 N.I.S.T. (USA)

Over the last fifteen years the Strategic Planning and Economic Analysis Group in NIST have conducted a large number of sectoral economic impact studies to effectively manage NIST research programs and characterize and estimate the size of various under-investment phenomena that require government co-operation with industry to address. A number of these studies have been included in the bibliography.

The quantitative metrics used are Net Present Value, Benefit-Cost Ratio, Social Rate of Return and Adjusted Internal Rate of Return. These are applied particularly to measurement standards projects where the benefits may be spread over a long period of time.

Two recent studies which directly relate to legal metrology are those on the electric utility industry (29) and Cholesterol standards (30).

The first of these related to the additional measurements required to capture the full benefits of wholesale and retail deregulation in the industry. The study identified a number of impact areas resulting from deregulation which could be addressed at least in part by measurement and standards. The estimates of economic impact were based upon interviews with forty industry experts.

The Cholesterol study limited its economic analysis to the impact of NIST standards on manufacturers and clinical laboratories, and surveys were undertaken with these groups to provide conservative estimates of economic impact

6.5 K.P.M.G. study of I.N.M.S. (Canada)

This study conducted case studies on a number of current and future INMS projects most of which, with the exception of future deregulation of the electric utility industry had small economic impact. In addition the study developed an ISO Proxy Model to measure the public good component of maintaining primary metrological standards. The model uses the costs of registration by Canadian firms for ISO 9000 & 14000 as a measure of their willingness to pay for a known uncertainty in measurement and by extension traceability to national standards. For the 10,823 registered firms the total annual cost is $C 18,929,427 and this is seen as a lower bound for market maintenance impact of primary standards.

6.6 K.P.M.G. study for CIPM

This study examines the potential economic impact of the CIPM mutual Recognition Arrangement (MRA) in terms of the efficiency of a multilateral arrangement over multiple bilateral arrangements and the reduction in technical barriers to trade.

The study is of particular interest to CIML which is currently finalising a MAA for pattern approval and possibly on pre packed goods.

The study conducted surveys of twenty-six NMI's who are signatories to the MRA and their cost of maintaining bilateral mutual recognition and estimated a saving of 75K Euros per annum in maintaining and establishing mutual recognition with each NMI compared with the cost pre MRA.

For the 48 members of the Treaty of the Metre the aggregate benefit is (n/2)(n-1) multiplied by 75k Euros ie 85M Euros per annum or about 2M Euros per member.

The study notes that a measure of the extent to which TBT might be limiting or raising the costs of trade has yet to estimated by the WTO, OECD the World Bank or other parties but noting that trade between 28 signatory nations is $4 trillion, a one tenth per cent increase in trade values would translate into an increase in value of $4 billion and this is viewed as a conservative estimate of the impact of the MRA on TBT.

6.7 European Measurement Project

This project "The Assessment of the economic role of measurement in modern society" is funded by DG-Research, of the European Commission as part of the GROWTH Programme.Twelve studies have been published and three have been reviewed.

Ref 75 on the scope and dimensions of measurement activity in Europe provides a compilation of information on measurement activity in the EU but it's economic analysis omits legal metrology. Making an assumption that 1% of industrial costs are spent on measurement it finds that expenditure on measurement in the EU, excluding legal metrology and social expenditure is 0.96% of GDP. It's estimates of application benefits and knowledge spillovers, but excluding externalities and benefits to society, provides benefits of 2.67% of GDP with a resulting Benefit to Cost ratio of 2.73.

Ref 72 the Summary of the Final Report considers the role of measurement in underpinning technologies that drive growth. It puts forward a model for quantifying the economic impact of measurement using the percentage of EU patents citing measurement activity as a percentage of total patents to provide a benchmark estimate of measurement innovation of 0.77% of GNP.

6.8 Summary

Generally the studies by NIST and DTI using detailed surveys of industry to estimate economic impact are credible but suffer from the limitations of the industry perspective of the people surveyed and are not likely to identify benefits for society as a whole. From a policy perspective the results obtained by interviews could be seen as subjective and internalised. The ISO Proxy Model developed by KPMG Canada and the growth model using patents developed by the European Measurement Project are imaginative attempts to solve the problem of quantifying the economic benefit of metrology but there are major qualifications about the applicability of the models.

There is some concern that the European Measurement Project seems to have limited knowledge of the metrology literature. In particular they do not seem to be aware of the the extensive work in the

USA from 1965 to 1985 on the expenditure by industry on measurement related activities and they propose a different definition of the National Measurement System to that which has been accepted in the metrology community for the last thirty years.

The following topics will be addressed in the final report

7 ECONOMICS OF LEGAL METROLOGY

7.1 Prioritizing resource allocation

7.2 Cost/benefit analysis

7.3 Costs and benefits of State versus private operated legal metrology

8 FURTHER STUDIES.

Attachment 1

Bibliography

GENERAL ECONOMIC TEXTS

1 Carlo M. Cipolla(editor), *The Fontana Economic History of Europe -The Industrial Revolution*, (Fontana/Collins.1976)

2 Francis Fukuyama, TRUST-*The Social Virtues and the Creation of Prosperity*,(Hamish Hamilton,1995)

3 John Kenneth Galbraith, *A History of Economics-The Past as the Present* (Hamish Hamilton 1987)

4 Human Development Report 2001 - Making new technologies work for Human Development (UNDP/Oxford University Press 2001).

5 Joan Robinson, *Economic Philosophy* (Penguin Books 1962)

6 Joseph A. Schumpeter, *Capitalism, Socialism and Democracy* (Unwin 1970)

7 Joseph E. Stiglitz, *Economics of the Public Sector* (Norton 3rd Ed 1999)

NATIONAL STUDIES

U.S.A.

8 R.D.Huntoon, Concept of a National Measurement System, *Science* 158, 67-71,October 1967

9 Raymond C.Sangster, Final Summary Report Study of the National Measurement System 1972-75, NBSIR 75-925, December 1976,1-35

10 Barry W. Poulson, Economic Analysis of the National Measurement, September 1977, A report from the 1972-75 Study of the National Measurement System by the NBS Institute for Basic Standards p1-37

11 J.S.Hunter, The National System of Scientific Measurement, *Science*,210, 869-873, November 1980

12 Gregory Tassey, The role of government in supporting measurement standards for high technology industries, *Research Policy* 11(1982) 10 pages

13 Gregory Tassey, Infratechnologies and the Role of Government, Technological Forecasting and Social Change 21, 163-180, 1982

14 Pasqual A. Don Vito, Estimates of the Cost of Measurement in the U.S. Economy, November 1984 Planning Report 21 NBS p1-42

15 Gregory Tassey, The Role of the National Bureau of Standards in Supporting Industrial Innovation, *IEEE Transactions on Engineering Management*, EM33, 3, 162-171, August 1986.

16 Albert N. Link and Gregory Tassey, The Impact of Standards on Technology- Based Industries: The Case of Numerically Controlled Machine Tools in Automated Batch Manufacturing, December 1986 32 pages

17 Brian Belanger, Metrology is more than Calibration, Letting others know that Measurements matter, NIST 9 pages

18 Gregory Tassey, The functions of technology infrastructure in a competitive economy, Research Policy, 20, 1991, 345- 361

19 Gregory Tassey, *Technology Infrastructure and Competitive Position* (Kluwer Academic Publishers, 1992) 303 pages

20 Gregory Tassey, The Roles of Standards as Technology Infrastructure, October 1993, NIST, 12 pages

21 Albert N. Link, An Evaluation of the Economic Impacts Associated with the NIST Power and Energy Calibration Services, January 1995, NISTIR 5565, 21 pages

22 Correspondence from Tina Butcher, Economic Impact of Weights and Measures in US, January 1998, 1 page

23 Tasc Inc., The Economics of the Technology based Service Sector, NIST Planning Report 98-2, 1998, 1-209

24 Gregory Tassey, Standardisation in Technology-Based Markets, NIST, June 1999, 1-21

25 Gregory Tassey, Lessons learned about the methodology of economic Impact studies: the NIST experience, *Evaluation and Program Planning* 22 (1999) 113-119

26 Gregory Tassey, R&D Trends in the U.S. Economy: Strategies and Policy Implications, April 1999,NIST Planning Report 99-2, 52 page13.

