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Metrication in Building Design, Production, and Construction

A Compendium of 10 Papers

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The National Bureau of Standards was reorganized, effective April 9, 1978.

METRICATION IN BUILDING DESIGN, PRODUCTION, AND CONSTRUCTION

*Special Publication

A Compendium of 10 Papers

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Abstract

This publication is a compendium of ten papers prepared during 1977 by Mr. Hans J. Milton, Technical Consultant on metrication and dimensional coordination to the NBS Center for Building Technology. It may be used as an information and general reference document in the metric subject area.

International experience has enabled the author to refer to precedent in other English-speaking countries which have preceded the United States in the change to metric (SI). The papers are directed at the disciplines of building design, production, and construction. However, they contain much information which could be adapted for use in other sectors of the economy.

Some of the subject areas addressed are: management and economics of metrication; specific product metrication; public construction sector role in metrication; building standards and codes in metrication; graphic design in metrication; and, United States' opportunities in metrication.

A subject index has been included for ready reference to specific metric topics.

Key words: Economics of metric conversion; harmonization; management of change; metric familiarization; metrication; rationalization; SI; standardization; transitional period.

Preface

Metric opportunities and benefits for the various sectors of the U.S. construction community form the central theme in this publication. The ten papers in this compendium were written by Hans Milton within the past year while serving as a Technical Consultant on metrication and dimensional coordination to the NBS Center for Building Technology.

In the period 1970 to 1974, Mr. Milton was a prominent figure in the Australian change to metric measurement in building design and construction. He was the author of the Australian Metric Handbook, "Metric Conversion in Building and Construction." Mr. Milton also was the Chairman of the Government Construction Sector Committee of the Australian Metric Conversion Board. Currently, Hans Milton is an Assistant Secretary in the Australian Department of Environment, Housing and Community Development, on loan since August 1976 to the National Bureau of Standards of the U.S. Department of Commerce.

Extensive assistance in the compilation of this document was provided by Ms. Sandra A. Berry. Ms. Berry edited and harmonized these ten papers, which were prepared each for a different audience, into a unified compendium. In addition, the cooperation of Ms. Laurie Ertter of the CBT Word Processing Center in typing this material is gratefully acknowledged.

This Special Publication contains papers which reflect an authoritative and practical view of various aspects of metrication--from managing the change itself, to questions that should be addressed prior to converting a specific industrial product group to the International System of Units. The papers provide a broad overview of how the change to metric (SI) could benefit the United States construction community.

James G. Gross, Chief
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Terms Used in Text

Metric System. A measurement system developed in France during the 1790's, based on the "meter" and a series of other fundamental units which traditionally have been standardized. The measurement system also contains a set of decimal prefixes which can be attached to reference units to alter their magnitude.

SI - The International System of Units. The "modern metric system," in which all units have a coherent (one-to-one) relationship; developed in 1960 by the General Conference on Weights and Measures (GCWM), which is an international treaty organization, SI has been adopted by all countries which have changed to metric measurement since 1960, and countries using pre-SI systems are changing those units that have been superseded.

Metrication. A term coined in Britain to describe "metric conversion;" any process of change from customary measurement to SI, including the planning and coordination necessary for the change.

Exact Conversion. The change from a customary value to its "precise" metric equivalent, generally expressed to a number of places of decimals.

Soft Conversion. A change in description only, but no physical change; generally a soft conversion is the rounding of an exact conversion within tolerances to a more workable numerical value.

Hard Conversion. A physical change from an existing numerical value to a new and "preferred" metric value, requiring a definite change in physical characteristics.

Rationalization. The selection, from all possible alternatives, of the most rational, preferred, and economical alternative(s), after research into the technical implications and on appraisal of the economic impact.

Harmonization. The unification of different or conflicting approaches during the change to SI.

Dimensional Coordination. The systematic application of preferred and related dimensions in the design of buildings and the manufacture and positioning of building components, assemblies, and elements.

Modular Coordination. Dimensional coordination based on the international building module, M, which has a dimension of 100 mm.

Preferred (Metric) Sizes. Sizes for building components or assemblies preferred over others --normally, selected multiples of the basic module of 100 mm.

M-Day. A point in time selected by an industry after which all activities should be carried out in metric (SI) units. In construction, the M-Day would be the point in time after which all new projects are constructed in SI units.

Metric Board. The United States Metric Board, established in the "Metric Conversion Act of 1975," to coordinate the voluntary conversion to the metric system. The 17-member Board has been appointed, with Dr. Louis Polk serving as Chairman. The Board is now operational and Dr. Malcolm O'Hagan is the Executive Director.

Note: These papers were prepared prior to the Board's appointment; therefore, in the original papers that referred to the establishment of the Board or "yet to be appointed," have been changed to reflect the U.S. Metric Board's existence.

ANMC - The American National Metric Council. A private and self-supporting national organization, established in 1973 to provide assistance in the conversion to metric measurement through coordination, planning and information services to its membership and all segments of society in the U.S. affected by metrication.

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SECTION 1

More Efficient Technology, Research, Industry and Commerce - The METRIC Opportunity

Article prepared for publication in Dimensions, magazine of the National Bureau of Standards. Published in part under the title, "Metrication Australian Style," in Volume 61, Number 6, June 1977, pages 2-7.

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INTRODUCTION

Many millions of words have been written in the United States about the opportunities and problems associated with the change to metric - and, specifically, the change to SI (the International System of Units). SI is the most up-to-date version of the metric system and is designed for universal use.

It is one of the paradoxes of history that the United States, the first nation to introduce a system of decimal currency in the late eighteenth century, will be the last major nation to make the change to a decimal system of measurement--SI--towards the latter part of the twentieth century.

There are at least two significant advantages for the U.S. in being the last to change:

1. the change from the outdated customary system of measurement to the most modern system devised by man can be made in a single step; and,
2. the successes and failures of preceding countries in metric conversion provide an indication of where to concentrate the U.S. effort, simplify, speed up, and most importantly, where to beware.

This paper is not written to add to any controversy, but rather to give metrication--the change to SI--a deserving perspective. This perspective was acquired with the advantage of hindsight gained in Australia, where the change to SI was made a national goal for the 1970's, a goal which substantially has been accomplished just seven years later.

A. Metrication: The Australian Experience as a Guide for the United States

Those who were connected with metrication in Australia are proud of their participation in a voluntary, coordinated, and national approach to the challenge of change; a change during which many opportunities were pinpointed and forcefully pursued.

The changes deemed necessary to an effective metrication program were carefully planned and carried out in an efficient manner. Most of the forecast problems simply failed to eventuate because they had become "non-events" before they could materialize. Australia has proved that metrication need not be feared, but rather should be welcomed like a breath of fresh air. It was also found that metrication was much less expensive and less time consuming in a coordinated program than first predictions indicated. This was due to man's natural tendency to overestimate time and cost factors in hitherto untried fields.

Australia has no monopoly on metrication experience. Many useful lessons can be learned from other countries that have recently undertaken the change from their 'English' systems of measurement to SI, such as Britain, South Africa, New Zealand, and Canada. However, the significant lesson from Australia is that metrication must be treated as a "management exercise with technical overtones." It requires positive management action based on executive commitment, community-wide cooperation, and preferably, leadership from the public (federal, state and local government) sector to give momentum to the change. The Australians found that the best approach to metrication was one which enhanced simultaneous involvement of the community in all areas, so that exposure to metric units was continually intensified. Organizational metrication should seek long-term gains for short-term sacrifices. This approach not only demands research and analysis before action, but also agreed time limits so action is not continually postponed. Australian industry made a wise move when the motto "Rationalization Through Metrication" was added to the change. All parties concerned were counseled to focus on opportunities and "not to look back." Problems can always be tackled if they happen to materialize. Opportunities, however, can be utilized only if they have been identified beforehand.

While many facets of metrication can be probed, this paper concentrates on just a few significant metric lessons which can assist the United States in selecting the best metric road to follow.

B. Metrication: Easier than Most People Imagine

The key to effective metrication is positive support for and commitment to change. But to some extent, people resist change from well established ways and routines. Many of those who oppose metrication know little about SI. Generally they are unaware that:

- a large number of SI units are already in common use. Typical examples are the base units second, ampere and candela, and the derived units watt, volt, ohm, farad, coulomb and lumen.
- the international system of units (SI) has far fewer units than the customary system. For example, one unit of length, the meter (m)--and its decimally-related multiples and submultiples such as kilometer (km) and millimeter (mm), will replace such a variety of customary units as the mile, furlong, chain and link, rod (pole), fathom, yard, foot, hand, inch, mil, and micro-inch. In addition, the change to use of the meter will correct the difference between the standard foot and the survey foot (which is two parts in one million longer), by replacing both of them.
- all SI units are coherent; they relate to each other by a factor of one. No change occurs in this unity relationship when derived units are transformed to constituent base and/or supplementary units in calculations. This is illustrated by showing the coherent derivation of the international unit for electrical potential, the volt (V):

$$1\ \mathrm{V} = 1\ \frac{\mathrm{W}}{\mathrm{A}} = 1\ \frac{\mathrm{J}}{\mathrm{s \cdot A}} = 1\ \frac{\mathrm{N \cdot m}}{\mathrm{s \cdot A}} = 1\ \frac{\mathrm{kg \cdot m^2}}{\mathrm{s^3 \cdot A}} \quad \text{or} \quad 1\ \mathrm{V} = 1\ \mathrm{kg \cdot m^2 \cdot s^{-3} \cdot A^{-1}}$$

  where meter (m), kilogram (kg), second (s) and ampere (A) are all SI base units; and newton (N), joule (J), watt (W) and volt (V) are coherent derived SI units.

C. SI: Simpler and International

Internal coherence, and decimal prefixes which can be attached to SI units to extend their working range from the sub-atomic (10^{-18}) to the astronomic (10^{18}), provide great simplicity and power. Some of the SI prefixes, such as micro (10^{-6}), milli (10^{-3}), kilo (10^{3}) and mega (10^{6}), already are generally known particularly in the electrical field. Most calculations in SI are facilitated, less error prone, and more accurate - thus saving time and money.

Electronic calculators and computers operate more efficiently with SI units. In many activities, an intrinsically decimal measurement system becomes a natural ally of decimal currency, and this simplifies work considerably. Internationally-recognized unit and prefix symbols, and agreed conventions for presentation and use of SI units and numerical values, facilitate the transfer of knowledge between nations.

SI is an integral part of modern international science and technology and the measurement language of international standards.

D. Metrication: Means Change - Change Creates Research Opportunities

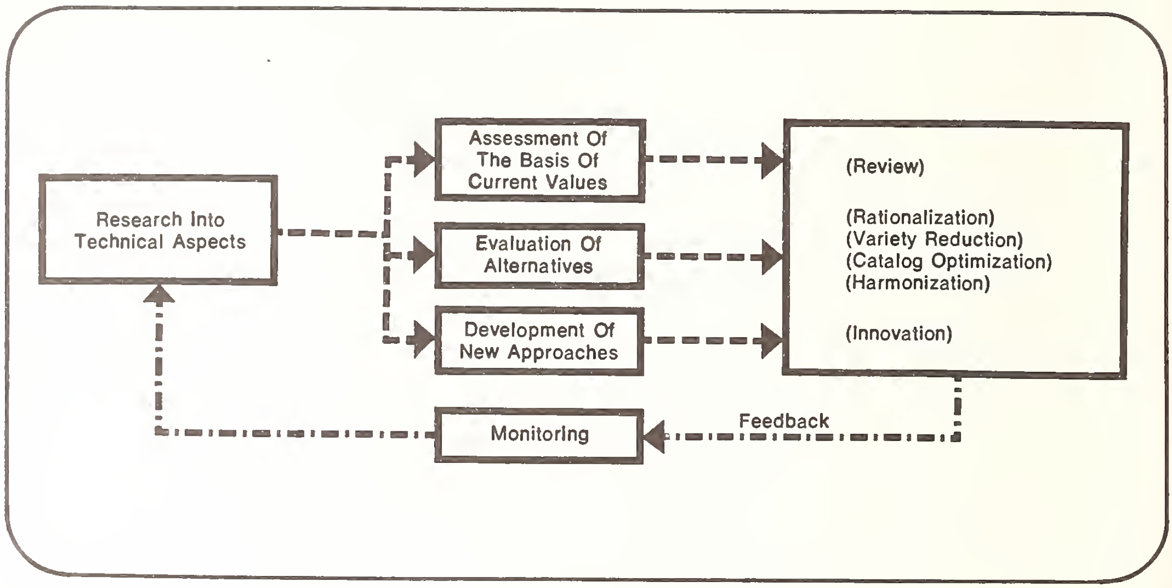
While research is normally designed to identify paths for beneficial change and pave the way for such change, metrication represents change. Many people think that metrication involves merely another description, such as 30 °C for a warm day's temperature, previously described as 86 °F. In most instances, however, metrication provides the opportunity to review customary values and sizes and to introduce preferred values or rationalized ranges of sizes. This process is known as making a "hard conversion," it is not a "soft" way out. For example, it may be beneficial to the concrete industry and its customers to replace the current range of 7 concrete strength grades between 2000 and 5000 p.s.i. with 6, or even 5, preferred metric strength grades. However, only in-depth analysis by the industry, designers and users will provide the best solution all round.

The change to SI represents a once-only chance to harmonize conflicting standards or regulations issued by the numerous political subdivisions and standards groups in the United States. But research is necessary to determine the "best" harmonized values. The change to SI can be described as the "most significant research opportunity in modern times," (see Figure 1.1) since no single traditional value or established benchmark should escape scrutiny when it comes to metrication.

Research into metrication ranges from the fairly simple substitution of customary values with the most suitable metric equivalent, through rationalization and optimization of entire ranges of values, to innovation and development of entirely new data and design aids.

The principal components of metrication research are illustrated in Figure 1.1.

Figure 1.1: Components of Metrication Research



E. Management: The Motor for Metrication

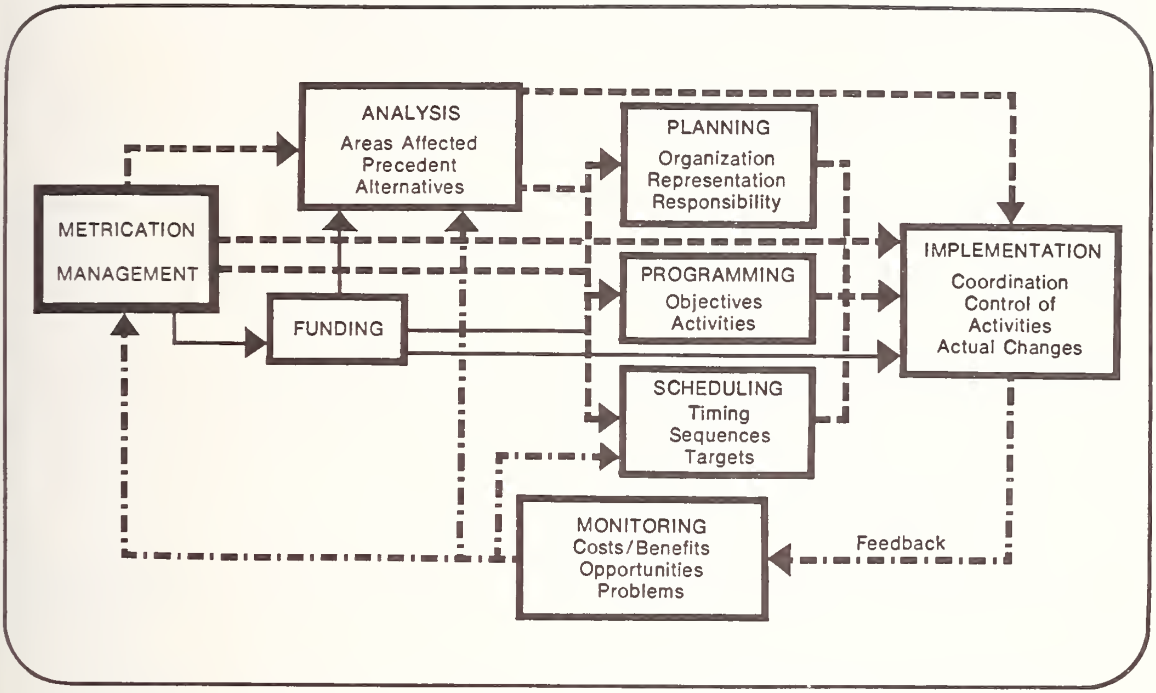
The change to SI will cost less if it is properly managed, nationally as well as within each individual organization. The top executive of each organization should give considerable thought to the selection of an appropriate "metric coordinator" or "director of metrication," to ensure that costs are minimized and opportunities maximized. A good metric manager will quickly repay his or her cost by:

- providing a focal point for inquiry and thus saving staff time, by averting some costly mistakes;
- identifying and opening up some lucrative opportunities;
- creating useful communication links;
- making possible active participation in decision-making rather than passive acceptance; and,
- ensuring that the funds allocated to metrication are sensibly spent.

A hard-working and knowledgeble metric manager is one of the key representatives of an organization during the change to SI.

The principal metrication management activities and their relationships are illustrated in Figure 1.2

Figure 1.2: Metrication Management Activities and Interrelationships



F. Preferred Values: Making the Most of Metrication

A major justification for the change to SI is the industrial and commercial opportunity to reduce variety in order to achieve economies of scale. A preferred product range from which "lame ducks" have been deleted creates longer production runs, better inventory control and turnover, more ready availability of items, and better quality control. These benefits suit the customer as well as the producer and distributor.

Even in the supermarket it is difficult to make value-for-dollar comparisons when confronted with a jumble of packaging quantities and container shapes. It would be much more effective to have an agreed, preferred range of packaging quantities and containers; not only from the viewpoint of the customer, but also in regard to handling, transportation and storage in warehouses, on supermarket shelves, or in cabinets in the home. Metrication holds the key to such a development.

In the construction community, previous attempts to coordinate building product sizes with building dimensions through a common fundamental unit of size (or module) and preferred multiples, have only met with limited success. No forceful catalyst existed to bring about "dimensional coordination." The change to SI is a unique opportunity to change to preferred dimensions and sizes - preferably those that have been agreed upon internationally - so that design, production and construction have a common reference framework, in which greater accuracy and less waste of materials, labor and energy occur.

These are typical examples of the long-term pay-off that could flow from an intelligent change to preferred metric values and more rational product ranges, and general variety reduction in areas where too much variety is costly and unnecessary.

G. Metrication: Not Everything Needs to be Changed

Common sense must prevail in metrication; rationalization should only be carried out where it benefits the community or is cost-effective in the longer term. This is another important lesson.

There are times when the "ardent decimalists" should be stopped, because a simple, direct conversion of existing values is the "only" solution. For example, it would be foolhardy to advocate the change of the 'standard railroad gauge' from the present 4'-8 1/2" to anything but the direct conversion of 1435 mm; the cost of changing to a "preferred dimension" of 1450 mm or even 1500 mm would be astronomical and totally unwarranted.

For most manufacturers, opportunities exist right now to launch new products as "metric products in disguise," by marketing preferred sizes or quantities under customary descriptions. This means that any subsequent change requires no more than a new label, one size or quantity fits the requirements of the customary and the new metric market.

H. The Most Effective Training is On The Job

Comprehensive metric training programs should be reserved for metric trainers! Most people in the community need no more than brief familiarization with job-related units and quantities. With the aid of an authoritative reference document on SI usage, any metric job can be tackled. Metric units are most readily learned in a work environment where they are directly applied; thus, familiarization should not be commenced too early.

The general public will need only a basic working knowledge of the key units for length, area, volume and capacity, mass (weight), and temperature. These units are quickly assimilated. Permanent metric recognition points can be easily remembered, such as height, body mass, length of arms or fingers, etc.

Despite the claims of some people, most tradesmen need no more than three or four units of measurement in their jobs; and, these units can be learned easily in just a few hours. However, engineers and scientists use a much greater variety of units in their daily tasks. It is fortunate that they have been trained to grasp new concepts readily, because they will be in the vanguard of those in the community who will work in SI first. Also, these disciplines can be expected to accept some of the burden of familiarization through self-training, so that they are able to guide others into metrication, when needed.

The ideal sentinels for correct SI usage are the proof-reader, the editor, the typist, and the type-setter. It is important that all of these professions receive some general instruction in correct SI usage, together with a reference manual on correct SI practices. While they cannot ensure that calculations or values shown are accurate, they can scrutinize the text for proper use of units, symbols, and punctuation.

CONCLUDING REMARKS

Metrication can be fun, provided people do not look for problems but keep a watchful eye for opportunities, and then grasp them.

The key to effective metrication is management, because only management can ensure that predictions and proposals become a reality.

It can be forecast with some certainty that 1978 will become an important metric date - the year in which the United States will cease its drift into metrication and establish a well-planned, national approach to the change in which all parties cooperate and coordinate their activities to bring about an SI United States.

A good start can be made by being metrically curious. Buy a metric measuring tape and/or ruler to measure some everyday objects; purchase a metric kitchen scale to see what "masses" are consumed, or bathroom scales to measure body mass in kilograms; or, set up a Celsius thermometer to find out where the freeze begins. There may even be some surprises in store. For instance, in the cover design of this publication the square with the heavy outline has sides of 100 mm--or, one building module.

SECTION 2

Metrication in the Construction Community -

The Role of the Federal Agencies and the Public Construction Sector

Paper prepared for presentation at the meeting of the Federal Agency Metric Construction Panel, Metrication Subcommittee of the Interagency Committee on Standards Policy, held on May 19, 1977, at Gaithersburg, Maryland.

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INTRODUCTION

Public building programs in the United States are initiated by

- agencies of the Federal (United States) Government,
- agencies of the fifty (50) State Governments, and
- a very large number of city and county administrations.

The Federal public sector finances over one third of the national building activity. It is estimated that 37 cents of the United States construction dollar are contributed directly or indirectly through taxes or rates collected from the community.

The impact of metrication will be large. It will change the entire measurement base of the construction community. In the public construction sector, metrication will be felt principally in software (paper based) activities. New guidelines, codes, standards, drawings, specifications and associated documents will need to be prepared and published in time to coincide with and support the national metric program. Staff will need to be familiarized with or trained in the use of SI to carry out tasks in a new "metric" environment.

The costs associated with conversion can only be recovered by extracting maximum benefits from the change in the medium- to longer-term. While costs are a one-time matter, benefits due to improvements made during the change will continue to pay dividends over a long period of time.

If overseas experience is a guide, the private sector will look to the public sector for advice, active support, and a certain amount of initiative in the form of early metric demonstration projects. However, unlike most other English-speaking countries, the United States has no single, comprehensive Federal design construction agency which could be designated to take on the role of a metric leader for the construction community.

It is most important that all Federal agencies with an involvement in construction have a clear and early awareness of the implications and opportunities that are associated with metrication. It needs to be appreciated that a joint Federal approach to the tasks associated with metrication is desirable, both to share effort and to avoid unnecessary duplication.

A. Overseas Precedent and Lessons for the United States

Among the many English-speaking nations that have abandoned their traditional measurement systems in favor of SI during the past ten years are five major ones: namely, Britain; South Africa; New Zealand; Australia; and Canada. The experiences of these countries during the period of change provide valuable lessons to the United States, because their planning and implementation mistakes need not necessarily be repeated and technical solutions developed can be analyzed and used as precedent.

In Britain, Australia, and Canada, the construction industry was a leader in the national metrication program and the government sector was significantly involved in planning and implementation.

The Departments which participated actively in the metrication program of the construction community elsewhere were:

Britain - Ministry of Public Building and Works (now part of the Department of Environment)

Australia - Commonwealth Department of Works (now Australian Department of Construction)

Canada - (Department of) Public Works Canada

In addition, regional (Britain), state (Australia) and provincial (Canada) governments provided active backing of the metrication program within their domains.

The development of a positive stance in the government sector in these other countries probably was due to early recognition that without federal and state involvement in metrication planning and responsible shouldering of some of the burdens of change, there would be a prolonged hiatus (with neither metric nor customary measures dominating the industrial scene) and correspondingly greater costs for all parties concerned. As all costs within an economic system are directly or indirectly borne by the consumer, a period of intensive planning, followed by a short, sharp change (with full support of the design sector and the materials production sector) represented the least cost metrication alternative.

B. Timing of Metrication

A national metrication program must be carefully planned. It should provide an optimum time cycle that allows each respective sector to accomplish the necessary changes at its own pace, but without delaying other sectors. Many producers can change to production in preferred metric sizes. However, widespread changes should be made only when a strong demand for metric products is felt or developed. Demand comes with contractor's orders for metric-size building products, components, assemblies and accessories. Demand does not come from designer's drawings. However, a significant volume of designs documented in metric (preferred) dimensions and values is essential to generate such demand. Without a proper plan for design and production, a vicious circle develops in which neither sector is willing to move.

A commitment by the government construction sector, both to metrication and to a program (timetable) agreed upon by the entire construction community, would serve to avoid a vicious circle of prolonged and costly inertia. Forward planning of construction projects in the government sector normally takes place over a somewhat longer time cycle than in the private sector. Therefore, it is easy to identify and designate projects falling into a metric production/construction period well in advance and to document these projects accordingly.

It is of the utmost importance to the success of a metrication program to designate a target or M-Day as a focal point for the construction community. The M-Day indicates the point in time after which all new projects should be constructed in metric (preferred) units. This would provide for a rapid build-up of demand for metric (preferred size) products which, in turn, would allow manufacturers to make a once-only change to metric production on or about that M-Day.

The M-Day concept, however, causes some problems for the design sector. There can be no single commencement date for fully metric design. In large or complex projects scheduled for construction after M-Day, metric design and documentation will have to commence a few years prior to the M-Day, while in small or simple projects the lead-time will be just a few months.

Metric design, in turn, requires a wide array of technical information (codes, standards, handbooks, product literature, and industry information in metric units). These data must be available even earlier because without them conscientious metric design is not possible. Therefore, the time it will take to commence an effective change-over in the construction community is the preparatory activity time needed to establish a comprehensive metric technical data base.

Once the "flywheel effect" has overcome inertia, it is expected that intensive activity will follow quickly and metrication will be effected without major problems. It can be predicted with some certainty that the government sector of the construction community will be called upon to play a significant role, both in the development of much of the essential metric technical information and in the commissioning of early metric projects.

C. A Time/Cost Framework for Metrication Planning

In general, the overseas precedent has demonstrated that total metrication costs for the construction community are strongly time dependent. The "total cost" of metrication is the sum of direct and indirect costs.

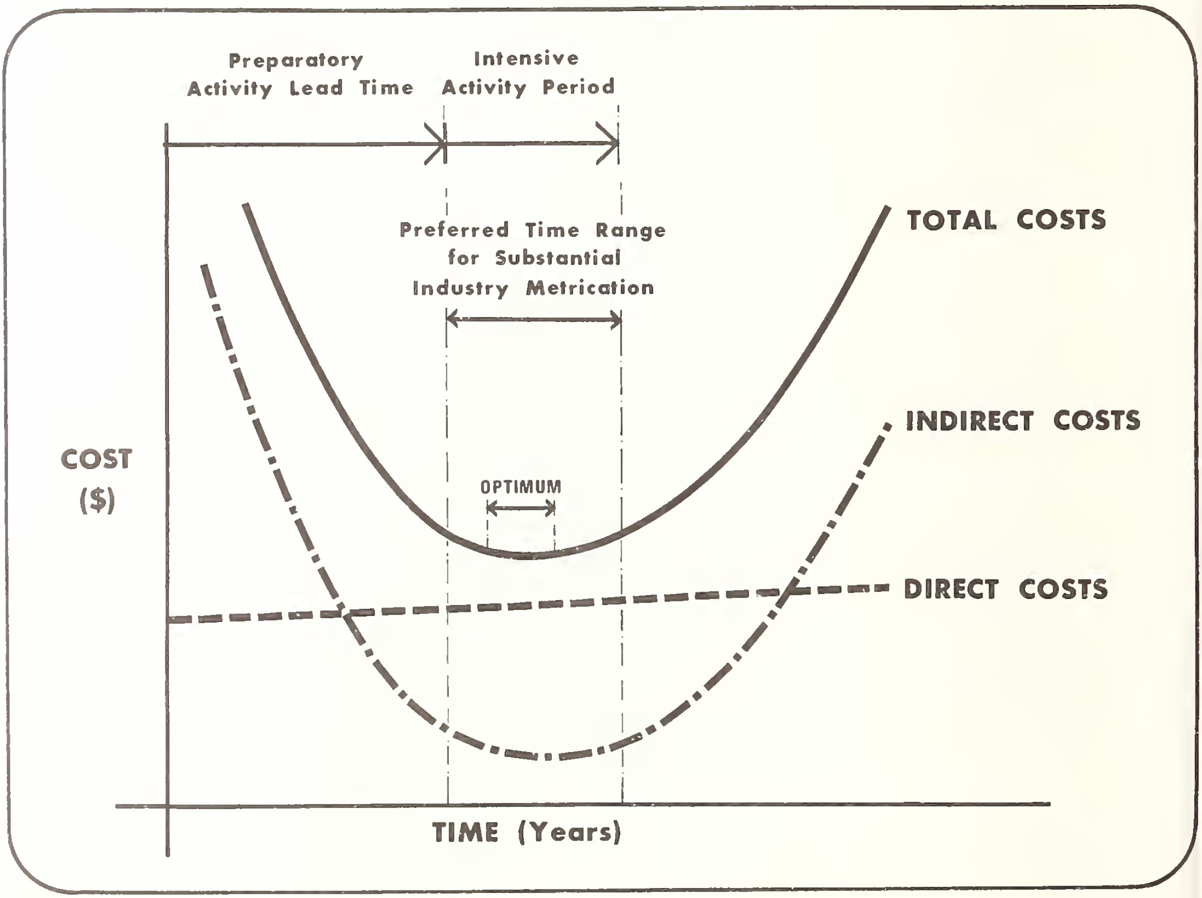
The "direct costs" of conversion increase with time. These are costs which are associated with procurement, replacement or modification of items, and the training of people. These are related to general increases in costs or inflation, and can be represented by a linear function.

The "indirect costs" of conversion are a different matter; they can best be represented by an exponential function. If the metrication period is too short and discourages rationalization in the interest of speed, leaving inadequate time for necessary preparatory activities and demanding a crash program on all fronts, then the indirect cost will be very high; the shorter the time the higher the cost.

One of the indirect "costs" is the loss of opportunities that, once foregone, will not come again. If, on the other hand, the metrication period is so drawn out as to be devoid of momentum, indirect cost will also rise dramatically. The greatest cost in a slow program is the undesirable and expensive requirement to run two systems and product lines side by side for an extended period of time.

The optimum M-Day will fall within the optimum time/cost phase, where total costs are at their lowest level. Intensive metrication activity should take place during the least cost period indicated in Figure 2.1 by the shallow porton of the cost curve.

Figure 2.1: Schematic Time/Cost Relationship in Metrication



Forward planning can establish an optimum time/cost frame for the metrication program in the construction community. Good management will achieve the targets that are set, if they are realistic targets. Metrication cost estimates, like metrication time estimates, tend to be on the conservative side. If too much time is allowed, the general momentum will be reduced and costs will increase.

The "lead-time" now available ought to be used for research, analysis and forward planning. It is invaluable because a start can be made on many key activities. Lead-time, once squandered, can never be fully recouped.

One man year of lead-time, effectively applied, will equal many man years of peak time effort.

D. <u>The Principal Benefits of Metrication in the Construction Community</u>

Basically, there are four (4) benefits flowing from metrication in the construction community.

1. A coherent, simple and more accurate measurement system (SI) for the design, production and construction industries will speed up all forms of calculation, estimating, and verification by actual measurement. Because both design and construction are very measurement intensive, a better and more easy-to-use measurement system will increase productivity.

2. The development and implementation of an industry-wide system of coordination of dimensions for design (preferred dimensions) and for production (preferred product sizes), based upon the internationally-recognized unit of size (100 mm module), will facilitate construction and reduce waste of time and materials. This is the key opportunity, the achievement of which - on its own - would make metrication worthwhile and repay all the costs incurred.

3. The reduction of unnecessary variety in building products, and the rationalization of product range, by substitution of in-between sizes or elimination of non-standard sizes, will simplify production, inventory and procurement processes and reduce costs to the manufacturer, supplier and customer.

4. The review, simplification, and harmonization of measurement sensitive procedures and of measurement intensive processes represents a significant fringe benefit of metrication. Some typical examples of this are:

   - Development of fully compatible design drawing scales for use by all professional design groups will facilitate comparisons on drawings, point out errors, and also eliminate much redundant information;

   - Reduction in variety of linear measuring instruments will speed up measurement and increase accuracy;

   - Facilitation of computer aided design and documentation techniques in a metric environment will increase productivity and offer a larger choice of cost-effective alternatives;

- Revision and harmonization of building codes and building standards and a reduction in the number of dual specifications (government and private sector) will assist the industry-at-large and save productive time in design, ordering, manufacture, construction and building control; and,
- Revision of the entire construction industry data bank, in line with the present day technology, should ensure that up-to-date principles are applied throughout the industry.

Much of this rationalization could, of course, be effected without metrication. However, any attempt to do so is likely to be impeded by traditional prejudices and resistance to change. The metric change is an opportunity to jettison substandard practices and to eliminate irritations and bottlenecks.

E. The Need for Federal Anticipation and Metrication Planning

Although former President Ford signed Public Law 94-168, the Metric Conversion Act of 1975, on December 23, 1975, the U.S. Metric Board provided by that Act, was sworn in only recently (March 31, 1978).

Over the past few years, the private sector of the construction community has embarked on a voluntary range of metric activities under the auspices of the American National Metric Council (ANMC). The Construction Industries Coordinating Committee (CICC) within that Council and its Sector Committees have examined issues relating to metrication of codes and standards, design, production, construction, and land measurement.

To develop a programmatic stance by Federal Agencies on metrication planning in the construction community, high priority should be given to the following activities.

- The development of a metrication impact awareness program to familiarize executive and top management levels in all Federal construction-related agencies with issues, potential problems, and opportunities in metrication.
- The appointment of a metrication coordinator with direct access to top management to plan, coordinate, and overview the activities required in support of full agency metrication. Depending upon the impact of metrication on the activities of an agency, this coordinator may range from a full-time director to a part-time official. Whatever level is assigned to the coordinator, an enthusiastic person will quickly repay his/her cost.
- The functional operation of an interagency metric policy committee or panel to act as a focal point on metric matters related to building design and construction. The coordinator suggested above would be the logical representative of his/her department or agency on this proposed panel.

Membership on such a Federal Agency Metric Construction Panel (hereafter referred to as the Panel) should be extended to all departments/agencies with:

- construction program development or overview responsibilities
- construction standards development or enforcement responsibilities
- financing or budgeting responsibilities with respect to the construction industry

Other Federal agencies could be invited as "observers."

F. Activities of A Proposed Federal Agency Metric Construction Panel

Activities of the Panel would include:

- Establishment of common goals and objectives for the Federal construction sector.
- Development of interagency channels for the exchange of metric information.
- Development of two-way communication channels within:
  - the Federal sector
  - the governmental sector (Federal, state and local government)
  - the construction community at-large.
- Development of a list of key activities, their sequence, and duration, as a basis for a Federal construction sector metrication program scheduled in harmony with an overall national timetable for voluntary conversion.
- Preparation of a detailed operational plan which allocates activities, responsibilities, and targets in an effort sharing program. (For instance, one set of metric practice documents ought to suffice for all Federal agency construction activities and provide a common format. The alternative--each agency developing its own guidelines and manuals--involves costly duplication and is more error prone.)
- The initiation and sponsorship of Federal metric construction research and demonstration building activities to guide the construction community at-large.
- The allocation of responsibility for effective liaison on metrication with Federal agencies in other countries, and on metric standards development at the international level.

