

MEASUREMENT GROWTH IN A TOTAL QUALITY PERSPECTIVE

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Abstract: Measurement is a key decision tool for a sustainable growth. In order to cope with this goal, total quality of measurement should be pursued at all operative levels, ranging from company or laboratory, through the national and macro-regional levels, up to the international dimension. In the paper, a framework for achieving required measurement quality is proposed and discussed. For each operation level, involved subjects are identified, concerned actions are considered and integration and harmonisation is addressed.

Keywords: measurement policy, sustainable development, quality management, measurement infrastructures, traceability

1 INTRODUCTION

Sustainable growth is a global challenge for the new millennium.

Growth is no more to be intended in a purely quantitative fashion, as an increase in the production of some kind of goods, but rather as any improvement of life conditions somewhere on the Planet.

Sustainability thus requires any growth plan to be integrated in the natural and human environment, accounting for resource limits, with a special eye to new generations inheritance.

On the methodological plane, this requires a *critical approach* to the design, implementation and management of any new project.

Now a most appropriate decisional support for such a critical approach is provided by *measurement*.

Indeed measurement, as both an investigation tool and a decision support, has gone through all mankind history. In modern times it has characterised the birth and development of modern science and has enabled technological progress. Neither the present shift of activities towards services, apparent in some highly industrialised countries, will diminish the social role of measurement, since its impact on health care, environment and safety is as high as on production.

More recently a significant synergy has developed between quality requirements, especially in highly industrialised countries, and the field of measurement.

Some trends may be recognised:

- measurement is necessary to ensure the quality of almost any industrial or service process; such a quality can not be better than that of the underlying measuring sub-process;
- it is important to identify and measure factors directly affecting quality, so that the degree of quality may be quantified and communicated, also to the consumer;
- quality of measurement need to be guaranteed as well;
- as long as a growth is foreseen in some field, required measurements are expected to increase at a higher rate, to satisfy above requirements.

On the other hand such requirements are not limited to contexts where a certification is needed, but for a natural "carrying effect", are becoming "good practice" codes whose benefits may be valuable for all kind of company at any technological level.

In the paper, conditions for a satisfactory growth of measurement are systematically investigated, at different scale levels.

2 TOTAL QUALITY PERSPECTIVE

The paper is intended to contribute to the definition of a framework for allowing measurement to meet all to-date requirements at various scale levels [1].

The common starting point is the assumption *that total quality of measurement requires a joint co-ordinated effort by all involved subjects.*

That will be discussed for different contexts, namely:

1. company or laboratory level;
2. national level;
3. macro-regional level;
4. international level.

For each intervention level, involved subjects will be identified and key actions envisaged.

3 COMPANY OR LABORATORY LEVEL

A company or a laboratory is the environment where measurements are usually produced.

Yet this two environments are in general quite different, since while in a testing laboratory measurements are the main product, in a company they are considered as a service, a sub-process supporting the main process.

Laboratories producing almost exclusively measurements have a significant economic relevance, in any industrialised country. We include in this category: metrological rooms in a company, autonomous calibration and testing centres, laboratories for clinical analysis, private and public, stations for environment monitoring, including surveillance for ionising radiation and electro-magnetic pollution; laboratories for food analysis and surveillance against sophistication, testing centres for marking; electro-magnetic compatibility testing facilities; centre for monitoring of seismic activity and meteorological stations. It may be estimated that roughly a laboratory exists for every 500 inhabitants in an industrialised country, with an average of 3-4 operators.

From the laboratory standpoint, measurement is a product, to be commercialised with due quality assurance. Such quality highly depends upon human factors: production procedures and uncertainty evaluation.

So laboratories may be a good reference for implementing quality of measurement but in other organisations a quite different situation may exist.

Indeed, if directly asked about, most people probably agree in recognising measurement as a *company-level* function. Yet an apparent paradox exists: measurement is virtually so *pervasive to all aspects* of company activity that is hardly recognised as a *specific function*.

This point is apparent if we just look back at the development of measurement topics within the ISO standards concerning quality.