27 Gregory Tassey, Assessing the Economic Impacts of Government R&D Programs, May 1999

28 Martha M. Gray, Applicability of Metrology to Information Technology J. Res. NIST,104 (1999), 567-578

29 Michael P. Gallaher, Stephen A. Johnston and Brendan Kirby Changing Measurement and Standards Needs in a Deregulated Electric Utility Industry, May 2000, NIST Planning Report 00-2,165 pages

30 TASC Inc., The Economic Impact of NIST Cholesterol Standards Program, NIST Planning Report 00-4, September 2000, 1-51

31 Hratch G. Semerjian and Robert L. Watters Jr., Impact of measurement and standards infrastructure on the national economy and international trade, *Measurement* 27 (2000) 179-196

32 Gregory Tassey, R&D and Long Term Competitiveness: Manufacturing's Central Role in a Knowledge Based Economy, NIST Planning Report 02-2,February 2002, 1-56

33 Gregory Tassey, The Economic Impacts of Inadequate Infrastructure for Software Testing, NIST Planning Report 02-3 May 2002

Canada

34 R.G. Knapp, Case study of the proportion of Gross National Product (GNP) subject to legal metrology measurement standards, (1997) 2 page note.

35 R.G. Knapp, Case study of the efficiency and effectiveness of Weights and Measures verification/reverification,(1997) 2 page note.

36 KPMG, Recommended Structure for a Marketplace Intervention Model for Trade Measurement, Report prepared for Measurement Canada February 1998, 1-38

37 Measurement Canada's Marketplace Intervention Model, July 1998 1-38 .

38 Measurement Canada's Assessment and Intervention Strategy for Canada's Marketplace, September 1999, 1-61

39 Measurement Canada, Trade Sector Review- Canadian Electricity Industry, September 1999, 1-30

40 Measurement Canada, Trade Sector Review- Canadian Downstream Petroleum Industry, September 1999, 1-17

Note: References 39 and 40 are two of twenty-seven sector reviews conducted by Measurement Canada.

41 Measurement Canada, Electricity Trade Sector Review-Ensuring Accuracy and Equity in Electricity Metering: A Discussion Paper September 2000, 1- 37 .

42 Measurement Canada, Electricity Trade Sector Review- What we learned from Electricity Sector Stakeholders during Preconsultation October 2000, 1- 23

43 Measurement Canada, Downstream Petroleum Trade Sector Review-A Discussion Paper on Establishing an Appropriate Level of Measurement Canada Intervention in the Downstream Petroleum Sector, March 2001, 1-100

44 Institute for National Measurement Standards: Economic Impact Study, Conducted by KPMG Consulting September 2001,1-74.

United Kingdom

45 P. Dean, A Case for Metrology-its Role for Industry and Society April 1988 5 pages

46 Department of Trade and Industry, White Paper, Measuring up to Competition,1989

47 J.S.Metcalfe and R.Smellie, Maintenance Activities and the National Measurement System, October 1991, 1-32

48 P. Clapham, Measurement for what it's Worth, Engineering and Science Education Journal, August 1992, 173-179

49 Jeremy Klein, Edward Stacey,Christopher Coggill, Mick McLean and Mary Sagua, Measuring the Economic Benefits from R&D: results from the mass, length and flow programs of the UK national measurement system, *R & D Management*,26, 1, 5-15, 1996

50 Jeremy Klein, Measuring the Economic Benefit from R&D: The Case of the National Measurement System, Science in Parliament, 53, 2, 1996, 25-27.

51 Department of Trade and Industry National Measurement System Policy Unit, Review of the Rationale for Economic Benefit of the UK National Measurement System, November 1999,159 pages

52 Steve Brown, Ian Bradley, Fiona Williams & Geoff Williams, Improving the Mapping Measurement Impact Model, National Measurement Partnership Conference, 1999, p 1-8

53 Department of Trade and Industry, Quinquennial Review of the National Weights and Measures Laboratory at Teddington, September 2000,32 pages

54 Andrew Wallard, Responding to the 21st Century Metrology Market, presentation to the Conference to celebrate 125 years of metrology in Hungary,2002

55 Department of Trade and Industry, Policy Framework for increasing the Economic Benefit derived from the National Measurement System, June 2001,23 pages

56 Shelley Charik, John Francis, Paula Knee and Ray Lambert, Setting Research Priorities for a National Measurement Programme: The Biggest Bang for the Tax-Payers Buck,2002 NCSL International Workshop and Symposium

New Zealand

57 Brian Easton, Metrology and the Economy, a Report for the Ministry of Consumer Affairs, November 1999,16 pages

58 Ministry of Research, Science and Technology, Foresight Strategy-New Zealands Standards and Conformance Infrastructure, January 2000, 21 pages

Australia

Following are some of the papers by the author that relate to this topic

59 Birch, J A (1996) Legal Metrology in Support of Economic and Social Development Presented at the First APEC Conference on Standards and Conformance held in Manila. Published in Conference Proceedings.

60 Birch, J A (1997) The Scope of Legal Metrology and its Role in Economic and Social Development. Presented at an ASEAN Workshop on Legal Metrology held in Surabaya, Indonesia. Published in Workshop Proceedings.

61 Birch, J A (1998) The Role of Metrology in Economic and Social Development. Presented at a seminar on the Role of Metrology in Economic and Social Development held in Braunschweig, Germany. Published in Conference Proceedings

62 Birch, J A (1998) Modernisation of Legal Metrology in the Asia-Pacific. Presented at the Second APEC Conference on Standards and Conformance, Kuantan, Malaysia.Published in Conference Proceedings.

63 Birch, J A (1998) Modernisation of Legal Metrology in the Indian Ocean IOR-ARC Workshop, Colombo, Sri Lanka.

64 Birch, J A (1999) Importance of Legal Metrology for the Economy of the Country and Foreseen Developments into the 21st Century. Presented at a Seminar celebrating 75 years of South African Trade Metrology, Pretoria, South Africa. Published in SABS Journal.

65 Birch, J A (1999) Modernisation of Legal Metrology in the Indian Ocean. Presented at the Second International Conference on Metrology, Quality and Global Trade, New Delhi, India. Published in Conference Proceedings

66 Birch, J A (1999) Modernisation of Legal Metrology in the Asia-Pacific. Address to the National Conference of Standards Laboratories, Charlotte, NorthCarolina USA. Published in Conference Proceedings.

67 Birch, J A (2000) Legal and Trade Metrology in the Asia Pacific Region. Invited Address to the New Zealand National Measurement Conference, Wellington, New Zealand 13-14 July 2000

68 Birch, J A (2001) The Role of Legal Metrology in Economic and Social Development in Papua New Guinea. Seminar at the Department of Trade and Industry, Port Moresby, PNG, 2 September

France

69 Christian Pierret, Address to Euro-Mediterranean Seminar on Metrology in the Service of Economic and Social Development Paris 30 November – 1 December 2000,7 pages

Germany

70 M. Kochsiek and A.Odin, An efficient metrological infrastructure- Benefit for industry and society, OIML Bulletin, XXXIX, 2, 26-32, April 1998

71 *Measuring Man –A Reader* (PTB June 2000)

Europe

The following are four of twelve studies produced by the European Measurement Project.

72 Geoffrey Williams, The Assessment of the Economic Role of Measurements in a modern society, Summary of Final Report ,April 2002, 1—42

73 Paul Baker,The economics of measurement in the natural gas industry, December 2001, 1-25.

74 Patrick de Bas, The economics of measurement of emissions into the air, June 2002, 1-21.

75 Christopher Spencer and Geoffrey Williams, The scope and dimensions of measurement activity in Europe, July 2002, 1-47

O.I.M.L.

76 Knut Birkeland, Legal Metrology at the Dawn of the 21 st Century (OIML 1999) 49 pages

B.I.P.M.