CONCLUDING REMARKS

Precedent has shown that the public sector of the construction community has an important role to play in the achievement of an efficient and effective metrication program. In other countries, the respective government sectors proved that they were willing and capable of providing the construction community with active support and momentum during metrication.

Notably, the government sectors of other countries were able to participate in an industry-wide system of dimensional control for buildings in conjunction with metrication. Such a system provides long-lasting benefits to all parties associated with the building design, construction and production processes, and to the community at-large, through building clients and users.

The metric opportunity to achieve a real up-date of the construction community will come only once and it should not be missed. Government agencies have a significant role in this transformation.

SECTION 3

The Principal Management Considerations in Metrication of Construction Standards and Codes

Paper prepared for presentation at the meeting of the Construction Codes and Standards Sector of the American National Metric Council's Construction Industries Coordinating Committee, held on January 24, 1977, at New Orleans, Louisiana.

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INTRODUCTION

Building standards and codes represent an essential ingredient of the technological framework of the construction community--and possibly, the most important part of this framework. These standards and codes establish guidelines and limitations for the design, production, and/or construction processes in the interest of community standards of health, safety, convenience, economy, technological capacity, and energy conservation. Normally, standards and codes are reactive--they are revised or supplemented by consensus processes only when community standards change.

However, metrication introduces a totally new element of review. The change to the International System of Units--SI--requires the almost complete replacement of the existing and familiar "quantitative" technical data base with "new" numbers and units expressed in SI. The selection of preferred metric values becomes an essential adjunct to the formation of the metric data base, because simple numbers are more easily memorized and used in technical or measurement activities. The conversion, rounding, and rationalization of standards, codes, specifications, and associated technical data must be substantially completed before a "real" metric environment is practicable--an environment in which design, production, and construction are carried out in metric (SI) units.

At first sight, the tasks associated with the development of an entirely new data base for the construction community seem to form an almost insurmountable barrier. Various ad hoc estimates have been made of the length of time needed to accomplish metrication of United States building standards and codes; but none of these estimates is optimistic that the work could be completed within three or four years. Metric precedent in other countries--such as Britain, Australia, and Canada--has provided many valuable planning lessons and has shown that many activities can be undertaken simultaneously rather than progressively, thus shortening the activity cycle.

This paper deals with the "management components" of a metrication program for standards and codes. The considerations are relevant at the national and regional levels, as well as at the level of the individual standards or codes writing organization. The recommendations are based on the experience of Australia and a number of other English-speaking countries which have preceded the United States in the change to metric units. While conditions may differ in the U.S., the experience of and precedent from other countries will yield useful conceptual assistance in the planning and management of a metric program. It is also suggested that the technical approaches to the review and rationalization of standards and codes during the changeover should be developed at the national level to minimize unilateral and conflicting proposals, and to emphasize preferred metric values rather than direct equivalents of existing benchmarks.

The "metric opportunity for unification, harmonization, simplification, and rationalization" will come only once, and the standards and codes sector of the construction community has the first chance to make good use of this opportunity to provide the best possible metric base for design, production, and construction.

Part I

METRIC MANAGEMENT IN PERSPECTIVE

The experience of countries that have virtually completed metrication in the construction community indicates that a successful transition in the standards and codes segment of that industry is greatly facilitated by:

- A positive approach and commitment to change at the national level.
- Balanced representation in committees concerned with metrication to guarantee an adequate presentation of viewpoints (geographical, political, and industrial) in all decisions with an industry-wide impact.
- Consensus procedures to guarantee that all voices are heard and that recommendations have full or majority support.
- An industry-wide communication network for two-way flow of information dealing with planning, scheduling, and implementation decisions.
- The establishment and support of task groups to ensure proper investigation of key technical and functional aspects of metrication and to provide optimum solutions for use in the solely metric environment of the future.
- The overall coordination of metrication processes by acknowledged metric planning committees which can provide mutual reinforcement and action at the right time by all sectors, and groups within a sector, to minimize the time and costs involved in metrication.
- The regular monitoring of the metric program to resolve problem areas, remove bottlenecks, and guarantee a timely and smooth implementation phase.
- The development of familiarization programs to assist people to work effectively in a metric measurement environment.

The key element in successful metrication is "good management," which provides the coordination for all activities. In Australia, metrication was described as a "management exercise with technical overtones," rather than as a technical activity with certain management aspects. In the developmental processes for metric building standards, codes, and associated technical data, it is essential that a management system is developed which will ensure that the many thousands of necessary documents will become available at appropriate times in the program, as well as in correct metric units and, desirably, preferred numbers.

Various aspects of the metrication management process in relation to construction standards and codes are discussed in this paper. The principal activities which have been selected for examination are:

- Organization - the development of a representative mechanism for the planning, scheduling, and coordination of decisions during the change-over period; and, the development of communication channels for information flow and feedback.
- Investigation - The analysis of areas affected by metrication and identification of key activities; the investigation of precedent; and, identification of potential problems and opportunities.
- Planning and Policy Formulation - the establishment of a set of general and/or specific objectives against which metrication accomplishment can be measured; the development of a metric policy (or policies) to guide the conversion process; the determination of alternative strategies for conversion; the selection of the most suitable and/or cost effective strategy by consensus procedures; and, the determination of activity sequences.
- Scheduling - the allocation of targets for commencement and completion of the major metric activities; and, the prioritizing of various components of each major activity to provide a hierarchy of sub-activities. (The scheduling activity in standards and codes development is regarded as a key element in the entire metrication program.)
- Implementation - the coordination of tasks; the development of awareness programs for the industry, and of familiarization/training programs for specific sectors or groups; the monitoring of progress and resolution of any problems; and, the conclusion of the transition when the orderly transfer has been substantially completed.

Part II

ORGANIZATION

A. Structure

The development of a responsive organizational structure for metrication is an essential precondition in any national conversion program. Precedent has shown that a simple, activity-oriented structure will result in fewer overlaps and communication problems. Therefore, it will expedite metrication compared with a detailed and complex structure. However, in a simple structure it may be necessary to limit representation so that committees remain workable and are not handicapped by excessive size.

In all countries that have preceded the United States in metrication, a hierarchical committee structure was adopted, in which successive layers of the pyramid reflected more and more detailed metric concerns. At the national level, overall planning for the metric change was normally handled by a Metric Board (or Commission) with a majority of private sector members. These members were selected for their representative status of major activities in the community as well as their geographical location.

Each sector or major activity area--such as construction--had a Coordinating Committee (or Advisory Committee, Steering Committee), again with national membership reflecting all specialist sectors in that industry. Each Sector Committee provided knowledgeable membership capable of planning and scheduling conversion activity within that specific sector component. Where necessary, subsectors complemented the sectors in specific and narrower activity areas, and at this level members of individual organizations with an active interest in metrication would come together.

In the United States, an informal planning mechanism for metrication--the American National Metric Council (ANMC)--was established by the private sector in 1973, to coordinate voluntary conversion activity at the national level. Within ANMC, a widely representative metric coordination group for construction--the Construction Industries Coordinating Committee (CICC)--was formed early on, and in 1975 the Construction Codes and Standards Sector (CCSS) was formed. The CCSS was specifically formed to address the metric issues facing those groups involved in the development and promulgation of essential reference publications of an official nature (such as standards and specifications). In turn, the CCSS has formed eight subsectors dealing with self-contained elements of the technical data scene. The subsectors will undertake metric management activities in task areas such as building standards and codes, mechanical standards and codes, electrical standards and codes, fire prevention standards and codes, etc.

While the structure outlined in brief has been established in an "informal" setting under the auspices of ANMC, it is likely to remain active when the U.S. Metric Board becomes operative.

B. Communication Networks

A major task, directly related to organization, is the establishment of communication links to all significant standards and codes writing organizations in the United States to provide two-way channels for the flow of information and liaison. There are over 120 building standards organizations, four major model codes, and thousands of relatively independent code promulgating jurisdictions. In addition, contact should be established and maintained with select organizations outside the United States, both at the international level--such as ISO, the International Organization for Standardization--and at the national level--such as with Canada, Britain, Australia, and other countries with useful technical precedent in this area.

Part III

INVESTIGATION

The lead-time between current voluntary activity and an ultimate commitment to a coordinated change to SI, within the guidelines of a nationally agreed timetable for the change, ought to be utilized for investigation activity.

Two broad investigative activities can be isolated. Firstly, relevant precedent from other countries that have been or are engaged in metrication might be assessed to obtain an idea of:

- the scale of conversion activity required,
- the "real" or principal issues, planning and scheduling sequences,
- the likely bottlenecks and problem areas, and,
- metrication opportunities.

Of these items, the latter is the most important.

After taking into account the structural differences and arrangements that exist in the United States, the investigative effort should be directed towards the analysis of "national," "regional," and "local" factors in metrication, leading to the identification of key activities in the conversion program. It is on these key activities that the bulk of the management effort should be concentrated to ensure an orderly progression within the program and, therefore, cost-effective metrication.

It is of extreme importance that the measurement sensitive parts of key activities be analyzed to determine the magnitude of conversion effort required, and to obtain a feeling for the interdependency and sequential relationships within activities.

Part IV

PLANNING AND POLICY FORMULATION

Planning activity in metrication for the standards, codes and essential reference publications segment of the construction community is a major element of the total program.

A. Establishment of Metrication Objectives

An early policy planning item is the preparation of a "statement of metrication objectives" for construction standards and codes. Metrication represents a once-only opportunity for review, rationalization and harmonization in the building standards and codes field. A major objective for the change should be the accomplishment of more uniform essential reference documents. Other objectives of a more general nature are the timely preparation of key reference documents, the minimization of a "dual period," and the avoidance of unnecessary cost or confusion.

With objectives explicitly set down, it becomes possible to measure all metric activities against these objectives, and to assess whether or not these objectives are met. Moreover, the availability of objective statements facilitates the monitoring of progress, as they provide goals for the sector, the subsectors, and individual groups within the sector in terms of "What ought to be achieved during metrication?"

B. Development of Metric Policies to Guide the Conversion Process

It is highly desirable for the sector to develop an overall high level "General Metrication Policy" which would represent the general goals and acceptable procedures. Each individual group could supplement the policy in specific areas, such as a policy for training or familiarization of staff; a policy on metric procurement; a policy on the acceptance of metric and/or rejection of non-metric drawings, specifications, or calculations during the transitional period; and, a policy on accounting for metric costs and benefits (savings).

Among the procedural determinations that ideally should be made at the sector level are the following:

- Are specifications or standards giving "dual values" acceptable, and, if so, for what period of time?
- If dual values are allowed, should the metric value be stated first? Or, should all customary values, because of their declining significance, be shown in brackets?
- Should a general (or "omnibus") decision be made which would allow a certain percentage deviation from customary values--say 5% or 2%--in the determination of metric values, to ensure that metric values are "preferred" or, at least, "convenient" values?
- Where it is decided to use a "hard conversion" approach to new and different magnitudes, should customary equivalents be provided in an Appendix--preferably one that used perforated pages so that it can be removed when no longer required?
- Where it is decided to use a "soft conversion" only--that is, a minimal change in description but no significant change in products or requirements--what degree of rounding can be applied to magnitudes?

C. Development of a Metric Practice Guide for Standards and Codes Conversion

The policy, procedural determinations or suggestions, and other helpful information for use in metrication of standards, codes and other essential reference publications, is best communicated by means of a "Metric Practice Guide," designed to provide a uniform basis for practical metrication. Such a guide would ensure that different groups and committees involved in metrication of standards, codes and associated technical data, will be able to proceed on the basis of common principles, procedures, and conversion/rationalization processes.

Alternative strategies for conversion should be discussed within the metric practice guide, and their effect illustrated, so that individual groups can determine which strategies are best suited to their needs without prejudicing their own interests or those of the sector at-large.

The practice guide could also show the names and affiliations of people connected with metric planning in the sector to provide a ready reference and contact points for two-way information flow.

D. The Determination of Activity Sequences and a Metrication Plan

The planning process for metrication leads to the development of a "planned sequence of conversion activities." This is a structured network of all major activities necessary to accomplish the change, showing their relationships either as parallel or sequential activities.

The development of the "sequence of activities" will indicate quite clearly which activities are "critical" activities, due to their strategic importance within the schedule. It will also show which activities can be commenced during the "lead-time" phase, prior to a formal commitment to a definite metric timetable for the change. Thus, it will provide a visual reminder for conversion activity. Activities that have been completed can be marked off on the schedule.

Part V

SCHEDULING (TIMING OF METRICATION ACTIVITIES)

A. General

Since the time frame for metrication in the construction community at-large is greatly dependent upon the time it will take to provide metric versions of the essential reference documents for the industry--standards, codes, and other technical data--the scheduling of conversion activity in the standards and codes sector is the key element of a metric conversion program.

From experience in other countries it is suggested that an overly long development phase in the standards and codes segment of the industry will militate against an effective metrication program, because it does not yield the sustained impetus that is desirable. It will require work with two measurement systems for a prolonged period of time with all the attendant additional costs, and will also cause antagonism in many people due to uncertainty.

Conversely, if the time frame is too tight, it will demand a crash program with considerable increased costs and loss of opportunities for review and rationalization. This will lead to "superficial" metrication with extensive use of a metric "veneer," due to soft conversions. Invariably, superficial metrication becomes costly in the longer run despite its apparent initial expediency, and requires a second change to more rational metric values at a later stage.

In terms of timing, the Construction Codes and Standards Sector is a "lead sector," with the bulk of its work required prior to an "M-Day" for the construction community.

B. Timing and Priorities

Scheduling involves the realistic time allocation for substantial--but not necessarily total--accomplishment of metrication of standards, codes and associated technical data; as well as the designation of priorities in terms of "what should be done when."

To establish firm targets within a calendar time scale, it is necessary for a sector program to be developed in harmony with an overall construction industries program. Precedent has shown that most metrication activities have some form of overlap, so that metrication can be effected substantially "in parallel," rather than "in sequence." Parallel scheduling makes it possible to reduce the total time commitment for the technical activities in the sector and, thus, in the industry. A lot of the technical work can be commenced now, long before the "official" starting gun has been sounded in the construction community. For example, new standards can be developed so that the values included are "preferred metric values," even if they are shown disguised by a "customary veneer" for the time being. This greatly facilitates the issue of a metric version of a standard, since it will minimize the technical discussions necessary, and not necessarily require an exhaustive committee process to approve the document.

In the development of sub-programs, individual standards, codes, or regulatory organizations need to be aware of their interrelationships and obligations with respect to other sectors of the construction community, or other bodies providing essential reference publications. The impact of metrication needs to be ascertained for data in three categories:

1. data developed internally and under full control;
2. data developed internally but separate from similar data prepared by external groups; and
3. input data required in the development process, but prepared by external groups an thus not under full control.

Within the sector, as well as within each major group, an orderly approach to metricatio needs to be scheduled, so that the important documents are developed in their order o hierarchy of significance. Targets should be set for the accomplishment of metricatio in various groups of priority.

C. A Precedence System for Metrication of Standards, Codes, and Other Essential Reference Publications

To allocate precedence in the metrication program for essential reference publications of an official and industrial nature, it is necessary to categorize such documents according to their significance in terms of impact and priority.

1. Categorization of Documents

All building standards, codes, and associated technical reference publications containing quantitative information that needs to be converted should be listed. In addition, a list should be prepared of topics for essential "new" metric documents--without any customary precedent--which are required to effect or facilitate the transition to a metric environment. These lists can then be classified into four categories of impact during the change to SI:

Category A - Development of new standards or reference publications required in SI units and preferred metric values.

Category B - Major review of existing standard, code or reference publications needed in conjunction with the change to SI units. Preferred values are desirable.

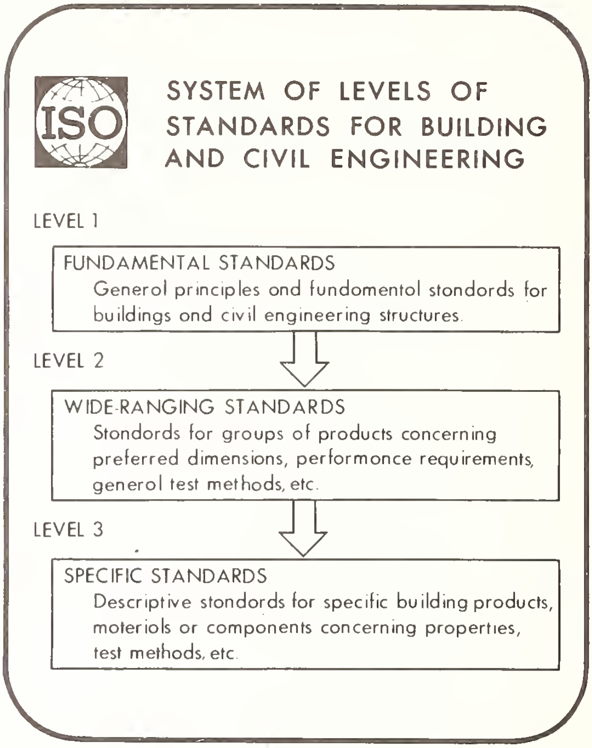
Category C - Conversion of existing standards, codes or reference publications to SI units and, where practicable, to preferred values.

Category D - Retention of existing standards or technical documents with an "interim" metric supplement, showing equivalent values and/or preferred values in SI units.

2. A Hierarchy of Standards

In the international standards development scene, a system of levels is used to structure building and civil engineering standardization efforts. The system has three levels which are arranged hierarchically from the "general," through the "wide-ranging," to the specific. Information from Level 1 feeds into Level 2, and information from Levels 1 and 2 feed into Level 3. The system of levels, shown in Figure 3.1, can be used to assess priorities in the standards development program, and also indicate links within the essential reference publication system.

Figure 3.1: A System of Levels



3. Criticality of Documents

To measure the criticality of standards, codes, and essential reference documents, it is suggested that each document requiring development or conversion be assigned a criticality index as a measure of its priority within the metrication program for technical information. A four level criticality grouping is suggested:

- Highest Criticality - A small group of absolutely essential fundamental or reference documents required at an early date to establish benchmarks and/or to form the basis for the preparation of other standards, codes, or essential data. This group will include new as well as some significant converted documents.

- Major Criticality - A larger group of essential and wide-ranging reference standards, codes and associated documents, required in design and production. This group will probably contain the major standards and other important documents which form the principal reference base for the construction community.

- Medium Criticality - This group will contain the bulk of general standards and other reference documents dealing with more specific practices for use in production or construction, and descriptive data on materials, components, test methods, etc. Input from the highest or major criticality groups normally would be required before these documents can be finalized; however, quite a number of the medium criticality standards can be prepared in parallel to the more significant ones.

- Low Criticality - All other standards, codes, or reference documents which can be converted to SI units and/or rationalized when convenient, but may be issued in the interim with a "Metric Supplement."

Work on the "highest criticality" metric standards and essential reference documents might be begun now, with a possible target for completion within two years. Work on "low criticality" documents preferably should be started only where their production will not detract resources from work of greater significance. The completion target for standards in this category could be in the order of four to five years, with a small ongoing component of residual work extending even beyond that target.

4. The Establishment of Work Precedence (Priorities)

A matrix method is recommended for the establishment of "work precedence" or "priorities" for metrication of standards, codes, and other essential reference documents.

One axis of a "precedence matrix" would show the four categories (A, B, C, D) used in the classification of documents. The second axis represents the assignment of the four criticality groups (1, 2, 3, 4).

Each square in the matrix can then be identified by an alpha-numerical code ranging from A-1 to D-4. A precedence matrix is shown in Figure 3.2, on page 34.

Precedence can now be established by grouping "priorities" within the matrix; for example;

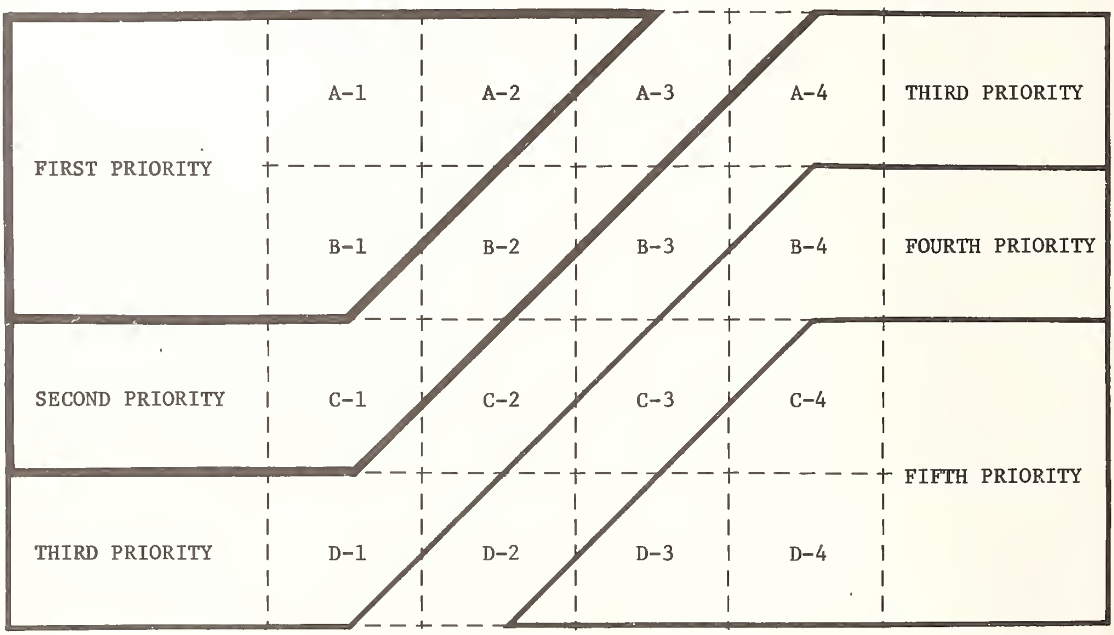
First priority: A-1, A-2, B-1
Second Priority: B-2, A-3, C-1
Third priority: C-2, B-3, A-4, D-1
Fourth priority: C-3, B-4, D-2
Fifth priority: C-4, D-3, D-4

A priority index, using the precedence matrix is shown in Figure 3.3, on page 34.

Figure 3.2: Precedence Matrix

CATEGORY		CRITICALITY			
		1 HIGHEST	2 MAJOR	3 MEDIUM	4 LOW
A	Requirement for a new document in SI units and preferred metric values	A-1	A-2	A-3	A-4
B	Requirement for a major review of the existing document in conjunction with the change to SI and preferred values	B-1	B-2	B-3	B-4
C	Conversion of existing document to SI units and convenient metric values	C-1	C-2	C-3	C-4
D	Retention of existing document and use of an "interim metric supplement"	D-1	D-2	D-3	D-4

Figure 3.3: Priority Index



5. Assignment of Priorities

Ideally, the priorities for conversion should be assigned at the national level for essential documents with national impact. Such priorities once allocated, then are likely to filter through to individual standards, codes, or reference publications developing organizations. These priorities then will be used for the planning of internal responses to satisfy the metric technical information needs of the construction community.

If every essential reference document can be assigned an alpha-numerical designation--and, therefore, a priority--it will be much easier to schedule work precedence and dates of completion, and to monitor any "slippage" in the required technical committee work.

To develop a priorities network based on a precedence matrix and a priority index, it has been suggested that the "Delphi Technique" be employed. This technique is a method of intuitive forecasting based upon the collective opinions of a panel or panels of "experts" with a knowledge of the technical data needs in the construction community.

From a listing of essential reference data, the experts would determine what new standards are needed or what type of revision of existing standards is required. Based on their knowledge of design/production/construction requirements, the experts would then indicate the criticality of these reference documents in the industry processes. A statistical display of all ratings--thus retaining individual anonymity--would be used to determine the need for additional opinions that would challenge or support responses which do not indicate a clearcut preference.

Members for such a Delphi study could be drawn from the ANMC Construction Industries Coordinating Committee, and its Sector Committees on Design, Construction Products, and Construction Codes and Standards.

The alternative to the formal development of a priorities network is to let the staff of standards, codes, and other technical publications organizations develop the priorities system. These organizations could develop such a system in the light of their knowledge of concerns within the construction community, actual sales data for reference publications, and/or an assessment of committee capabilities to deliver metric documents when required.

To assure the best possible start for metrication in the construction community, it is essential that the documents included in the first priority be identified as early as possible, so that work on these documents may be commenced. To further underline their significance, it is suggested that this group be confined to the "Top 20" or "Top 25" documents.

Part VI

IMPLEMENTATION

Implementation of a development program for essential metric reference documents--such as standards, codes, and associated technical data--requires a number of major activities.

A. Coordination of Activity

After the identification of priorities, metrication tasks should be allocated to different groups, committees, panels, or task forces, in such a manner that duplication of effort is avoided as far as practicable. The task allocation should be accompanied by a format for progress reports, as well as target dates (or deadlines) for draft and final documents.

The coordination of metrication activity involves "interfaces" between different community segments (such as transportation and construction), or different sectors of the construction community. This is especially critical where determinations in one area are dependent upon or influencing decisions in another area. The coordinating group--such as a sector committee for metrication--will become the focal point for task allocation and interface coordination. In addition, it may need to establish a mechanism or group to assess metric "harmonization opportunities," such as the unification of currently differing or conflicting requirements in standards, codes, or reference publications.

B. Awareness and Familiarization

Combined with coordination activity is the need to develop an awareness program to keep the standards and codes generating organizations, technical data publishers, building officials, industry groups, other parts of the construction community, and the public at-large informed on:

- the steps that have been taken to prepare a metric data base;
- progress that has been made in general metric implementation;
- any difficulties that may have been experienced; and,
- any other recommendations that could affect business operations.

This activity might best be undertaken under the auspices of the U.S. Metric Board.

The preparation of familiarization material, which will assist standards and codes users in the speedy assimilation of metric conventions and values during the transitional period, is a major challenge which, ideally, should also be coordinated at the sector level. Again, this may need to be undertaken under the auspices of the U.S. Metric Board.

While a national organization--NACA (The National Academy of Code Administration)--may be the logical vehicle to develop metric familiarization programs for building code officials, any familiarization program needs to be launched prior to the actual application of metric standards and codes, whether on a voluntary or mandated basis. Such familiarization and training should enable code officials to interpret metric documents as they emerge in the construction community.

C. Overview and Monitoring

The progress of metrication of construction standards, codes, and other essential reference documents should be monitored at regular intervals. Such monitoring will determine whether and where special effort may be required, and will ensure that agreed availability dates for documents are met. This overview and monitoring requires a reporting mechanism which ensures that problem areas or bottlenecks are actually reported, rather than covered up. Some irritations will arise during the metrication program. However, it is not possible to smooth them out unless they are identified and made known.

CONCLUDING REMARKS

It has already been suggested that the Construction Codes and Standards Sector holds the key to the metric program for the construction community. It is the technical "lead sector" in the conversion program. Without the availability of suitable metric standards, codes, and technical data, there is little chance of metric design, production, or construction. In addition, chaos might well ensue without a systematic and well thought-out management approach to metrication in this lead sector.

The recommendations in this paper are based on experiences gained during active participation in the management program for essential metric reference publications in other English-speaking countries. The precedent from elsewhere demonstrates that the tasks are not overwhelming; they can be carried out more smoothly and rapidly than might be anticipated prior to the active involvement in metric planning and development; and, the end--a new, unified, and up-to-date data bank for the construction community--is ample justification for the effort.

SECTION 4

Managerial and Economic Considerations in the Change to a Metric Production Environment

Paper prepared for presentation at the 39th Annual Convention of the National Association of Architectural Metal Manufacturers (NAAMM), held on May 10, 1977, at Tarpon Springs, Florida.

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INTRODUCTION

It is almost certain that industry and commerce in the United States will become increasingly involved in metric activity by the 1980's, and that by the year 2000 the customary measurement system will have been replaced in nearly all facets of national activity. Optimists even argue that the full transition to metric (SI) units in the construction community conceivably could be accomplished by 1985.

The timing of such major changes should be largely influenced by the economics of the change--the trade-off between metrication costs and benefits across all activity areas in the construction community, such as design, production, and construction. Both costs and benefits are time dependent. If inadequate time is allowed for the necessary changes, then costs will be high and benefits low; if too much time is set aside for the change, then the "nuisance costs" of operating in a hybrid, dual-system environment will be large, and many benefits associated with metrication will not materialize.

This paper examines the principal factors that impinge upon the economics of metrication--the process of bringing about fully metric operations. This is done from the vantage point of hindsight derived in a very successful metric program in Australia.

It is postulated that metrication is a management exercise with technical overtones; an exercise in controlled change based upon proper analysis, planning, coordination, control, and monitoring. With good and dedicated management, it will be possible to turn the "metric problem" into a "metric opportunity;" a different approach which is positive rather than negative and which will have a significant effect on the economics of the process. Therefore, the "cost of metrication" largely can be regarded as the opportunity cost of failing to use the change as a beneficial chance to review and rationalize traditional practices, procedures, processes, and products.

Metrication costs are incurred only once, while all of the benefits that can be derived during the change will continue to pay dividends for a long time to come. Most nations, as well as organizations, that have completed the change to a metric measurement environment have found that the actual costs of metrication are much lower than original or even revised estimates.

Part I

METRICATION MANAGEMENT - THE KEY TO "ECONOMIC" METRIC CONVERSION

Metrication is the process required to achieve a successful transition from the customary system of measurement to the "modern metric system." This system is better known as the "International System of Units," and is commonly abbreviated "SI." Metrication is a management activity involving effective organization at all levels to insure the implementation of necessary changes within the most cost-effective time frame and with the least disruption to community activities. The tools in metrication management are research, analysis, planning, coordination, and monitoring.

In a national metric program, objectives are set and decisions are made at various levels. It is likely that any individual organization will be faced with a time frame for the change, determined by consensus, which it either can follow or disregard. However, if every organization were to establish an individual program for the metric change, regardless of interrelationships within its industry or relations with its customers and suppliers, then almost certainly the result would be chaos. Therefore, it is quite important that each organization develop an interest in the hierarchical metrication management structure that will carry out the national or regional planning for metrication, so that useful information can be contributed as well as received.

A. Levels in Metrication Management

Metrication in the United States has proceeded on a "voluntary" basis, with coordination provided under the aegis of the American National Metric Council (ANMC). The ANMC is a private and self-supporting organization established in 1973, to provide assistance through coordination, planning, and information services to all segments of society in the United States involved in the conversion to metric measurement. The appointment of a U.S. Metric Board to coordinate the voluntary conversion to the metric system, was mandated in legislation (Public Law 94-168) signed by President Ford in December 1975. This Board has only recently been appointed (March 1978).

The legislation specifically states that the Board shall take into account activities already underway, and it is likely that the planning structure developed by ANMC will be retained by the eventual formal metric authority. The ANMC structure consists of a large number of sector committees with the function to plan and coordinate metric activities in the respective sectors of the economy. These sectors are grouped under five coordinating committees, which represent broad segments of the economy. Each sector committee may have a number of subsectors.

Table 4.1 indicates the various levels in metrication management, the major management activities, and examples of representative organizations or activities in descending order.

Table 4.1: Management Levels and Activities

LEVEL	MANAGEMENT ACTIVITIES	TYPICAL REPRESENTATION
NATIONAL	Development of metric policies and overall metric coordination	U.S. Metric Board American National Metric Council
SEGMENTAL [COORDINATION]	Metric coordination within an industry or activity segment; establishment of metric timetable	Construction Industries Engineering Industries Materials
SECTORIAL	Planning for metrication within sectors of industry or commerce; establishment of metrication objectives and guidelines for sectors of the economy	Design Construction Products Metals Codes and Standards Construction
SUBSECTORIAL	Organization of overall metric plans and activity within specific subsectors of sectors in the economy	Engineering Design Architecture Steel Products Building Codes
TASK GROUP or ASSOCIATIONS	Liaison and program coordination in a specific task area, product group, or technical activity	Mechanical Engineering Fasteners Fabricated Steel Products
INDIVIDUAL ORGANIZATION	Corporate metrication management and control: scheduling of corporate metric implementation	Design Firm Steel Fabricating Company Professional Society
SUB-ORGANIZATION	Metrication implementation in a branch, division, office, or unit within an organization	Pressed Steel Division Structural Design Branch Data Processing Unit
INDIVIDUAL ACTIVITY	Detailed implementation of metric decisions	Production Supervisor Press Shop / Press Operator

It is important to realize that the committees or groups charged with the planning and coordination of metrication will not carry out the "actual metrication." Actual metrication will take place in the individual organization, extending down to the individual person within the organization.

Each organizational level has its own specific function in metric management:

- National level - establish the overall policies and guidelines for metrication
- Coordinating, sector, and subsector levels - establish objectives and plans leading to a time frame for metrication
- Corporate level - management activities are predominantly task-oriented; that is, they relate mainly to analysis, planning, scheduling, and implementation of the "real" change.

B. Some "Metric" Questions for Organizational Management

The most important task for management is to establish a metric policy for the organization, and coupled with this, a "set of metric objectives" against which progress, costs, and benefits may be measured.

In a manufacturing organization, a basic and not very detailed objective might be: "To achieve the least costly, least disruptive, and most rewarding change to metric measurement in line with nationally-agreed timetables and goals for the production of preferred metric products established within the construction community." More specific objectives might be developed as the metric program progresses.

It is important to organizational welfare in the transition to metric units that a clear responsibility for metric activity and actions be established. While at first sight metrication may appear to be merely a part-time activity, the appointment of a full-time metric coordinator very quickly will pay back any costs connected with such an appointment. Not only will a metric coordinator provide an internal focus on metric matters, but also will provide a valuable link to the outside world. This link will enable an organization to maintain up-to-date information on metric decisions made outside the firm. As a high-level management exercise, the metric program in a large organization ought to be led by a responsible metric manager or director of metrication.

Metrication management involves a series of value judgments. These judgments should be based upon the thorough analysis of all relevant factors and precedent. Metrication means asking and answering a lot of questions, because without analysis it is inevitable that many of the decisions will be suboptimal. Ad hoc decisions on metric issues could become very costly.

A few of the questions that typically might arise in an industrial production environment are listed below. They are shown for illustrative purposes only and by no means constitute an exhaustive list.

- What changes are necessary or unavoidable (must be made); what changes are desirable (ought to be made); what changes are possible (could be made)?
- What is the optimum time frame for metrication?
- What is the best sequence of activities to bring about cost-effective metrication? Can some important activities be undertaken now?
- What are the advantages and penalties of being an early starter? What are the risks and potential costs of being a late starter?
- What major problem areas now exist? Can any of these be eliminated during metrication?
- How can the best use be made of wastage and planned obsolescence?
- Is there any need for two product lines? If so, how can the organization best cope with two product lines? How should they be differentiated?
- Is it possible to introduce metric products prior to general metrication? If so, what are the requirements, costs and benefits? How can additional metric items or metric replacement items best be introduced into the product line?
- How long will it take to achieve substantial (80%) metric operations?
- How can metrication costs, benefits, problems, and opportunities best be identified, monitored, and evaluated?

These few questions illustrate the role that metric management needs to play. Moreover, answers to these questions should be available very early in the transitional period, so that the most cost-effective strategies can be selected.

Management must determine the "optimum time frame" for the change. This is a delicate judgment because the timing of metrication will affect both costs and benefits associated with the change.