In the ISO 9000 series, released in 1994, the accent was on the measurement devices. The related requirement, included in paragraph 4.11 of ISO 9001-2-3, was soon recognised as hard to implement, and related failures were recognised as one of main causes of non-conformity. More detailed guidelines on how to implement such requirements were given in ISO 10012, which was released in two parts, treating separately the confirmation of measuring systems and the control of measurement processes [2-3]. This was an important step forward, allowing accounting for the complete measurement process, not only for the equipment. Finally in the present revision of the ISO series, called "Vision 2000", on one hand it seems that measurement and monitoring are becoming one of the four major topics of the whole architecture of the quality, on the other hand it is not clear what the role of instrumentation is going to be, whether a part of the process, a resource or something else.

So while the strategic relevance of measurement is increasingly recognised, a lack of awareness of measurement as a *specific company-wide function* still persists. The risk is that individual measurement tasks are allocated to different departments without a proper co-ordination. In the Vision 2000 perspective a special emphasis is given to reaching effectiveness: now the key point is that effectiveness in measurement *requires a holistic approach*, based on a well-grounded measurement culture.

How can then the measurement function be implemented?

Answer to this question is not simple and several distinct actions are in general required.

Let first consider the measurement of traditional physical quantities of technical interest, then spend a word about "new quantities" involving *perceived quality* of products and services (including internal company functions).

For usual technical measurement tasks, it is important to recognise a proper decision structure, for the organisation under consideration. One such structure is proposed in table 1, basically applying to an SME architecture, but still quite general [4].

Related documentation is also proposed in the same table.

How to implement such a structure?

Surely a co-ordination position is mandatory: we call it the "*responsible of measurement*". It should correspond to a specific *new professional profile*, to be discussed later. The presence of such a position is important both for the technical contribution it may carry and as recognition, by the top management, of the measurement function as a specific company wide function.

Table 1. Decision hierarchy.

DECISION LEVEL	INSTRUMENTATION	MEASUREMENT	RELATED ACTIVE DOCUMENTATION
STRATEGY (Company)	Calibration policy (external vs. internal) Organisation of internal metrological service.	Measurement policy Process instrumentation Personnel qualification	Quality Manual
TECHNICAL MANAGEMENT (Department)	Planning of confirmation, maintenance, and replacement. Instrumentation database.	Experiment design. Surveillance of the measurement process.	Management procedures.
OPERATION (work station, process)	Calibration procedures including data processing and uncertainty calculation.	Measurement procedures. Evaluation of final uncertainty.	Operation procedures and/or instructions.

Then individual tasks may be allocated to pertinent departments. Top level decisions may be in charge of the management, while intermediate level ones may be assigned to different departments, depending upon the kind of organisation.

It should be noted how the three level decision structure corresponds to the general trend toward a three- level qualification of personnel involved in measurement: strain measurements and CMMs are good examples.

Let then spend a few words about the measurement of “new quantities” involving *perceived quality* of products and services. There is an increasing technical interest to these matters. We think the best approach is that of considering such measurement as an extension of classical measurement and try to apply as close as possible metrological general concepts. Most of the studies in measurement theory in the 20th century have gone in that direction [5]. So there is again a need for a profound measurement culture, to be discussed further in the paragraph dedicated to education, at the national level.

4 NATIONAL LEVEL

Here main subjects may be identified as:

- Primary Metrology Institutes;
- National Systems for Calibration and Testing;
- Systems for mandatory measurements;
- University and education companies;
- Accreditation Bodies;
- Special category associations.

Most important actions include metrological infrastructure, education and research [6].

The recent signature of the Mutual Recognition Agreement among Primary Institutes of the Countries adherent to the Metre Convention (Paris, October 1999) poses the problem of costs related to the quantitative assessment of the MRA, i. e. the degree of uncertainty on the equivalence of conformity certificates from different countries.

Two kinds of problems arise.

1. A large number of international comparisons is in order for verifying both the uniformity of high accuracy fundamental measurements and of measurements in critical application fields, such as avionics, health and environment, medical devices and the like. In particular it is not easy to extend to the second group results from the first one.
2. A large number of metrological institutes are presently active, with difficult harmonisation. For instance in EU we have 15 Primary Metrological Institutes, to be compared with only one in USA and only two, strictly complementary, in Japan, while related influence commercial area are similar. A possible rationalisation may be obtained by a hierarchy of functions, to support top-of-the-line requirements and medium-low service, the latter still very important for a large number of industrial applications.