77 T.J.Quinn, Metrology, its Role in Today's World (BIPM 1993)

78 D. Kind and T Quinn, Metrology: Quo Vadis? IEEE Trans. on Instrum.and Measurement, 44, 2, 1995 85-89

79 J.Kovalevsky, What place for Metrology in France at the beginning of the 21st Century

80 CIPM, National & International Needs Relating to Metrology-International Collaborations and the Role of BIPM, January 1998 , 51 pages.

81 J.Kovalevsky, Metrologie et Societe, *Bulletin du BNM*,117,3-9 1999

82 KPMG, Potential Impact of the CIPM mutual Recognition Arrangement, April 2002, 1-127

UNCTAD

83 Chairpersons Summary Report, Expert Meeting on Diversification of Production and Exports in Commodity Dependent Countries, Including Single Commodity Exporters for Industrialization and Development, taking into account the Special Needs of LDCs, Geneva 26-28 June 2002

W.T.O.

84 Vivien Liu, The WTO Agreement on Technical Barriers to Trade and Metrology, Euro Mediterranean Seminar, Paris, November 2000 8 pages

World Bank

85 World Development Report 1997-The State in a Changing World (The World Bank/ Oxford University Press 1997)

86 World Development Report 2002- Building Institutions for Markets (The World Bank/Oxford University Press 2002)

SECTORAL STUDIES

Petroleum & Gas

87 J.R.B.Hinton, Some thoughts on the economic justification of flow measurement, *Measurement and Control*, 19,56-57 June 1986

88 J.Napper, Economic consequences of measurement errors, *Measurement and Control*,19,59-62, June 1986

89 R.C.Gold, Flowmetering in the oil industry, *Measurement and Control*, 19, 63-66, June 1986

90 G.Peignelin et al, Economics of gas flow measurement, *Measurement and Control*, 19, 72-74, June 1986

91 Mark Leigh, Fiscal flow measurement in the millennium: an operators view, *Measurement and Control*, 31,293-297, December 1998.

92 Jairo Mantilla and Damian Flegel, Why Calibrate Custody Transfer Meters, *Pipeline and Gas Journal*,29-31 July 20

93 C.P. Hoeks, Legal Aspects and Traceability of High Pressure Gas Measurements in the Netherlands, undated 15 pages

94 Harry H. Dijstelbergen, Gas Measurement in the 21st Century undated 12 pages

High Capacity Weighing

95 Jens Chr. Lange, High Capacity Bulk Weighing for Iron Ore, OIML Seminar on Testing of Bulk Weighing Installations, April 1985, 14 Pages

96 David R R Gowdie and John Van Der Linden, Weighing of Copper Concentrate, OIML Seminar on Testing of Bulk Weighing Installations April 1985, 10 pages

97 H.Colijn, Weighing of Bulk Solids, *Bulk Solids Handling*,11 113-119 March 1991

98 John P.Kelly, Trade by Draft Survet or by Belt Weighing, *Bulletin OIML* 126,51-55,march 1992

99 Bill McHale, Loading Coal Down Under, *Bulk Solids Handling*, 19, 387-389, July/September 1999.

Fishing Industry

100 R.Kleppan, E.Koren, T.Myklebust and B.Schultz, Resource Control by use of belt weighers in the fishing industry, *OIML Bulletin*,38 24-28, October 1997.

Textiles

101 P.S.Palaniswami and P.Muthukumaraswamy, Metrology and Quality For Export Competiveness in Textile Spinning Mills, Proceedings of 2nd International Conference on Metrology,Quality and Global Trade,45-49, New Delhi, February 1999

Dairy Industry

102 J.B.Hoyle and T.Cheesman,The development and economics of milk metering, *Measurement and Control*, 19, 67-71, June 1986

Road Safety

103 Michael Le Faou, Fraud on Taximeters, OIML conference on Software, September 1999,17 pages

104 World Disasters Report 1998,Chapter 2 *Must millions more die from traffic accidents*,(OUP 1998)

105 Anthony Ockwell, Road Safety –who cares,*OECD Observer*,216 March 1999.

Standards

106 Charles P Kindleberger, Standards as Public, Collective and Private Goods, Kyklos, 36, 1983, 377-396

107 Albert N. Link, Market Structure and voluntary product standards, *Applied Economics*, 15, 1983, 393- 401.

108 Donald J. LeCraw, Some economic effects of standards, *Applied Economics*, 16, 507-522, 1984.

109 Joseph Farrell and Garth Saloner, Standardization, compatibility, and Innovation, Rand Journal of Economics, 16, 70-83, 1985

110 Joseph Farrell and Garth Saloner, Coordination through committees and markets, Rand Journal of Economics, 19, 1988, 235-251.

111 Sanford V.Berg, The Production of Compatibility:Technical Standards as Collective Goods, Kyklos, 42, 1989, 361- 383.

112 Shane M. Greenstein, Invisible Hands and Visible Advisors: An Economic Interpretation of Standardization, J. of the American Society for Information Science, 43, 1992, 538-549.

113 Richard J. Forselius, A return on investment model-measuring ROI in Standards development organisations committee participation, *ASTM Standardization News*, 32-36, December 1997.

114 OECD Working Party of the Trade Committee, Regulatory Reform and International Standardisation, January 1999, 37 pages

115 OECD Working Party of the Trade Committee, An assessment of the costs for international trade in meeting regulatory requirements, February 2000, 118 pages

116 Richard E.Baldwin, Regulatory Protectionism, Developing Nations and a two-tier World Trade System, July 2000,40 pages

117 Keiya Iida and Raymond Schonfield, International standards and regulations- improving the link, *ISO Bulletin*, 5-8, July 2000

118 World Bank, Standards, Developing Countries and the Global Trade System,1-29, December 2000.

Miscellaneous

119 Phillip Nelson, Information and Consumer Behavior, J. of Political Economy, 78, 1970, 311-329.

120 George A. Akerlof, The Market for "Lemons": Quality Uncertainty and The Market Mechanism, Quart. J. of Economics, 84, 1970, 488-500.

121 Edwin Mansfield, Contribution of R & D to Economic Growth in the United States, Science, 175, 1972, 477-484

122 Kenneth J.Arrow, Gifts and Exchanges, Philosophy and Public Affairs, 1, 1972, 343-362.

123 Christopher Freeman, *The Economics of Industrial Innovation*,(Penguin 1974), 409 pages

124 Geoffrey Heal, Do Bad Products Drive out Good?, Quart. J. of Economics 90, 1976, 499-503.

125 National Academy of Sciences (US), Science and Technology-a Five Year Outlook (H.Freeman and Company 1979)

126 J.G.Tewksbury, M.S.Crandall and W.E.Crane, Measuring the Societal Benefits of Innovation, *Science*, 209, 658-662, August 1980.

127 Wassily Leontief, The Choice of Technology, *Scientific American*, 252, June 1985, 25-33.

128 Jeremy Bray, The impact of systems thinking in government, *Measurement And Control*,19, 175-180,July 1986.

129 Zvi Griliches, R & D and Productivity: Measurement Issues and Econometric Results, *Science*, 237, 1987, 31-35.

130 W.Spriggs & M.W.Pritchard, Scientists Guide to Economics,New Zealand *Journal of Technology*, 1987, 3, Pt 1 173-184, Pt 2 185-194

131 Frances E. Zollers, The Federal Government and Technology Transfer, Regulating Technology: Can Administrative Agencies Cope with Technological Change?, Technology Transfer, 1989, 26-31.

132 Paul M. Romer, Endogenous Technological Change, *Journal of Political Economy and Technological Change*,98, S71-102, 1990.

133 Paul Wallich, The Analytical Economist, *Scientific American* ,55, June1990

134 W. Brian Arthur, Positive Feed backs in the Economy, *Scientific American*, February 1990, 80-85.

135 Paul Wallich, Experimenting with the Invisible Hand, *Scientific American*, August 1992, 100.

136 Lewis Branscomb ed, Empowering Technology, (MIT Press 1993)

137 Kenneth J. Arrow and ors., Is there a Role for Benefit-Cost Analysis 1n Environmental, Health and Safety Regulation?, *Science*, 272, 221-222

138 J.D.Heydon, Cross on Evidence, 6th Ed., (Butterworths 2000)

Attachment 2

Review of the Literature

This review highlights issues in some of the key publications in the bibliography (numbering has been kept the same) which are relevant to the economic and social analysis of legal metrology. A major issue is the quantification of the economic and social benefits of (legal) metrology.