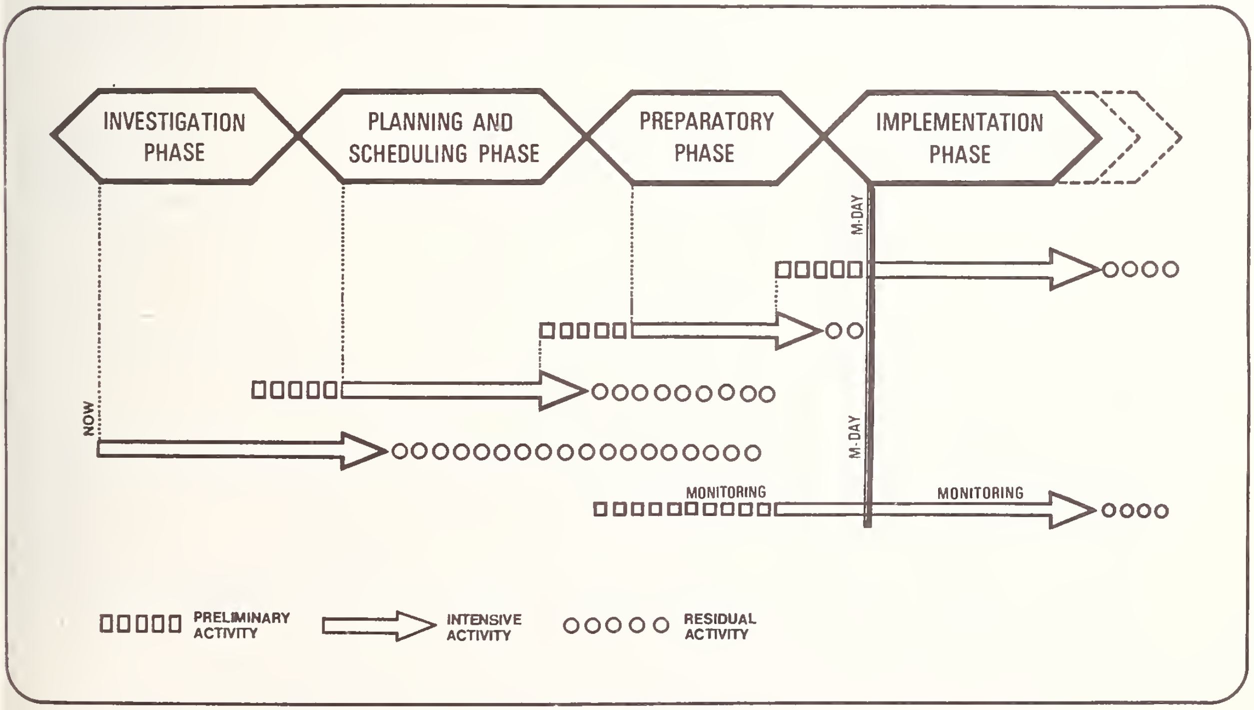
C. Four Phases in Metrication Activity

There are four distinct phases in any organizational metric program:

1. The Investigation (or Preliminary) Phase
2. The Planning and Scheduling (or Problem Solving) Phase
3. The Preparatory (or Commitment) Phase
4. The Implementation (or Action) Phase

The four phases are shown in Figure 4.1, and are discussed individually in this section.

Figure 4.1: The Four Phases of Metrication



In some instances there also will be a "finishing off phase," during which all residual matters should be resolved, so that a fully metric environment is accomplished. Such a phase may extend over a number of years. However, it should take less time than, for example, the disappearance of the "inch" in some metric European construction industries, which took almost a century.

Each metric program has many activities, some of which overlap into sequential phases. And each program activity has its own cycle with a "lead-up component," an "intensive (involvement) component," and a "residual component." In addition, the activity of "monitoring" the results of metric decisions begins in the scheduling phase and extends through the implementation phase.

1. The Investigation Phase

The Investigation Phase is the period for research and analysis, and should now be underway. The principal management activities during the investigation phase are:

- Identification of all areas or activities affected by the change, and the assessment of the extent to which they are affected (e.g., completely, significantly, moderately, or slightly).
- Assessment of international and other precedent, and its relevance to an organizational metric program.
- Examination of alternative strategies for metrication, and their estimated cost-effectiveness.
- Identification of metric opportunities in production, stocking, and sales.
- Establishment of metric communication channels and liaison on metrication with suppliers, customers, industry associations, research bodies, consumer organizations, and national metric coordination bodies.
- Creation of basic metric awareness within an organization.

2. The Planning and Scheduling Phase

The Planning and Scheduling Phase is the period for increasing involvement with metric issues, coordination of activities within an organization and with industry, and the establishment of a time frame for the change. In the assessment of approaches to metrication, alternatives might be stratified into three categories: necessary changes, desirable changes, and potential (possible) changes. The principal management activities during the planning and scheduling phase are:

- Allocation of metric responsibility within an organization for:
  - overall coordination of the change
  - implementation in individual task areas.

- Establishment of a corporate metric policy, and communication of that policy.
- Development of a statement of corporate metric objectives, against which alternative strategies can be assessed.
- Selection, from all identified alternatives, of "optimum cost/benefit strategies."
- Participation in national and/or industry metric planning activities.
- Planning of an organizational metric program, based upon:
  - a listing of all required activities and activity sequences (in a network)
  - the identification of "critical" activity sequences (critical path)
  - the allocation of targets (target dates or periods) for each major activity, resulting in a "metric timetable" for an organization.

3. The Preparatory Phase

The Preparatory Phase is the period during which binding commitments are made to implement the selected metric decisions in production, inventories, and marketing. The key management activities during the preparatory phase are:

- Allocation of funds for metrication in each major activity area.
- Procurement of metric aids, instruments, manuals, etc.; and the modification or replacement of plant and equipment.
- Preparation of essential metric technical data for use within an organization and product information for customers.
- Familiarization (training) and involvement of personnel affected by the change.
- Metric trial (pilot) production.

4. The Implementation Phase

The Implementation Phase is the culmination of all prior activity. During this phase, the actual transition to a metric measurement environment is initiated and substantially accomplished. The implementation phase will take place at different times for different activities. For example, implementation (action) in standards activities normally needs to be very advanced or completed before effective metric design becomes practicable. In turn, metric construction cannot be effectively implemented without metric design or metric products.

To ensure that implementation in dependent activity sectors proceeds on course, with the implementation phase the national coordination effort changes from planning and scheduling to monitoring. The principal activities during this phase are:

- Sequential changes to metric operations in research, design, and production.
- Transfer from a non-metric to a metric inventory.
- Provision of a metric decision point or service, in the event that metric problems arise which cannot be easily resolved.
- Monitoring of costs and benefits of metrication, as well as problems and opportunities associated with the change.
- Finalization of the transitional period by executive action when the organization has become substantially metric, such as the restriction of non-metric work.

The best implementation is one that involves a short, sharp change after the ground has been well prepared during the investigation, planning, and scheduling phases.

D. The Importance of an M-Day

There are some activities in the community where a change to a metric measurement environment can be made almost instantaneously, around a designated focal point in time, or M-Day. However, by their nature building design, production, and construction involve lengthy time cycles. Thus, a single changeover date for all activities is impractical. It is possible to set a "key date" in any metric program, relative to which all program activities can be scheduled.

In the Australian construction community and its associated industries, the metric program was developed around an M-Day (Metric Day), which signified the agreed date for the commencement of the actual, physical changes to a metric measurement environment--the changes in the hardware. Both the production of building materials and the construction of building projects after this agreed date were to be undertaken voluntarily in preferred metric units. The date was carefully selected as January 1, 1974; the start of the new calendar year signifying a metric new year's resolution.

The M-Day provides an overall target in time, relative to which all preceding and essentially paper-based activities can be phased. In the analysis of "lead-times" for necessary specifications and designs (blueprints), secondary target dates may also be indicated, to clearly show the "deadlines" for the accomplishments of significant preliminary activities. In a production environment, this process is not very different from the critical path that is established for the development, production, and marketing of new products. The major difference is that a "learning program" should be built into the planning cycle, to phase-in familiarization or training periods for staff members who are expected to switch from a customary measurement environment to the metric system of units (SI).

A check can be instituted on the entire metric program and all essential activities to ascertain whether the lead-times set aside appear to be adequate for the accomplishment of the necessary changes. This check can be accomplished by working backwards from the agreed upon M-Day. The M-Day for production determines the lead-times for equipment replacement or modification, as well as staff familiarization programs. It also provides guidance as to when the liquidation or run-down of the non-metric inventory should begin and be completed.

Metrication within an industry is almost certain to lose the sense of urgency and commitment without an M-Day. In general, the most sensible approach to metrication is to establish, by consensus, an industry M-Day within the appropriate sector committee of the overall metric authority (such as the U.S. Metric Board, the Metric Commission in Canada, the Metric Conversion Board in Australia, etc). While the change to metric is completely voluntary, the M-Day concept will allow an industry to build up considerable common momentum in all of its activity areas, thus providing a reinforcing effect that permits a fairly rapid transition. It would be unwise for an individual organization to ignore the M-Day and institute a program which either precedes the M-Day, or lags behind it by a considerable margin. While the "early starter" may have difficulty developing a metric market on its own, at least the organization will be geared to operate to full advantage in a metric world. By contrast, the "late starter" could encounter problems and lose traditional markets to more active competitors. And, a market once lost can be regained only with difficulty and at great expense.

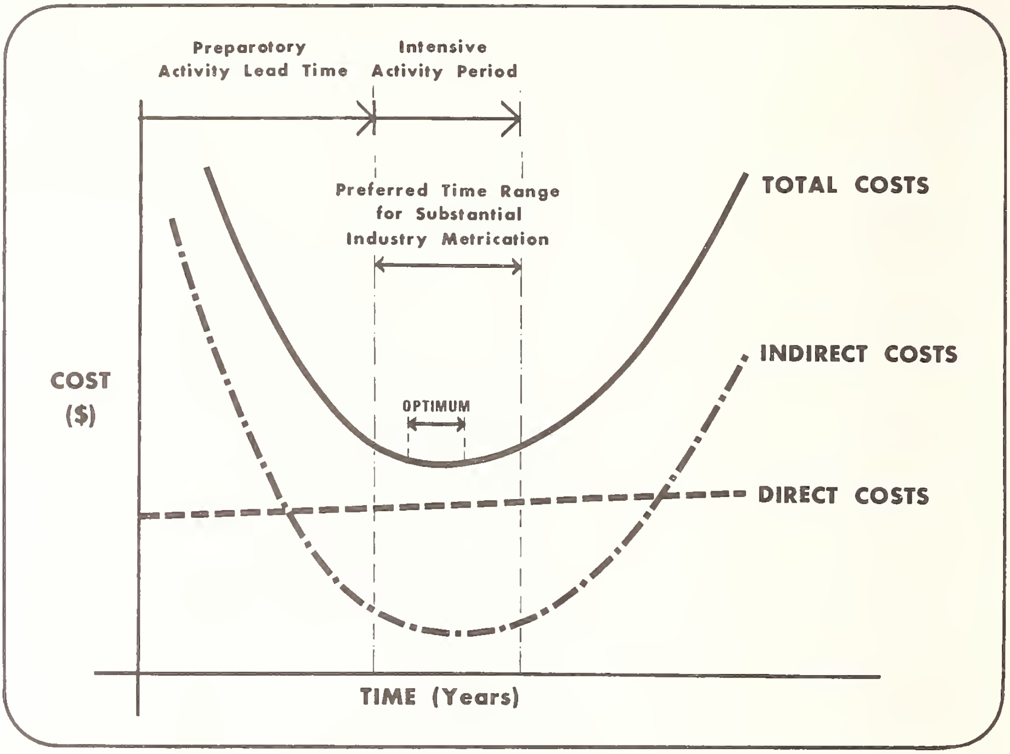
E. Seeking the Optimum Time/Cost Relationship

The most critical activity in the entire metric program is to establish the optimum time/cost framework for the change.

Costs of the change are the combined "total cost" derived by adding the direct and indirect costs associated with metrication. The "direct costs" are fairly predictable and occur once only. They may increase over time only with normal escalations of cost due to natural factors or inflation. Direct costs include the expenses connected with procurement, replacement, or modification of items; familiarization of people; and, the overall management of the change. Direct costs can be shown as a linear function with a slight upward gradient in a time/cost curve. (See Figure 4.2.)

The "indirect costs" associated with metrication are a different matter. They are strongly time-dependent and are best represented by a quadratic function. If the time allowed for metrication is too short and discourages rationalization in the interest of speed, thus leaving inadequate time for all necessary preparatory activities and demanding a crash program on all fronts, then the indirect costs will be very high. The shorter the time, the higher the costs. A major component of such indirect costs is the loss of any opportunities which, once missed, will rarely ever come again.

Figure 4.2: Time/Cost Relationship



On the other hand, if the metrication period is so drawn out as to be devoid of any urgency or momentum, then costs will start to rise dramatically. The longer the period during which two systems operate side by side, the higher the costs. The greatest single cost in a slow metrication program is the undesirable and expensive requirement to live with two product lines. In this situation, neither line can approach the production volume of a single product line, and connected with this is the maintenance of two inventory systems, two sets of records, and two marketing systems.

A lengthy phase-in period simply means having the disadvantages of both measurement systems, and the advantages of neither. This course will inevitably turn out to be the most costly and irritating approach to the metric change. It does not encourage rationalization or more efficient production, but rather it demands many undesirable compromises in order to cope at all.

In the construction industries of other countries that have preceded the United States in the change to metric, the optimum time cycle has been a period between three (3) and five (5) years. This period represents the total time involved from the commencement of formal planning to the implementation date (M-Day) for production and construction. In the time/cost curve shown in Figure 4.2, this optimum point should fall within the shallow part of the total cost curve. Furthermore, it shows that if the shallow portion of the time/cost curve is assigned to the intensive activity period (substantial metrication within the industry), then the lead-time for preparatory, planning, and scheduling activities is clearly indicated.

The M-Day is at the interface of the preparatory activity (software) phase and the intensive activity (hardware) phase.

Management should endeavor to determine the optimum time/cost relationship at an early date, and then adjust its metrication effort accordingly. Where realistic targets are set for the various stages of the metric program, they are likely to be met. Targets will preserve a continued momentum in the change and will avoid a stop-start metric program, because it is human nature "that when targets are set, they will generally be met." It is important to realize that "lead-time" for research and development is an extremely valuable part of the metrication effort. One year of lead-time applied effectively will equal many years of peak-time effort. Once the natural lead-time has been squandered it can never be fully recouped, even with overtime.

Part II

SOME COSTS AND BENEFITS IN METRICATION

Metrication costs are "non-recurring" costs of a "once only" nature, while any benefits derived from the change will continue to flow for a long time beyond the transitional period. Whereas many of the costs incurred in metrication can be quantified, most of the benefits are "qualitative," and their "value" can be assessed only in terms of "estimated" gains, rather than by direct cost accounting procedures.

As a general rule, management should juxtapose costs and benefits in all major aspects of metrication, and apply the "rule of reason;" that is, costs should be incurred only where unavoidable or in instances where the estimated benefits are likely to exceed the costs of making the change. The consequence of this approach is that in the medium- to longer-term, metrication will reduce costs rather than increase them.

A. International Precedent

For many years, the cost of metrication has been advanced as the principal reason in non-metric countries for the retention of the customary system of measurement. The change to metric in Britain set into motion a wave of metrication activity in the English-speaking world. This change was initiated by the Federation of British Industries in 1965 as beneficial to British interests, and was subsequently supported in principle by the British Government. As a result of this action in Britain, 44 English-speaking countries are now going metric or have accomplished the change. In most instances, costs and benefits played a prominent role in the decision to change. Even where benefits could not be accurately estimated, there was general agreement that a metric change was inevitable and that the longer it was delayed the greater would be the cost to the country.

Metrication without costs is quite impossible. However, experience in countries that have preceded the United States in the change to metric (SI) measurement indicates quite clearly, that good planning and management can reduce the costs of the change, as well as increase organizational efficiency. The experience has been that benefits accruing from the change will quickly compensate for the once-only costs incurred, and that these benefits will continue for a long time. Such gains should be reflected either in better products for the consumer, or in stabilization or reduction in prices.

The basis of the Australian approach to metric conversion, as well as that of Canada, Britain, New Zealand, and South Africa is that metrication constitutes a "voluntary but coordinated process, in which costs ought to be carried out where they are incurred." In these countries, each sector of the economy and each individual organization was advised to be guided by its own appreciation of short- and long-term interests in the change, without passing on the costs of the change. This provided each segment of the economy with a significant incentive to look beyond costs to identify and pursue the opportunities and benefits associated with the change.

B. Incremental Costs in Metrication

In the determination of metrication cost, it is essential that only the "real costs" are calculated. Any costs not directly attributable to the change should not be included. For example, where a replacement item is required in any case, only the additional cost, if any, of a "metric" replacement item compared with a customary replacement item should be counted. This applies especially to the replacement of machinery, other equipment, tools, and reference books. Similarly, where the metric replacement is cheaper than a customary replacement (such as for certain tools), any saving should be counted on the other side of the ledger as a positive gain from the change. Where an item is rendered obsolete by metrication and needs to be replaced before its normal replacement schedule, only the residual or undepreciated value of the item, and not its total cost, should be counted against metrication.

The understanding of this "incremental cost" concept is necessary to proper and cost-effective metrication management. In many instances, management can decide to hold off the purchase of a non-metric replacement item to obtain the benefit of a fully metric one at an equivalent cost and without running the risk of having acquired a prematurely obsolescent item. In other instances, it may be justified to advance a replacement schedule to an earlier point in time, again replacing current items with fully metric ones. An early awareness of new or replacement item requirements or of modification requirements due to the metric change can trim costs considerably.

The most significant savings in procurement costs will be where the range of metric replacement items has been rationalized or reduced compared with the customary range. An excellent example of variety reduction related to the Australian construction community occurred

Table 4.2: Some Typical Costs and Benefits Associated with Metrication

SOME METRICATION COSTS	SOME METRICATION BENEFITS
DUPLICATION - dual equipment requirement - dual product line - dual inventories and records - return of incorrect orders	VARIETY REDUCTION - rationalization of product line - production of preferred products - establishment of a more logical range for new markets - standardization
LOSS OF MARKETS - competition from metric countries - competition from specialist manufacturers	DEVELOPMENT OF NEW MARKETS - expansion of sales into new areas - export of skill
LOSS OF PRODUCTIVITY - work slowdown during transition - work slowdown through unfamiliarity - errors - loss of staff time in training	INCREASES IN PRODUCTIVITY - simplicity of decimal measurement - speedier and more accurate calculations - greater accuracy in measurement and production [fewer errors]
METRIC PROGRAM COSTS - metric program manager - additional support staff and facilities - time lost in meetings/conferences	REVIEW AND RATIONALIZATION - simplification of administrative and technical procedures/detail - rationalization of organizational practices and work processes - harmonization of differing approaches [specifications, standards, codes]
DEVELOPMENT/ACQUISITION OF NEW DATA - need for new technical literature - need for new reference data, forms, charts, guidelines, etc.	DATA IMPROVEMENT AND REVISION - opportunity for data review and improvement - up-to-date information or technology - worlwide exchange of technical data
COSTS OF NEW OR MODIFIED EQUIPMENT - new tools and measuring instruments - modification or recalibration of equipment - incremental equipment costs	MORE EFFICIENT PRODUCTION - redesign of old products/techniques - use of planned obsolescence to acquire efficient equipment - better product quality and longer production runs
TRAINING AND FAMILIARIZATION COSTS - cost of training program - cost of familarization of suppliers and customers	BETTER COMMUNICATION - better informed staff [updating of skills] - improved communications within the organization and with suppliers, clients or customers

with drawing scales. One metric construction industry handscale has replaced a variety of customary scales.

It is recommended that each organization establish an equipment schedule which shows a comprehensive listing of all items requiring complete replacement, partial replacement, or modifications only. The schedule should have columns for timing of replacement or modification, estimated cost, budgeted cost, and actual cost incurred. The direct costs of metrication will be clearly identified and can be controlled much more easily with the use of such schedules.

C. Comparison of Costs and Benefits in Metrication

Table 4.2, lists a selection of costs and benefits (or opportunities) that were associated with the change to metric in the production industries of other countries. The list is by no means exhaustive, but it provides a general indication as to the areas where management effort could be usefully applied to minimize costs and to maximize benefits.

D. The Cost of Mistimed Metrication

Among the most significant potential costs in the change to metric measurement is the "cost penalty" of mistiming, or of making the change out-of-phase with the competitive environment. In general, a premature change in the market sector will involve additional effort and costs in marketing and customer familiarization, as well as a potential lack of market acceptance of metric products. On the credit side, this approach could result in an increased share of the eventual metric market, due to the availability of a fully developed and tested product line at the time when most competitors are still in the process of transition.

A belated change is potentially far more dangerous, and it may mean that some customers are needlessly surrendered to the competition. To regain lost customers frequently is more difficult than to attract new ones.

Part III

THE TRANSFER TO A METRIC PRODUCT LINE

The transfer to the "optimum" metric product line involves a number of major management decisions and activities.

A. Analysis of Current Production, Market Factors, and Precedent

It is desirable for a producer to spend some effort on a thorough assessment of key factors involved in the existing operations which might be affected by or affecting the metric change before embarking on the change to metric production. Such an analysis ought to include the identification of the major revenue earners among the line of products, so that such items may be retained in any "dual product line" decision. The following questions indicate areas where statistical information might be collected prior to any firm metric decisions:

- Which products are the high volume production items?
- Do such products coincide with those products that have the highest demand in the market sector?
- Which products are low volume production items? Is this because of special orders? Are they priced differently? Are they profitable?
- Are there any "loss leaders" in the current production line?
- What is the inventory turnover for all current products?
- Do pricing practices take into account all costs in production, inventory, and marketing?
- How are overhead costs assessed and allocated? Are they charged to individual products, product groups, or total production?
- Which products now have dimensional production tolerances that encompass preferred metric sizes?
- Can production equipment cope with metric production by way of simple adjustment? Which equipment needs to be modified? Which needs to be replaced? What are the lead-times for modification or delivery?

Depending upon the manufacturing context, there will be many other questions to indicate the type of analysis that ought to be performed in a production organization. Examples shown are for illustrative purposes. Another major question that arises in connection with the change to metric is whether demand factors will remain similar, or whether there are likely to be signficant changes. If changes are probable, it will be an integral part of the market intelligence to find out where these changes in demand are likely to occur, and what effect they might have on operations. For instance, how will the anticipated change to preferred metric dimensions in building, based on selected multiples of the international building module of 100 mm, affect the structure of a product line?

Secondly, there is the important question of metric demand. Can demand be forecast with any degree of certainty? Is demand induced by decisions in the product sector, or does demand derive from designers? What is the lead-time between metric design in preferred metric sizes, and orders for suitable products? These questions highlight the need for an industry-wide time frame and an agreed M-Day for metrication.

Overseas precedent can provide many useful answers to such questions, because the same or similar issues have been raised elsewhere. But, due to different market patterns and construction practices, overseas demand patterns are not always a reliable guide. Nevertheless, the study of precedent is highly recommended and is certain to provide many useful lessons to the construction products sector. The United States is not just adopting a new measurement system, it is joining a metric building world.

Figure 4.3: Alternative Strategies for Metrication in Production

EFFECTS / COMMENTS

1. SOFT CONVERSION [Retention of the existing product line; product characteristics are expressed in metric units, rounded within tolerances]

(12)

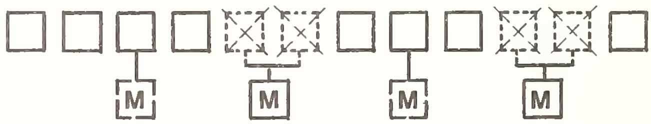
No actual change is made; therefore there will be no gains from metrication. However, a potential for losses exists if customers change to metric preferred products.

2. SOFT CONVERSION WITH A REDUCED RANGE OF PRODUCTS [Retention of part of the existing line of products, but deletion of unprofitable or low-turnover items]

(9)

No actual change is made other than a reduction in the product catalog. It is desirable to retain all products that fall within production tolerances of preferred metric sizes. New metric sizes can be added whenever it becomes opportune to do so.

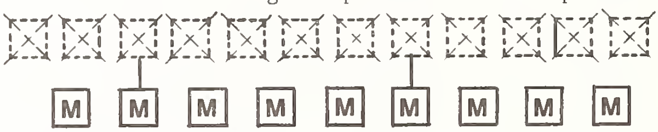
3. HYBRID PRODUCT LINE (SOFT CONVERSION WITH SUBSTITUTION) [Retention of certain customary products; those deleted are replaced with fewer preferred metric products]



(10)

This is an adaptive strategy in which the most profitable products are retained as an interim measure, and new metric products are added to fill gaps. The net effect is a smaller inventory and reduced variety.

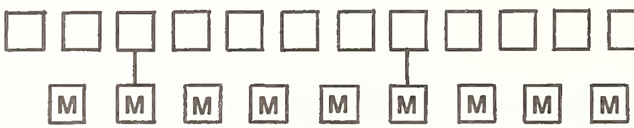
4. HARD CONVERSION [A once-only change to a rationalized range of preferred metric products]



(9)

This is the most costly approach initially, but also likely to provide the highest long-term benefits. Hard conversion should lead to a optimum product catalog.

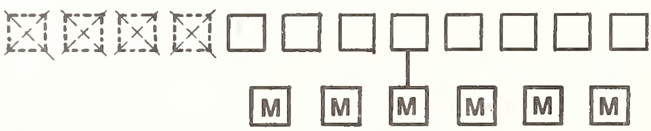
5. DUAL PRODUCT LINE [Simultaneous production and marketing of two product lines, including customary as well as preferred metric products]



(21)
[19]

This approach will meet all customer demands, but is also the most costly and inefficient one - it requires dual inventories and leads to much smaller production runs. A dual product line ought to be avoided.

6. DUAL PRODUCT LINE FOR A PARTIAL RANGE [Market specialization by withdrawal from a particular market segment, and concentration on the residual market with a dual product line]



(14)
[13]

This approach may yield the best short- to medium term results, as both markets are covered. If part of the range is deleted, it ought to be in the least profitable portion of the product line.

Code used in the diagram:

 Customary Product

 Deleted Product

 Preferred Metric Product

 Coincidence Within Tolerances

B. Alternative Strategies for the Development of a Metric Product Line

Approaches to the metric change can vary from a "soft conversion" (which means no actual change to products, as the only changes made are confined to "software," such as paper-based information) to a "hard conversion" (which means that products are physically changed to new and preferred metric characteristics and that the product line is rationalized), with various stages of "variety reduction" in between.

A fundamental management decision is required as to whether the change to metric should be undertaken with one product line only, or with two product lines to serve both the declining customary market with existing products, and the increasing metric market with new metric products.

Figure 4.3, depicts six alternative strategies for metrication. Strategies 1 to 4 involve a single product line only; and strategies 5 and 6 involve a dual product line. In addition, a number of other possible combinations of the strategies are shown.

C. Selection of the Most Suitable Strategy and Timing of Market Entry

The most appropriate strategy for metrication in any particular building product area depends upon a number of factors. The principal factor is the ratio of "new product demand" to "replacement product demand," as well as the versatility of the new metric product to serve as a replacement product in an historical environment based on customary sizes.

There are a few product areas where the replacement demand is higher than new demand. In these instances, it will be necessary to retain existing products and to market them under "soft converted" metric designations for an extended period of time. A typical example is the fluorescent light tube. Its replacement demand accounts for four fifths of its total production. Rationalized metric lamps could be introduced as an additional market option in the way that new products have been introduced in the past. Metric lamps also may be marketed with an adaptor, to suit both preferred metric fixtures and customary fixtures. Finally, metrication offers a unique opportunity to have a look at more efficient design, and in the case of fluorescent lamps this could mean a new and improved lampholder (bipin) base design.

In some product areas, such as in some architectural metal components, many products are not dimensionally critical and might be changed to a rationalized or preferred metric range early in the change, or even prior to metrication. In the latter case, one product would then suffice to serve both markets--a "nominal" description for the customary market, and a preferred metric description for the metric one. A typical market area for this type of change would be in trim patterns and moldings, where industry-wide preferred metric shapes could be developed with the objective to reduce the variety of existing products by a significant percentage.

Of the six strategies indicated in Figure 4.3, it is likely that Strategy 4, the "hard conversion" to a new and preferred metric product range, will provide the most profitable approach in the medium- to longer-term. It will, however, put quite a lot of pressure on the marketing personnel in the short- to medium-term to win clients over to a rationalized range.

In the context of an industry-wide system of dimensional coordination, the dimensions for metric products will flow directly from the dimensional preferences established in national standards. It is important to producers and producer associations to be represented in the deliberations on such preferred sizes, without letting the dictates of the past rule the future. Preferred dimensions for building will almost certainly derive from the international building module of 100 mm, and a series of selected multimodules (whole multiples of 100 mm) or submodules (whole fractions of the module such as 50 mm and 25 mm). To produce building products that do not match such preferred dimensions could be a very risky strategy indeed.

The optimum point of entry into the metric market lies just prior to or at the industry M-Day. As already indicated, the early starter can build up a metric reputation and expertise on early metric projects, and thus develop a series of case histories which could prove to be very useful to product marketing in the eventual fully metric building world. And again, the risks associated with a belated entry into the metric world could be very much higher.

D. Factors in Metric Production

A useful way in which the transition from the customary measurement environment into the metric building world can be made smooth is to engage in metric trial (or pilot) production. Thus, assessment could be made of market factors, production factors, product performance, and organizational competence to cope with the change. From a marketing point of view, trial products could very well be produced for metric trial building projects in each major market region. This would provide a visible association with the metric building world, as well as an appreciation of performance requirements in a metric building environment.

Prior to full-scale metric production, it is necessary to have a full set of metric technical data and product literature. These would provide designers, contractors, and other customers with metric details in a change-over environment. Technical data and product literature should be checked carefully as to its accuracy in the presentation of units and values.

A second issue connected with metric production is the replacement or modification of plant and equipment. This is best carried out in conjunction with plant maintenance schedules, or during periods of plant shut-down, such as in a holiday season.

Production and warehousing (distribution) staff should be familiarized with the essential aspects of a metric work environment just prior to the commencement of fully metric operations. In general, there is little need for full-scale training programs.

The determination of the optimum inventory levels in relation to the metric change is an important management function. The customary inventory run-down and the metric inventory build-up ought to be timed in such a way as to reinforce the optimum time/cost transition, and reflect factors in the marketplace.

Finally, metric production represents the watershed between the old and the new, because metric products will remain the basis of a permanent metric building world. Fewer and preferred metric products should ensure longer production runs, with all the attendant economies of scale, as well as more profitable inventories.

CONCLUDING REMARKS

The United States is one of the last links in the chain of nations that have abandoned their customary measurement systems in favor of the International System of Units (SI)--the "modern metric system." Among the others that have yet to take formal steps to do so are Brunei, Burma, Liberia, and the two Yemens.

Far more significant, however, is the fact that there is no record of any country ever having abandoned metric measurements after having changed to them. This fact introduces an inevitability about the impending changes that even the critics of metrication grudgingly acknowledge. These critics generally belabor the issue of metrication cost, and they postulate that such costs will be of an astronomic magnitude. But international precedent has shown time and time again that, once a firm commitment has been made to change to metric, metrication becomes a "non-event," and costs are much less than any of the estimates, whether the first guess, or the second revised and reduced estimate, or subsequent further revised and reduced estimates.

The question of the "economics of metric conversion" is very dependent upon "how" and "when" the change is tackled, not the "why." An unnecessarily lengthy, disjointed, or haphazard approach to metrication will invariably cost more and bring fewer benefits than a well-planned and coordinated one.

At the core of the change are people; people who plan, schedule, carry out, and accept the changes. It is worthwhile to remember that the greatest costs in metrication are not necessarily the once-only costs of obtaining the hardware to make metric products, but the hidden costs attributable to human factors, such as:

- lack of awareness (or inadequate knowledge);
- fear of the unknown (or apprehension);
- lack of commitment (or inadequate involvement); and
- resistance to change (or obstruction).

A positive approach to the metric challenge will pay handsome dividends, but a negative attitude will do no one any good, least of all those who persevere with an anti-metric stance. The time for investigation and familiarization with the issues is now. The better use we make of this "lead-time," the more economical and beneficial the change is bound to be.

The advice from Australia is simple: "Don't concentrate all your thinking on the 'cost of metrication,' or you may lose sight of many of the benefits and thus miss out on the metric opportunity."

SECTION 5

Metrication and the Contracting Community

Paper based on remarks made at the meeting of the Contractors Sector of the American National Metric Council's Construction Industries Coordinating Committee, held June 14, 1977, at the Headquarters of the Associated General Contractors of America (AGC). Revised for distribution at the Metric Conversion Committee Meeting during the 1977 Midyear Board Meeting of AGC, held on September 16, 1977, at Atlanta, Georgia.

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INTRODUCTION

The first formal commitment by the United States to join the metric world was made in December 1975, with the signing into law of the "Metric Conversion Act of 1975," (Public Law 94-168). This Act declares "that the policy of the United States shall be to coordinate and plan the increasing use of the metric system in the United States and to establish a United States Metric Board to coordinate the voluntary conversion to the metric system." While the Act does not endeavor to enforce a rapid change to SI--the modern metric system--or to precipitate hurried action, it represents a watershed in the official U.S. stance towards metric measurement. The Act itself acknowledges that "although the use of metric measurement standards in the United States has been authorized by law since 1866, this Nation today is the only industrially-developed nation which has not established a national policy of committing itself and taking steps to facilitate conversion to the metric system." In relying upon voluntary action, it places the emphasis on commitment to change rather than compulsion. Once the initial momentum has been generated, it is far more likely that a voluntary change will be successful than a coercive one.

There is ample metrication precedent among some fifty predominantly English-speaking nations that have abandoned their traditional measurement systems in favor of metric during the past 15 years. Most of these nations have had a national policy of planned and coordinated conversion, and their experiences are of interest even though none of them approaches the U.S. in population or industrial significance. While the pessimists see the size of the U.S. as a handicap in metrication, its size provides a significant advantage--it spreads the load in the preparation of technical data, and it facilitates the phasing-in and phasing-out periods.

In most other countries that have "metricated," the construction industries were in the forefront of industrial change; not so much because the conversion created new trade, construction, or consulting opportunities, but rather because it represented a once-only chance to reappraise and rationalize practices, procedures, and products. In all cases it has provided the opportunity to move towards an industry-wide system of metric dimensional coordination, designed to facilitate not only design and production but, more significantly, the processes of construction. Therefore, the contracting sector has an important role in consultations. The choices before the Associated General Contractors of America lie between "being led into metric;" "being part of the guidance system for the industry;" or "leading into metric." The experience in other parts of the world clearly shows that the first option will yield the least returns and the most problems.

This paper examines aspects of metrication in the contracting community, based upon practical experience in Australia and a number of other English-speaking countries, outlines major metric activities, and discusses ten selected key metric issues.

A. Metrication in Australia - Some Key Lessons

In Australia, there was a voluntary, but coordinated, metric program--one very much like that proposed for the United States. However, there was a commitment to a ten-year conversion period as one of the objectives of this national program. It appears that Australia will meet the target of substantially completing the change to metric measurement well within that ten-year period, and at a much lower cost than was forecast.

A major reason for that success was that the formal planning mechanism--the Australian Metric Conversion Board--was established right at the start of metrication. This Board concentrated its program on the broadest front, thus involving all activities and people in its program. The Metric Board started operations in late 1970, established about one hundred planning committees during 1971 and 1973, and facilitated the development and completion of the majority of conversion programs between 1973 and 1977. It is estimated that Australia's conversion is now over 75% completed.