Some trend in this sense is already in act, as a result of certification, both within each individual National Calibration System and among different National Systems. Similar criteria could be used for Primary Metrological Institutes, so that interdependency and hierarchy could be assessed. This could also simplify inter-comparisons and enhance traceability.

It should also be an important step toward unification of different aspects of metrology, such as technical-scientific, legal, sanitary, environment, radiation, and so on. Unity should not be intended strictly as convergence into a unique organisation, but surely requires a proper task allocation and identification of responsibility. In this process two actors are highly involved: education and accreditation bodies.

University in particular should ensure a proper diffusion of measurement culture, including standardisation. Accreditation Bodies should promote the application of common rules among industrial laboratories and laboratories acting in other fields, such as medical devices or environment.

Considering education, it should be stressed that effectiveness in measurement may only be achieved as a result of well-grounded measurement culture.

So the role of education is vital.

In these days in many countries a debate takes place on the organisation of higher studies.

In Europe for instance the European Ministers of Education have recently signed a declaration aiming at developing "the European space for Higher Education" [7].

So there is a unique chance for measurement culture to find its natural place in the curricula, on the basis of some international recommendation, recognising standard education levels. Some international committee, made of experts of the field, should define the minimal requirements, depending upon the kind and level of studies.

A tentative table of such contents is proposed in table 2.

Table 2. Sample contents for higher education.

Level	Contents	Remarks
Basic	<ol style="list-style-type: none"> 1. Comprehension of the logical aspects of measurement and ability of evaluating uncertainty 2. Methods for the analysis and synthesis (design) of measuring systems 3. Components of measuring systems, including real-world aspects influencing the result of measurement Units, instrumentation and methods for the measurement of specific quantities	<i>Contents mandatory for all scientific and technical faculties.</i> <i>Items 1 to 3 quite independent from the subject of the studies, while item 4 more specific.</i> <i>Item 1 to be proposed also for behavioural sciences.</i>
Advanced	<ol style="list-style-type: none"> 4. Advanced measuring techniques for specific quantities 5. Advanced data and signal processing 6. Methods for the measurement of new quantities; generalised measurement and evaluation procedures 	<i>All items to be proposed for scientific and technical faculties, mandatory for experimentation-oriented curricula.</i> <i>Item 7 to be proposed also for behavioural sciences.</i>

A more specialised curriculum should be devised, to prepare the "responsible of measurement", ensuring necessary professional skills.

A tentative prospect of minimum requirements is proposed in table 3. An estimate of the corresponding studying load is also provided, in ECTS (European Credit Transfer System) units, one unit corresponding to an average studying load of 30 hours.

Table 3. Sample curriculum for the responsible of measurement.

Contents	Credit (ECTS unit)
University level basic measurement culture	Not less than 12
Economics and management basics	Not less than 6
Quality management basics	Not less than 6
Technical management of measurement functions	Not less than 6
Specific measurement techniques	Not less than 6

Finally, concerning research, although many good projects may be ongoing, measurement is probably not recognised as a key topic, in national research objectives. To this aim a strong input should probably come at the macro regional level (see below).

5 MACRO-REGIONAL LEVEL

The macro-regional level is *nowadays the level where coordination among national policies takes place*. Coordination of metrological activities and infrastructures may be the guiding paradigm, as will be shown below. A similar coordination action should be extended to include all relevant aspects of measurement, namely research, education and standardisation.

To probe further this concept, the authors consider here the European scenario, as more familiar to them. Yet many concepts may to a large extent be referred to other contexts as well.

Starting from metrology, we see that a strict co-operation has been established between EUROMET, the organisation in charge of co-ordination among metrological institutes, and the European Commission (CE). Together they have recently finalised an agreement with NIST (USA) for the harmonisation of measurements in vital sectors for relationships between the two markets: avionics, environment, medical devices, electromagnetic compatibility, health and safety on work sites.