8 R.D.Huntoon, Concept of a National Measurement System, *Science*, 158, 67-71, October 1967

This paper notes that "The National Measurement System evolved in this country with little formal recognition as a system (but) is now being examined in this way" and details the magnitude and scope of the system viz.

1 Estimated 20 million measurements a day (in USA)

2 those industries that account for two-thirds of the GNP($400 million)invest annually about $14billion of operating expenditure and 1.3 million man years in measurement activity

3 About $25 billion invested in measuring instruments and increasing at $4.5 billion per year

And notes that

> *" If we judge the value of a service by what the user is willing to pay for it, then the value of the National Measurement System to the nation is in excess of $15 billion a year."*

The paper notes that the nationwide need for a complete and consistent system of physical measurement, properly co-ordinated with those of other nations requires;

1 The ability to make accurate, reliable, precise and compatible measurements in terms of a common language of units and methodology.

2 A systematic and readily accessible body of accurate, reliable, precise and consistent data on the properties of materials in different environments and for information, reference materials and conceptual knowledge that will make possible the effective use of such data.

9 Raymond C. Sangster, Final Summary Report Study of the National Measurement System 1972-75, NBSIR 75-925, December 1976,1-35

This study was conducted by the NBS Institute for Basic Standards on the structure and operation of the US system.

The U.S. National Measurement System is defined as comprising all of the activities and mechanisms-intellectual, operational, technical and institutional –used by the country to produce the physical measurement data needed to create the objective ,quantitative knowledge required by our society. This knowledge is used to describe, predict, communicate, control and react in many aspects of our personal and social lives, science and technology. The structure was seen as having five levels

1 The conceptual system that defines measurement quantities and units

2 Basic technical infrastructure that provides the tools and techniques to implement the conceptual system

3 Realized measurement capabilities, that allows the measurement of specific quantities to known accuracies

4 The institutional dissemination and enforcement network

5 End-use measurements, which all other levels of the system exist to support

This study was one of the first to attempt an economic analysis of the national measurement system. The report conducted for NBS summarises a macroeconomic study that was conducted of the cost of labour and equipment used for making measurements in each of 78 major industry group in the US. Labour costs were estimated from staffing schedules and job analysis sheets in the period 1967-1972 and expenditure on measuring equipment from the 1963 Input-Output model of the U.S. economy.

Measurement was found to cost and estimated 6% of GNP of which 85% was for labour.

The study emphasised that measurement is part of the knowledge or information sector and stressed the importance of examining the relation of measurement information to the information sector as a whole.

It is that a weakness of the study is that it was conducted from the perspective of the physical scientist and the specific measurement function he is concerned with. An alternative approach would be to focus on the user of measurement, and further notes that the standpoint of consumers has been almost untouched by the study and that the perspective of consumers would make it easier to explore secondary impacts of costs and benefits of measurement for the society as a whole.

10 Barry W. Poulson, Economic Analysis of the National Measurement, September 1977, A report from the 1972-75 Study of the National Measurement System by the NBS Institute for Basic Standards p1-37

This study was one of the first to attempt an economic analysis of the national measurement. The report conducted for NBS summarises a number of previous studies on economic aspects of the US national measurement system and particularly the 1963 NBS study on measurement intensity for industry sectors which measured the cost of labour and equipment used for making measurements and the 1972-75 economic analysis of the system conducted by the NBS Institute of Basic Standards. The report is divided into four parts viz.

1 Economic characteristics of measurement

2 Measurement in the US economy

3 Economic analysis of costs and benefits of measurement in the Private Sector

4 Economic analysis of costs and benefits of measurement in the Public Sector

The National measurement System is seen as having five interacting levels viz.

1 Conceptual system of measurement phenomena, quantities and units

2 Basic Technical infrastructure

3 Realized measurement capability

4 Dissemination and enforcement network

5 Organizational input-output transactions in the market place

The report emphasises that measurement is a component of the information sector and identifies a number of economic characteristics of measurement viz

1 Measurement is a form of information that is used as an input in production and in transactions by both buyers and sellers

2 Improved measurements may not yield benefits in an economic sense, in particular it will depend on the extent to which it satisfies wants or maximises profits.

3 Costs and benefits of measurement to society may be significantly different from the sum of the costs and benefits to individuals due to complex secondary effects arising from political and humanitarian goals of society

The report notes the public (ie collective) goods characteristic of measurement and identifies a number of areas where reliance on the private sector could result in a misallocation of resources. This public goods characteristic also creates difficulties in conducting cost-benefit analysis for measurement resource allocation and the report suggests that cost effectiveness analysis ie comparing the cost of alternate ways of achieving a specific pre determined goal, may be a more useful analysis.

The report considers a number of micro studies of the costs and benefits of NBS programs but notes(page 35) that these studies are from the perspective of the physical scientist and the specific measurement function he is concerned with. An alternative approach would be from the perspective of the user and in particular the consumer and notes that measurement problems for the consumer probably encompass most types of physical measurement.

The report notes (page 14)

> *"that an analysis of the total measurement system, especially in a quantitative benefit-cost mode, is bound to failure: Since a modern society could not function without a systematic way of acquiring measurement data, the value of having a measurement system is incalculable."*

11 J.S.Hunter, The National System of Scientific Measurement, Science,210, 869-873, November 1980

This study notes :

> *"The NBS estimates that the taking of measurements of all kinds costs 6 percent of the gross national product. It was estimated that in 1977 the federal government alone spent $690 million on the collection of data, and that approximately 43 percent of the data was generated by or for the environmental agencies. If the direct cost of making measurements is large, the indirect cost of making poor measurements must be huge."*

And concludes as follows;

> *"The responsibility for and control of the nation's measurement systems is poorly centralized. It is possible that this diffusion is healthy for the development of viable measurements. Further, it is probably impossible to coalesce the nation's diverse measurement requirements into any single pattern. But clearly the quantity of the scientific measurements now required by our measurement-intensive laws and regulations are piling up, while many of the desirable physical and statistical characteristics of good measurement methods and associated measurement systems are being given short shrift. The result is that the quality of many scientific measurements is*

suspect. The time appears ripe for a review of the adequacy of our present approach to scientific measurement."

14 Pasqual A. Don Vito, Estimates of the Cost of Measurement in the U.S. Economy, November 1984 Planning Report 21 NBS p 1-42

This report provides the first comprehensive estimate of the economic role of measurement. It estimates of the cost of measurement and the value added (defined as the value of goods and services sold less non-labour costs plus certain other items such as profits and indirect business taxes).The cost of labour is typically the largest component of value added.

Using value Department of Commerce, Bureau of Economic Analysis figures for value added by each of the 81 industry sectors of the US economy, estimates of value added by measurement were calculated using survey estimates of measurement labour intensity (the labour component of value added was used as a surrogate for total value added)

The average value added from measurement related activities for all sectors of the U.S. economy was then estimated to be 3.5 per cent of GNP. (See 49, 50 & 59 for comments on this analysis.)

For the twenty most measurement intensive sectors, that collectively contributed 15 per cent of GNP, their measurement related activities were 13.4 per cent of their contribution to GNP and 50 per cent of the total economy expenditure on measurement related activities.

The total cost of measurement to industry (capital plus labour expenditure) was $163 billion in 1984, approximately two per cent of sales.

Of the twenty most measurement intensive sectors in 1979 electricity gas and water utilities had more than twice the measurement cost of any other sector and also contributed the greatest added value. Other major contributors were chemical and chemical products, petroleum refining and related products, telephone and telegraphic services, electric transmission and distribution and glass and glass products all of which have a significant trade metrology component.

24 Gregory Tassey, Standardisation in Technology-Based Markets, NIST, June 1999, 1-21

Views standards as striking a balance between the requirements of users, the technological possibilities and associated costs of producers, and constraints imposed by government for the benefit of society in general

The function of standards are to provide;

1 Quality/reliability

2 Evaluated information

3 Compatibility/interoperability

4 Variety reduction to attain economies of scale.

And notes that;

1 The unavailability of standards at different points in a technologies life cycle can result in large economic inefficiency.