There are many similarities between Australian pragmatism and the pragmatism of the United States. However, there are many sectors in the U.S. that do not appear to face metrication as a welcome challenge. These sectors immediately raise many obstacles - most of which are intangible and imagined problems. To concentrate on problems becomes the real obstacle to a pragmatic goal of achieving the most beneficial and cost-effective metric change.

Many opinions have been expressed as to why metrication in the Australian construction community was so very successful. It is interesting to note that the Australian construction community itself decided to become the first individual sector to tackle metrication. In addition, it was the first industry to effectively complete the change. Why was it possible that an industry largely unaffected by international considerations in the change to metric measurement could be so successful? There are many reasons:

- Most of the key decision-makers involved in metric planning held a senior executive position in their respective organizations or associations and could, therefore, influence activities in the real building world.
- Government and industry cooperated in the planning and implementation of the necessary changes to effect a metric building environment.
- The building sector in Australia (representing the contracting community) took a prominent stance on metrication from the beginning. In the Australian Building and Construction Advisory Committee--equivalent to the Construction Industries Coordinating Committee (CICC) in the United States--the Chairman was always a practicing building contractor.
- The foremost reason was that many people realized that metrication provided a unique "opportunity" as well as a "problem."

All of these reasons provide a lot of food for thought!

B. The Role of the Contractor in Metrication

The contracting community should be deeply involved in metrication planning at the national level, rather than leaving the decision-making to other groups in the construction community, and then having to accept the consequences in a metric building world.

The contractor brings to the whole metric exercise more realism and pragmatism than any other single participant in the building process. The design sector is comprised of many theorists who believe that whatever demands they create in terms of building geometry can, and will, ultimately be met by the contractor. Many producers of building products do not have a detailed knowledge of design and construction factors, nor of the actual functional use of their products. The contractor is the "meat in the sandwich." He is the realist who provides the force that reconciles the demands made in specifications and drawings with various building products of differing geometric and functional characteristics obtained from different suppliers, and combines these inputs into actual buildings. During the metric transitional period, there are bound to be some complications in the construction processes. Therefore, responsibility for any "problem" should be firmly established at an early date, as should the procedures to eliminate or overcome such problems.

The contractor, not the designer, is the only true "order giver" in metrication. There has been much talk about the vicious circle in metrication involving metric demand and metric supply. Producers have argued that they do not wish to manufacture metric products until designers have firmly established a metric demand; and, designers have stated that there is little incentive to design metric buildings until there is some commitment by producers to manufacture products in preferred metric sizes. Both groups seem to have forgotten the third party to the building process--the contractor. The real fact of life is that there will be no demand for metric products until such time as the contractor orders metric-size products for metric building jobs. Thus, in many ways, real metrication depends quite significantly on activities that involve the contracting community.

C. The Timing of Metrication

In Australia, metrication was phased in such a way that a schedule (timetable) was produced and a metric target date was set for the construction community. The date was January 1, 1974. After that date all new construction and materials production was to take place in metric dimensions and preferred sizes. This was extraordinarily ambitious, because Australia had commenced planning only three years earlier, and had to provide a comprehensive metric data bank during this period. Conversely, the tight schedule maintained a continuing sense of urgency in all activities. It was a major factor in stimulating manufacturers to make a once-only change to metric preferred sizes, and in the conditioning of designers to plan their designs for a metric building environment after the target date. The target date, referred to as M-Day for the construction community, became the demand and supply target for the industry. In addition, it also represented a focal point in time relative to which all paper-based activities could be scheduled after varying lead-times were taken into account. The development of metric codes, standards, and other technical information had to precede metric design, production, and construction. The design-related standards had to be prepared first because, in the natural sequence of metric involvement, designers come before producers, and design and production precede construction.

Initially, the design groups took exception to the concept of a production and construction-related M-Day, because they felt that this would place the greatest burden on them. They argued that it would be much neater to have a target date, after which all design could be undertaken in metric units. However, metric planners pointed out that if all designers were to start metric design after a specified starting date, then it would be impossible to obtain the concentrated demand necessary to effect a fairly rapid transition to a metric building world; small projects with a minor impact demand would be ready in six months to one year, whereas, the larger projects with a major impact on metric demand would not be ready for two or three years.

If the construction community could agree on an implementation date, after which all new construction would be scheduled to be in metric units and preferred metric dimensions, then designers and manufacturers would be aware of the natural lead-times that applied relative to such a date. For a design project with a two year lead-time to the bid stage, but a period of two years or less to the M-Day, documentation should be in metric units. In smaller or less complex projects, the lead-times relative to the M-Day would be correspondingly shorter.

This approach to the timing of metrication in the Australian construction community worked extremely well. It meant that metric activities were determined by and related to a "time-table logic system," in which the overriding consideration was to facilitate and effect the least costly and disruptive transition for all parties.

D. Metric Trial Projects

Metric design and construction was possible even before the construction industry M-Day in Australia. This was proven by the federal government, several state governments and a number of large private organizations. These groups took it upon themselves to build a few "metric trial projects" (or "pilot projects"), in conjunction with the production and construction sectors of the building community, to assess whether there would be any metric problem areas and, if so, what such problems were likely to be and where they would appear.

The trial projects were highly successful in paving the road for a smooth transition. They proved conclusively that the physical change to metric in construction and production is a "non-event," provided that the design and overall planning that goes into a metric project is well done. The trial projects also showed that on-site personnel (tradesmen and site labor), have no problems in adjusting to a metric building environment. A little more care is taken on-site and, in fact, personnel soon reach the stage where they prefer operations in metric units over those in customary units. And, building accuracy is greatly improved.

Despite the fact that trial projects were priced in line with customary pricing practices without any loading for work in metric units, contractors who undertook these projects lost no money on them. In addition, successful contractors were on the front of the queue for future and more significant metric projects, due to the experience gained early-on in the new building environment.

E. The Role of the Government Sector During Construction Metrication in Australia

In Australia, a cabinet-level Federal department--the Commonwealth Department of Construction [Works]--existed at the time of metrication. This Department, with a responsibility for nearly 10 percent of all construction in Australia, provided a single major influence in building design and construction; an influence significant enough to generate visible and considerable metric demand in its own right. From an early stage in metrication, the Australian Department of Construction was a "lead organization" in metric planning and data development. It provided much of the technical base that was subsequently used by the entire construction community. Unfortunately, there is no equivalent agency in the United States that could provide a similar "benevolent leadership."

As metrication developed, federal, state and local government construction agencies joined forces in the "Government Construction Sector" and developed a joint timetable for the change. In this joint approach to metrication by all the government components in Australia, over one-third of the construction dollar in the nation was backing a planned transition to metric measurement. This unique cooperation between the three tiers of government was entirely sensible, because all agencies realized that if they went into metrication in their own separate way, not only would they create greater problems for themselves, but also more upheaval and hardship for the entire construction community.

F. Metric Activity in the United States Construction Industries

To date, the U.S. metric activity has centered around voluntary coordination under the aegis of a self-sustaining private sector organization--the American National Metric Council (ANMC). As an interim coordination device, ANMC has done a very creditable job. The U.S. Metric Board, called for in legislation signed into law in December 1975 by former President Ford, has just recently been appointed (March 1978).

Presently, the only focal point for the construction community is the ANMC Construction Industries Coordinating Committee (CICC). The Contractors Sector of the CICC has remained dormant since its initial meeting in April 1974. It has been argued by some people that there is little reason to become involved at this stage, because metric construction is still many years off.

This point of view is potentially dangerous. It is important to have a voice in any decisions that might be made in the next few years, because those decisions that are made are likely to remain in force for some time into the metric future and cannot be reversed without difficulty. If there are issues that involve the contracting and contract labor community, any relevant point of view should be put forward positively and productively. Organized labor has recognized that metrication is an issue that demands attention. To remain passive on metrication could be even more dangerous than to voice opposition to certain aspects of the change.

G. Some Key Metric Issues

There is a series of metric issues of direct relevance to the contracting community and this paper touches on some of the more significant ones.

1. Metric Units for Use in Building Design and Construction

In the countries that have preceded the United States in metrication, it has been recognized that one of the foremost tasks is the timely establishment of a set of conventions for the use of metric (SI) units in building design and construction.

In the traditionally metric countries, there are quite a few superseded and non-SI units in use, because their metric systems date from a period long before the development of the recent and most significant version--the International System of [Metric] Units--best known by its abbreviation "SI." The United States will be moving to SI in one single step and, eventually, will be more advanced in its measurement system than many other countries that still have to change from their traditional metric systems to SI.

2. Metric Dimensional Coordination

The second issue and, perhaps the greatest single opportunity in construction metrication, is the once-only opportunity to develop a comprehensive and harmonious system for the dimensioning of buildings, as well as the sizing of building products; namely, dimensional coordination.

Historically, various building product manufacturers have developed a large range of generally dimensionally unrelated building products. This is because there never has been an overall consensus on preferred dimensions and sizes. At the other end of the construction community, designers (and particularly architects) have been trained in design schools that require each undergraduate design project to have unique and individualistic features. Thus, designs were never repeated and never looked alike. There is a carry-over from this training into reality. Most designs are highly individualistic, and it is demanded that the construction process make all the required trade-offs between the specified building geometry and building products from different sources of supply. That is certainly a challenge to ingenuity, but it is also somewhat counter-productive in terms of the waste of effort and time it takes to construct such edifices, not to mention the waste that occurs in the shaping and fitting of components. The many trucks leaving a building site that carry away the costly debris which accompanies the building process provide an appreciation of the lost effort and resources in a building environment without a great deal of dimensional coordination.

The metric change-over in other countries has provided the opportunity for an industry-wide system of preferred dimensions for building design and preferred sizes for building components, directly linked through a common system of preferred dimensional values (modules). It is in this area that the contractor can obtain one of the greatest fringe benefits from metrication. The Contractors' Sector should have a pragmatic and positive voice in the decision making on metric dimensional coordination.

Without such representation, the evolving metric dimensional discipline could run the risk of becoming a nice theoretical dimensional system, suitable for design but not very much more effective than the present approaches on the construction site. In addition, if designers suddenly start to use a new terminology and various new drawing techniques, then metrication could possibly cause even more headaches in the building process.

Much time can be devoted to the discussion of the issues and principles that are involved in a comprehensive system of preferred dimensions and preferred sizes. But, in the simplest form, it means that where there is a choice in design, a selection is made from those dimensions that are multiples of the basic unit of size--100 mm--and provide the most useful geometric properties. In other words, the most preferred dimensions for rooms would be those that can be fitted by preferred-size metric building products without any undue wasteful cutting or shaping. Vice-versa wherever possible, the sizing of building products should be in simple multiples of the basic module, so that products can be easily referenced, identified, measured, and verified.

The overall discipline of metric dimensional coordination, combining preferred dimensions and related preferred product sizes, as well as tolerances and limits of fit, represents the most significant advance that can be gained in construction in this century. As such a challenge, it needs considerable early involvement and vision to devise the best approaches. When metrication gets into full swing after the completion of the investigation phase, the lead-time to ponder about the trade-offs that should be effected to make the system work best for the entire construction community will have disappeared.

3. Construction Techniques in an Environment of Preferred Metric Building Dimensions and Building Product Sizes

One of the main beneficiaries of a comprehensive system of metric dimensional coordination is the contractor; and so far that has not been stressed. Metric dimensional coordination, properly applied, will greatly improve productivity on the building site.

In Australia, it was found that even partial dimensional coordination simplified the assembly and construction processes. If particular products are unavailable, dimensional coordination permits the substitution of alternatives with much greater facility than at present. Metric dimensional coordination will be especially useful in fast-track projects.

It is important that a comprehensive system of coordination is applicable also to the techniques that are used in setting-out of the building, and in the assembly of elements. The working techniques on the building site must complement the system to take full advantage of preferred dimensions. For instance:

- Does the method of centerline setting-out reconcile with architectural dimensioning based on finished surfaces?
- Will the metric change in construction be facilitated by expressing levels and benchmarks in just one measurement unit, instead of decimalized feet, and feet, inches and fractions?
- Will dimensional coordination be assisted by the use of laser levels and scanning lasers?
- To what extent can the industry standardize construction techniques without unduly restricting the freedom of individual organizations to follow their historically preferred individualistic processes?

The expertise of the contracting community represents an important input into the development of an industry-wide dimensional system and will be invaluable on these and other issues.

4. Linear Measurement - The Principal Physical Quantity in Construction

In Australia and in other countries that have changed to metric measurement in recent years, the millimeter (mm) was selected as the principal unit of measurement for length in building construction. Its selection has the major advantage of avoiding the use of fractions altogether. The use of millimeters to express small as well as large dimensions has resulted in a communication system in which all linear measurement is expressed simply by the number that denotes the numerical value in millimeters. An example could be 2400 for 2400 millimeters in a panel size or ceiling height. While a simple 5-digit number can express any length up to 328 feet, the individual millimeter provides an accuracy to the nearest 1/25 inch. This has great advantages over the customary measurement system, which uses decimalized feet in site work and feet, inches, and binary fractions in construction work.

The use of whole numbers greatly accelerates the processes of addition and subtraction which are most common in construction operations, as well as the division and multiplication processes, which occur less frequently on the construction site than in design. There are cumbersome mathematical processes in the customary system: in the addition of dimensions first the fractions have to be added after having reconciled them to a common denominator; then the inches have to be added and the addition converted to feet and inches; and, finally the feet have to be added to arrive at the sum.

That process is both time-consuming and error prone. Subtraction of dimensions is a little more difficult. In multiplication or division, decimalized feet, or inches are used, as appropriate.

The message from other metric countries is certainly loud and clear: when all calculations are made in a single measurement unit, metric building design and construction operations will be much faster and more accurate. Productivity in some operations may double. In estimating, the decimally-based measurement system becomes a natural ally of the decimal currency.

In Australia, it was found that comparable simple additions of lengths in building operations could be accomplished with at least twice the speed and with only one fifth of the error rate occasioned in customary measurement. The advantage of treating linear measurement in construction as simple numbers represents one of the great gains from metrication which considerably improves productivity after an intitial learning phase.

5. Familiarization of Site Personnel

Linear measurement cannot be discussed without encountering the issue of metric training for on-site staff and labor. This is an area where some very extravagant claims have been made already. Table 5.1 shows an extract from the Australian Metric Handbook SAA MH1 "Metric Conversion in Building and Construction;" namely, the various types of metric working units for different construction trades. The interesting aspect of the table, however, is how few metric units will be required in the day-to-day work of each trade. In nearly all instances, the variety of units will be greatly reduced. This type of information is needed in the construction trades to provide a perspective of the simplicity of the metric system. The carpenter, for instance, can effect all his operations with just a knowledge of meters and millimeters. There is little need to study every unit within the modern metric system, SI, if just one or two units are all that is necessary to everyday tasks.

Table 5.1: Chart of Key Metric Units for Use in Various Construction Activities

[Reproduced from Standards Association of Australia Metric Handbook, SAA MH1-1972, "Metric Conversion in Building and Construction," p.33]

6.18 Units for Use by On-site Tradesmen and Operatives

On-site staff should not be overtrained or confused with detailed descriptions of SI, if the understanding of only a few new units is necessary for them to carry out metric work.

The change has novelty value, and experience has shown that measurements will be made with increased accuracy. Management should not underestimate the ability of staff and operatives to work in new units on the construction site.

In most cases a basic appreciation of linear measurement, and units for area, volume and mass (weight) is all that is required.

The key units for use in various building activities are outlined below:

Activity	Quantity	Unit	Symbol
LAND SURVEYING	Linear measure Area	kilometre, metre square kilometre hectare (10 000 m²) square metre	km, m km² ha m²
EXCAVATING	Linear measure Volume	metre, millimetre cubic metre	m, mm m³
CONCRETING Constituents Reinforcement	Linear measure Area Volume Temperature Water-capacity Mass (weight) Cross-section	metre, millimetre square metre cubic metre degree Celsius litre kilogram, gram square millimetre	m, mm m² m³ °C l kg, g mm²
TRUCKING	Distance Mass (weight)	kilometre tonne (1000 kg)	km t
PAVING and PLASTERING	Linear measure Area	metre, millimetre square metre	m, mm m²
BRICKLAYING	Linear measure Area Mortar-volume	metre, millimetre square metre cubic metre	m, mm m² m³
CARPENTRY/JOINERY	Linear measure	metre, millimetre	m, mm
STEELWORKING	Linear measure Mass (weight)	metre, millimetre tonne (1000 kg) kilogram, gram	m, mm t kg, g
ROOFING	Linear measure Area Slope	metre, millimetre square metre millimetre/metre	m, mm m² mm/m
PAINTING Paint-tint:	Linear measure Area Capacity	metre, millimetre square metre litre, millilitre	m, mm m² l, ml
GLAZING	Linear measure Area	metre, millimetre square metre	m, mm m²
PLUMBING	Linear measure Mass (weight) Capacity Pressure	metre, millimetre kilogram, gram litre kilopascal	m, mm kg, l kPa
DRAINAGE	Linear measure Area Volume Slope	metre, millimetre hectare (10 000 m²) square metre cubic metre millimetre/metre	m, mm ha m² m³ mm/m
ELECTRICAL SERVICES	Linear measure Frequency Power Energy Electric current Electric potential Resistance	metre, millimetre hertz watt, kilowatt megajoule (1 kWh = 3·6 MJ) ampere volt, kilovolt ohm	m, mm Hz W, kW MJ A V, kV Ω
MECHANICAL SERVICES	Linear measure Volume Capacity Airflow Volume flow Temperature Force Pressure Energy, Work	metre, millimetre cubic metre litre metre/second cubic metre/second litre/second degree Celsius newton, kilonewton kilopascal kilojoule, megajoule	m, mm m³ l m/s m³/s l/s °C N, kN kPa kJ, MJ

NOTES:

1. The alternative spelling "meter" and "liter" is advocated in the United States.
2. The term "metric ton" rather than "tonne" is recommended for use in the United States.
3. The use of the symbol "L" [capital ell] for "liter" is recommended for use in the United States, to avoid possible confusion of a lowercase ell with the numeral one (1). (The potential for such confusion can be seen in the fifth last line of the Chart, which shows the symbol for litre per second as l/s).

In Australia, it was found that the British approach to train construction personnel for weeks on end was, at best, a risky proposition. This was particularly true if there was no continuity of metric work to follow the training as a practical challenge. Most of the contractors in Australia, with full concurrence of the Australian Council of Trade Unions, embarked on a program of on-the-job familiarization at the time of involvement in metric work. This very stimulating approach to learning by direct involvement minimized the problems for all parties. It quickly became clear that the claimed difficulties were non-existent and that it would be easy and fun to work in metric units.

Metrication provides a fruitful avenue for cooperation between employers and employees. This certainly was the case in Australia. A lot of the imagined problems never materialized, which showed that most of the intellectual effort spent on imagining possible problems and searching for alternative solutions to such problems is wasted.

Australia had a considerable advantage in metric familiarization, inasmuch as metric conversion was tackled on a broad front. Thus, most people could not avoid becoming exposed to a metric environment in a number of areas at the same time. People quickly had become accustomed to the statement of outdoor temperatures in degrees Celsius (°C) through weather reports on television and in the news media. These reports were presented solely in metric after the futility of dual expression had been realized. Early in the conversion program, horse racing had changed to preferred metric distances and handicaps were expressed in kilograms. After some initial argument, this was quickly accepted as a fact of life. Also, early in the program an increasing number of commodities changed to true metric packaging quantities, such as sugar being sold in kilogram bags, and beer in a new bottle size--the liter bottle--at a somewhat lower cost.

To most people, the metric bogey soon lost its fearsome characteristics.

6. Contractual Aspects in the Metric Transitional Period

The Contractors' Sector can benefit from an early involvement in metrication in the area of building contracts during the transitional period. Such questions arise: What form of contract should be used during the introductory phase of metric construction to protect all parties from costly errors? Who should be responsible and pay in the event of unforeseen difficulties, delays, or excessive cost?

In Australia, it was found that relatively few contractual disputes occurred in early metric projects. With hindsight, it can be said that this matter had occupied many minds for much more time than was necessary. At the outset, in the Building and Construction Advisory Committee, it was decided that no party should be disadvantaged or lose out as a result of metrication, unless unnecessary costs had been incurred by avoidable incompetence.

Contractors wanted to be protected in case specified metric products would not be available, so that they would not be responsible for any unplanned costs. They argued that additional costs incurred in such instances would be treated as extras. Extras can add up very quickly!

Similarly, designers had little desire to go back to their clients to explain that some "little metric problem" would cost an additional twenty or thirty thousand dollars to correct, and that the client should accept responsibility for such costs. So everyone was thinking about finding a potential "metric scapegoat;" although ultimately either the client has to pay, or else the contractor suffers.

As it turned out in Australia, both the designer and the contractor took a little bit of extra care in what they were doing in a metric project. A designer who specifies a product that simply cannot be obtained in the marketplace should be responsible if an alternative solution costs more money and there should be no attempt to off-load such costs onto the contractor. If, on the other hand, the contractor tries to extract some quick profit by pursuing alternatives that differ from those specified and agreed upon, then there are also some solutions to that case.

Fortunately, there were very few disputes during the early metric period in Australia. In retrospect, it seems that the construction community had achieved a gentlemen's agreement that if a problem was found, the parties concerned would talk to each other to find an expedient solution. And, as likely as not, the result of such discussions would be that in total the problems would cancel out. There were some items that would advantage one party, and others that would disadvantage the same party, but in the long run they would equalize. With the high degree of realism and pragmatism that is so typical of contractors, most of the short-term adaptation problems can be solved in some manner or another anyway.

7. Problems and Opportunities

A major issue which might well be investigated at an early stage will be the methods of assessment of potential "adaptation problems" during the transition period to a metric building world. The word "problem," shifts the emphasis to "defensive thinking;" thus, causing people to forget about "opportunities."

In Australia, it was found that talking about opportunities in metrication and setting out to pursue these opportunities, negated many of the problems that we might have imagined would show up. And any problems that do arise, still can be solved in the way that they are generally solved--with ingenuity. If all the contractors in the United States were to write about all the problems they encounter in the present building processes, their summaries would fill a library. But somehow, when buildings are completed, all of these problems have been solved in some fashion or another. It might be very useful to gain an appreciation of some of the problems and irritations in contracting operations. There are bound to be many instances where metrication can quietly remove the cause of these problems.

Each group blames another for causing problems. One group will say, "It is the designer;" another will state "It is the building regulator;" yet another will blame the manufacturers; and maybe some contractors would accuse their subcontractors, labor, the government, or even divine intervention. In summary, there would always be someone else in the wrong - and that is the real problem.

During metrication, all sectors of the construction community will begin to talk a common language of dimensions and, hopefully, preferred dimensions. This will act as a great unifying influence within the industry as communication channels are developed and expanded. This new and powerful communication system between all parts of the diversified construction community will be a significant fringe benefit flowing from metrication. Interaction during the planning and implementation phases and better communication will become the main means of avoiding a situation where everyone blames everyone else for creating metric problems.

8. <u>The Harmonization of Building Controls During Metrication</u>

One issue that is close to the hearts of many groups in the construction community is the greater harmonization and unification of existing building codes and standards. It is astounding that the U.S. construction environment can operate effectively with the enormous variety of standards and codes that affect it. There are historical and other reasons for much of this variety, but the construction processes in the modern building world have become more similar, rather than more diversified. For instance, the situation in Europe, where differing languages and traditions have caused differing regulations and standards can be understood. However, to have three entirely different building requirements in a territory of less than 20 square kilometers, (such as when working in Montgomery County, Maryland; Northern Virginia; and the District of Columbia - all of which adjoin), seems very unnecessary and must have some effect on regional construction operations.

Metrication provides the opportunity and the unique catalyst to weed out some of the unnecessary differences, provided that the opportunity is recognized early-on and utilized as a welcome challenge, rather than squandered in resigned acceptance of the status quo.

There may be very sound reasons to have three or four major regional building codes in the United States; but, excessive variety is counter-productive. It is beyond the capacity of any modern professional to study, in detail, every code that is required in day-to-day business operations, as well as to keep up with changes to them. Such an understanding of the implications of building requirements would require a full-time involvement. There are much more lucrative and fruitful ways to spend time. Yet undeniably, building requirements and standards have a significant effect on design, production, and construction decisions.

Metrication will be of significant value well beyond a simple change in measurement units, if taken as the challenge to make a concerted effort in the harmonization of requirements. It provides a never-to-be-repeated opportunity to do so. As a first step towards more sensible requirements the objective should be to achieve a common framework and internal structure for all building requirements. Thus, a specific numerical or alpha-numerical designation would always deal with a specific subject area in metric requirements. The professional, manufacturer, contractor and even the building official could work more effectively in such a situation.

For example, to assess requirements in different localities dealing with a specific building part or element (such as geometric requirements for stairs, exit limitations, etc.), a standard heading could be looked at. That first step would make it possible to start to compare and assess alternative approaches, and also to find the reasons for such differences. A lot of differences have arisen for historical reasons or as a result of well-meant individual approaches to an issue in different parts of the vast geographical area of the United States. In addition, many of the differences are simply unnecessary or irrevelant in a modern building world.

This does not mean that the large model code organizations are unaware of the impact of metrication. These organizations already are studying many of the issues which could occur as a result of the change of all technical data contained in the codes and associated standards to metric units and preferred values.

What may be achieved is best illustrated by way of an example from Australia. One State in Australia, with an area about two-and-a-half times the size of Texas, has 131 municipalities. All of these municipalities had their own and mostly differing building requirements prior to metrication. Some of these requirements were simply unbelievable - they seemed to have been taken directly from the code that was written soon after the Great Fire of London in 1666.

As a result of metrication, the 131 municipalities had a choice of two alternatives:

- To change all existing requirements to metric units individually and approximately at the same point in time to prevent disruption in the construction community.
- To develop greater uniformity by preparing and adopting a number of regional or even a statewide metric code.

Just prior to the start of the metric program in Australia, a "national model building code" was prepared by the Interstate Standing Committee on Uniform Building Regulations. It was fortunate that this document was ripe and ready for launching into a pure metric environment. The internal contents and structure previously had been agreed on by all the States and two Federal Territories of Australia, which have constitutional jurisdiction over building activity.

To have had a national model building code at the time of metrication was fortuitous. The availability of this national model enabled most of the administrations in Australia to make a one-time switch to this model in conjunction with the change to metric units. There were only very minor additions or deletions to the model in a few instances. This meant that regulatory harmony had been achieved in most of the border areas for the first time in Australian building history. The greatest achievement was made by the State of Queensland, where 131 local requirements were superseded by a statewide code based on the national model.

The harmonization problem in Australia may have been of lesser dimension, because there are far fewer states and territories than in the United States. But the principle of utilizing metrication to achieve greater harmony is the important message to be related. It has been said by some people in Australia, that the emergence of more uniform national building requirements alone has made the change to metric worthwhile in the building community. Unfortunately, there are no cost/benefit figures to substantiate such a claim. However, there has been no negative feedback from any builder, designer, or producer - none whatsoever.

9. Costs versus Benefits in Metrication

A few brief remarks on costs and benefits of metrication are appropriate. The change to metric without costs is impossible. If anyone were to come along and state that there will be no cost in metrication, that would not be true. But, if the significance of metrication is not grasped, it is very possible to have a change without any of the benefits that will compensate for the costs which may be incurred.

If metrication is properly planned, coordinated, and implemented, then the benefits that can be achieved in an industry as diverse, fragmented, and haphazard as the construction community will easily outweigh the costs.

Metrication costs are incurred only once, and then they are really not very large. If the "real costs of metrication in constuction," were tabulated, the findings would illustrate that many of the imagined costs would be incurred even without metrication. The remainder of the costs would be very small in relation to the total operating cost within an organization.

The benefits that can be obtained as part of the change within an individual organization, as well as within the construction community at-large, will continue to flow for a long time to come.

In the Australian Department of Environment, Housing and Community Development, it was estimated that the greatest single cost of metrication would be a staff productivity loss, and a one percent loss for one year was expected. This was felt to be a very reasonable estimate for such a massive exercise. In reality, that cost just could not be effectively measured, because productivity did not drop on early metric projects or subsequent projects. On the contrary, many activities were accelerated. The metric budget, which had been set correspondingly, was excessive and a greatly reduced second estimate had to be made. The real cost was even lower. The greatest battle was to disband the Metric Office when the job was done, because some funds for a continuation of work were left over.

In general, metric cost estimates in Australia were given away as a meaningless exercise. It had been decided that costs should lie where they fall. Consequently, most organizations made quite sure that costs were kept at a minimum and, probably, very much lower than with the aid of estimates.

However, if a "soft conversion" had been made then that easy way out would ultimately have been the most costly solution.

10. Hard Conversion versus Soft Conversion

While it is desirable to effect a one-time change to the most preferred metric size or characteristic, there are some areas where a "metric veneer" or a soft conversion approach is the only practical one. There are a number of instances in the manufacture of building products, where it is not worthwhile to contemplate anything but a metric equivalent of customary dimensions. For example, it would be foolish to change the dimension of wash basins, water closets, and other fixtures, just to arrive at a preferred dimension. Many of these items are designated in "nominal" dimensions and when the conversion to metric units is made, the "actual" dimension may be a preferred one. But, for bathtubs, prefabricated shower stalls, kitchen units, and built-in appliances, a soft conversion is not the best approach. These units have a direct relationship to the room geometry in the space that surrounds them.

The purpose of these statements regarding soft versus hard conversion is to draw attention to the need not to get carried away with the metric problem of change. While all technical data will have to be changed, not all articles will have to be changed.

Many items can be changed to new and preferred metric dimensions in the normal business cycle of replacement, model change, and innovation. At present, it is feasible to design and market items in preferred metric sizes, even if this is done under the "customary measurement veneer" of dimensions in feet, inches and fractions. Some items could be designed and marketed in nominal sizes in feet and inches, where only a nominal accuracy is required and dimensions are not very critical. However, in a metric environment, based on the millimeter as the unit of length for use in production and construction, the "nominal" concept has no place.

There could be a few complications in the sudden change to metric preferred sizes for floor or ceiling tiles, or for concrete reinforcement. But, it is well within the capability and ingenuity of the construction community to cope. If the supply of floor tiles for a building project were in metric sizes, the tile layer could still lay a floor without too many problems. With metric reinforcing bars, the spacing can be adjusted to suit structural requirements.

The greatest effort needs to be concentrated where a direct dimensional relationship is necessary to make use of the reciprocality between the geometry of a building and the sizes of building products. In this area, it becomes very important to achieve preferred, hard converted metric sizes for use within the ultimate metric building world. To adopt the most convenient, least-change, or soft conversion solution is of little long-term benefit, and will create the largest number of problems in the contracting community.

CONCLUDING REMARKS

Metrication is regarded by many as a problem, by others as a nuisance, and by some as a unique, never-to-be-repeated opportunity to introduce greater efficiency into the construction community.

Those people who are mainly preoccupied with "problems" can be assured that metrication is not nearly as tragic as it first appears. Otherwise, the countries that have preceded the United States on the metric road would have had great difficulty in effecting the change.

The most valuable lesson in Australia was provided by metric trial projects. These projects showed quite clearly that the "metric problem" was mainly in the mind. Given a metric tape and a set of metric drawings, most of the people could set about constructing a simple project right now; and, possibly with much better accuracy as a result of the inherent advantage of working without common fractions.

Most people will agree that a metric United States is inevitable, although estimates vary widely as to when this might happen, and how long the transition period might be. A few people are completely opposed to a change - at least to any change within their lifetimes.

Others look at metrication with resigned acceptance. And, there are quite a few people who have given freely of their time and effort to ensure that any changes that are induced will at least be made on the basis of proper investigation, planning, and coordination.

Metrication will provide a great unifying influence within the entire construction community--an influence that cannot yet really be conceived. For the first time, there will be a common objective to bind all sectors together; namely, the discussion of how to minimize the difficulty of changing the largest industry in the nation to a different measurement system.

- How can this goal be achieved within an optimum time frame, without upsetting everyone or creating a disadvantage for some sectors of the construction community?
- How can the opportunities that are associated with such a wholesale change be identified, harnessed, and maximized?

And there is ample precedent to show that these objectives can be achieved by participation, proper planning, and positive pursuit of the metric opportunity - but not by procrastination.

To speak with a strong and considered voice in all areas that affect the interests of the contracting community, it is important for the Contractors Sector to be aware of the implications of the change to metric measurement. The most effective way to do so is to be organized, informed, and prepared to speak out at an early stage.

SECTION 6

Metrication - A Concrete Opportunity

Paper based on Keynote Address to the American Concrete Institute (ACI) 1977 Annual Convention, held on March 16, 1977, at San Diego, California. The paper was printed in ACI Journal, November 1977, pages N13 - N21. A summary of the actual Keynote Address was published under the title, "Metrication: Take the Tide at its Flood," in Concrete Construction, Volume 22, Number 8, August 1977.

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INTRODUCTION

Within the next decade the U.S. construction community will almost certainly face one of the greatest challenges in its history - the change from its customary measurement system to metric measurement, or more accurately, to the International System of Units, best know by its abbreviation SI.

This challenge is seen by many as a "unique opportunity" to join the metric building world and to introduce new and more rational approaches to design, construction and production, together with the change to the most rational measurement system yet devised by mankind. Others have claimed that metrication is unnecessary and a "most difficult task, fraught with costs, irritations and many problems."

This paper sets out to clarify the implications of metrication and to demonstrate that the impending change represents a never-to-be-repeated opportunity for the construction community to establish the best possible technical data base and procedural format for future operations. Metric awareness and good management should ensure that opportunities are not squandered or diluted by sub-optimal solutions.

For the United States, the time has come when a continued drift into a metric world may be hazardous and counter-productive in the longer term, because it could easily lead to "technological isolation." This risk is greatest in all areas where there has been a traditional technological supremacy. It is not surprising that nearly all of the largest corporations in the United States, who are also leaders in the world of multi-national organizations, have recently become protagonists of metric change after many years of avoiding the issue. Their analyses have clearly shown that the benefits of universal development and exchange of data, elimination of uneconomical products, sizes and shapes, streamlining of inventories, and general rationalization made possible by metrication will very quickly outweigh the costs of making the change. What is more significant is that the benefits will flow for a long time, while costs occur once only.

Concrete and steel are building materials that have changed the face of the earth in the twentieth century. Much of the technological foundation for the use of these materials was developed in the United States. Yet, insistence on an isolationist measurement system is bound to deprive designers, manufacturers, contractors, and publishers of an effective contribution to and share in the world scene.

A. International Precedent in Metrication

In the confrontation with the change to SI, the International System of Units, the U.S. construction community is not without international precedents that provide valuable lessons or shortcuts. During the past decade, the construction industries of Britain, South Africa, Australia, New Zealand, and many other English-speaking countries have abandoned their customary measurement systems in favor of SI. Canada is now in the transitional phase. The experiences of these other countries, both positive and negative, provide much useful guidance and many indications where special effort might be applied to yield the highest returns.

Australians who were involved in metrication are proud of the way in which their well-managed, but voluntary change rapidly replaced the customary system with SI. In a review of the major factors which made successful conversion to a metric environment possible, the following stand out as the principal ingredients:

- Coordination - The change was coordinated through a government-funded Metric Conversion Board; established at the outset to help plan and facilitate the change.
- Communication - Metrication was communicated as a unique opportunity for rationalization and improvement and not as a problem.
- Constructive Use of Lead-Time - Alternatives were investigated by task forces and representative groups to devise the most suitable solutions to technical considerations for all parties affected.
- Consensus Procedures - Agreement on planning and scheduling of the change was reached after concurrence and endorsement by the construction community.
- Conditioning of People - People were assisted to conquer their fear of the unknown by progressive involvement which dispelled "metric difficulty."
- Commitment - All levels of Government (federal, state, and local) supported the change by participation and, at times, leadership.
- Cooperation - Metrication has been the greatest single cooperative exercise in the history of the construction community.