This is the result of a long process, during which the Commission, within Framework Programmes and through a specific bureau (BCR) has promoted harmonisation of measurements within EU. Such a process is considered as an essential part in the overcoming of technical barriers against free circulation of goods in the EU. It is the basis for the trend summarised by "one product, one characterising measurement, free circulation".

A similar co-ordination action has been carried on by EA (European Co-operation for Laboratory Accreditation). Finally, a special mention need to be done of the area of chemical measurements, for its present rapid evolution. EUROCHEM, the European co-ordination of chemical activities, has recently (1998) started a close co-operation with EUROMET to jointly reach a harmonisation of chemical measurements.

Concerning research, the Fifth Framework Programme of the EU is meant to support RTD&D (research, technology development and demonstration) for the policymaking, over industrial and related service sectors, for the challenges of the new millennium and to generate a strategic vision of research throughout Europe. The programme focuses on identified needs so as to improve the information available to policymakers about the implication of technological and organisational change and opportunities for, and the effectiveness of, policy measures.

Measurement and testing has been identified within the RTD programme for sustainable growth as one of the three generic technologies helping to develop the scientific and technological base, as well as qualified human capital in critical areas, and giving support to innovations across a range of applications. This will be implemented by cooperative research projects leading to novel instrumentation, improved methodologies and certified references, the socio-economic objectives being given in Table 4.

Table 4. Relations among research objectives and socio-economic objective, in the 5th Framework Programme of EU

Research objective	Socio-economic objectives		
	<i>Support to standardisation</i>	<i>Fight against fraud</i>	<i>Improvement of quality</i>
<i>Instrumentation</i>	/	Sensors, screening systems and instruments for the fight against fraud	Instrumentation for improvement of quality
<i>Methodologies</i>	Methodologies to support standardisation and Community policies	Measurement and testing anti-fraud methodologies	Measurement and testing methodologies in support of quality
<i>Reference materials</i>	CRMs for European standards	Reference substances and materials for anti-fraud	CRMs for traceability and calibration

Some comments are then in order.

- The strict relations between research and socio-economic goals is a recognition of important role that measurement plays in the society.
- Measurement is considered in a *holistic fashion*, including software, and a special attention to "capabilities required by the end-users, such as improved performance and reliability, intelligent operation, cost efficiency and suitability for use".
- The measurement of perceived quality of industrial products and services is included.
- On the other hand, while in the fourth Framework Programme, Standard Measurement and Testing were included as specific programme, measurement activities are now a part of the Sustainable Growth section: this should not turn to a trend finally yielding to a *loss of autonomy* of measurement activities.

Finally, education. Despite of the already mention development of a European Higher Education Area, no specific action for the co-ordination of education activities in the area of measurement seems to be ongoing.

6 INTERNATIONAL LEVEL

At this level present trend in metrology shows an organic development of macro regional areas, accounting for cultural common features, with mutual recognition agreements, regarding each area as a whole, which could be extended to the whole measurement business. Such agreements include mutual recognition of Primary Metrological Institutes, as an extension of the Metro Convention. The globalisation of economy requires technical barriers to be removed at a global level, which is far to be achieved, at time being.

On the other hand, some general norms, such as those regarding the evaluation and expression of measurement, should be devised at an international level from the very beginning. Moreover worldwide communication, highly enhanced by global networking, should take advantage from the language and methods of measurement, which is an international language as well.

7 CONCLUSIONS

Measurement growth is somehow at a turning point nowadays. The total-quality paradigm is a good reference. It essentially means *active participation of all involved subjects*. Measurement has naturally a key role in a modern society, involving vital aspects as scientific and technical progress, socio-economic sustainable growth, environment protection, health care... The reasons for that are not only *technical* (measurement provide information), but also *cultural* (measurement provides a basis for a critical consciousness of our relationships with empirical world). Such a role is at the same time a source of strength and of weakness. It may be a strength, if the recognition of the role leads to the recognition of the *autonomy* of measurement science, with proper allocation of resources; it may turn into weakness, if measurement activities are confined within specific application fields, with a progressive loosing of the specificity of measurement culture.

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