2 Multiple standards may exist for prolonged periods, limiting economies of scale

3 Standardisation over a technology life cycle has a dynamic character

4 The process of standardisation frequently must be managed as a system.

25 Gregory Tassey, Lessons learned about the methodology of economic Impact studies: the NIST experience, Evaluation and Program Planning 22 (1999) 113-119

This paper considers how the basic tools of economic impact assessment need to be modified when applied to infratechnologies. The knowledge gained is used for project management, strategic planning and policy analysis. The quantitative metrics used are Net Present Value, Benefit-Cost Ratio, Social Rate of Return & Adjusted Internal Rate of Return all of which need to be assessed for their applicability to specific projects. Examples are provided of technical outputs and qualitative and quantitative economic outcomes of a range of projects.

Outcomes for measurement standards projects are primarily in improvement in industry wide infrastructure and in stimulating new product or service commercialisation. However both the research projects and their benefits may be spread over a long period of time greatly affecting the benefit-cost ratios and net internal rates of return and this is compounded by the difficulties in identifying benefits and outcomes for these types of projects.

26 Gregory Tassey, R&D Trends in the U.S. Economy: Strategies and Policy Implications, April 1999, NIST Planning Report 99-2, 1-52

This paper provides a detailed analysis of technology policy needed to support long term economic growth. Strategy must be based on a much more pervasive technology-intensive sector which will require greater investment in generic technology and technology infrastructures.

Market failure occurs in a range of technology based industries including

1 emerging technologies that entail high-risk and long gestation periods but create new markets with significant added value

2 systems technologies that provide infrastructure to many product and service technologies and thereby drive growth in major economic sectors.

3 enabling or multi-use technologies which benefit multiple segments of an industry or group of industries, but encounter economies of scope and diffusion investment barriers.

4 infratechnologies which leverage investment in both development and use of proprietary technologies, but which require distinct competencies to develop and common ownership (such as standards) to effectively use.

One significant negative impact of these market failures arises from the fact that many of to-day's most important technologies have complex system structures, which require equally complex interfaces to enable market entry by small and medium suppliers and system optimisation by users. Without the needed infrastructure, inefficient industry structures evolve.

29 Michael P. Gallaher, Stephen A. Johnston and Brendan Kirby

Changing Measurement and Standards Needs in a Deregulated Electric Utility Industry, May 2000, NIST Planning Report 00-2, p 1-165

The objectives of this study were to identify the additional measurement and standards needed to capture the full benefits of wholesale and retail deregulation of the Electric Utility Industry and the economic impacts of not meeting those needs. The needs will arise from

1 Increased growth in the number and complexity of transactions

2 Increased number of market players and their information needs

3 A shift from reliance on voluntary agreements among formerly integrated utilities to explicit contracts among many providers of different services.

It is estimated that the economic impact of prospective opportunities that may be lost by not meeting these needs ranges from $US3.1 to $US 6.5 billion

Key areas in which the value of measurements and standards are increasing in the electric power industry are

1 Competitive metering of energy generation and ancillary services at the supplier and customer level

2 Monitoring bulk power flows and transactions

3 Monitoring transmission and distribution system conditions

4 Communicating and controlling generation, transmission and distribution systems.

5 Monitoring power quality along these systems and in customer facilities

6 Assessing system conditions and contract compliance through the use of advanced diagnostic tools.

The electric power industry represents approx, 2.5% of the US Gross Domestic Product and 1998 had retail sales of $217 billion.

The components in the retail cost of supplying electricity are

generation	75.6%
transmission	2.5%
distribution	5.6%
market transactions	16.3%.

Real time pricing in a competitive market has potential for significant savings by reducing peak demand. However there are potential costs associated with deregulation viz

1 Increased transaction costs to support market transactions.

- Transaction costs include contracting, metering, communication and processing of information, billing and dispute resolution These costs account for 11% of the cost of supplying electricity.

2 Increased bulk transmission requirements

- caused by competitive markets increasing the average distance electricity is transported.

3 Increased monitoring costs to support system reliability and Power quality

4 Potential decrease in overall system reliability and power quality.

- these changes could significantly increase costs to industry

Generally there is potentially a trade off between cost of power supply and its reliability and power quality. A role of measurement may be to provide the infrastructure to allow the supply of electricity with different levels of reliability or power quality to different groups of customers.

30 TASC Inc.,The Economic Impact of NIST Cholesterol Standards Program,NIST Planning Report 00-4,September 2000, 1-51

This study identifies four levels of economic impact in the supply chain that delivers medical services to the consumer viz,

1 .Lower production costs for manufacturers of cholesterol measuring systems

2 Reduced transaction costs between manufacturers and clinical laboratories

3 Lower costs for clinical laboratories in maintaining quality control systems

4 Higher quality medical services for consumers

Surveys of manufacturers and clinical laboratories were undertaken to provide conservative estimates of the economic impact on the first three levels viz,

Performance Metric	Lower Bound Est.
Net Present Value 1999 $	$3,573,812
Social Rate of Return	154%
Benefit-cost-ratio 1999	$ 4.47

34 R.G. Knapp, Case study of the proportion of Gross National Product (GNP) subject to legal metrology measurement standards, (1997) 2 page note.

Surveys conducted by Measurement Canada in the 1980's indicated that the total value of goods traded over all classes of trade weighing and measuring instruments totalled $C203 billion in 1989/90 or 32% of GNP. This did not include pre packaged goods or utility metering

35 R.G. Knapp, Case study of the efficiency and effectiveness of Weights and Measures verification/reverification,(1997) 2 page note.

Combining the information from the above study with information gathered on instrument compliance rates Measurement Canada were able to estimate for each class of instrument annual "dollars at risk" ie the sum of short and over-measure.

When these figures were related to the cost of verification and reverification activity it was found that for each dollar spent on regular periodic inspection 11.4 dollars of non complying measurement was corrected. By targeting inspection activity towards those instruments with higher dollars at risk this "benefit/cost" ratio increased to 28.7.It was also found that on average total trade measurement inequity was comprised of 65% short measure and 35% over measure.

On average each inspector on an annual basis discovered and corrected about $2 million of total measurement inequity.

36 KPMG, Recommended Structure for a Marketplace Intervention Model for Trade Measurement, Report prepared for Measurement Canada, February 1998,1- 38

This report developed a model for ranking trade measurement sectors on basis of need for regulatory intervention and determining the most appropriate level of intervention by Measurement Canada for each sector.

Ranking of the sectors was based upon assessment of the following factors

1 Reliance on trade measurement as the basis for commercial transactions

2 Economic significance of the sector

3 Potential economic risk to the vulnerable party in trade transactions

4 Dependency of the vulnerable party on the counter party to ensure accurate measurement

5 Compliance Rates

6 Measurement consistency and device conformance to established standards.

Stakeholder consultations were undertaken to confirm the appropriate level of intervention.

38 Measurement Canada's Assessment and Intervention Strategy for Canada's Marketplace, September 1999, p 1-61

This paper describes Measurement Canada's Marketplace Intervention Model that was developed to focus limited resources on those areas where the return to the taxpayer was greatest and to ensure accuracy and equity in the market place.

The scope of transaction covered by the model includes traditional measurement of quantity of commodities(weights & measures), the sale of electricity and gas and quality measurements and grading that determine the unit price but excluding measurements used for collecting excise or taxes.

The Model analyses and scores each of Canada's trade sectors. with respect to their economic significance, dependent party vulnerability and metrological practices. These scores are then used for negotiating with stakeholders a level of intervention in the sector, that is aligned to internationally accepted standards and includes national compliance sampling. In some cases sectors where combined eg when no additional measurements took place downstream as with pre packed goods in the food manufacturing and wholesaling sectors.

The model scores each sector using six indicators viz.

1 Reliance on trade measurement

2 economic significance of the sector

3 economic risk to the vulnerable party

4 dependence of the vulnerable party to receive accurate measurement

5 compliance of trade measurement devices in the sector

6 consistency and conformance of those devices with established standards.