Australia's achievement of a fully metric construction environment within six (6) years from the commencement of initial planning, clearly indicates that the actual changes are certain to be less time-consuming, less traumatic, and less costly, than predicted by the prophets of gloom. Once on the road to metric, Australians did not look over their shoulders, nor did they pay attention to those who tried to hinder the metric program by hinting all kinds of imagined obstacles or problems.

The Australian concrete industry played a prominent part and deliberately assumed the role of a lead sector in metrication. The change to (preferred) metric concrete quantities and characteristics took place six months before the agreed M-Day of January 1, 1974, thus signaling that metrication had arrived.

B. Some Terms Used in the Change to a Metric Environment

During the change to metric measurement a number of descriptive terms which have been used elsewhere to identify certain concepts connected with the change will emerge. A brief explanation of the most significant of these is provided.

- SI - is the worldwide abbreviation for the International System of Units (from the French "Système International d'Unités"). SI denotes the measurement system developed and maintained by the General Conference on Weights and Measures, an international treaty organization to which the United States is a signatory.

  It is important to recognize that the change before us is not simply a change from our "customary system" to the "metric system," but a change to the most modern measurement system in the world. SI, although based on the "old metric system," supersedes it, so that even traditionally metric countries are now changing to SI. Thus, by changing to the "international system," the United States is spared the agony of a two-stage conversion, first to the old metric system, and then to SI.

- Metrication - is a term coined in Britain and subsequently adopted by other countries engaged in the change to SI, to describe any activity connected with the change to a metric environment.

- Exact Conversion - is the change from the customary value to its "exact" equivalent in metric units, generally to a number of places of decimals. Unless the customary value was one of extreme accuracy, an exact conversion would provide an unnecessarily cumbersome value. Exact conversions are rarely appropriate in design or construction.

- Soft Conversion - represents a change in description only, but nc physical change, and is generally an exact conversion rounded to a value within existing tolerances. In a soft conversion, the only change that is made is one on paper, or in the "software" - thus the name.

- Hard Conversion - represents a physical change from an existing numerical value to a different and "preferred" metric value. It involves a definite change in dimensional characteristics.

  Hard conversion will generally lead to incompatibility between customary and metric products, and is, as indicated by the word, more difficult to effect. In terms of linear measurement, the dominant product characteristic in construction, metric preferred dimensions are generally slightly smaller than their customary counterparts. Thus, metric components might fit customary spaces while customary products are unlikely to suit metric spaces.

Table 6.1, on page 86, illustrates exact conversion, soft conversion, and hard conversion.

Table 6.1: Exact Conversion, Soft Conversion, and Hard Conversion of Customary Values

CUSTOMARY VALUE	EXACT CONVERSION	SOFT CONVERSION	HARD CONVERSION	% CHANGE
24 inches [2 feet]	609.6 mm	610 mm	600 mm	- 1.6
1 square [100 sq.ft]	9.2903 m^2	9.3 m^2	10 m^2	+ 7.6
4 cu.yd	3.058 m^3	3.1 m^3	3 m^3	- 1.9
1 quart	0.946 L	0.95 L	1 L	+ 5.7

One common objection to metrication is that "costs" will be incurred in the change before any "benefits" are gained. But a word of caution is appropriate: a "soft conversion" which is nothing other than the use of a "metric veneer" for a customary product is almost never the "least cost strategy" for metrication, as suggested by some people. In the longer run it represents the most futile approach to change as it offers no tangible benefits to outweigh the costs of the change.

Genuine metrication involves "hard conversion" to new and preferred values in most instances; the only exceptions occur in those areas where functional or other factors prohibit or inhibit change, such as in the case of the "standard rail gage," where any attempt to introduce a hard conversion would be unrealistic.

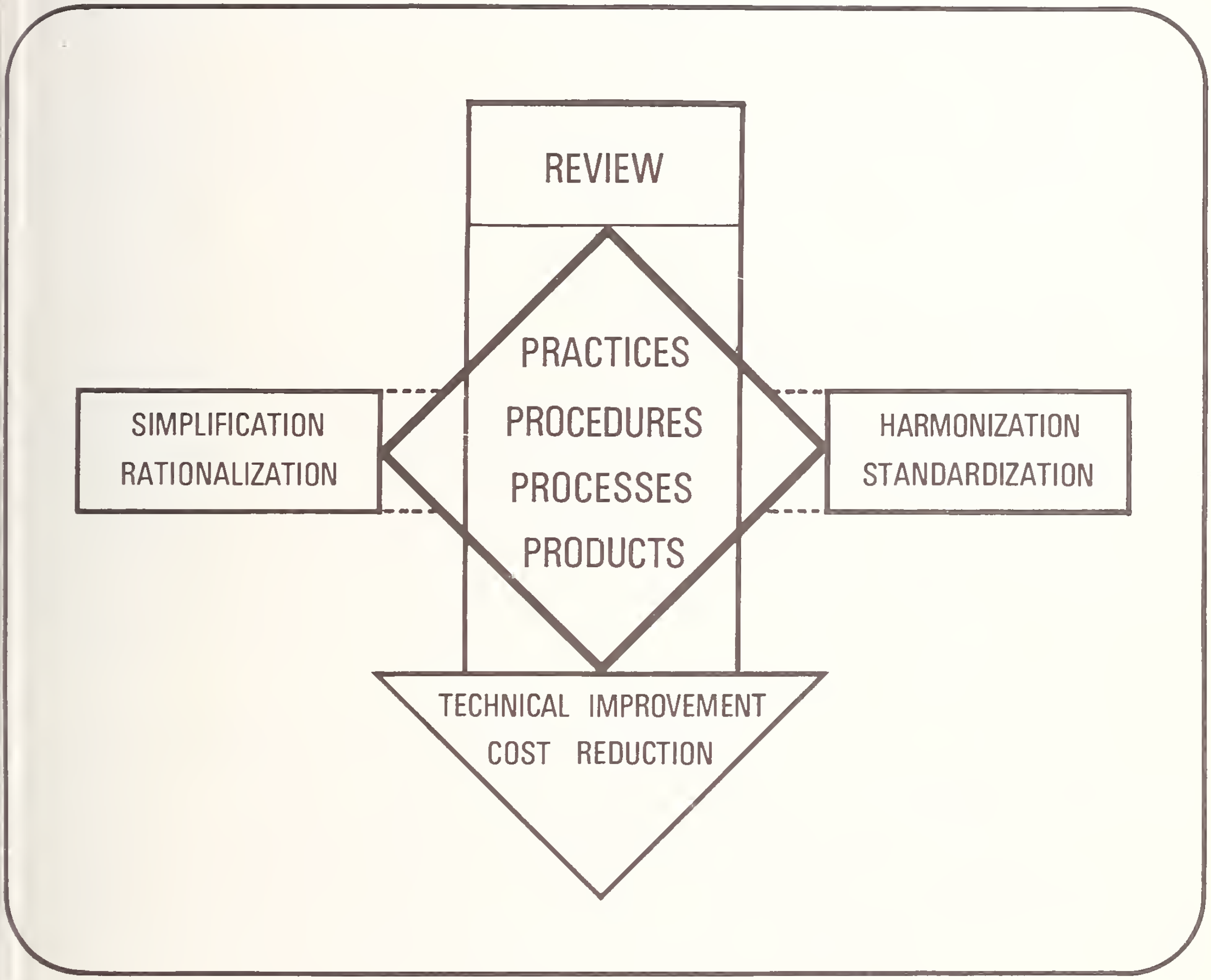
C. Metrication for Benefit

In Australia, "rationalization through metrication" became a byword in the change to SI within the construction community. It was quite remarkable to find how much rationalization was practicable and could be painlessly introduced in conjunction with the change. In many cases, more rational approaches would have been possible even in the customary measurement environment; however, they had never been forcefully pursued because of the difficulty of achieving agreement. To achieve a quick return on the expense connected with metrication, the construction community became committed to reappraisal and review, to "dust the cobwebs off haphazard practices that had accumulated over time."

The best results in metrication are achieved where research and analysis are applied to metric issues so that the objectives of "review" become "technical improvement and/or cost reduction." The main tools for technical improvement as well as cost reduction are simplification, rationalization, harmonization, and standardization.

Figure 6.1 illustrates how the review of customary practices, procedures, processes, and products should be accomplished through a sieve of "simplification, rationalization, harmonization, and standardization," to ensure technical improvement and/or cost reduction.

Figure 6.1: The Metric Review Opportunity



The "sieving process," represented by the four "opportunities" outlined in this paper, probably is the most significant single task in the construction community. Metric solutions, once determined, are likely to stay for a long time, and any bad solutions are likely to be costly for a long time. Solutions which involve all parties in the construction community are inevitably superior to those involving a single viewpoint only.

Metrication represents a research task. The main ingredients are:

- Review of the principal components and relationships within each existing field of activity.
- Identification of all areas affected by the change to metric measurement.
- Investigation of precedent for change, of the solutions adopted elsewhere, and (if possible) of the reasons for such adoption.
- Assessment of alternative approaches and opportunities - through examination, evaluation, experimentation (development), and innovation.
- Monitoring of changes when they are made to assess costs vs. benefits, and the emergence of problems, if any. This is an ongoing activity.

It is desirable to assume that the bulk of the existing technical data bank will be replaced by new and preferred values to ensure that the investigation of the most suitable metric values is not restricted at the outset by compromises. The theme should be "Metrication for Benefit."

D. Opportunity One: Simplification Through SI

The first opportunity in metrication arises directly out of the advantages that are connected with the change from the "customary measurement system" to SI. The inherent simplicity and decimal nature of SI will lead to easier understanding of mathematical processes, greater speed and accuracy in calculations, and greater convenience and coherence in all operations involving measurement. A decimally-based measurement system is also a natural complement to a decimal system of currency, which the United States has enjoyed for longer than any other nation.

The principal features and strengths of SI are:

- Unique Units - There is only one recognized SI unit for each physical quantity.
- Internal Coherence - All units in the system are derived from 7 base and 2 supplementary units and have a one-to-one (or unity) relationship to each other.
- Standard Prefixes - An agreed set of prefixes is part of SI, which allows a change in magnitude from the sub-atomic scale (10^{-18}) to the astronomic scale (10^{18}).
- Internationally Agreed Symbols for Units and Prefixes - Regardless of the surrounding language or script, SI unit symbols have an agreed form and the same meaning worldwide.
- Constant Review - SI is under constant scrutiny by an international treaty organization to ensure that the system meets the needs of modern science and technology.

Some examples are provided to put these features into perspective:

1. Instead of six principal and a number of other units of length in the customary system, SI recognizes only one unit--the "meter." The meter can be prefixed to suit a particular application. Micro-biologists, building designers, surveyors, airline operators, and astronomers all work with linear measurement, but in a different range of the measurement system. In SI, each group can select and use an appropriately prefixed submultiple or multiple to suit its purposes, while still retaining a direct decimal relationship to the base unit meter.

   Most of the standard prefixes, such as micro (one millionth), milli (one thousandth), kilo (one thousand times), and mega (one million times), are already familiar to us. In the measurement of length, four units--the micrometer, millimeter, meter, and kilometer--cover a range of one billion (1 000 000 000), compared with a range of 63 630 in the customary system covered by all the units between the inch and the mile.

2. In construction, where the most commonly used physical quantity is length, SI facilitates both design and construction. SI will end the days when a wide variety of units impacted on concrete construction: width and length being specified in feet and inches; depth in inches and often fractions of an inch; finished floor levels in feet and hundredth; concrete volume in cubic yards, after a set of tedious and at times inaccurate multiplications and divisions; and where for site mixing of concrete, coarse aggregates are delivered in tons, sand in cubic yards, and cement in 94-pound bags, while the water for the mix is measured out in gallons.

Table 6.2 illustrates the "simplification" in basic metric calculations relative to two examples of a simple concrete floor slab:

Table 6.2: Simplification of Basic Metric Calculations

	Customary Measurement	Metric [SI] Measurement
Width [Span]	16' 6"	5000 mm [5.0 m]
Length	25' 8"	7800 mm [7.8 m]
Depth [Thickness]	5"	125 mm [0.125 m]
Concrete required	$\frac{16.5 \times 25.67 \times 5}{12 \times 27} = \underline{6.54 \text{ cu.yd}}$	$5 \times 7.8 \times 0.125 = \underline{4.875 \text{ m}^3}$
Order quantity	7 cu.yd	5 m^3
Number of processes of calculation	2 multiplications 2 divisions	2 multiplications

The use of preferred dimensions, with one coherent measurement unit for each quantity, will greatly facilitate metric design, documentation, and construction. Fewer calculations will speed up work and increase accuracy.

3. SI is based on a decimal concept in the form of prefixes, therefore, it does not include or need common fractions. This will further speed up work in many circumstances. It is difficult to divide a difference in level into equal steps. How long does it take to work out the rise of a step in a stair flight with 9 risers in a total rise of 5'-6"? How close can we get with fractions of inches so that the maximum variance within the flight is within acceptable limits? This is important as any variance in risers is a major contributing factor to accidents on stairs.

   A 9-riser flight of 1650 mm difference in level to the nearest millimeter can be discerned more quickly and accurately than for the customary example. Of course, if 9 risers were to be unacceptable under existing (or new) regulations because of an excessive height per riser, the height per riser of a flight with 10 steps is immediately obvious.

4. Finally, a good part of SI is already in common use in conjunction with the customary system. Familiar terms, such as the second, ampere, and candela (all base units), and the volt, watt, ohm, coulomb, and lumen, are just some examples. But all these familiar units are fully coherent within SI. This can be best demonstrated by the unit derivation of the unit for electric potential and electromotive force, the volt (V), which relates to the base units for length (meter), mass (kilogram) and time (second), on a one-to-one basis:

$$1\,\mathrm{V} = 1\,\frac{\mathrm{W}}{\mathrm{A}} = 1\,\frac{\mathrm{J}}{\mathrm{s\cdot A}} = 1\,\frac{\mathrm{N\cdot m}}{\mathrm{s\cdot A}} = 1\,\frac{\mathrm{kg\cdot m^2}}{\mathrm{s^3\cdot A}}$$

$$\therefore\ 1\,\mathrm{W} = 1\,\frac{\mathrm{J}}{\mathrm{s}} \qquad \therefore\ 1\,\mathrm{J} = 1\,\mathrm{N\cdot m} \qquad \therefore\ 1\,\mathrm{N} = 1\,\frac{\mathrm{kg\cdot m}}{\mathrm{s^2}}$$

Even if the measurement system is so much simpler to us and more accurate in the results, this alone is hardly sufficient justification for the construction community to join the metric building world.

The real pay-off from metrication lies in the area of "rationalization."

E. Opportunity Two: Rationalization Through Metrication

In the context of the construction community, rationalization can be described as "the selection, from all possible alternatives, of the most rational, preferred, and economical (metric) alternative(s), after research into the technical implication and an appraisal of the economic impact."

1. Preferred Building Dimensions and Preferred Product Sizes

In conjunction with metrication in the construction community, the most significant area for rationalization is that of building geometry and building product sizes. In a metric world, some dimensions will be significantly better than others for the purposes of the development of an industry-wide system of coordinated preferred dimensions for buildings and structures, and preferred sizes of building products for use in their construction. All countries that have preceded the United States in metrication have endorsed the internationally agreed fundamental unit of size (or module) of 100 mm as the basic generic dimension for a system of "dimensional coordination." The task before the U.S. is to strategically select a group of preferred multiples of 100 mm for the sizing of products, so that such "preferred products" will fit buildings designed to strategically chosen and compatible "preferred dimensions" with a minimum of waste in materials or labor due to cutting and fitting.

Some interesting aspects of preferred dimensions and sizes are highlighted:

- Calculations with multiples of 100 mm are much easier than those in the customary system using a 4" module. How many modules are in 5'-8"? Most people within the construction community take at least 10 seconds to answer that question, and quite a few give the wrong answer! But even with a non-preferred multiple of 100 mm, such as 1700 mm, the multiplier factor (17) is immediately obvious.
- Area and volume, as well as other derived quantities in a coherent and decimal measurement system, are obtained directly by multiplication. The use of a 100 mm module--the original basis of the liter cube--provides further simplification in calculations involving mass, force, stress, etc. A 100 mm cube of normal concrete has a mass of 2.3 or 2.4 kg, or exactly one-thousandth of the mass density in kg/m^3. With acceleration due to gravity in SI being approximately 9.8 m/s^2, such a cube exerts an "absolute force" of 23 or 24 newtons (N) in static calculations.
- The selection of preferred building dimensions, such as floor-to-floor height, will provide new incentive to the production of standardized story height components for use in high-rise buildings, such as precast stairs, ducts, shafts, and cladding panels. Optimum design can be combined with off-site manufacturing techniques to increase quality, accuracy, and speed of construction at an economical cost.
- The application of an industry-wide system of preferred dimensions will simplify communication, and give additional impetus to the use of computers for design and detailing.
- The concrete industry has a long legacy of dimensional rationalization of its products. There may be some "adaptation problems" in changing products designed for a customary environment to suit a preferred metric environment. However, the real opportunity arises from greater rationalization of building dimensions, and it is in this area that concrete-based products will become even more competitive.

Concrete could become the first "metric" building material with very few problems.

2. Variety Reduction

The second ingredient of rationalization is variety reduction, by using the metric opportunity to reduce unnecessary and/or uneconomical variety. This can be achieved in part by deletion from a product range, or by substitution of one product for a number of products within the range, or by the introduction of an entirely new range of products, specifically rationalized to suit a certain purpose.

Two items of interest to the concrete industry were chosen to demonstrate how a range of alternatives might be examined before a metric range of characteristics is selected. These are design strength (compressive strength at 28 days) of ready mixed concrete, and deformed steel bars for concrete reinforcement.

Example 1: Concrete Design Strength

Concrete design strengths for general use are contained in ASTM C94-74a (Table 1), and in the various building codes. They are set down in seven increments of 500 psi, from 2000 psi to 5000 psi. While it is recognized that 2000 psi represents a very weak concrete, and that design strengths far in excess of 5000 psi are being used, the approach outlined will cover strengths up to 7000 psi.

Table 6.3: "Rounded" Values for Concrete Strength

Customary Design Strength [in psi]	2000	2500	3000	3500	4000	4500	5000	(6000)	(7000)
Soft Conversion [to MPa]	13.8	17.2	20.7	24.1	27.6	31.0	34.5	(41.4)	(48.3)
Rounding to Equal Steps [MPa]	13.5	17	20.5	24	27.5	31	34.5	41.5	48.5
Rounding to Nearest Integer [MPa]	14	17	21	24	28	31	35	41	48

Neither set of rounding provides a very good set of metric values for concrete design strength. To stop "metric conversion" at this stage would mean to forego the opportunity of rationalization through variety reduction. Thus, the objective of research should be to identify the "best range" of concrete strengths from the producer's, designer's, and user's (contractor's) point of view.

A number of questions arise:

- Is there a "preferred group" of design strengths for concrete which would best suit the requirements of present day construction?
- Can the requirements be met with equal or greater economy by the use of fewer design strength grades? Is there any "natural" selection process in the construction industry now, which favors certain strengths over others?
- Is there any relevant precedent from other countries that have changed to metric?
- Are arithmetic intervals, such as the ones used now, more (or less) suitable than geometric ones? For example, would it be better to have a selection where each successive design strength increases by approximately the same ratio over the preceding strength? Is a selection from the internationally preferred series of numbers, the ISO R-Series outlined in ANSI Z 17.1-1973 "American National Standard for Preferred Numbers," more appropriate?

These questions are significant, and in providing a number of illustrative alternatives of rationalization, it is not intended to prejudice any industry-wide decision.

The alternatives shown have been developed on the basis of two assumptions:

- The "general purpose" range for concrete design strengths lies between 2000 psi (13.8 MPa) and 5000 psi (34.5 MPa), with 1000 psi increments (6.9 MPa), thereafter.
- Metric strengths could be higher at the bottom end, but should not differ so much as to make "substitution" in ongoing projects falling into the transitional period impracticable.

Arithmetic Variety Reduction

Table 6.4: Arithmetic Variety Reduction

(a) Strength grades at 4 MPa interval:
(Reduction from 7 [9] to 6 [8])

Strength in MPa	14	18	22	26	30	34	[42]	[50]
Equivalent in psi	2030	2610	3190	3770	4530	4930	[6090]	[7250]

(b) Strength grades at 5 MPa interval:
(Reduction from 7 [9] to 5 [7])

Strength in MPa	15	20	25	30	35	[40]	[50]
Equivalent in psi	2175	2900	3625	4350	5075	[5800]	[7250]

An examination of overseas precedent shows that the Australian concrete industry adopted new concrete design strengths of 15, 20, 25, 30, 40, and 50 MPa, which represents a further reduction in variety from b. above, as the 35 MPa strength grade was deleted.

Geometric Variety Reduction

Geometric variety reduction should cover a similar range, but with a system of preferred numbers which represents approximately the same percentage increment between consecutive strength grades.

Table 6.5: Geometric Variety Reduction - Selection of Strength Grades from ISO R'10 Series

Approximate ratio between steps 1:1.25
(Reduction from 7 [9] to 4 [6])

Strength in MPa	16	20	25	32	[40]	[50]
Equivalent in psi	2320	2900	3625	4640	[5800]	[7250]

Example 2: Deformed Steel Bars for Concrete Reinforcement

Similarly, reinforcing bars for concrete lend themselves to variety reduction during metrication. A number of technical considerations are involved:

- Can variety reduction facilitate rather than complicate design?
- Can a range of metric sizes which will allow the "direct substitution" of some of the new bars for customary bars during the transitional period be obtained?
- Is it practicable to select and designate metric bars in terms of cross-sectional area, the single most important demand (design) characteristic?
- How can the use of materials be optimized?

The principal characteristics of customary reinforcing bars, in metric units, were derived from ASTM Standard Specification A 615-76a (Table 1):

Table 6.6: Principal Characteristics of Customary Reinforcing Bars, Expressed in Metric Units

Designation	#3	#4	#5	#6	#7	#8	#9	#10	#11	#14	#18
Diameter (mm)	9.52	12.7	15.9	19.0	22.2	25.4	28.7	32.3	35.8	43.0	57.3
Area (mm^2)	71	129	200	284	387	510	645	819	1006	1452	2581
Mass per unit length (kg/m)	0.56	0.99	1.55	2.24	3.04	3.97	5.06	6.40	7.91	11.4	20.2

The data indicate that a soft conversion to metric designations would not be a desirable approach to metrication. With a soft conversion there is no benefit of rationalization in numbers or in the total range.

Precedent shows, that both Britain and Australia rationalized the metric reinforcing bar range by changing to a reduced range and new "preferred" diameter designations.

Britain: (8 metric bar sizes): <u>10</u>, <u>12</u>, <u>16</u>, <u>20</u>, 25, <u>32</u>, <u>40</u>, <u>50</u>

Australia: (10 metric bar sizes): <u>10</u>, <u>12</u>, <u>16</u>, <u>20</u>, 24, 28, <u>32</u>, 36, <u>40</u>, <u>50</u>

(common sizes are underlined)

The British bar sizes, designated by nominal diameters, reflect almost exactly the ISO R-10 Series of preferred numbers, while Australia has opted for an arithmetic increment of 4 mm between 12 mm and 40 mm.

The metric 16 mm, 32 mm, and 36 mm bars were within production tolerances of existing bars and thus could be safely substituted. Similarly, the 10 mm and 20 mm bars, while a new product, could be used on-site in transitional projects, because they vary on the safe side. In most instances, a 25 mm diameter bar, while smaller than a #8 bar, would allow direct substitution.

The major question is whether metrication might be taken as the opportunity to change reinforcing bar designations to preferred cross-sectional areas, while at the same time reducing variety.

This issue has been tackled by the Canadian reinforcing steel industry. A new standard for metric reinforcing bars is based upon cross-sectional areas that are multiples of 100 mm^2, and the range of bars has been reduced from 11 to 8.

<u>Canada</u>: (8 metric bars sizes - areas in mm^2):
100, 200, 300, 500, 700, 1000, 1500, 2500

At first sight, this range represents an appealing "rationalization." However, a closer examination shows that some "doubling up" in areas occurs when 2 or 3 bars are used, so that the only additions to the range of cross-sectional areas between 100 mm^2 and 2500 mm^2 are:

400	-	(2 x 200)		
600	-	(2 x 300)	or	(3 x 200)
900	-			(3 x 300)
1400	-	(2 x 700)		
2000	-	(2 x 1000)		
2100	-			(3 x 700)

As a further refinement, the introduction of a 1600 mm^2 bar in lieu of the proposed 1500 mm^2 bar, would provide a more useful geometric step for design purposes.

The United States reinforcing steel industry does not face the same urgency of commitment to metric reinforcing bar sizes, although it would be highly desirable to establish one "North American" product range. There are, however, few obstacles in changing to a preferred metric product range even before the industry at-large changes to metric measurement. The argument for variety reduction should be equally strong in the present environment.

To optimize the use of material and to simplify production and inventory control, the now available lead-time ought to be beneficially utilized to analyze customary demand factors and the impact in economic and technical terms of alternative metric reinforcing bar ranges.

There are a number of alternatives, including selections based upon the ISO R 5 and R 10 preferred number series, such as:

- ISO R 5: (8 metric bar sizes - areas in mm^2)
  100, 160, 250, 400, 630, 1000, 1600, 2500

  (Intermediate steps, such as 200, 320, 500, 800, 1260, 2000, etc., are formed by doubling the number of bars.)

- ISO R 10: (8 metric bar sizes - areas in mm^2)
  80, 125, 200, 315, 500, 800, 1250, 2000

  (Again, intermediate steps, such as 160, 250, 400, 630, 1000, 1600, 2500, etc., are formed by doubling the number of bars. In addition, 4 bars are within manufacturing tolerances of existing bars and could be directly substituted: 125 for #4, 200 for #5, 500 for #8; 800 for #10.)

There is a good chance that a North American change to deformed reinforcing bar designation by preferred metric cross-sectional area would be followed by other countries in the metric building world.

The two examples, while brief and by no means exhaustive, indicate that variety reduction for improvement and cost reduction provides an excellent topic for technical research and economic analysis; namely, the optimization of catalogs. But in order to optimize, we should go back to a "zero base."

F. Opportunity Three: Harmonization

There are many examples where metrication can and will assist in the harmonization of differing practices, processes, or procedures. In most instances, harmonization can be linked with rationalization.

Two areas for harmonization, which is the unification of differing approaches, are given to serve as examples:

1. Drawing scale ratios for use in building drawings are generally agreed for the main working drawings, but, in detailing, the different design professions follow their own preferences or at times, the dictates of paper size or residual space on a drawing.

   In metric drawings of buildings or building components in preferred dimensions, drawing scales in the ratios 1:1, 1:2, 1:5, 1:10, 1:20, 1:50, 1:100, and 1:200 are most suitable. This is because they simplify work. The designer can make judicious selection of a set from the above range, such as 1:100, 1:20, 1:5, and 1:1, to show progressively greater detail.

   However, what is far more significant, is that metrication will become the external factor to unify the detail scales used by architects and engineers which, traditionally, have differed. Drawings prepared on transparent media can then easily be superimposed to show any misfit or omissions, but this is only practicable when the drawing scales are in harmony. Fewer scales in a harmonious range have a number of fringe benefits: they make work easier and faster; they lend themselves well to computer aided techniques; they facilitate reduction or enlargement; and, they certainly assist those on the construction site, who only work with one scale, full size or 1:1.

2. Building codes have been developed at the local or regional level. Twentieth century mass production techniques, and a national/international scale of operations in technology, design, and construction have created growing pressures for greater "harmonization" of the regulatory requirements. The catch phrase is that diversity leads to cost increases. Whether this is true or not, metrication is likely to become the external factor in the harmonization and unification of building requirements and associated criteria. This does not mean "one building code," but it certainly means that in some areas of community-wide significance "all" building codes should have compatible requirements.

   A cogent example is that of stair geometry in buildings. For no apparent reason, the limitations on stairway dimensions differ in different codes - while the functional, anthropometric and safety requirements of the U.S. community have common denominators. The change to a metric (preferred dimensional) building environment will also produce more "harmonious" requirements.

G. Opportunity Four: Standardization

Modern society relies on a framework of "standards" to describe desired and preferred characteristics for a wide range of physical conditions, products, or performance. Standards constitute one of the principal vehicles for rationalization, but at times they can also become an equally significant obstacle.

Metrication is likely to lead to a renewed standards effort in all areas because it has a multiple impact on standardization:

- All measurement sensitive standards and associated data--nearly all of the information used in the construction community--will be subject to review. Now available lead-time would be well spent to plan the most effective format for the new metric standards data bank for the construction community, to obtain the best and most workable information base for the long metric future.
- Duplication of effort is costly and should be avoided, wherever possible. One metric consensus standard could well suffice in any areas where a number of standards presently deal with the same issue.
- The development of SI, and the change by all countries to SI, have instilled a great impetus to the international standards movement. A United States, on the way to metric, will be very much better equipped to speak with an authoritative voice in the metric building and building standards world.

All who participate in some way in the development of standards will probably soon begin to see the full extent of the metric "opportunity."

H. Metrication - How to Proceed from Here?

It is easy to postulate what might be done, but how do the individuals and the organizations become involved? Large questions loom: Which areas are affected by the change? When should we start to get involved? Who should make the necessary decisions and who can participate? What do we get out of it?

Many answers are suggested in this paper, but the key replies in shorthand form are:

- All measurement sensitive areas will be affected by metrication. In many of them it will be a "hard" change, which involves more than just a change in the description or a new label. The more complex the activity, the more likely it is to be affected, but the more scope there is bound to be for beneficial review and technical improvement.
- The time to get acquainted and involved is now - the more the system and the issues involved in metrication are understood, the better the position to extract benefits from the change and to minimize the costs of it. It can be a consideration in future planning and actions. Producers may be able to start new product development in preferred metric units, rather than in customary units. One product may serve both a declining customary market, as well as a growing metric market, if it is designed in metric units, but sold for an initial period under a "customary veneer."
- As far as practicable, decisions should be consensus decisions that enjoy the support of designers, producers, contractors, and the user/community alike. There is ample room for all "positive" contributions to the change.

- In general, metrication provides as much as is put into it. More awareness will mean fewer obstacles. "Metrication can be fun, if treated as a challenge and an opportunity for improvement, rather than as a problem."

CONCLUDING REMARKS

The change to the International System of Units represents one of the great challenges of our time. It is a once-only chance for modern society to review the entire technical data base and technical procedures, and then to "simplify, rationalize, harmonize, and standardize," so that improved solutions become permanent in a metric environment. This is a task of major significance which should not be undertaken lightly or superficially. It is the construction community's most significant research opportunity, and one chance where "research should pay off handsomely."

Most people favor "progress," as long as it does not involve too much change. "Change," however, is the mainspring of progress. And progress rarely occurs without a few people who are upset, and possibly never without a "few problems." This paper suggests that the "metric problem" should not be overemphasized, because it is mainly a phychological one rather than a physical one. Overseas experience has shown quite clearly that, where problems are not accorded prominence, many of the forecast problems simply fail to materialize.

Opportunities, on the other hand, rarely appear without prompting. To materialize, "opportunities must be identified and then be forcefully pursued." The benefits from opportunities realized should easily pay for the costs of the change.

Metrication is not a dull chore; it is something to get excited about. It needs people with vision, energy, and persistence to get the best out of it. If metrication can be seen in a new light and as a "worthwhile challenge," rather than merely as another "problem," then it can be tackled as a "concrete opportunity."

SECTION 7

Metric Sizes for Building Lumber and Other Wood Products:

The Issues, International Precedent, and Suggestions for the U.S. Wood Products Industry

Paper prepared for presentation at the Society for Wood Science and Technology Seminar, "Metrication...Impact on Wood Products," held on July 3, 1977, at Denver, Colorado.

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INTRODUCTION

There is widespread recognition and philosophical acceptance that a metric North America is inevitable and almost certain to be a fact in many industries within the next decade. While Canadian building products manufacturers have geared up for their construction industry M-Day (January 1, 1978), their United States counterparts will have a considerably longer "lead-time," until large-scale metric production is required. The main question before U.S. industry in this passive phase of metrication is how to make the best use of the available lead-time to insure the wisest long-term choices in the conversion of product sizes and characteristics. These choices should be based upon a thorough analysis of the issues involved, the examination of precedent, and informed judgment on the relative importance of all items affected by metrication.

It is fairly certain that metric choices, once determined and implemented will remain long into the future as part of a metric construction environment. For this reason, it is important to minimize haphazard or timid choices. If such casual choices are made they will leave a legacy which will inevitably require further changes later on, with all the unnecessary cost, disruption, and possible loss of market position that derives from a second, superfluous change.

This paper discusses some of the principal issues that should be investigated before irrevocable decisions are made. It examines some aspects of recent international precedent in metrication of lumber and other wood products for use in building; and, finally, it suggests a number of worthwhile areas for research prior to a "final" metric judgment.

Part I

ISSUES IN METRICATION WITHIN THE WOOD PRODUCTS INDUSTRY

A. Approaches to Conversion and Rationalization

There are two extreme options for the product manufacturing industry: "soft conversion" and "hard conversion."

In a "soft conversion," products remain unchanged within normal manufacturing tolerances; just their description is changed to metric (SI) units. The term "soft conversion" signifies that the only changes occur in the paper-based data - the software. This approach to metrication, while more expedient at first sight, has generally been recognized as yielding inferior solutions in the long run.

In a "hard conversion," the product and, sometimes, the entire product range are changed physically to new, preferred, and different characteristics. Changes are made not only to product data, but to the product--the hardware--thus the term. In most instances, a "hard conversion" is the more difficult form of change, but it is almost certain to yield better dividends in the long run.

It is possible to combine rationalization and reduction of the product line with either form of conversion. However, only in a "hard conversion" can an optimum product catalog be obtained. An optimum product catalog is the least number of preferred properties for the best coverage of end use requirements.

Thus, a progression in approaches to metrication is obtained.

Approach 1: Conversion and rounding within tolerances (Soft Conversion);

Approach 2: Reduction of product line (Deletion of unnecessary products);

Approach 3: Conversion to new and preferred sizes and properties (Hard Conversion); and,

Approach 4: Catalog optimization (Selection of the optimum product range).

There also are some other alternatives that fall between Approaches 2 and 3, such as the substitution of one preferred size product for two or more customary products, which represents a "partial hard conversion."

Some products have more than a single demand characteristic; thus, some factors may be hard converted, while others are soft converted, to achieve the most economical conversion. For example, building lumber is differentiated by size of cross-section, length, condition (dry or green), strength grade, and species (which remains unaffected by the change). While cross-section and length may be hard converted, and strength grades rationalized, it is unlikely that the dividing line between dry and green lumber will be changed as a result of metrication.

Compared with most other industries which produce dimensioned products, the sector of the wood products industry that manufactures building lumber and panels faces the forthcoming change to metric product sizes and product characteristics with a great deal more flexibility. Adjustments to a manufacturing plant necessitated by a change to metric sizes can be accomplished with little cost and disturbance. Very little equipment would be rendered obsolete because it cannot produce metric sizes.