Six cumulative levels of intervention were defined in the Model viz

1 Traceability of measurement standards

2 Establish rules for accurate measurement of products

3 Establish mechanisms to enforce 2

4 Establish mechanisms for dispute resolution

5 Establish metrology rules for measurement devices

6 Establish mechanisms for device performance disputes.

44 Institute for National Measurement Standards: Economic Impact Study, Conducted by KPMG Consulting September 2001,1-74

This study was designed to provide an objective measure of the current and expected impact of INMS activities on the Canadian economy. The current economic impacts were calculated through "bottom up"case studies. The market maintenance impact(pure public good) dimension of INMS primary standards is measured by using the cost of annual registration for ISO 9000 & 14000 as a measure of organizations willingness to pay for maintenance of primary standards which provides a known uncertainty of measurement and by extension traceability to national standards(ISO proxy Model)

Three core economic benefits of INMS functions are identified

1 Market Maintenance (Public Good),which take the form of reduced transaction costs. Estimated currently, at a lower bound, as $18.9 million annually

2 Quality of Life (Public Good) associated with social welfare benefits (not quantified)

3 Direct Benefits to Industry/Consumers (Private Goods). Estimated currently at $140.8 million annually with future additional expected benefits over the next five years for new thrust areas of $340.6 million, mainly arising from deregulation of the Ontario electricity market.

46 Department of Trade and Industry, White Paper, Measuring up to Competition, 1989

This UK Government White Paper made explicit the rationale for government funding of the national measurement system viz

> *"Since a measurement standard will typically be used by a very wide range of individuals and firms, the investment necessary to develop and maintain it will yield benefits which accrue to all. The private benefits to be obtained from committing funds to work on measurement standards are therefore overshadowed by the broader benefits they confer on the user community as a whole-a strong disincentive to investment by individual private firms. If left to itself, therefore, the private sector can be expected to devote fewer resources to the development of measurement standards than is desirable from the point of view of the economy as a whole."*

The benefits to the economy were

1 Facilitating free and open trade

2 Encouraging innovation and the spread of new technology

3 Promoting quality

47 J.S. Metcalfe and R.D.Smellie, Maintenance Activities and the National Measurement System, October1991, 1-32

This paper has a interesting discussion on metrology standards and public goods viz,

Page 22 Metrology Standards and Public Goods

33 The public good rationale requires closer scrutiny. A public good is defined in terms of two important economic characteristics:

(a) Non-rivalry in consumption. A public good is used but not consumed in the sense that an unlimited number of users can have equal access to it without the stock of that 'good' being depleted. Apart from marginal dissemination costs it costs no more to supply many customers as it does to supply a single customer. It is therefore argued that the good should be available to all who value it. Off air broadcasting is a prime example of a non-rivalrous public good: no additional broadcasting costs are involved when more individuals tune to the appropriate signal. Knowledge in general has this public good property , one individual's knowledge of relativity theory is not at the expense of anybody else's knowledge.

(b) Non excludability .. Access to the public good cannot be limited or monitored to identify who users are. From this it follows that rational users have no incentive to truthfully disclose the values they individually place on the public good. If it is provided they can make use of it. The inability to control access to the good and the difficulties inherent in valuing its benefits makes it impossible to charge for public goods, allowing users to free-ride. From this it follows that private provision through a market cannot be achieved, the demand side of the market is said to fail.

34 These two characteristics define a pure public good. However, whilst the non-rivalry condition is always present that of non-excludability need not be. Excludability varies along a spectrum with degrees of impurity whereby there is potential for partial or complete excludability . The degree of excludability is vital to the case for public provision by non market methods.

35 It is the pure, non excludable public good argument which generates strong conclusions about public provision. Such a good or service should be made available to all individuals willing to pay the costs of dissemination and its production should be financed from general taxation. In principle it should only be provided if the total value all users place on its use exceeds the costs of provision, although in practice there is no way of knowing what user valuations are. Lacking a market to assess demand and willingness to pay it is impossible to assess an appropriate supply of the public good. Underprovision or overprovision are likely to be the norm and there is no simple basis for making investment and production decisions. While there are many different kinds of public good those which flow from the generation of knowledge and information are particularly relevant to the current discussion.

36 The Dobbie report (1989)* accepted the pure public good argument in its appraisal of the MNS concluding,

"Except in a minority of instances it is neither possible nor desirable that a price should be charged for the use of measurement standards". (para. 3.8)

We do not agree. The argument that it is impossible to charge is valid only for pure public goods. More generally it does not follow that if a method of charging could be devised it would be undesirable to use it. At root the argument for public provision is practical, not substantive, and hinges on the degree of excludability which can be imposed.

37 When excludability is enforceable quite different principles can operate. For example, whilst off air broadcasting is a pure public good, satellite and cable TV turn it into an impure one with a strong excludability regime. Off air broadcasting has to be financed from licence revenue and advertising, cable and satellite TV charge customers directly in proportion to the services they consume. In general the excludability problem can be dealt with in one of two ways:

(a) Embodying the public good in a private good with strong proprietary properties.The book, the record or tape are each examples of how public goods in the form of knowledge and entertainment services are made excludable. The sale of hard copies of British Standards (specification standards produced by the British Standards Institute) provides a more direct analogy from the world of engineering.

(b) Building the provision of the public good around a club arrangement. Cable and satellite TV achieve this as does any concert theatre. A barrier to access is created and with it the basis for charging for the provision of the service.

38 These points are substantiated in Annex 5 of the Dobbie Report (part 2) entitled 'Economic Rationale for Government Funding of Work on Measurement Standards'.

After a thorough review of the non-rivalry and excludability issues the annex notes the situations where charging may be feasible. In particular , where the user community are dependent on researchers who have built a sophisticated facility for the provision of calibration and other services, ... "the organization which developed the standard will be able to levy a charge on the use of the standard. ... Such a charge will fmance the .development and maintenance (our emphasis) of the standard" - to which the rider is added that limits to charges are set by the cost of users developing the expertise and knowledge themselves (p.7). With this view we agree entirely.

The fundamental point is this. Access to standards knowledge is not open, as a general rule it is gained through buying calibration services provided by the NAMAS accredited laboratories and ultimately traceable back to national standards institutes.

These institutes have a strong comparative advantage in the support and development of standards. Measurement services provide access to their expertise and identify the customers: a basis for charging therefore exists.

Raising revenue from calibration services is not the only option, it may be noted. In particular , R&D club arrangements are a further way of identifying users who benefit from work in the NMS. NEL, for example, has a number of clubs with instrument makers to disseminate generic information on principles of measurement. These clubs are 50% funded by DTI and cover 14% of total programme costs.

1 Department of Trade and Industry, 1987, Review of DTI Work on Measurement Standards., Part I.

49 Jeremy Klein, Edward Stacey, Christopher Coggill, Mick McLean and Mary Sagua, Measuring the Economic Benefits from R&D: results from the mass, length and flow programs of the UK national measurement system, R & D Management,26, 1, 5-15, 1996

This paper rejects the Don Vito analysis (13) as follows:

> *"DonVito (1984) aimed to measure the value added (contribution to GNP) from measurement-related activity in the US. He first surveyed US industry on a sector-by-sector basis and determined the cost of measurement-related activities as a proportion of sales. He then multiplied these proportions by the value added for each sector in order to*

calculate the 'value added by measurement'. He deduced that the cost of measurement was $163 billion in the US and that the average value added from measurement was 3.5% of GNP.

In our view, the use of the labour ratio as a measure of the proportion of GNP affected by measurement activity is questionable because it measures costs or activities rather than benefit. It is only necessary to observe that improvements in the efficiency of making measurements would lead to a reduction in cost of measurement activities, resulting in a reduction in the value added from measurement if calculated using Don Vito's method. In fact, improved measurement technologies should increase the value added by measurement. Furthermore, the high economic value for measurement which results from this method has tended to be used uncritically as a justification for correspondingly high levels of government support."

Recognising the difficulty in calculating the value of the national measurement system a more focussed investigation of the marginal effects of reduced expenditure on particular parts of the national measurement system is adopted. This approach was driven by the political imperative of convincing policy makers.

The study limited its approach to direct impacts , excluding any indirect benefits. The main value creation mechanisms investigated were;

1 Traceability to primary standards

2 Generating new measurement technologies which are turned into products & services

3 Using leading edge metrology to support advanced products.

4 Providing an expert service to industry to diagnose and solve measurement related problems

5 Providing leadership in frontier technologies through workshops, training courses and collaborative clubs

This analysis was then applied to the impact of not funding in 1993 a number of measurement infrastructure projects in mass, length and flow at a cost saving of 5 million pounds. On the basis of industry surveys it was found that the industry sectors affected had an annual output of 212 million pounds and a trading profit of 46 million pounds and the effects of the cuts would be to reduce growth in these sectors from 3.79% to 3.07% per annum. The split of economic value between the mechanisms was found to be

Traceability 5%

Commercialisable Products 2%

Leading-edge calibrations 8%

Consultancy 54%

Leadership 30%

50 Jeremy Klein, Measuring the Economic Benefit from R&D: The Case of the National Measurement System, Science in Parliament, 53, 2, 1996, 25-27.

This paper criticised the Don Vito analysis in the following terms

"We were hampered initially by some unfortunate assumptions in the metrology community: A questionable American study from the mid-80s had attempted to measure

the value of measurement standards by looking at the costs to industry of making measurements. Though the fallacy of estimating output value from input costs should be obvious, the conclusion that the "value added by measurement" in the US economy was 3.5 per cent. of GDP, some $163bn, had become accepted inter alia as a justification for high levels of government support. Furthermore, the 1989 UK White Paper had nurtured the belief that the NMS produces benefits which, although substantial, are neither tangible nor quantifiable."

51 Department of Trade and Industry National Measurement System Policy Unit, Review of the Rationale for Economic Benefit of the UK National Measurement System, November 1999, 1-159

This review was limited to the peak technical and organisational metrology infrastructure organisations that are funded by the UK Government ie NPL, NEL, LGC & NWML and contractors under competitive tender arrangements. The determination of the benefits was limited to an industrial perspective and it was found that measurement as a whole delivers impact into the economy of 0.8% of GDP.

52 Steve Brown, Ian Bradley, Fiona Williams & Geoff Williams, Improving the Mapping Measurement Impact Model, National Measurement Partnership Conference, 1999, 1-8

Using an improved version of the method developed by Klein and ors (46) the model delivers an economic benefit measure which estimates for each project funded by DTI the value of the additional benefit, in terms of increased gross profit, that UK industry can expect to gain as a result of the project

The value creation mechanisms used are the same as in 46 with an additional mechanism

53 Representing UK interests on international bodies.

The three main data inputs to the model are:

1 Financial data about the industries affected

2 An assessment of the impact on industries of the projects

3 Strength of the the interaction mechanism for each project

Using small scale equations for impact profiles across the sectors and applying appropriate discounting techniques a present value figure is derived as a measure of the overall economic effect over a particular time frame.

53 Department of Trade and Industry, Quinquennial Review of the National Weights and Measures Laboratory at Teddington, September 2000,p 1-32

This review focussed on organisational issues, particularly with respect to the changing role of national Legal metrology authorities in the wider European market, and there was little economic analysis of the contribution of NWML to the UK economy.

There was recognition of the need to maintain a UK Centre of Excellence in Metrology, to maintain a good regulatory system for the benefit of consumers and UK industry and to continue the policy, legal and regulatory activities to sustain open and competitive markets

The need to continuously measure outcomes to ensure optimum resource allocation was recognised

56 Shelley Charik, John Francis, Paula Knee and Ray Lambert, Setting Research Priorities for a National Measurement Programme: The Biggest Bang for the Tax-Payers Buck,2002 NCSL International Workshop and Symposium, p 1-12

DTI provides 50 million pounds to a wide range of UK metrology organisations through a customer - contractor relationship which is assessed on the efficiency of delivery of the funded program. This paper considers analytical tools for measuring the prospective effectiveness of programs in delivering quality of life benefits, including consideration of uncertainty budgets as a factor in determining value for money

The paper describes a Mapping Measurement Impact (MMI) tool developed to measure for industrial metrology the increase in business profit or value adding resulting from metrology. The MMI provides a projected Economic Benefit Measure (EBM) representing the 10 year cumulated additional growth as a measure of the metrology impact.

The MMI approach was applied primarily to metrology in high technology applications and it underemphasized the role of measurement in underpinning continuous improvement across industry (the pervasive effect of the system)

Due to modelling and bias problems with the MMI model other alternatives are being considered that are more transparent and less ambitious. One alternative is to consider sectoral measurement intensities as a proxy indicator for the influence of measurement

In considering quality of life, monetary values are derived using an economic equivalents model (EEM) based on surveys of public willingness to pay and the value of a statistical life (VOSL) estimated by road traffic accident prevention analysis. A table of economic equivalents for aspects of QOL is provided.

Finally the paper provides information on Decision Conferencing (DC) procedures which integrates the analytical data and expert judgement to assess funding proposals.

59 Birch, J A , Legal Metrology in Support of Economic and Social Development Presented at the First APEC Conference on Standards and Conformance held in Manila. 1996, Published in Conference Proceedings.

This paper detailed some qualifications to the Don Vito analysis (13) viz.

"Any discussion on the role of metrology in economic development needs to consider the economic impact of measurement. The most commonly quoted figure is that measurement related activities add 3.5% to the gross national product of industrialised nations. This figure was derived from labour and capital expenditure in the US economy in 1979 (3).

However I have five qualifications about this economic analysis:

1 With the introduction of mutual recognition of measurement and testing there will be a significant reduction in expenditure on measurement related activities resulting in a reduced contribution to gross national product and a reduction in added value. However from the point of view of the metrologist the mutually recognised tests and measurements would have greater value than the multiple tests and measurements.

2 It is assumed that all measurements are fit for purpose. However a percentage of measurements are wrong or misleading. We need a complementary survey on the cost of bad measurement.

3 Only labour and capital inputs are considered. However the greater part of measured growth in industrialised countries arises from technical progress. The development of measurement systems and technologies makes a significant contribution to technical progress. Indeed measurement has been described as the hallmark of the remarkable advance in understanding the physical universe in modern times4.

4 The economic analysis does not include the benefits from confidence in the measurement system which minimises disputation and transaction costs. Poulson5 in his 1977 Economic Analysis of the National Measurement System said:

"Economic analysis of the total measurement system, especially in a quantitative benefit-cost mode is bound to failure, since modern society could not function without a systematic way of acquiring measurement data, the value of having a measurement system is incalculable."

5 The analysis does not take account of the social benefits that arise from the application of metrology. A significant social benefit arises from legal measurements for the control of health and safety, environment and police traffic control. In addition the application of metrologv in community activities provides a significant social benefit, in this regard sport is particularly measurement intensive.

On balance, taking account of these issues should significantly increase the total benefits obtained from measurement. The clarification and quantification of these issues is important not just to give metrology its due but more importantly to underpin decisions by governments on investment in metrology."

This paper also highlighted the economic and social benefits of legal measuring devices-breathalysers and radar speed measurements-in reducing the road toll in Australia.

60 Birch, J A, The Scope of Legal Metrology and its Role in Economic and Social Development. Presented at an ASEAN Workshop on Legal Metrology held in Surabaya, Indonesia, 1997, Published in Workshop Proceedings.

This paper estimated that the total annual value of trade measurement transactions in Australia was $A 300 million or about 60% of the GNP about 25% of this value was in the retail sector

The paper also noted that the benefits to industry, commerce, government and consumers of an effective trade measurement system were manifold and included

1 Consumer Protection.

2 Providing a level playing field for commercial transactions.

3 Facilitating effective stock control.

4 Reducing disputation and transaction costs.

5 Providing control of Fraud.

6 Ensuring full national benefit is obtained for commodity exports.

7 Ensuring full collection of government taxes based on measurement.

61 Birch, J A , The Role of Metrology in Economic and Social Development. Presented at a seminar on the Role of Metrology in Economic and Social Development held in Braunschweig, Germany, 1998, Published in Conference Proceedings

"Significant economic and social benefits can be obtained from these legal measurements. Their application to public highways provides an example of their cost effectiveness. Development and maintenance of public highways is a major expenditure for governments in both developing and developed countries.