This paper concentrates predominantly on framing lumber for light-frame construction. Some portions, however, are addressed to worked lumber and wood-based panels.

B. Wood Products for Use in Building - The Diversity of Interests in the Marketplace

It has been stated that the wood products industry has been active in developing contingency plans for metrication; that many of the issues affected by metrication already have been resolved; and, that the wood industry is ready for the implementation of a "metric environment" when the time is appropriate.

This certainly is a progressive approach; but, the question arises as to whether all parties with a strong interest in wood-based building product sizes and properties have been consulted or have been involved in the "metric decision" processes. Decisions relevant to wood products affect some 33 parties to a greater or lesser extent:

1. Resource Owner or Lessee (Forest Owner or Lease-holder)
2. Raw Material Harvester (Logger)
3. Raw Materials Processor (Sawmill, Chip Plant, Pulp Plant, Ply Plant, etc.)
4. Secondary Processor (Remanufacturing, Resawing & Finishing, Board Manufacture)
5. Exporter of Lumber or other Wood-based Building Products
6. Importer of Lumber or other Wood-based Building Products
7. Lumber Wholesaler or Broker
8. Lumber/Wood Products Distributor or Dealer (Lumber Yards, Lumber Merchants)
9. Manufacturing Consumer of Lumber/Wood Products (Prefabricators, Component Industry, Truss Manufacturers, etc.)
10. Manufacturers of Wood Processing Equipment
11. Manufacturers of Accessories and Fasteners for Lumber/Other Wood Products
12. Retailers of Equipment, Accessories and Fasteners for Wood Products
13. Building Contractor
14. Subcontractors
15. Building Trades Working with Lumber/Wood Products (Carpenters, Joiners)
16. Site Operative and Site Labor
17. Private Customer of Lumber/Wood Products (Handyman)
18. Building Owner/Manager/Client
19. Architect/Building Designer
20. (Wood Products) Design Engineer
21. Specification Writers and Services
22. Drafting Services
23. Wood Products Research and Development
24. Building Research
25. Testing Facilities (Laboratories)
26. Technical Information Services

27. Scientific Data Centers and Technical Libraries

28. Producers' Data Services and Catalogs

29. Standards Writing Organizations

30. Codes Writing Organizations

31. Educational Facilities for Designers (Universities, Technical Colleges)

32. Educational Facilities for Building Trades (Colleges, Trade Schools)

33. Metric Education/Familiarization Services (Internal or External)

While this is an impressive list of diverse groups with an interest in wood products for use in building, not all groups would be directly involved in decisions relating to metric sizes or product characteristics. However, most of these groups would be affected either by the changes in product characteristics or the changes in technical data that are caused by metrication.

C. <u>Interface Areas and Impact of Metrication</u>

Table 7.1 was developed to illustrate which activity groups are likely to be influenced by different effects of metrication of wood products for building. In addition, it denotes the degree of influence; either strongly (due to a major impact or interest), or "partially" (due to a limited impact or interest of an indirect nature).

Table 7.1 shows two categories of the "effect of metrication:"

A. direct impact due to metrication of the product; and

B. indirect impact due to associated changes or considerations.

In general, the indirect impact items are related also to direct impact items. For example, while lumber (log) yield is not affected by a "soft conversion," it is certainly affected (positively or negatively) by a change to metric preferred sizes.

The principal purpose of the Table is to alert the wood products industry that there are many impacts of metrication decisions which should be taken into consideration in the determination of metric product characteristics.

D. <u>Some Questions Related to Metrication in the Lumber/Wood Products Industry</u>

As a result of both the diversity of interest in the marketplace and the interface areas outlined in C above, there are many questions that should be asked and considered, before a binding commitment is made to produce a specific set of metric products or product sizes. The answers to some of these questions may show that those aspects that superficially appear to be more important, are not necessarily the most significant across the entire construction community.

Table 7.1: The Impact of Metrication in the Wood Products Industry on Various Activity Groups Associated with Construction

EFFECT OF METRICATION ON WOOD PRODUCTS FOR BUILDING	PRODUCTION & DISTRIBUTION			PRODUCT USE				DESIGN		R & D		INFORMATION		
A: Direct Impact B: Indirect Impact	Producer	Wholesaler	Lumber Dealer	Manufacturing Customer	Contractor	Site Labor	Private User [Handyman]	Engineering Designer	Architect	Wood Research & Development	Building Research	Technical and Product Data	Codes and Standards	Educational Activities
A1 Metric Product Description	o	o	●	o	o	o	o	●	●	●	o	●	o	o
A2 Preferred Metric Sizes	o	●	●	●	●		o	●	●	●	●	●	o	
A3 Need for Special Sizes		o		●	o			o	o		●			
A4 Metric Lengths	●	●	●	●	●				o	o		o		
A5 Tolerances	●			●	o			●	●	●	o	●	●	
A6 Geometric and Structural Properties	o	o		●	●			●	o	●	●	●	o	o
A7 Other Properties	o			●	o			●	●	●	●	●	o	
A8 Design Information		o		o	o			●	●	o	●	●	●	●
A9 Construction Details		o	o	●	●	●	o	o	●	o	o	●	o	●
A10 Jointing Techniques				●	●	●		o	●	●	o	●		o
A11 Test Methods	●			●	o			●	●	●	●		●	
A12 Identification/Marking	●	●	●	●	●	●	o			o		●	●	
A13 Product Availability	o	●	●	●	●		o	o	●			o		
A14 Price		o	o	●	●		●		●					
B1 Lumber [Log] Yield	●									●				
B2 Processing Techniques	●			●						●				
B3 Processing Cost	●			o						o				
B4 Grading Systems	●	o		●	●			●	o	●		o	●	
B5 Inventory Turnover	●	●	●	●	o									
B6 Competition from Other Product Alternatives	●	●	o	●	o			●	●	●	●			
B7 Trade: Export	●	o		o						●				
B8 Trade: Import	o	●	●	●	o			o	o	o			●	
B9 Retrofit/Rehabilitation					●	●	●		●		●		o	o
B10 Metric Education or Familiarization	o	o	●	●	●	●	o	●	●	o	o	●	o	●

● strong impact or interest   o some impact or interest

Detailed answers are not provided to the following questions, which are set out under a number of headings:

Wood Products End Use

- What percentage of wood product is used in each of the major market segments (pulp and paper, wood chip, plywood, building lumber, heavy structural timber, boxes and crates, furniture)?
- What percentages of each market segment are hardwood and softwood?
- Is the home building market the principal market for framing lumber and other wood products?
- If so, is it this market that should determine structural and other product sizes and characteristics?
- Are special products or sizes required in secondary processing for use in building construction; i.e., doors, windows, panels, moldings, steps, handrails, furniture, etc.?

Wood Products as a Resource

- Are building lumber and other wood products for use in construction a scarce resource?
- To what extent can existing lumber be reused?
- Which alternative materials or products are competitive, or potentially competitive, in a metric building market?
- Will a reduced product range improve wood utilization?

Wood Products in Manufacture and Distribution

- Will new (preferred) sizes affect log yield? If so, in what way?
- Will new (preferred) sizes affect production techniques, production capacity, production costs, and production equipment? If so, to what extent?
- What are the costs of changing from one size or set of sizes to a new size or sizes?
- What are the savings associated with longer production runs?
- Will new (preferred) sizes affect the inventory and distribution system?
- Is it more economical to produce/stock fewer sizes, even if some customers who demand "special" sizes are lost?
- What are the sizes with the best turnover? Are there any cyclic changes?
- What are the sizes with the highest profitability? Is profitability related to turnover?
- What are the best lengths for stocking and distribution?
- Are all the present trim patterns and worked lumber profiles required? Is there any reason that metric (preferred) trim patterns cannot be produced and distributed now, if necessary under customary measurement designations?

- Is it possible to develop a national catalog of "standard metric" trim patterns and moldings in preferred dimensions for use throughout the United States? If not, what are the reasons?
- What is the value of "nominal sizes?" Does a "board foot" yield more or less lumber than suggested by the "nominal size?"

Wood Products Design

- What are the principal design factors relating to lumber and other wood product use? What is their interaction?
  - Geometric Factors: span, spacing, face width, wall thickness, panel height, stud length, connections, etc.
  - Structural Factors: span, spacing, section properties (section modulus), strength grade (modulus of elasticity), loading, connections, fasteners, etc.
- What percentage of structural framing lumber is used for studs, joists, rafters, posts and beams, etc.?
- Will the introduction of metric dimensional coordination create new or differing design approaches to structural framing?
- Is a greater emphasis on energy efficient design likely to lead to new requirements and new product sizes, which might be introduced as metric preferred sizes from the outset?
- Is it possible to select spacings and spans that will limit the number of sizes of framing lumber required to satisfy the principal design requirements? Or, is spacing dependent upon cladding and cover materials?

Wood Products in Construction

- Are there practices in lumber framing and other wood products' usage which are extravagant, unscientific, or unnecessary? If so, would it be practicable to eliminate them during metrication to achieve greater efficiency?
- Do lumber framing practices vary in different States? If so, why?
- Are there product sizes which are superior in a system of centerline setting-out in construction?
- What is the minimum stud thickness (face width) for effective fastening of panel materials?

Introduction of Metric Wood Products

- How should the change-over be planned so that old stocks are not left unmarketable? How can two product lines best be avoided?
- What education/familiarization effort is required for designers, contractors, contracting labor and tradesmen, general customers, and educational institutions?

- What are the most suitable means of metric familiarization for production staff, office and marketing personnel, managerial staff, and distributors?
- When, where, and by whom, are metric product standards for lumber and other wood products required?
- What is the best time frame for a metric education/familiarization effort?

These questions simply provide an outline and are a representative sample of the type of questions that will need to be answered. In many areas, they will need to be expanded in detail and in terms of different product groups. However, until evidence has been gathered, assembled, and documented, it will be impossible to achieve the most cost-effective and beneficial change to a metric wood products environment. While a "soft conversion" of existing sizes, properties, and practices, provides one possible approach to metrication, it is by far the most suspect approach because it ducks too many questions.

At a more fundamental level, metrication will become the catalyst for a beneficial cross-examination of traditional approaches and practices.

E. A Set of Metrication Objectives for the Wood Products Industry

To obtain the best foundation for metrication and a guiding framework for its implementation, it is desirable to have a "set of metric conversion objectives," against which questions may be asked, as well as the merit of various alternative answers or approaches assessed. The simple objective to get metrication over and done with as expeditiously and cheaply as possible is unlikely to yield adequate dividends for the efforts and costs expended.

In relation to metrication, the overall objective for the wood products industry might well be: "To achieve the most cost-effective but least disruptive transition to metric sizes and properties, in order to ensure the greatest facility in use of wood products in a metric building world, and to preserve or enhance the competitive status of the wood industry."

Part II

INTERNATIONAL PRECEDENT IN METRICATION OF LUMBER AND WOOD PRODUCTS

International precedent in metrication of framing lumber and other wood-based products for use in building may offer a number of useful lessons to the U.S. wood products industry by:

1. highlighting the issues that are likely to arise in the change;
2. indicating the type of difficulties which may be expected;
3. drawing attention to the opportunities associated with metrication; and,
4. showing alternative solutions adopted elsewhere.

Historical factors and the differing availability of wood resources have caused various countries to develop different approaches to the production, use, and description of wood products for building. Before it becomes practicable to contrast alternative approaches, it will be necessary to briefly examine some of the concepts that are used to describe building lumber and, to a lesser extent, other wood-based products for use in building.

The concepts deal with the description of sizes and their variation due to changes in moisture content, as well as with permissible deviations or tolerances.

A. Units of Measurement

In all countries that have preceded the U.S. in metrication, cross-sections of framing lumber, face areas and thicknesses of panels, profiles of patterned sections, and tolerances have been described in millimeters.

Lengths of framing lumber have been described in meters or in millimeters.

B. Size Designations for Framing Lumber

Various concepts of "size" are used internationally to describe cross-sections of framing lumber. The most significant of these are examined and contrasted below:

- Nominal Size (or Call Size) - the size originally derived from the rough sawn and unseasoned dimension, and it has been used to describe lumber in commercial transactions. One reason for nominal sizes was the desire to avoid the use of designations in fractions of inches.

  The nominal size is always larger than the "actual" size to allow for the shrinkage factor during drying, for surface dressing, or for any further processing for the purposes of attaining uniformity of size.

  Due to the much greater inherent precision of the metric measurement unit--the millimeter--which provides an accuracy interval of 1/25 inch, nominal sizes have little value in a metric environment and, therefore, should be abandoned.

- Actual Size - the true size of cross-sections obtained by measurement; will change with changes in moisture content.

  Actual sizes should be within the tolerances specified to allow for production deviations.

- Basic Size - a concept used in Britain to indicate designated cross-sectional sizes at a specified moisture content, in respect of which tolerances are established.

- (Guaranteed) Minimum Size - the least cross-section that is permissible in "green" or "dry" lumber. A "guaranteed minimum size" has no negative tolerances.

- Resawn Size - a smaller than regular size, obtained by resawing from a larger section into two or more smaller sections.

From the different size designations indicated above, it is clear that the metric framing lumber environment could benefit from a concept of "designated sizes." Such designated sizes are representative of the guaranteed minimum size at a specified moisture content (M.C.).

This concept is discussed in Part III, Suggestion 8.

C. Size Variations with Changes in Moisture Content - Shrinkage

As wood dries below the fiber saturation point, shrinkage occurs across the grain and there is a reduction in cross-sectional area. Shrinkage along the grain can normally be ignored. For every 5% reduction in moisture content below the fiber saturation point (25 - 30% moisture content), shrinkage across the grain is 0.5 - 1.5% for most softwood lumber, and 0.5 - 2% for most hardwood lumber.

Ideally, dry dressed dimensions of framing lumber should be related to moisture content at the time of production. Moisture content may be measured by electric moisture meters or by laboratory testing. It is recognized that moisture content (M.C.) can vary significantly even within a single piece of lumber; therefore, many other countries specify size in relation to a "moisture content range."

Table 7.2 shows moisture content values for "dry" and "green" building lumber in the U.S. and a number of other countries. Generally, lumber in the range from 10-20% moisture content is considered to be "dry."

Table 7.2: Assumed Moisture Content Values for "Dry" and "Green" Building Lumber

COUNTRY	"DRY LUMBER"	"GREEN LUMBER"	REMARKS
U.S. and Canada	less than 19%	more than 19%	
Australia	12%		Range 10 - 15%
Britain	14 - 20%		Precision Lumber
New Zealand	14 - 18%	more than 26%	
South Africa	15% 17%		Merchantable Utility

In Britain, the "basic size" of lumber is related to an "average moisture content" of 20%. For every 5% reduction in M.C., a 1% reduction in size is permitted; for every 5% increase in M.C., a 1% increase in size is required. This concept accounts for size variations due to moisture content similar to the U.S./Canada concept of allowing for a 1% (0.7%) shrinkage after dressing for each 4% change of moisture content below 19% for softwood lumber (except Redwood, Western Red Cedar, and Northern White Cedar - see also page 122).

D. Tolerances (Permissable Deviations)

Some countries permit additional adjustments to lumber sizes to allow for other factors causing deviations from the designated size. If a meaningful comparison of international lumber sizes is to be made, any such permissible deviations must be taken into account.

The various concepts of tolerance in use can be categorized as follows:

- Plus-and-Minus Tolerance (Equal) - has been used historically for hardwood lumber, and it relates to a mid-size. (For example: 50 [+2, -2] indicates that any size from 48 to 52 would be acceptable.)
- Plus-and-Minus Tolerance (Unequal) - normally sets a larger positive limit than negative limit. (For example: 50 [+3, -1] indicates that any size from 49 to 53 would be acceptable.)
- Specified Negative Tolerance - sets specific lower limits, but no upper limits on size. (For example: -1 mm for each 50 mm [or part thereof] means that 49 would be acceptable in lieu of 50, and 196 in lieu of 200.)
- Zero-Negative Tolerance (With an Upper Limit) - indicates a "guaranteed minimum size," which cannot be less than the designated size, but may be larger within the specified limits. (For example: 50 [+2, -0] indicates that any size between 50 and 52 would be acceptable.)
- Zero-Negative Tolerance (Without an Upper Limit) - indicates a "guaranteed minimum size," which cannot be less than the designated size, but is open-ended on the positive side, thus relying on market factors to provide the upper limit. It is based on the consideration that producers of framing lumber will not unnecessarily give away any cross-sectional area.

In building applications, the concept of "zero-negative tolerance" (sometimes called "no-minus tolerance") means that the customer obtains at least the size of section that is required for his purposes and for which he will pay. It is also the most desirable concept in terms of design detailing. Furthermore, the "guaranteed minimum size" introduces a greater incentive to produce accurately sized framing lumber.

E. Precedent in the Conversion of Lumber and Other Wood Products

In the study of international precedent in metrication of framing lumber and other wood products for use in buildings, both a "hard conversion approach" to new and preferred sizes and a rationalized product range, and a "soft conversion approach" to metric equivalents of customary sizes (within tolerances) can be observed.

Table 7.3 depicts the various metrication approaches to lumber and other wood product characteristics adopted in Australia, Britain, Canada (suggested), New Zealand, and South Africa.

Table 7.3: Approaches to Metrication of Wood Products for Building in Other Countries

PRODUCT CHARACTERISTICS	HARD CONVERSION					SOFT CONVERSION					REMARKS
	Australia	Britain	Canada	New Zealand	South Africa	Australia	Britain	Canada	New Zealand	South Africa	
SOFTWOOD LUMBER											
a. Size[s] - green						●[1]		●[3]	o	●	[1] Nominal sizes retained
- dry	●[2]	o					o	●[3]	o	●	[2] Guaranteed minimum sizes - positive tolerances only
b. Tolerances	●[2]	o		o	o		o		o	o	[3] Provisional only
c. Lengths	●	o		●	o					o	
d. Strength Grades						●				o	
e. Method of Sale	●	●									
HARDWOOD LUMBER											
a. Size[s] - green						●	●				
- dry							●				
b. Tolerances						●					
c. Lengths	●	●									
d. Strength Grades						●					
e. Method of Sale	●	●									
WORKED LUMBER [DRY] (Patterned, Matched, Shiplapped, etc.)											
a. Profiles	o			●		o	●			●	
b. Lengths	●	●		●	●						
PLYWOOD & PARTICLE BOARD											[4] Increasing availability of preferred metric sizes
a. Size	o[4]	o[4]		o[4]	o[4]	o	o		o	o	
b. Thickness	●				o		●		●	o	

o partial hard conversion and partial soft conversion

● one form of conversion only

In some instances, both a "soft conversion" and a "hard conversion" were affected. For example, in panel materials, the gradual transfer to a metric building environment in Australia, Britain, New Zealand, and South Africa, was accompanied by an increasing penetration of metric preferred panel sizes, and a decline of traditional, soft-converted sizes.

Not all the information from the five precedent countries is available. However, Table 7.3 provides a guide to the type of analysis of precedent that might be employed by individual sectors of the wood industry, or by individual organizations within the industry.

F. Comparison of Metric Sizes for Dry Dressed Softwood Framing Lumber Adopted or Recommended in Other Countries

In this paper, dry dressed softwood lumber was selected as a specific example for a more detailed study of precedent. This is because in deliberations to date, the greater emphasis has been on metric sizes for softwood lumber.

Unfortunately, there is no international standard dealing with recommended sizes for dry dressed softwood lumber. In fact, the only international standard prepared within ISO, the International Organization for Standardization, that deals with framing lumber is ISO 3179 - 1974, "Coniferous Sawn Timber - Nominal Dimensions."

This standard lists 143 preferred sizes of coniferous sawn lumber at a 20% moisture content, ranging in thickness from 16 mm to 300 mm, and in width from 75 mm to 300 mm. Also indicated is a range of non-preferred thicknesses, which further increases the number of alternatives. However, in presenting such a variety of alternatives, the international standard more resembles a catalog of international sizes than a vehicle for greater worldwide standardization.

Appendixes A to E provide details on metric sizes of structural softwood lumber adopted or proposed in Australia, Britain, Canada, New Zealand, and South Africa (Appendixes A to E, respectively).

The Appendixes clearly demonstrate that no international uniformity exists in the sizing of "dry dressed" or "finished" softwood lumber (timber). However, they also show some very interesting differences in the selection of framing sizes. With the exception of the provisional sizes indicated by Canada, in all instances the change to metric has been utilized as an opportunity to define a preferred range of sections, by selecting from all combinations of thickness and width only those sizes that are especially suitable for building purposes. This approach is best illustrated in the selection of sizes in common use shown in Appendix D (New Zealand). This Appendix relates typical section sizes to specific purposes.

In assessing the preferred sizes within the range 19 mm to 100 mm for thickness, and 35 mm to 400 mm for width, the following numbers of preferences were identified in different countries:

- Australia — 25 preferred sizes
- Britain — 81 basic sizes
- New Zealand — 43 preferred sizes
- South Africa — 30 preferred sizes

It appears that a product range of 30 to 40 structural framing sizes is quite adequate. Such a total might be further subdivided into a "first preference" (the most preferred sizes) and a "second preference" (other sizes).

Part III

SOME "METRICATION SUGGESTIONS" TO THE U.S. WOOD PRODUCTS INDUSTRY

Research activity is an essential part of the metrication process in the early or "investigation" phase of a metrication program. The results of thoughtful inquiry are certain to provide a better basis for the transfer into a metric building world, than a unilateral "soft conversion approach."

This paper offers ten suggestions to the U.S. wood products industry, outlining ten selected areas where metric investigation, analysis, and action can lead to a better information base for the eventual decision making. The objective of the suggestions is to create an awareness of some of the obligations and opportunities before the industry--the trade-off between which should be effected in such a way as to preserve and enhance the competitive position of lumber and other wood products for use in a metric building world.

The suggestions are not necessarily stated in their order of significance. Examples are included merely to illustrate a point, and they do not constitute an endorsement of a specific course of action.

A. Suggestion 1 - Establishment of a Metric Wood Products Research Group

Metrication is too big an issue in the long term, to be left to just a few decision makers. Serious thought should be given to the establishment of a full-time Metric Wood Products Research Group (MWPRG), appointed for a limited period of time. This Group would receive suggestions, evaluate alternatives, and prepare proposals dealing with metrication of wood products, to assist the high-level committees charged with the final determination of metric sizes and properties. The Group also would provide technical input into standards-writing activities involving metric wood product characteristics.

The MWPRG would be comprised of experts from the following areas: production, marketing, design, construction, and codes/standards writing; thus forming a multidisciplinary team of no more than ten people, who can readily liaise with each other on all issues.

Before embarking on any recommendations, the Research Group would gather comprehensive information on present techniques in production, distribution, design, and construction; their geographical distribution and variances, if any; their merit; known problem areas; cost factors; and associated matters. This alone would shed more light on metric opportunities and problems, and it would ensure the development of the best possible information base for eventual decisions.

This Research Group would be the logical vehicle to study the issues outlined in the other nine suggestions.

B. Suggestion 2 - Preparation of a Comprehensive Report on Issues in Production and Distribution of Lumber and Other Wood Products

Many statements that have been made in relation to complexities connected with metrication in the wood industry can be likened to "shooting from the hip." When questioned on details, the spokesmen often appear to lack a knowledge of the important considerations. To obtain a balanced perspective of "real" versus "imagined" issues, it is suggested that a report be prepared which, inter alia, might address the following questions:

- What current production techniques are used in the U.S. wood products industry?
- What percentage of building lumber is produced by sawing single sizes from logs, compared with sawing of multiple sizes? What percentage is resawn after drying?
- What percentage of cross-sectional area is lost in the finishing processes (dressing or working)? What is the minimum dressing allowance per side?
- Does the material that is removed in the finishing process have any commercial value?
- How adaptable to change are the various production techniques?
- How were changes to reduced sizes in softwood lumber handled at the time of their introduction, approximately 10 years ago? What were the costs of equipment modifications at that time, if any? How were the new sizes handled in inventory?
- What are the demand preferences in the marketplace, if any? Is supply dictated by demand factors, or by production schedules?
- Would a "system of size and length preferences" assist the producer and distributor (lumber dealer)?
- How are building lumber and other wood-based products for use in buildings marketed and distributed? What percentage is handled within integrated operations?
- What percentage of lumber is produced in each of the major different sizes? Do such sizes represent any "natural preferences?"
- What special sizes, if any, are demanded by and produced for consumers engaged in remanufacturing, truss manufacture, and prefabricated building?

- What is the typical inventory of the producer, the wholesaler (if any), the lumber dealer, and the large customer? Which lumber sizes have the highest turnover?
- What are the typical stock lengths, and their relative turnover?

It will not be easy to obtain comprehensive answers to these questions. Additional questions will need to be asked to obtain data for a variety of derived products, such as plywood and reconstituted wood-based building boards.

However, with reliable answers to questions such as those outlined, serious work on metrication can begin.

C. Suggestion 3 - Preparation of a Comprehensive Report on Issues Concerning Design and Construction with Lumber and Other Wood-based Products

In connection with the report referenced in Suggestion 2, it is recommended that a companion report be prepared. This report should address the technical issues that are likely to be most significantly affected by metrication in building design and construction. Such a report should highlight different approaches to lumber design and construction, the distribution of different techniques, and any known areas of concern. It also might assess the effects of a "preferred dimensional environment" on metric lumber and other wood product dimensions.

Some typical questions might include:

- Are there any wasteful or inefficient design practices in relation to lumber? If so, where do they occur, and why?
- Are there any wasteful or unscientific construction practices involving lumber and other wood-based building products? If so, where do they occur, and why?
- Are there any trends that are likely to affect lumber design and construction in the future? (For example: energy-related requirements.) If so, do such trends alter size or spacing requirements? Can new sizes be produced in such dimensions that they will integrate directly into an optimum metric range?
- What percentage of framing lumber is used in walls, floors, and roofs? What sizes are predominant?
- Could any of the traditional (typical) details be improved? If so, how, and at what cost savings? Is there any value in sizes that can be doubled, or halved, to fit with other sizes?
- How do preferred metric dimensions affect lumber lengths and sizes? (For example: stud length, spacing of members, etc.)
- Are there any optimum truss spans? How will metric spans affect truss member sizes, if at all?

- What is the minimum section thickness for effective fastening of panel materials? Is this the same for all panel materials or all fastening techniques?

The answers to these and associated questions should greatly assist in the determination of optimum metric sizes and characteristics for lumber and other wood products, as well as in the preparation of metric technical data and information.

D. Suggestion 4 - Development of an Improved Lumber Grading System in Conjunction with Metrication

There have been claims that the lumber industry has not yet arrived at a comprehensive and reliable grading system for structural framing lumber. The question is whether the potential structural merit of a large range of different strength grades will actually reduce cost, or whether it will merely lead to a more highly differentiated inventory, or supply problems. Can all the strength grades shown in design tables actually be obtained in the real world? Or, does unavailability of particular grades lead to use of higher strength grades rather than structural redesign?

If an improved and simplified grading concept could be developed during the next few years, it should be developed to suit preferred metric descriptions for use in the eventual and permanent metric building world. The groundwork for such an objective can be laid now.

E. Suggestion 5 - Development of a Preference System for Lumber and Wood Products

Metrication offers a unique opportunity to introduce the concept of preferences into the lumber and wood products scene to reflect real market factors.

A "preference system" simply means differentiation between products, so that those products which account for the bulk of demand are accorded a higher preference. A higher preference might even be reflected in a lower price. The development of a preference system will reinforce demand and supply factors; assist in improving inventory turnover (and therefore profitability); provide more reliable production decisions; and, generally guarantee better availability of preferred sizes in the marketplace, thus facilitating design and construction.

For example, "first preferences" in building lumber sizes would include those sections and lengths which account for the largest demand. In current production, this would include such sections as the 2" x 3", the 2" x 4", and the 2" x 6", as well as a number of smaller and some larger framing lumber sizes.

In a few instances, it should be possible in a change to metric sizes to substitute one in-between size for two adjacent existing sizes. This would reduce variety and also create a higher order of preference. Furthermore, some possible metric preferred sizes already may exist in the customary range of sizes (they would fall within the tolerances established for "nominal" sizes); and, such sizes would be earmarked for a high preference in a catalog of preferred sizes.

Certainly, neither the designer nor the contractor wishes for a vast assortment of lumber sizes, lengths, and strength grades. They would support a catalog of "preferred lumber sections" to streamline their operation. One factor which will become more prominent in the metric building environment is the need for careful checking in the initial phase to ensure that correct lumber sections have been used. The fewer sizes which are specified and supplied, the easier the work will be.

The same advice on "preferences" can be applied to other wood products, such as plywood panel sizes and thicknesses.

F. Suggestion 6 - Development of a Standard Catalog of Trim Patterns and Worked Lumber Profiles

In conjunction with a concept of "metric preferences," it would be desirable to develop a "U.S. Standard Catalog of Metric Wood Profiles" (Moldings, Trim, Finish, Flooring, Stepping, Worked Lumber, etc.). Such a catalog would reduce the vast number of size and shape variations now in existence to a standard and preferred set of patterns. If anything, variety reduction in this area will benefit all parties, from the producer to the consumer. Most of the production equipment is sufficiently flexible to be changed to a preferred set of patterns without undue cost or trouble.

The existence of a preferred wood profiles catalog would facilitate much greater standardization of design and construction detailing, and should allow for longer production runs in manufacture. Generally, excessive variety is excessively costly and the standard catalog simply channels excessive variety into "sensible variety."

To make use of obsolescence, as well as to take advantage of the introduction of new shapes and sizes, it would be desirable to make the development of a preferred set of metric profiles a priority item. Profiled shapes generally are used on the surface and not in concealed situations, thus, they are less restricted in terms of size variation. For instance, it would be quite feasible now to introduce new and preferred metric profiles and shapes even though marketing until the actual change-over date, or M-Day, for wood products in building would continue under a "nominal" customary description. This would mean that <u>one</u> product could serve both the declining customary market and the growing and ultimately permanent metric market.

G. Suggestion 7 - Abandonment of "Nominal" Descriptions in a Metric Environment

There is no need for nominal descriptions in metric building, because fractions will disappear with the change to millimeters as the general unit for linear measurement. Therefore, nominal sizes and marketing descriptions should be abandoned, and "real" or "guaranteed" descriptions of products substituted. Not only will this reduce the possibility of confusion in the transitional period, but it will lead to better accuracy in building activity and associated applications, and give far greater credibility to the wood products industry.

In calculations, assembly operations, and verification some metric dimensions are intrinsically better than others. This fact should not be overlooked in product sizing. With centerline setting-out, any even number is superior to an odd number, because it can be halved and still provide a whole number.

In a metric building world, the following dimensions (shown in descending order of preference, and in millimeters) are preferred:

n x 600, n x 300, n x 100, n x 50, n x 25, n x 10, n x 5, n x 2, and n x 1

This means that where a choice exists, it should be made on the basis of aiming for the highest preference possible. For example, if an exact conversion were to yield a value of 122.7 mm, in general the preferences would be as follows:

1. <u>125</u> (n x 25); 2. <u>120</u> (n x 10); 3. <u>124</u> or <u>122</u> (n x 2); 4. <u>123</u>

The " soft conversion," in this case 123 mm, would be the fourth preference.

Similarly, the description of bulk lumber by "board measure" is an anachronism that is likely to fall by the wayside during the change to metric. It likely will be replaced by a unit description involving cross-section and length. This will shift the emphasis onto "net" size, which is more important in the real world than "nominal" size. With modern wood processing techniques, the nominal "board foot" in fact yields more "nominal size lumber" than when the concept was developed.

The variation in "net lumber per board foot" is quite significant--1 board foot of dimension lumber yields the following "net" amounts of lumber:

71.5% of 2" x 16" (Dry dressed)
70.3% of 2" x 12"
68.8% of 2" x 6"
65.6% of 2" x 4"
62.5% of 2" x 3"
56.3% of 2" x 2"

Whatever metric measure of lumber volume or quantity is adopted, it is almost certain it will emphasize the "consumer aspects" of lumber, rather than the producer aspects.

H. Suggestion 8 - Development of a Concept of Guaranteed Size for Building Lumber

As an extension of the remarks dealing with the "elimination" of nominal sizes, it is suggested that a concept of "guaranteed (minimum) size" be developed for building lumber. A guaranteed size would be one that establishes the "absolute minimum size" in relation to moisture content in a tabular form, rather than using a single moisture content (19%) as the "great divide" between "green" and "dry" lumber, and then allowing an additional reduction in size on the basis of shrinkage after manufacture. An example is provided in the "Dry Size Requirements" (Clause 5.6.3) in the American Softwood Lumber Standard, already referred to on page 112.

It is recommended that a "designated size" be established for a specific moisture content. For example, 15% M.C. In addition, the guaranteed minimum sizes should be shown for each 4% (or 6%) change in moisture content.

As an example, a tabulation for an assumed "designated size of 100 mm" might look as follows:

Designated Size	Guaranteed Minimum Size	Redwood, Cedar
	102 mm @ 23% M.C.	101 mm @ 21% M.C.
	101 mm @ 19% M.C.	
100 mm @ 15% M.C.	100 mm @ 15% M.C.	100 mm @ 15% M.C.
	99 mm @ 11% M.C.	99 mm @ 9% M.C.
	98 mm @ 7% M.C.	

A 100 mm size has been chosen for illustrative purposes because percentages can be calculated directly. For any dimension in millimeters, stated in whole numbers, percentages can be found more quickly and accurately than percentages of inches and fractions of inches. For example, if the designated size were to be 40 mm, then for every 10% change in M.C., there would be a 1 mm change in size.

The adoption of a concept of designated size would provide quality assurance in respect of sizes. Ideally, the designated size should represent the moisture content that is most likely to be found in framing lumber at the time of construction. The concept would be useful, regardless of whether a "soft conversion" of lumber sizes is adopted by the U.S. wood products industry or whether a "hard conversion" to new and preferred sizes is made.

I. Suggestion 9 - Detailed Investigation of Proposals for a Preferred Range of Metric Lumber Sizes

Metrication, as an opportunity to rationalize product ranges by reducing variety and introducing preferred product sizes (and other characteristics), will only come once. To pass off this opportunity without any attempt to assess, in detail, all the factors that influence a product range would be very unwise. Whatever sizes and properties are chosen for the metric transition period, these are bound to stay with the production/design/construction community for a long time. To get locked into a sub-optimal set of sizes can only harm the industry in the long run.

Therefore, it is strongly recommended that proposals for a more suitable product range should be investigated and assessed on an industry-wide basis, rather than discarded on insufficient evidence or with far-fetched excuses.

There is some evidence that a soft-converted customary product range will yield, within tolerances, quite a few preferred metric values. However, it is not very practical to depart too far from the ISO Series of Preferred Numbers (also known as the Renard Series) in the development of an optimum product range. This series provides the most logical steps of an almost equal geometric increment for numbers in a decimal number system.

For example, the ISO R10 series provides increments of approximately 25 percent in consecutive numbers, such as 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, and 1000; a total of 10 geometric steps between 100 and 1000, or 10 and 100, or 1 and 10. Within the range of millimeter designations of interest to the lumber industry, the following preferred numbers exist:

20, 25, 32, 40, 50, 63, 80, 100, 125, 160, 200, 250, 315, 400

By comparison, the "soft conversion" of existing dry dressed lumber dimensions, rounded to the nearest millimeter, shows the following values.

19, <u>25</u>, <u>32</u>, 38, 51, <u>63</u>, 76, 89, 102, 114, 139, 165, 184, 210, 235, 260, 285, 335, 385

Common values have been underlined. In addition, the values 51 and 102 are within 2 percent of the preferred numbers 50 and 100, and the values 19 and 38 are within 5 percent of the preferred values 20 and 40. The comparison of the two series illustrates quite clearly the advantage of the ISO series above 63 mm (up to which dimension customary and preferred number steps are almost identical). The range from 80 mm to 400 mm is covered in 8 preferred steps, compared with 13 steps in customary lumber sizes. Production and distribution (inventories) would benefit very markedly from a softwood lumber product range based upon preferred number designations.

A second advantage of the ISO series is of specific interest to the designer and the contractor. Sizes based upon such a series can be doubled to form new sizes. This would eliminate a serious complaint against the current situation. For example, the framing over openings would be greatly simplified in such a situation.

It is also possible to resaw a number of larger sizes into smaller sizes, if a 5 mm sawing and dressing allowance is included; for example:

Original Dimension	Reduced Dimensions	Cutting Allowance
250 mm	3 x 80 mm	2 cuts @ 5 mm
200 mm	3 x 63 mm	2 cuts @ 5.5 mm
160 mm	3 x 50 mm	2 cuts @ 5 mm

In addition, it would be possible to cut combinations out of larger sizes, using the same cutting allowance; for example:

315 mm	2 x 125 mm; 1 x 50 mm
100 mm	2 x 20 mm; 1 x 50 mm

This example was included to show that there may be some hidden factors which could add to the weight of evidence in favor of preferred numbers in a metric product range.

In an alternative approach, the preferred numbers themselves could be reduced by a 5 mm resaw allowance. This would produce an excellent series from a production point of view, because it can be progressively reduced into parts of the series. The only disadvantage in that approach is that the resulting numbers are not nearly as easy to use in calculations or verification. At least such a proposal should be evaluated against existing production techniques for dry dressed softwood lumber, to ascertain whether they would simplify production, or whether the whole concept of resawability lacks substance.

The series below represents the ISO R10 preferred number series, reduced by a 5 mm resaw allowance, and with the value 315 changed to 320 for continuity in halving:

15, 20, 27, 35, 45, 58, 75, 95, 120, 155, 195, 245, 315, 395

The series provides the following tabulation in progressive halving:

395 = (2 x 195) + 5 = (4 x 95) + 15 = (8 x 45) + 35 = (16 x 20) + 75
315 = (2 x 155) + 5 = (4 x 75) + 15 = (8 x 35) + 35 = (16 x 15) + 75
245 = (2 x 120) + 5 = (4 x 58) + 13 = (8 x 27) + 29
195 = (2 x 95) + 5 = (4 x 45) + 15 = (8 x 20) + 35
155 = (2 x 75) + 5 = (4 x 35) + 15 = (8 x 15) + 35
120 = (2 x 58) + 4 = (4 x 27) + 12
95 = (2 x 45) + 5 = (4 x 20) + 15
75 = (2 x 35) + 5 = (4 x 15) + 15
58 = (2 x 27) + 4
45 = (2 x 20) + 5
35 = (2 x 15) + 5

Similar tabulation is possible for a resaw allowance of 4 mm.

The major disadvantage of the sizes shown is that only one size (75 mm) would be close to a soft converted customary size (76 mm).

This suggestion was addressed in considerable detail, because a range of preferred softwood lumber framing sizes, based on the ISO preferred number series, would present a unique opportunity for comprehensive rationalization, as well as a suitable basis for a world standard on dry dressed lumber sizes. It does not appear that the special factors outlined above have been taken into account in the deliberations to date.

J. Suggestion 10 - Preparation of a "Metric Handbook" on Lumber Design and Construction

Lastly, it is suggested that much of the preliminary work indicated for the investigation phase of metrication--the lead-time available until binding decisions have to be made--could provide the basic material for a handbook dealing with metric lumber design and construction. Such a document would be an invaluable and essential ingredient to ensure a smooth transition in the design and wood products user sector. Such a handbook would be needed especially in the transitional period.

It is worth remembering that a considerable portion of the basic metric research for such a handbook can be undertaken now.

CONCLUDING REMARKS

Metrication provides an ideal communication vehicle for dialogue between the various sectors and groups in the design/construction/production community. Before that community embarks on firm and irrevocable decisions involving metric sizes and properties for individual products, producer associations and producers would find considerable benefit in acquiring a thorough understanding of the principal factors and considerations relating to product end use. This will also provide a much better awareness of market opportunities.

Similarly, designers and product users should increase their understanding of the issues involved in production and distribution of building products. Only through greater awareness of relative concerns can the construction/production community arrive at an "optimum catalog" of building materials. This is especialy true for the producers of lumber and wood-based building materials.

One of the best examples of catalog optimization occurred during the metric change to new lumber (timber) sizes in the new nation of Papua New Guinea. The approach is outlined in Appendix F. It is based on the premise that "preferred sizes have been kept to a minimum, as a large number of sizes would defeat the purpose of preferences." What is incredible is that only seven (7) light-timber (lumber) framing sizes have been established. Other sizes are not even specified in detail, except by the inference that where such sizes are needed their thicknesses should be in multiples of 10 mm, and their widths in multiples of 50 mm, up to 200 mm. While this approach provides an extreme example, it is certain to lead to considerable standardization of design and construction detail, as well as guaranteeing a ready supply of preferred sizes.

By placing greater emphasis on accuracy and tolerances, the change to millimeters and the abandonment of nominal sizes should assist the U.S. construction community in its work. The lumber sector will be one of the principal beneficiaries in that regard. The change to metric measurement also provides the incentive to shed a variety of extravagant, unscientific, and unnecessary practices. It would be of great value to have a "problem book," which shows the kind of problems and irritations that occur in present construction practices; because it is fairly certain that quite a few of these irritations could be eliminated forever during the change to new units and new values.

It would be a great pity if this large and diversified industry did not utilize all of the available lead-time to investigate and evaluate all affected areas, to study precedent from other nations that are or have been involved in metrication, and to seek out alternative approaches to optimization in product characteristics and in product range.

The alternative of remaining shackled to the past in a soft conversion or "no-real-change-approach" can only be described as "lumbering into metrication."

Appendix A: Metrication of Softwood Structural Lumber [Timber] in Australia

The Australian softwood lumber industry markets 30 preferred metric sizes of dry dressed Australian softwoods [except cypress pine] in hard converted dimensions. All dry finished [dressed] sizes are "guaranteed minimum sizes" without a negative [-] tolerance, and green lumber has to be larger by an appropriate shrinkage allowance.

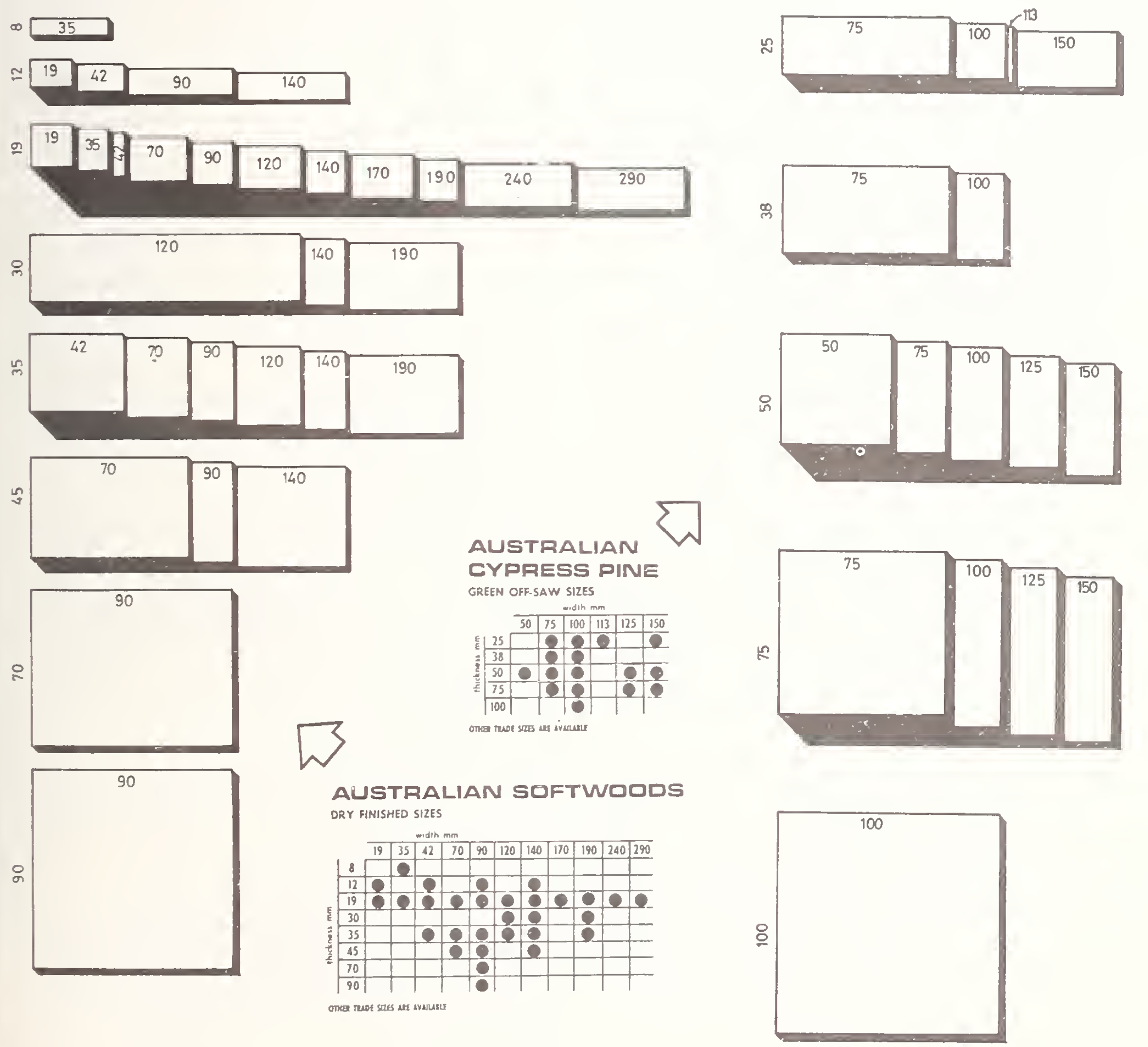
Australian cypress pine is marketed in 16 metric sizes green-off-saw. All sizes are nominal, and positive as well as negative tolerances apply.

In addition, there are 22 metric sizes of imported softwood lumber [Oregon and Canada pine], again related to green-off-saw sizes with positive and negative tolerances.

Preferred metric softwood lumber sizes for use in Australia are shown in the figures below, which are extracts from Australian metric publications and posters.

Australian Softwoods [dry dressed] - 30 sizes

Australian Cypress Pine [green-off-saw] 16 sizes



All softwood lumber is sold in increments of 0.3 m [300 mm], starting from 1.8 m [1800 mm].

Appendix B: Sizes for Metric Softwood Lumber [Timber] in Great Britain

A two-stage approach to dimensions for softwood lumber is indicated in BS 4471-1971 "British Standard Specification for Dimensions for Softwood;" firstly, basic sizes are set down for sawn softwoods [Table 1]; and secondly, reductions from the basic size are established which can be applied to determine the permissible finished sizes when processing two opposed faces.

There has never been a British Standard for a range of softwood dimensions before metrication, so that the change from customary measurement provided the opportunity to adopt a simplified and rationalized range of sizes. The result is a list of 91 metric cross-sectional sizes.

A reduced size extract from BS 4471 - 1971 is shown below:

BS 4471 : 1969

SPECIFICATION

1. SCOPE

This British Standard specifies dimensions for a range of sawn softwood sizes in metric measure, and provides a table of reductions by manufacturing processes from the original sawn softwood sizes for various categories of products and for accurately dimensioned 'precision timber'.

2. DEFINITIONS

For the purposes of this British Standard the definitions in BS 565* apply together with the following:

(1) *Precision timber.* Timber which being at a moisture content between 14% and 20% and averaging 18% is regularized on at least one face and one edge to a specified size.

(2) *Regularizing.* A machine process by which the thickness and/or width of a piece of timber of rectangular cross section are made uniform throughout its length.

3. MOISTURE CONTENT

3.1 General. Moisture content is defined as the amount of moisture in timber or other material, expressed as a percentage of its oven dry weight.

3.2 Instrument. For the purposes of this standard measurement by means of an electric moisture meter shall be adopted. The meter shall be regularly recalibrated in accordance with the maker's instructions and against oven drying tests.

3.3 Sampling. When agreed between the buyer and the seller, testing shall be carried out on at least 10 pieces or 5% of the pieces of any one cross section, whichever is the greater, in any parcel. The material for test shall be selected at random.

3.4 Method of measurement. The test shall be carried out according to the instrument maker's instructions at a point not nearer than 1 m from either end.

4. SIZES AND PERMISSIBLE DEVIATIONS OF SAWN SOFTWOODS

4.1 Basic sizes. The basic cross-sectional sizes shall be as shown in Table 1, and the basic lengths as shown in Table 2.

TABLE 1. BASIC SIZES OF SAWN SOFTWOOD (CROSS-SECTIONAL SIZES)

Thickness	Width 75	100	125	150	175	200	225	250	300
16	x	x	x	x					
19	x	x	x	x					
22	x	x	x	x					
25	x	x	x	x	x	x	x	x	x
32	x	x	x	x	x	x	x	x	x
36	x	x	x	x					
38	x	x	x	x	x	x	x		
40*	x	x	x	x	x	x	x		
44	x	x	x	x	x	x	x	x	x
50	x	x	x	x	x	x	x	x	x
63		x	x	x	x	x	x		
75		x	x	x	x	x	x	x	x
100		x		x		x		x	x
150				x		x			x
200						x			
250								x	
300									x

(All dimensions are in millimetres)

*For 40 mm thickness, designers and users should check availability.

NOTE. The smaller sizes contained within the dotted lines are normally but not exclusively of European origin. The larger sizes outside the dotted lines are normally but not exclusively of North and South American origin.

TABLE 2. BASIC LENGTHS OF SAWN SOFTWOOD

All dimensions are in metres

1·80	2·10	3·00	4·20	5·10	6·00
	2·40	3·30	4·50	5·40	6·30
	2·70	3·60	4·80	5·70	
		3·90			

4.2 Resawing allowance. When smaller sizes are produced by resawing from larger, not more than 2 mm reduction of size of each piece so produced shall be allowed, this reduction is not additional to those in Table 3. Sellers offering or supplying such timber shall describe it as 'Resawn ex larger'.

4.3 Permissible deviations on sizes as originally produced

4.3.1 *Cross section.* Minus deviations in cross section are permissible on not exceeding 10% of the pieces in any parcel of sawn softwood.

4.3.2 *Thicknesses and widths.* In thicknesses and widths not exceeding 100 mm, the permissible deviation is minus 1 mm, plus 3 mm.

In thicknesses and widths over 100 mm, the permissible deviation is minus 2 mm, plus 6 mm.

4.3.3 *Lengths.* On lengths, no minus deviation is permissible, but over-length is unlimited.

4.4 Actual sizes. The actual sizes of any piece of timber will vary with its moisture content at the time of measurement. The sizes in Table 1 are to be measured as at 20% moisture content. For any higher moisture content up to 30% the size shall be greater by 1% for every 5% of moisture content in excess of 20%, and for any lower moisture content the size may be smaller by 1% for every 5% of moisture content below 20%. For any higher moisture content than 30%, no larger size will be required than at 30%.

5. REDUCTION OF SAWN SOFTWOOD SIZES BY PROCESSING

5.1 General. Processing of softwoods to accurate finished sizes involves reductions of size varying with the size and the process. Exact figures cannot be established for each process since the original sawn size is not precise. Average figures, however, can be established by calculation and by experience that are economic, workable and not wasteful.

5.2 Reductions. The reductions appropriate for a number of end-uses appear in Table 3. Any finished sizes in British Standards covering particular timber products and components will take preference over those obtained from Table 3. Other end-uses not specifically mentioned should adopt the same figures as one of those listed. Intermediate figures would be unlikely to achieve an average of any greater accuracy and would tend to confuse.

TABLE 3. REDUCTIONS FROM BASIC SIZE TO FINISHED SIZE BY PROCESSING OF TWO OPPOSED FACES

All dimensions are in millimetres

Purpose	Reduction from basic size to finished size for sawn sizes of width or thickness: 15 to and including 22	Over 22 to and including 35	Over 35 to and including 100	Over 100 to and including 150	Over 150
(1) Constructional timber surfaced	3	3	3	5	6
(2) *Floorings	3	4	4	6	6
(3) *Matchings and interlocking boards (4) Planed all round	4	4	4	6	6
(5) Trim	5	5	7	7	9
(6) Joinery and cabinet work	7	7	9	11	13

*The reduction of width is overall the extreme size and is exclusive of any reduction of the face by the machining of a tongue or lap joint.

5.3 Permissible deviations. For all finished sizes after processing a manufacturing deviation of plus or minus 0·5 mm shall be allowed.

6. PRECISION TIMBER

6.1 General. Any size in Table 1 may be converted to precision timber by regularizing when dry on at least one edge and one face with a reduction to finished sizes 1 mm less than the basic sawn size, and shall be described as that basic size.

6.2 Moisture content. Precision timber shall be regularized, measured and supplied at a moisture content within the range 14% to 20% with an average not exceeding 18%.

Lengths are specified in meters, with increments of 0.3 m [300 mm] starting at 1.8 m.

Appendix C: Canadian Proposed Metric Lumber Sizes for Dimension Lumber and Boards

Due to the fact that a large percentage of Canadian softwood lumber production is exported to the United States, no firm decisions on preferred metric sizes of structural softwood lumber have been reached, and metric sizes essentially represent a "soft conversion."

The tables below list Canadian metric lumber sizes proposed by the Subsector Committee 8.2.1, Softwood Lumber, of the Metric Commission Canada, in 1977.

Canadian Metric Softwood Lumber Sizes

Metric sizes recommended for dimension and boards listed in Tables 1 and 2 are those recommended by the Canadian Sector Subcommittee 8.2.1, Softwood lumber.

TABLE 1 Existing and Proposed Dimension Lumber Sizes

Nominal Sizes (Inches)	Green Sizes			Dry Sizes		
	Actual (Inches)	Metric Equivalent (Millimetres)	Proposed by Canada (mm)	Actual (Inches)	Metric Equivalent (mm)	Proposed by Canada (mm)
2 x 2	1 9/16 x 1 9/16	39.7 x 39.7	40 x 40	1 1/2 x 1 1/2	38.1 x 38.1	38 x 38
2 x 3	2 9/16	65.1	67	2 1/2	63.5	65
2 x 4	3 9/16	90.5	93	3 1/2	88.9	90
5	4 5/8	117.5	118	4 1/2	114.3	115
6	5 5/8	142.9	144	5 1/2	139.7	140
7	6 5/8	168.3	170	6 1/2	165.1	165
8	7 1/2	190.5	195	7 1/4	184.15	190
9	8 1/2	215.9	221	8 1/4	209.55	215
10	9 1/2	241.3	247	9 1/4	234.95	240
11	10 1/2	266.7	272	10 1/4	260.35	265
12	11 1/2	292.1	298	11 1/4	285.75	290
14	13 1/2	342.9	350	13 1/4	336.55	340
16	15 1/2	393.7	401	15 1/4	387.35	390
3 x 4 etc.	2 9/16 x 3 9/16	65.1 x 90.5	67 x 93	2 1/2 x 3 1/2	63.5 x 88.9	65 x 90
4 x 4 etc.	3 9/16 x 3 9/16	90.5 x 90.5	93 x 93	3 1/2 x 3 1/2	88.9 x 88.9	90 x 90

TABLE 2 Existing and Proposed Board Sizes

Nominal Sizes (Inches)	Green Sizes			Dry Sizes		
	Actual (Inches)	Metric Equivalent (Millimetres)	Proposed by Canada (mm)	Actual (Inches)	Metric Equivalent (mm)	Proposed by Canada (mm)
1 x 2	3/4 x 1 9/16	19 x 39.7	19 x 40	11/16 x 1 1/2	17.5 x 38.1	17 x 38
1 x 2	13/16 x 1 9/16	20.6 x 39.7	21 x 40	3/4 x 1 1/2	19 x 38.1	19 x 38
3	2 9/16	65.1	67	2 1/2	63.5	65
4	3 9/16	90.5	93	3 1/2	88.9	90
5	4 5/8	117.5	118	4 1/2	114.3	115
6	5 5/8	142.9	144	5 1/2	139.7	140
7	6 5/8	168.3	170	6 1/2	165.1	165
8	7 1/2	190.5	195	7 1/4	184.2	190
9	8 1/2	215.9	221	8 1/4	209.6	215
10	9 1/2	241.3	247	9 1/4	235.0	240
11	10 1/2	266.7	272	10 1/4	260.4	265
12	11 1/2	292.1	298	11 1/4	285.8	290
14	13 1/2	342.9	350	13 1/4	336.6	340
16	15 1/2	393.7	401	15 1/4	387.4	390
1 1/4 x 2 etc.	1 1/32 x 1 9/16	26.2 x 39.7	27 x 40	1 x 1 1/2	25.4 x 38.1	25 x 38
1 1/2 x 2 etc.	1 9/32 x 1 9/16	32.5 x 39.7	33 x 40	1 1/4 x 1 1/2	31.8 x 38.1	32 x 38

Appendix D: Metric Dimensions for Building Lumber [Timber] in New Zealand

In conjunction with the change to metric dimensions, the New Zealand lumber industry has adopted the terms "call dimension" and "call size" to indicate dimensions by which lumber is to be referred in commercial transactions. The actual dimensions will differ from the call dimensions because of specified tolerances, and according to the condition of lumber; for example "green" or "dry;" "sawn," "gauged" or "dressed." Dry lumber has a moisture content between 14% and 18%, and green lumber is specified as having a moisture content equal or higher than the fiber saturation point, which lies between 26% and 30% moisture content, depending upon the wood species.

Dry dressed lumber [timber] means dry lumber where appearance and finish are important and where dimensional accuracy is required. Green gauges lumber [timber] means green lumber, but where dimensional accuracy is required.

The table below is reproduced from page 3 of the "Directory of Metric Building Materials" [1974 Edition], prepared by the Divisional Committee on Building Materials of the New Zealand Metric Advisory Board, and it summarizes the recommendations on metric lumber dimensions. The table shows a total of 43 preferred sizes, with 9 widths and 6 thicknesses.

Timber

Preferred Range of Call Sizes (mm)

Call Dimensions THICKNESS	Call Dimensions — WIDTH 50	75	100	125	150	200	225	250	300
25	x	x	x	x	x	x	x	x	x
30			x		x				
40	x	x	x	x	x	x	x	x	x
50	x	x	x	x	x	x	x	x	x
75			x	x	x	x	x	x	x
100			x	x	x	x	x	x	x

PREFERRED LENGTHS (in metres)

1.8	3.3	4.8
2.1	3.6	5.1
2.4	3.9	5.4
2.7	4.2	5.7
3.0	4.5	6.0

Finished Dimensions (mm)

Call Dimension	Finished Dimension: Green Gauged Timber	Dry Dressed Timber
25	—	19
30	—	25
40	37	35
50	47	45
75	69	65
100	94	90
125	119	115
150	144	140
200	194	180
225	219	205
250	244	230
300	294	280

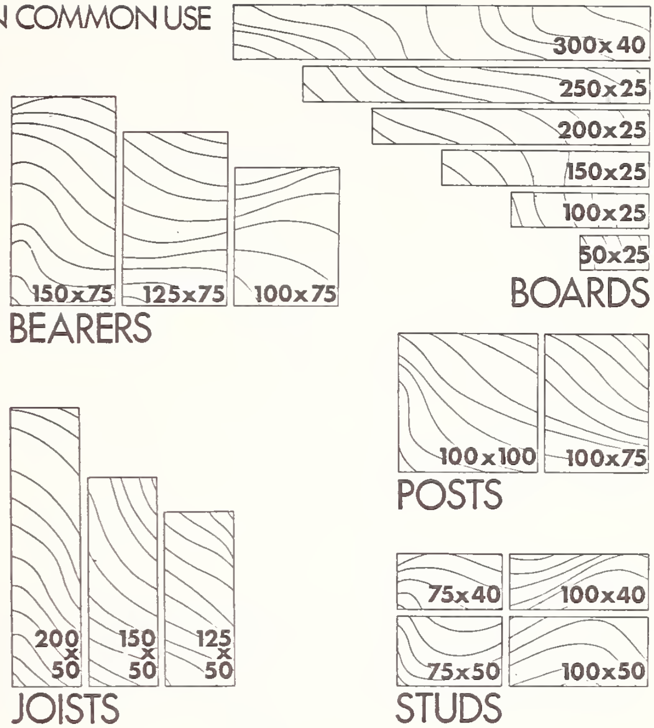
Conversion Date
Cessation of production in imperial sizes: December 1974. Commencement of production in metric dimensions: January 1975.

Further Information:
The New Zealand Sawmillers' Federation Inc., NZ Timber Merchants' Federation Inc., Timber Research & Development Association. See NZS 3601 : 1973 "Metric Dimensions for Timber" Standards Association of New Zealand.

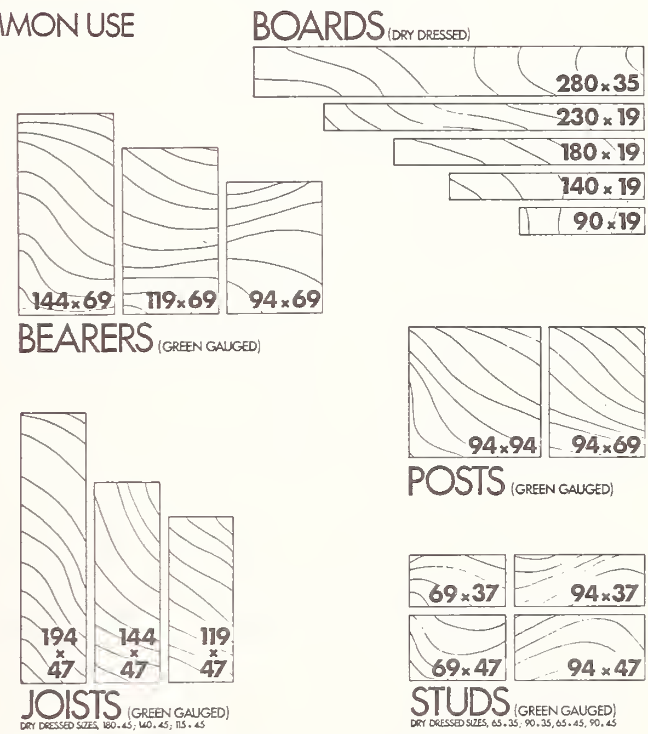
A tolerance of ± 0.5 mm is allowed in New Zealand Standard NZS 3601 : 1973, "Metric Dimensions for Timber," on finished dimensions of dry dressed and green gauged lumber, except that no minus tolerance is permitted on the thickness of the 19 mm dry dressed size.

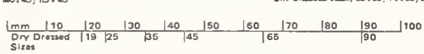
The facing page shows two reduced size extracts from a New Zealand poster prepared by the New Zealand Timber Research and Development Association with the title "Sizes of Timber in Millimetres." The selection shown concentrates on "preferred sizes" in common use.

TYPICAL FULL SIZE SECTIONS IN COMMON USE



FINISHED DIMENSIONS IN COMMON USE





T.R.A.D.A.

PREPARED FOR THE TIMBER INDUSTRY by
N.Z. TIMBER RESEARCH & DEVELOPMENT ASSN. P.O. BOX 308 WELLINGTON

Appendix E: Metrication of Softwood Structural Lumber [Timber] in South Africa

The change to metric measurement in the structural softwood lumber industry in South Africa was handled predominantly as a "soft conversion" of customary wood products.

Structural lumber is marketed in 33 preferred sizes, comprising combinations of 6 thicknesses and 10 widths. General measurements and preferred sizes are shown in the tabulation and the figure, extracted from South African Bureau of Standards publication M 19 - 1971, "Metrication for the Family," pages 30 and 31.

Structural softwood lumber is commercially available in lengths that are multiples of 250 mm.

Tolerances on length and cross-sectional dimensions are shown below. They are extracted from South African Bureau of Standards publication SABS 563 - 1971, "Specification for Softwood Structural Timber (Metric Units)," page 10.

Measurements for sawn timber

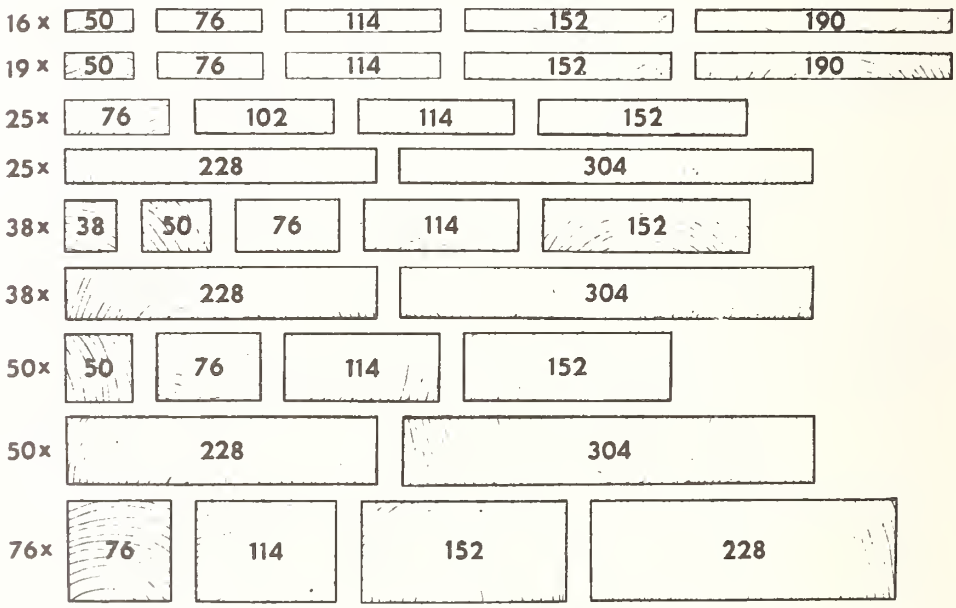
(a) Softwood structural timber:

thickness	:	16; 19; 25; 38; 50 and 76
widths	:	38; 50; 76; 102; 114; 152; 190; 228; 266 and 304
lengths	:	0,25 m — increments starting from 1 m

Preferred sizes for softwood structural timber in mm

thickness		widths
16	:	76; 102 and 152
19	:	76; 102 and 152
25	:	76; 102; 152; 228; 266 and 304
38	:	38; 50; 76; 114; 152; 190; 228 and 266
50	:	38; 50; 76; 114; 152; 190 and 228
76	:	38; 50; 76; 114; 152 and 228

NOTE: It will be noted from the details given in the tables that timber measuring 25 mm x 102 mm, 50 mm x 50 mm, etc. replaces timber measuring 1 inch x 4 inch, 2 inch x 2 inch, etc. Also note that the sizes for wood as shown in the figure on the following page do not include all the preferred sizes and that certain non-preferred have been included in the figure. Despite the preferred sizes, non-preferred sizes as illustrated will also be available from dealers if the demand is large enough.



Tolerances	Tolerance, mm
a) Length	Plus 75. No minus tolerance shall be allowed
b) Width	
1) Less than 114 mm	Plus 5) minus 3 (but minus 5 in the case of
2) 114 mm or more, but less than 228 mm . .	Plus 6) resawn graded timber)
3) 228 mm or more	Plus 8)
c) Thickness	
Less than 50 mm	Plus 3 or minus 2
50 mm or more	Plus 5 or minus 2

Appendix F: The Approach to Lumber [Timber] Rationalization in Papua New Guinea

[Extract from Metric Handbook SC PNG MH1 - 1973, "Metric Conversion in Engineering and Construction in Papua New Guinea," pages 60 and 61; published by the Standards Association of Australia for the Metric Conversion Commission of Papua New Guinea.]

SC PNG MH1—1973 METRIC BUILDING MATERIALS

12.9 Metric Sizes for Building Timbers

12.9.1 General The change to metric measures in the Papua New Guinea timber industry will have most benefit if it is accompanied by a rationalization of sizes supplied to the industry.

Infrequently used sizes will be omitted. Rather than make a conversion to the nearest metric equivalent of popular imperial sizes, the opportunity will be taken to introduce a framework of integral metric values. The use of rational numbers in specifying timber sizes will simplify statements in modern building codes and regulations.

Service to the dwelling construction industry is of prime importance as this segment accounts for the greatest use of sawn timber.

A building system that permits the use of a minimum of end sections, cannot rigidly specify the spacings for studs, rafters and ceiling joists and floor joists. However emphasis is to be given to a 600 mm spacing, and variations should be on a 100 mm increment.

12.9.2 End Section Sizes End section sizes for building timbers will be specified in millimetres (mm).

The distinction in sizes between softwoods and hardwoods is to be dropped. The sale of timber by nominal sizes is to be discontinued. Specified sizes will relate to timber dressed 4 sides and dried to mean equilibrium moisture content. Allowances for drying and dressing are to be made for timber sold green or rough sawn. Negative tolerances for dried dressed timber will be 1 mm for dimensions up to 50 mm, and another 1 mm for each additional 50 mm. For example a 50 x 200 mm size will be rejected if it falls below 49 x 196 mm.

Marketing for export requirements will necessitate mills cutting to customers' demands.

The preferred sizes have been kept to a minimum, as a large number of sizes defeat the purpose of preferences. Other sizes which may become necessary should be chosen from the framework suggested in Table 19, i.e. width increments of 50 mm and thickness increments of 10 mm, giving emphasis to thicknesses already preferred viz 20, 30 and 50 mm.

TABLE 19
PREFERRED METRIC SIZES FOR PAPUA NEW GUINEA TIMBERS

Thickness (mm)	Width (mm)			
	50	100	150	200
10				
20	×	×		
30				×
40				
50	×	×		×
60				
70	×			
80				
90				
100				

Architects using these sizes will require some adjustments in design. The following table shows proposed sizes for various end uses.

TABLE 20
PROPOSED USES FOR PREFERRED SIZES

Size	Uses
20 × 50	Mouldings, battens
20 × 100	Flooring, bracing
30 × 200	Weatherboards, fascias, barge boards panelling, valleys
50 × 50	Scantling, framing
50 × 70	Scantling, framing
50 × 100	Scantling, framing
50 × 200	Bearers, heavy construction

12.9.3 Length Timber will be sold in metres, in increments of 0.1 m.

12.9.4 Method of Sale Sale of timber will be by linear measure for each end section.

SECTION 8

New Measures in Graphic Design and Publications - The Advance of the Metric System

Article prepared for publication in Federal Design Matters, information publication of the National Endowment for the Arts; extract published in Issue No. 12, November 1977, under the title, "Designers Have a Key Role in Metric Conversion," pages 4 and 5.

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INTRODUCTION

The basis for a worldwide system of measurement was created in 1960, when the General Conference on Weights and Measures--an international treaty organization--developed the International System of Units (SI). This system is better known as the "modern metric system." Since the mid-Sixties, 44 predominantly English-speaking countries have actively embarked on the process of "metrication." This process involves the abandonment of customary measurement systems, and the planned and coordinated introduction of SI, the international (metric) system.

The United States has been a non-metric island in a metric measurement world--a world that has been joined by Britain, South Africa, Australia, New Zealand, and Canada in recent years. The U.S. Metric Conversion Act of 1975 provides for a "voluntary change to the predominant use of the metric system in the United States," and establishes a U.S. Metric Board for the purpose of the overall coordination of the conversion. The Board has only just been appointed in March 1978.