The use of vehicle load weighing devices to control overloaded vehicles can provide significant saving. As the damage to road structures increases as the fourth power of the load, detecting a 10% overload can reduce road damage by nearly 50%.

The social (and economic) benefits of legal metrology are most clearly demonstrated by their impact on road fatalities. Over the last twenty years road fatalities in Australia have decreased from 3700 to less than 2000 (Figure 2) per year despite an increasing population and increased car ownership. Whilst improved roads, driver education and compulsory seat belts have all made a significant contribution, legal measuring instruments viz. radar speed devices and breathalysers have also contributed to this decline (Figure 2). These measuring devices greatly increased the probability of apprehension and there was a high degree of community confidence in the accuracy of the measurements. One study conducted in the State of Victoria estimated the saving to the community over a three year period from a reduction in road fatalities of 380 was approximately $1.6 billion. The economic benefit to Australia in reduced injuries and fatalities over the last twenty years would be in excess of $5 billion per year to which legal metrology would have made a significant contribution. Legal metrology has been most effective in changing drivers' behaviour. The choice for governments is expensive civil engineering aimed at avoiding accidents or cost effective social engineering using legal metrology devices."

68 Birch, J A , The Role of Legal Metrology in Economic and Social Development in Papua New Guinea. Seminar at the Department of Trade and Industry, Port Moresby, PNG, 2September 2001, 1-13.

This paper noted the importance of an effective trade measurement system for the responsibilities of the government of Papua New Guinea Viz;

"In this regard it is worth noting that:

- Mineral products contribute 70%of PNG export income and 17% of government revenue
- PNG has recently changed its taxes on alcohol and tobacco from an ad valorem tax to taxes based on weight and volume
- There is a proposal to develop the PNG natural gas deposits and export the gas to Australia by a high pressure gas pipeline

All of these sources of government revenue and national income rely on accurate and consistent measurement."

71 Measuring Man –A Reader , PTB June 2000, 1-78

This booklet provides excellent descriptions of the application of metrology to a wide range of everyday life situations, most of which are in the field of legal metrology.

72 Geoffrey Williams, The Assessment of the Economic Role of Measurements in a modern society, Summary of Final Report April 2002, 1—42

The study considers the mechanism and extent to which the market can develop and capture new measurement technologies and the role of market failure in providing one example of government involvement,

Other drivers are legal metrology and the need for harmonisation of measurements. In addition constraints on the application of measurement technologies can impede technological progress and international trade.

Direct benefits of measurement are seen in terms of profits to business, improvements in technologies, the growth of trade and social benefits arising from improved environment, safety and quality. However measurement techniques are seen as having little saleable benefit of their own accord and the greatest impact of measurement arises indirectly in the form of externalities and spillovers. These can arise from making markets work better by reducing transaction costs, by increasing productivity and through innovation.

The paper then considers the role of measurement in underpinning technologies that drive growth. In this regard it is noted that whilst most R& D is carried out in specific sectors the value added is more widely distributed. This is particularly true of measurement R &D.

To quantify the impact of measurement R& D on growth a survey of EU patents in the period 1995-2000 was undertaken and those patents citing measurement activity as a key input were identified. This was used to provide average estimates of measurement related patents in the total, and from this were derived benchmark estimates of the impact of measurement innovation, viz 0.77%GNP.

73 Paul Baker,The economics of measurement in the natural gas industry, December 2001, 1-25.

This study examines measurement issues within the gas supply chain from the transport stage to delivery to the final consumer. However due to an absence of available quantitative data on measurement activities in the gas sector it was not possible to make even selective estimates of the "economic" costs and benefits of measurement activities in the gas sector.

75 Christopher Spencer and Geoffrey Williams, The scope and dimensions of measurement activity in Europe, July 2002, 1-47

This study provides a description of the scope and dimensions of measurement and testing activity in the EU. Funding of NMI's Accreditation Services turnover, certification costs and expenditure on measurement and instrumentation are tabulated for each EU country and internal spending by industry on measurements, based on discussions with industrial users, is estimated at 1% of total industrial costs. Legal Metrology and social spending is not included. Total spending on Measurement in EU is found to be 0.98% of GDP.

Total benefits comprise Application Benefits which are estimated based on econometric estimates of measurement contribution to aggregrate final demand(GDP) and Knowledge Spillovers which are based on econometric estimates of measurement knowledge contribution to economic growth. Externalities and benefits to society are not estimated. Total benefits are found to be 2.67% of GDP giving a benefit to cost ratio of 2.73

76 Knut Birkeland, Legal Metrology at the Dawn of the 21st Century, OIML 1999, 1- 49.

This strategic study of legal metrology addresses many of the underlying issues of this review. The study defines the concept of a global measurement system in the following terms

> *"The global measurement system provides a coherent structure which ensures that measurements can be made on a consistent, appropriately accurate, transparent and internationally recognised basis throughout the world. It comprises all activities that provide measurement data as a basis for decisions in many aspects of life - politics, commerce, industry, science, engineering, international trade, human health and safety, environmental and resource protection"*

79 J. Kovalevsky, What place for Metrology in France at the beginning of the 21st Century, Summary and Recommendations of a Review of the French Metrology System

> *"Metrology, be it primary or legal, is in the heart of a severe international competition. At a time when European harmonisation of regulations is taking place, countries with a strong legal metrology will be the most able to defend their interests successfully."*

82 KPMG, Potential Impact of the CIPM mutual Recognition Arrangement, April 2002, 1-127

This study examines the potential economic impact of the CIPM Mutual Recognition Arrangement (MRA) in terms of

1 The gains in cost efficiency for National Metrology Institutions (NMIs) in establishing mutual recognition multilaterally through central co ordination rather than bilaterally.

2 Economic efficiency resulting from reductions in technical barriers to trade(TBT).

Based on information provided by a survey of NMIs it is estimated that there is a notional saving to participating NMIs of 75K Euros per annum in the cost of establishing and maintaining mutual recognition and the total notional saving to the community of NMIs is of the order of 85M Euros

The study notes that a measure of the extent to which TBT might be limiting or raising the costs of trade has yet to be estimated by the WTO, OECD ,the World Bank or other parties. However based on the value of the trade between nations participating in the MRA a saving of $US4billion is conservatively estimated.

86 World Development Report 2002- Building Institutions for Markets (The World Bank/Oxford University Press 2002), 1-249

This report is interesting for it's lack of recognition of measurement as an institution that facilitates markets and reflects a common failing of policy to overlook measurement. There are a number of case studies in the report where whilst measurement is central to the issue discussed it is neither mentioned or recognised eg p18 rice marketing and standardisation, p107 regulation of overloaded trucks and p 154/155 long distance transmission of petroleum by pipeline and transmission of electricity.

95 J.C. Lange, High Capacity Belt Weighers for Iron Ore, OIML Seminar on Testing of Bulk Weighing Installations, April 1985 p 1-14

This paper describes the upgrading of the belt converyor weighing system in the port of Narvik in northern Sweden to reduce the uncertainty of measurement from 0.5% to 0.2%.The cost of the extra

equipment was 5 million FF and the increased annual return to the exporter due to the reduced uncertainty was 8.6 million FF.

134 Kenneth J. Arrow et al., Is there a Role for Benefit-Cost Analysis 1n Environmental, Health and Safety Regulation?, Science, 272, 221-222

The paper proposes eight principles on the appropriate use of benefit-cost analysis viz;

1 Is useful for comparing the favourable and unfavourable effects of policies

2 Decision makers should not be precluded from considering the economic costs and benefits of different policies in the development of regulations. Agencies should be allowed to use economic analysis to help set regulatory priorities.

3 Benefit cost analysis should be required for all major regulatory decisions

4 Agencies should not be bound by strict benefit cost tests. Factors such as equity within and across generations may be important

5 Benefits and costs should be quantified wherever possible with uncertainties.

6 External review of regulatory analysis

7 Economic assumptions used should include the social discount rate, the value of reducing risks of premature death and accidents and the value associated with other improvements in health.

8 Distributional consequences should be identified.