In many activity areas, metric measures already have arrived. Metric units are in regular use in international sporting disciplines, photography, and medicine. In the electrical and lighting fields, unbeknown to most people, metric units have been used for a long time. The ampere (A), volt (V), watt (W), ohm (Ω) and lumen (lm), are all examples of international (metric) units.

Many activities in industry and commerce now are being changed to preferred metric units. In general, this is being done quietly and without many problems. This is due to the realization that a decimally-based international measurement system with few and coherent units is greatly superior to the customary system with its many non-decimal and unrelated units. The automotive industry is a good example of an industry committed to a gradual change to metric units.

But when "official" metric conversion, based on national consensus programs commences, there is bound to be a rush by others to join. In addition to being at the end of the queue, those without plans or proper metric management are likely to make quite a few embarrassing or costly errors. So, the time is with us now to become acquainted with the system, to analyze the issues and implications, and to prepare for the change. This "lead-time" is valuable and should not be squandered.

A. What Does it Mean to Change to Metric?

The change to the metric system will mean that all measurement related data will need to be changed to SI units. Products either will remain the same but be described in metric units or they will be changed to new and preferred sizes and properties. In either case, the paper-based information will need to be replaced. This will require the design and printing of new technical publications, standards, design aids, charts, posters, maps, and many other documents with new or modified information. Metrication will lead to an information explosion, as new and up-to-date data are prepared by all sectors of the economy to provide metric in lieu of customary information.

Early awareness of "lead-times" is required to schedule graphics, typesetting, proofing, and printing during the metric change. Demands for each of these services is likely to escalate. Each of these functions is important but, in addition to being functional and attractive, metric data should be accurate and "correct;" therefore, the proofing function assumes special importance. Nothing would be more detrimental to an orderly change to metric than incorrect information.

There are three principal types of metric information:

1. General Advisory or Instructive Material - This information comprises general data and guidelines for the initial phase of metrication, and represents the "basic" material to illustrate the correct use of the International System of Units. Much of this information is "new data," and will need to be developed especially for the change.

2. Detailed Metric Technical Material - This information includes all technical and commercial reference material in metric units for use in the transitional period and throughout the eventual fully metric economy. It comprises handbooks, codes, standards, specifications, product literature, price lists, etc. In many instances, the structure and layout of existing data may be retained, although diagrams, charts, tables, and other graphic material may need to be revised and redesigned.

3. Visual Information and Aids - Visual information for the initial and transitional periods in metrication includes metric posters, charts, maps, special aids, and metric identification symbols. The principal purpose of such data and devices is to facilitate the change to a metric environment.

The development of a new technical data bank and its presentation in a meaningful and effective manner represents a considerable challenge, not only to technologists and scientists, but also to the graphic arts and printing industry. Metrication is the opportunity for review, rationalization, and improvement. In most instances, it represents the challenge to do things once more and better.

B. Preferred Dimensions, Sizes and Quantities

The change to metric units will not change the qualitative aspects of design, such as composition, balance, suitability for intended purpose, impact, and relationship to the environment. However, due to the decimal and coherent nature of metric units of measurement, quite a few design-related matters will be subject to review.

In many activities, the change to metric is certain to be accompanied by a simultaneous change to rationalized and preferred dimensions, sizes, and quantities. In building and engineering, the dimensions of structures and components will be coordinated by the use of a common set of dimensional preferences. This "dimensional coordination" will affect approaches to planning, design layout, and detailing, particularly in rectilinear structures. An extension of dimensional coordination is the "standardization" of products and details.

C. Metric Drawing Scales

Scale ratios are either reduction ratios or enlargement ratios. Traditional drawing scales have indicated enlargement ratios by a ratio factor, and reduction ratios by a unit relationship (inch-to-foot, inch-to-chain, inch-to-mile), rather than a direct ratio. For example, a scale was identified as 1" = 40'-0" or 1/40" = 1'-0", rather than 1:480. Generally, metric scale ratios which are multiples of 1, 2, or 5, are preferred due to the decimal nature of the measurement system.

In other countries that have made the change to metric measurement, the number of scale ratios in use has been reduced significantly, as indicated in Table 8.1., on page 140.

The advantage of working with fewer scales is obvious, not only from a procurement and replacement point of view, but from interface considerations where scalar changes are involved between different activity areas. In building design documentation, the use of 6 scale ratios for all drawings has proved to be completely adequate. For example, 1:1; 1:5; 1:20; 1:100; 1:500; and 1:2000, will cover the range from full-size detailing to small-scale location plans.

D. International Paper Sizes

In Britain, South Africa, and Australia, the change to metric measurement was accompanied by a change to the international paper size series (ISO 'A'-Series), to extract maximum benefit from the unique opportunity for rationalization and variety reduction. The 11 preferred ISO sizes have replaced many hundreds of traditional paper formats. The advantages to producers, merchants, printers, and customers have been significant. The reduced product range has resulted in longer production runs, better availability, savings in storage space, optimum stock rotation, simpler and tidier filing, more economical photocopying, more efficient microfilming or enlargement, and an associated reduction in the number of envelope or packaging sizes. In addition, the advantages of international information exchanges on a uniform paper size should not be ignored.

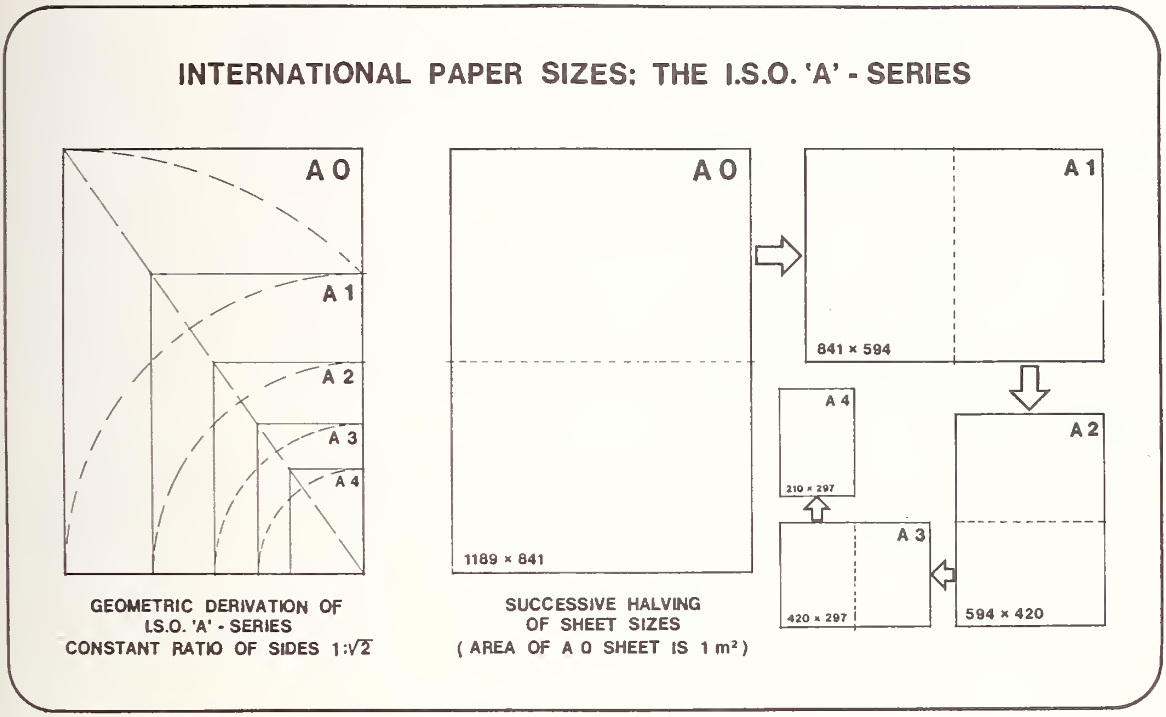
The ISO A-Series of paper sizes, shown in Figure 8.1, is designed to minimize wasteful cutting of paper. All sizes in the series are based on a constant ratio between length and width, and successive halving of the paper size, starting from the largest size of

Table 8.1: Reduction in the Number of Scale Ratios

TRADITIONAL SCALES [Expressed as Ratio]		METRIC SCALES PREFERRED	METRIC SCALES OTHER	REMARKS
Full Size	[1:1]	1:1		No change
Half Full Size	[1:2]		1:2	No change
4" = 1'-0"	[1:3]			
3" = 1'-0"	[1:4]			
		1:5		
2" = 1'-0"	[1:6]			
1 1/2" = 1'-0"	[1:8]			
		1:10		
1" = 1'-0"	[1:12]			
3/4" = 1'-0"	[1:16]			
		1:20		
1/2" = 1'-0"	[1:24]			
			(1:25)	(Limited Use)
3/8" = 1'-0"	[1:32]			
1/4" = 1'-0"	[1:48]			
		1:50		
1" = 5'-0"	[1:60]			
3/16" = 1'-0"	[1:64]			
1/8" = 1'-0"	[1:96]			
		1:100		
1" = 10'-0"	[1:120]			
3/32" = 1'-0"	[1:128]			
1/16" = 1'-0"	[1:196]			
		1:200		
1" = 20'-0"	[1:240]			
			(1:250)	(Limited Use)
1/32" = 1'-0"	[1:384]			
1" = 40'-0"	[1:480]			
		1:500		
1" = 50'-0"	[1:600]			
1" = 60'-0"	[1:720]			
1" = 1 chain	[1:792]			
1" = 80'-0"	[1:960]			
		1:1000		
Total: 24		9	1 (2)	

841 x 1189 mm, which is exactly one square meter. The most common stationary size, A-4, is 210 x 297 mm, or one-sixteenth the largest size, slightly larger in area than the American quarto size of 8 1/2" x 11", which converts to 215 x 280 mm.

Figure 8.1: International Paper Sizes



Many arguments have been advanced as to why the U.S. paper industry cannot change to international paper sizes and there is some likelihood that neither the U. S. nor Canada will change to the ISO A-4 stationary size. The reasons given are predominantly concerned with short-term economic considerations, rather than a long-range assessment of costs and benefits. An optimum point in time for the change to an internationally preferred range, such as that provided by the metric change, will come only once; and, therefore, it is most desirable that all points of view be carefully examined.

E. Familiarization and Involvement of People

The first reaction of most people to a change in the measurement system is one of concern, opposition, and rejection. Arguments of better international trade, simpler calculations, or benefits associated with the change do little to counteract the fear of the unknown. The quickest way to turn nonacceptance into approval is to familiarize people with the system and to involve them in metric activities, because the inherent simplicity and greater accuracy in work speak for themselves. Not only are physical measurements simplified, but all calculations are speeded up. Just compare a typical graphic design task of subdividing a space into a number of smaller spaces; in feet, inches and fractions on one hand, and in millimeters on the other. The task in metric units will be much faster, as well as more accurate. Work on layouts, reduction or enlargement calculations, and actual drafting will be simpler and quicker. Working in millimeters the accuracy of work involving addition, subtraction, multiplication, and division will be to the nearest millimeter (or 1/25th inch), resulting in fewer errors and better fit.

Most people will require only a very small part of the entire system of measurement units to carry out their daily tasks. There is no need for long and costly training periods, if only two or three measurement units are used in the work situation. Those units that are used should be fully understood, but to go into a full-scale metric training exercise is not only expensive, but may even be counter-productive. People should, however, be given a grasp of the system and of the presentation of units, so that they can discern errors made by others. The graphic designer and the editor occupy an important and strategic position to insure the correct application of SI.

F. Metric Posters and Other Visual Aids

The most useful aids in the transition to a metric measurement environment are metric posters and metric articles in preferred dimensions and sizes. They provide mental images and recognition points for people during the transitional period. Thus, they form an important link in the adaptation process to "think metric." Therefore, it is critical that the information presented is concise, correct, and convincing.

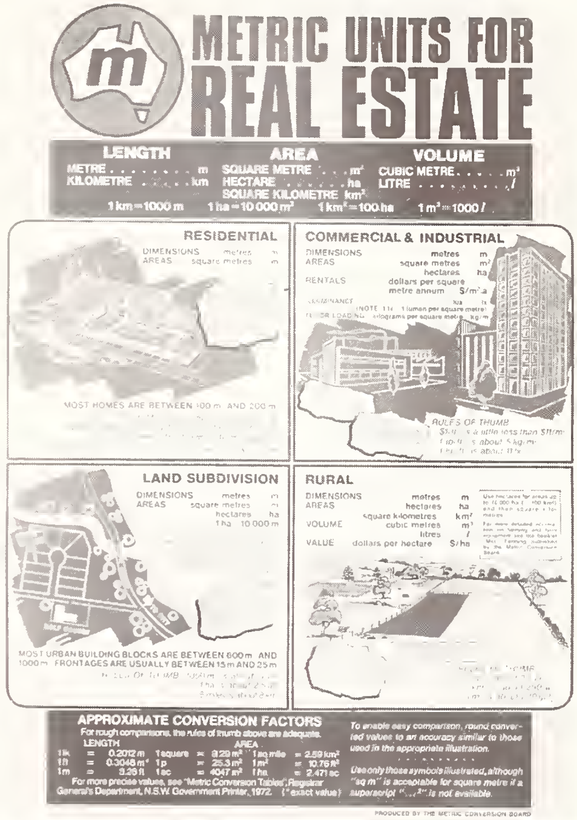
Metric posters from other countries and a variety of metric posters designed in the United States show both good and bad examples of visual presentation, and differing degrees of accuracy in content. A common failing in metric posters is to attempt to show "too much" information, so that the visual impact and educational value is negated.

Figure 8.2 represents an excellent example of a "single impact poster." Designed by the British Construction Industry Training Board, it shows the underside of a human foot with a two-line message: "This is not a foot its 300 mm," and a further line with the words "Think Metric." This poster reinforces the important basic consideration in the construction community that the foot (305 mm) has been replaced by a preferred dimension of 300 mm.

By contrast, the Australian Metric Conversion Board Poster on Metric Units for Real Estate shown in Figure 8.3, has so much information that it suffers from visual indigestion. The data presented, while technically accurate, provide sufficient material for four posters.

Figure 8.2: British Metric Poster

Figure 8.3: Australian Metric Poster



Although most of the early metric posters designed in the United States are interesting designs with good visual impact, many of them suffer from technical inaccuracy or sub-optimal examples. This indicates that they have been designed with good intentions but without adequate research.

Typical examples of common failings are:

- The use of non-preferred prefixes, taken from the "old" metric system, such as "hecto," "deka," "deci," and "centi." Of these, only centi combined with meter (centimeter--one hundredth of a meter), is likely to achieve any significant use in a metric environment. In building and construction, it has been recommended that the centimeter not be used.
- The inclusion of superseded and non-SI metric units, such as the "bar" for pressure, the "kilogram-force" for force, and the "calorie" for heat or energy.
- The incorrect presentation of all values smaller than "one," or unity. In an SI metric world, all numbers smaller than one always require a zero to be prefixed before the decimal point. For example, one half is shown as 0.5, and not as .5; one eighth is shown as 0.125, and not as .125.
- The incorrect presentation of symbols. In the International System of Units (SI), symbols represent an internationally recognized shorthand, regardless of the type of surrounding script, and there is only one recognized symbol for each SI unit. For

example, the symbol for meter is always "m" (a lower case "em"); the symbol for volt is always "V" (a capital vee); and symbols for prefixed units are always combined. The only exceptions are made in computer applications where the equipment has limited character sets.

- Frequently, poorly selected examples are used to demonstrate recognition points. It is preferable to show dimensions or other characteristics of common articles as preferred values (for example, 100 mm), rather than as a "soft conversion" of a customary preference (for example, 102 mm, which merely is a metric veneer for 4 inches). In the same vein, it is better shown that one liter has a volume approximately equal to 34 fluid ounces, or 1.05 quarts, than to be shown that one quart equals 0.946 liter. Figure 8.4 shows an example of an interesting metric poster distributed in the United States. This example fails on two counts--cluttering and the use of non-preferred prefixes.

Figure 8.4: United States Metric Poster

Metric posters are a valuable means to create both public awareness of and publicity for an emerging metric world. Posters should be changed at intervals so that fresh, and, preferably sequential, information is presented from time to time.

It is suggested that an annual "metric poster competition" could be sponsored by the U.S. Metric Board or the National Endowment for the Arts, to assist in educational activities. Such a competition could be judged on the basis of purpose, content, visual impact, and correct presentation of information. Alternatively, an award could be established for the best metric poster designed within the preceding calendar year.

G. Identification of Metric Products, Information, or Work

Many instances will arise where it will be necessary to differentiate metric items from customary ones. This is especially important in inventories and stored records. This can be accomplished in a number of ways by means of separate location, color coding or differing markings, or the affixing of a "metric symbol" to indicate that an item has been metricated.

Most of the countries that have preceded the United States in the change to metric have established a "national metric symbol," or "logo," to:

- draw attention to metric items, such as drawings, maps, publications, products, or machinery;
- differentiate metric products or objects from customary products or objects to facilitate their identification during the transitional period; and,
- provide a national theme for the creation of metric awareness.

Figure 8.5: Selected Metric Symbols

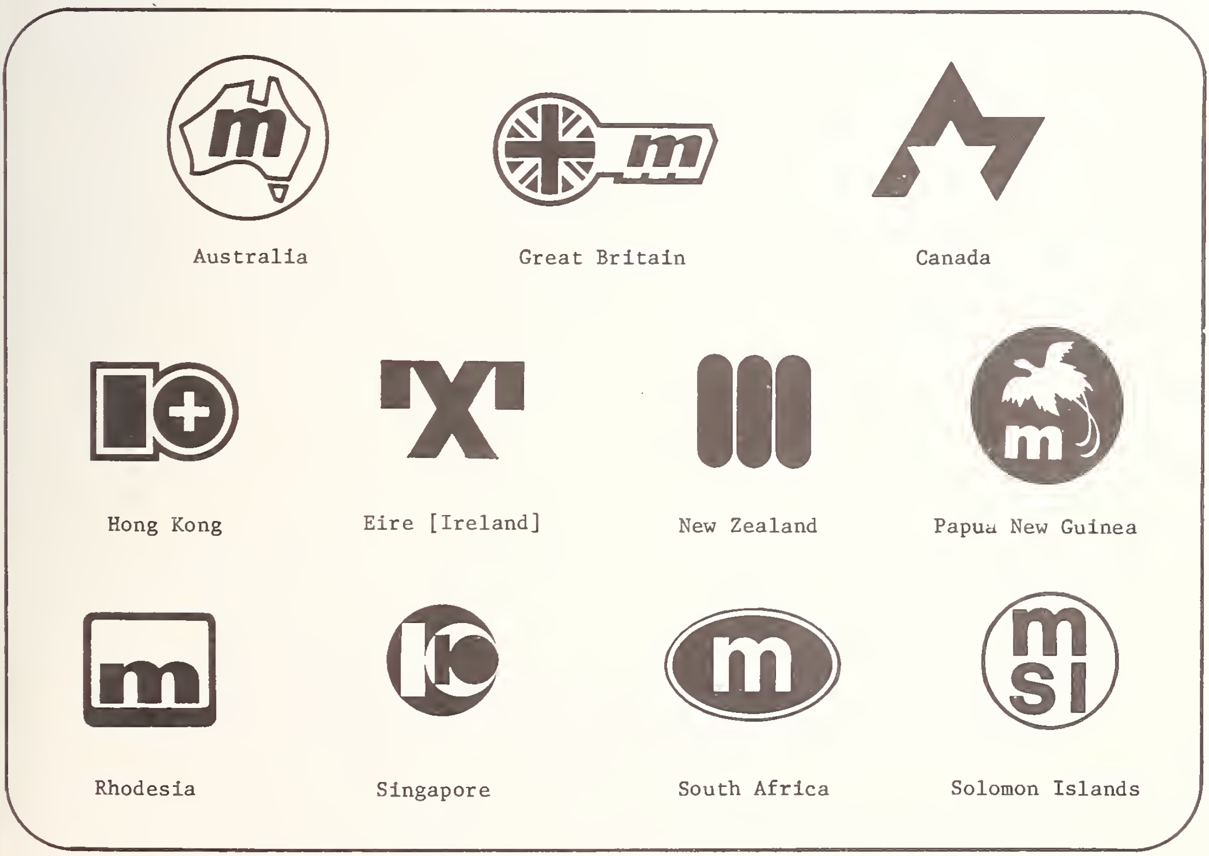


Figure 8.5 shows selected metric symbols from a number of other countries. These symbols vary significantly in design and symbolism, but all of them are "catchy" and provide a distinct identification. Quite a few of the symbols play on the "m" (for "meter") symbol. The Australian metric symbol features the "m" within a stylized map of Australia, surrounded by a circle representing the globe. The British metric symbol "key" contains the "m" in the blade of the key and also features a circular national flag. The South African "m" is contained within an ellipse that has been interpreted by some as a symbolic football. Symbols of other countries have a "local" symbol logic.

It is suggested that one of the early activities of the U.S. Metric Board could be the initiation of a national graphic design competition for the development of a "U.S. Metric Symbol" for use in all suitable metrication situations. An appropriate award for the selected symbol, as well as the best unsuccessful designs, would stimulate the graphic arts sector of the economy to demonstrate creative ingenuity. Simultaneously, it would fulfill an important function in creating a wider awareness of the metric change.

CONCLUDING REMARKS

The change to metric measurement represents a unique and never-to-be-repeated opportunity to review, revise, and rationalize. Both the graphic design industry and the publishing industry will be called upon to play a prominent and significant role in bringing about the necessary changes. The better informed these industries will be at the outset, the better will be their contribution to a metric United States.

Not only is the international (metric) system advancing - it is coming to stay. There is no record of any country in history after having made the change to the metric system, changing away from it. In the not too distant future the visionary prediction of the French statesman Talleyrand, made in 1790, will become reality: "One system of measures for all people and for all time."

SECTION 9

Metric Training and Familiarization of Personnel

Material prepared as basis for a section in the "AIA Metric Building and Construction Guide," at present under development within the American Institute of Architects.

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INTRODUCTION

The issue of metric familiarization and/or training of staff and operatives can be approached as a matter of either individual or organizational responsibility. There are many differing opinions as to the desirability, value, or necessary extent of a formal metric education program for the design or construction environment. Precedent indicates that a brief, well conceived, suitably timed, and task oriented metric education program will ultimately save money. Such a program will remove individual resistance to or fear of the metric change, and provide a common basis for the application of metric units.

In countries that have preceded the United States in the change to a metric building environment during the past decade, approaches to training have varied.

In the British design and construction community considerable formal preliminary and on-the-job training was applied, and the primary responsibility for such training rested with the employer organization. In many instances, this approach led to over-training and caused a negative reaction where no metric work involvement was available to test and utilize newly acquired skills. However, there were two compounding factors; firstly, the simultaneous change to dimensional coordination throughout the construction community required an additional, though associated, education program; and, secondly, the change to decimal currency in 1971 demanded a further learning and conversion program in regard to costs and prices.

South Africa, which was the next country to undertake metrication in the construction community, opted for a minimum of formal training and considerable individual responsibility in becoming acquainted with the new measurement environment. This has been termed the "sink-or-swim" approach.

Australia, New Zealand, and Canada, have taken a middle course. This middle course involved the creation of a climate conducive to metric familiarization by the individual, overlaid with a limited and well constructed formal program phased immediately prior to involvement in metric tasks.

It could be argued that educated staff engaged in professional or technical work require no training, because such personnel should be capable of effecting the change on their own. However, the cost savings of a "no-training-policy" must be measured against the indirect costs resulting from:

- A lack of serious involvement in metric work and resistance to change by some individuals.
- A loss of uniformity of approach within the organization.
- The postponement of benefits obtained from the proper use of SI units and simplified calculations.

- Additional time taken by untrained personnel in unnecessary and incorrect activities, such as the conversion to and from customary units.
- The increased likelihood of error.

For these reasons, some form of planned metric familiarization is desirable in most organizations.

Part I

TRAINING NEEDS

It must be remembered that the change to metric measurement (SI) will be gradual and may not affect many people for quite some time. In the construction community, personnel involved in the preparation of metric standards, codes and technical data will need to become involved prior to personnel engaged in design and documentation. Both groups will work in metric long before production or construction personnel. The training or familiarization needs of people will vary according to the type and specialization of work. A consulting engineer, for example, will need a different re-education program from an architect, and a completely different one from a building tradesman or laborer.

Comprehensive metric training should be reserved for the "metric trainers," who have the task to familiarize others! Most groups in the community require no more than a brief introduction to the main, job-related SI units and quantities and accepted rules for their application. The most effective training is on-the-job, where metric measurement can be directly applied.

A. A Metric Training Policy

It is recommended that a metric training policy be established early on in every organization to facilitate the transition to a metric working environment. The policy should set out the objectives of the metric education program and the obligations of individuals, groups, and the organization.

Some objectives of a training policy might be:

- To facilitate general awareness of the change to metric within the organization.
- To clearly delineate the timing of the change and the implications for the individual and groups (sections, departments, branches) arising from the metric program of both the organization and the construction community.
- To provide a working knowledge of the use of SI in design, production, or construction applications, according to the activities of the organization.
- To develop a small group of experts in each location or task area, who may subsequently be called upon to involve or familiarize others, or to resolve metric difficulties.

Where there is no training section or metric office within an organization, the responsibility for overview and implementation of metric education should be established at an early stage. An individual or a small group might be appointed to act as "metric apostle."

B. A Metric Training Program

The analysis of industrial and organizational activities, and the identification of all measurement sensitive areas, should enable the definition of the following aspects of a metric training program:

- Timing of familiarization or training and any planned follow-up;
- Segmentation of training for different groups;
- Scope (contents) of training or familiarization program;
- Type of training; and,
- Training media.

C. Timing of Metric Familiarization or Training

In an organizational metric familiarization program, personnel should be involved progressively as the change-over proceeds in line with the established timetable for change. The initial training should be provided for staff engaged in metric trial (pilot) projects or the first metric project.

Suitable durations of familiarization programs should be established according to the degree of involvement in metric work, and the expected amount of additional and voluntary self-training.

Precedent has shown that most professional staff do not need more than two days of formal metric training, preferably spaced out over a series of training sessions with practical involvement and examples. Some professional groups which already work extensively in SI units (electrical, illumination, and acoustic engineers), may need as little as one-half day of formal metric familiarization.

Similarly, technical support personnel do not require extensive training. In most disciplines, a total period of one day will be adequate for task-related familiarization.

In most cases, administrative personnel require very little metric training to continue in their assigned functions. However, typists should be given a thorough appreciation of the need to show correct spelling, correct symbols, and notation.

Site personnel will need only limited and basic instruction in aspects related directly to their work.

In general, any metric familiarization or training which is not immediately followed by an involvement in metric tasks is highly undesirable and may be counter-productive.

D. Segmentation of Training for Different Groups

Many organizations will need a number of different metric familiarization or training programs to cover specific needs. For example, a large design/construction organization may require training programs aimed at the following constituents:

- Executives/Senior Management - A general program designed to create metric awareness, with discussions relating to objectives, opportunities, and management action necessary to bring about a successful and cost-effective change to metric measurement.

- Professional Staff - A specific program or series of programs designed to deal with all aspects of metrication and dimensional coordination relevant to the efficient performance of metric tasks. Due to a higher level of abstraction in the conceptual tasks carried out by these groups and the allied use of a wide variety of SI units, a detailed explanation of new concepts is necessary. A task-oriented metric program with actual metric exercises should precede staff involvement in actual metric projects. Suitable and accurate technical support literature also is required.

- Technical Support and Drafting Staff - A basic program of task-oriented familiarization with SI units and limited explanation of concepts, followed by actual exercises in metric technical work.

- Administrative/Clerical Staff - A brief and basic program containing essential information only to enable them to work effectively in a metric technical environment.

- Typists/Stenographers - A specific, task-oriented training program emphasizing correct presentation of units, names, symbols, and notation, reinforced by a reference sheet showing correct and incorrect practices.

- Construction Site Personnel, Tradesmen and Labor - A specific task-oriented training program in those areas of measurement that are directly related to the performance of tasks. This should be given just prior to commencement of metric work. Familiarization exercises such as measurement on-site, setting-out, or positioning of items in line with a metric drawing should be included. A basic pocketbook or guide summarizing the main training information in simple terms should be issued at the end of the program.

E. Scope of Metric Training Program

To assist in the preparation of a training program for personnel engaged in building design, production, or construction activities, the following items describe information that could be incorporated selectively into different training programs.

1. <u>General Information</u>

   Responsibility for conversion activities

   Timing of the change and vital dates (for the industry and the organization)

   Organizational metric policy

   Need for personal involvement to overcome problems and to identify opportunities (metric suggestion scheme)

   The basis of SI--the "modern metric system:" coherence, decimal nature, only one unit for each quantity, international (worldwide) system and symbols

2. <u>The Modern Metric System - SI</u>

   Metric measurement - units and prefixes

   Basic and derived units and their relationships

   SI units and non-SI units accepted for use with SI

   Use of SI units and rules and recommendations for presentation

   Thinking in metric: examples

3. <u>Application of SI</u>

   Exercises, calculations, and worked examples

   Conversion of customary values, rounding and rationalization

4. <u>Coordination of Dimensions in Building</u>

   Basic principles

   Application of preferred dimensions and preferred product sizes

   Accuracy and control on-site

5. <u>Presentation</u>

   Notation on metric drawings and in specifications

   Drawings and scale ratios

   Rationalized documentation

6. <u>Cost Estimating</u>

   Metric units and unit rates

   Metric cost schedules

   Sizes of building materials and estimating practices

7. <u>Setting-out on-site</u>

   Use of metric measuring equipment

   Linear measurement, angular measurement, and levels

   Horizontal and vertical setting-out

8. <u>Legal and Contractual Aspects</u>

Contract clauses for the transition period

Special conditions or arrangements; e.g. substitution

Building regulations

Metric building standards, specifications, and codes of practice

9. <u>Building Products (Manufacture, Distribution, Sales)</u>

Metric dimensions of key products

Metric properties and performance characteristics

Tolerances and fits

Substitution of products

It is recognized that the assembly of suitable material in the various categories will not be an easy task. However, approved and authoritative handbooks should be available by the time the training is required.

It is recommended that a "metric training matrix" be developed by each organization. Such a matrix would show different groups and respective input from items 1-9 above, and any additional items that may be necessary in the context of organizational activity.

F. Type of Training

The following forms of training could be adopted, either singly or in combination, with or without modifications:

- A formal internal training program, in a classroom atmosphere, either in-house or at an off-site location.
- An on-the-job training program individually or in a group, related directly to the task situation.
- An external training program through suitable courses or seminars, either during normal working hours, or outside normal working hours.
- Self-training, assisted by suitable reference documents provided by the organization.

The most appropriate type of training depends to some extent on the size of staff and operatives in an organization, as well as the access to facilities. Metric training groups should not be larger than 20 people.

G. Training Media

Familiarization or training on their own are not sufficient. They should be backed up by suitable lectures, visual aids, and reference publications.

Appropriate media should only be selected after timing, scope, and intensity of training have been determined, and the number of people to be trained have been established. The training course or familiarization program represents an appropriate time to provide personnel with a folder of metric material (including a scale rule and, preferably a metric measuring tape), to assist in their work situations and to increase metric curiosity.

H. Metric Lectures and Informal Talks

To cultivate and maintain interest in the metric change, at the outset of metrication metric lectures or informal talks might be organized involving all staff affected by the change.

Not only is it important to create awareness among technical and operating personnel, but it is equally important to generate metric impact awareness among management and administrative personnel. It would be highly desirable to plan regular informal addresses to top management. The purpose of these would be to brief executives on proposals and decisions within the industry sector, related industries, and at a national level in the construction community and associated sectors of the economy. A metric program without "metric education" of management is bound to be sub-optimal.

Such metric briefings to management should outline areas of industry or organizational operations which might be improved or rationalized in conjunction with metrication, and to pinpoint specific opportunities arising from the change which might be pursued. The need to time the change relative to a nationally agreed metric conversion program should be highlighted. There are advantages and disadvantages connected with an early involvement, but mostly disadvantages when the change is left too late.

General lectures to staff should point out the objectives in metrication and dimensional coordination (as appropriate), and what should be done to make a well planned and executed transition, fairly quickly, and with a minimum of upheaval or cost. Emphasis should be placed on real examples that show where the change can be utilized to achieve more efficient practices in most areas affected by the change.

I. Reference Publications and Follow-up

To assist in a metric training program, reference and educational publications and data sheets will need to be produced or procured, and distributed. Such documents or advisory data should be specifically directed at each training segment, and may also include specific instructions dealing with metric policy decisions within and outside the organization.

While a formal familiarization or training program and published information will assist personnel to work in a metric work situation, there are bound to be occasions when special advice or information will be required, or when a resolution of conflicting information becomes necessary. An internal metric coordinator, or metric advisory service, can best deal with such requirements. The monitoring and assessment of internal requests for information will indicate where special needs exist which might have to be addressed in follow-up training.

Part II

AIDS TO METRIC FAMILIARIZATION

In the solution of both simple and complex problems, people rely on "mental models" of the world around them. These models--or mental images--provide the basis for comparisons and assessments, for estimating, and for abstraction. Many mental images have measurement approximations connected with them. In the change to SI, people need to become familiar with the new mental images in metric reference units, without having to constantly revert to the time consuming and error prone process of direct conversion.

It will take a while to acquire a "feel" for metric units--such as millimeters and meters--when the mental data bank is in inches, feet and yards. The quickest way to make metric units meaningful, is to generate "metric recognition points." These recognition points are generated by direct measurement or comparison, and should be supplemented by actual work on "metric examples" in measurement and calculations. Rulers and other measuring devices are indispensible tools in making the transition to metric, and no training program should be without "correctly marked" rulers, tapes, and scales to relate estimated to "actual" values. Metric visual aids also will assist in any metric familiarization exercise. The metric data bank will be supplemented over a period of time and will be extended at about the rate at which the customary reference points are "blotted out."

A. Personal Recognition Points

In any metric training program, one of the quickest and most meaningful ways of developing mental images is to establish personal recognition points, based on human sizes and functions. For example, a person's body mass (weight) in kilograms can be established very quickly, and then provides a useful reference value to relate the mass of objects.

Human dimensions change far less than mass (weight), and are important reference points in the judgment of dimensions in the metric world--particularly in a highly measurement sensitive industry, such as construction. It is a simple and interesting exercise to measure people's height, forward reach, upward reach, shoulder height, and other body dimensions during the training program, and to enter them on a "body dimensions reference sheet." Particular attention should be paid to natural dimensions which are exactly or close to modular sizes--that is whole multiples of 100 mm. The width of a man's hand is approximately 100 mm, and the span of certain fingers may be 200 mm, such as the point-to-point distance between the thumb and index finger when pressed down. While individual dimensions vary, the reference values are unlikely to be forgotten once they have been established and recorded. Typically, a male who is 1.85 m (or 1850 mm) tall, will have an upward reach (with both heels on the ground) of 2400 mm, a shoulder height of approximately 1600 mm, and a forward reach (which can be measured adjacent to a door leaf with the shoulder against the door edge) of 800 mm. Personal metric recognition points humanize the metric environment and make it more meaningful.

B. General (Object) Recognition Points

A second stage in "object familiarization" in a metric training program would be to assign metric values to everyday objects, and thus to create recognition points. There are many everyday objects which can be measured or weighed, and will yield excellent recognition points. For example, when the dimension of 2 mm is recognized as the thickness of a nickel (5¢ coin), it yields a useful reference point. A stack of five nickels is an excellent approximation to 10 mm (or 1 cm, although the centimeter will not be used in construction). It will also make it possible to visualize the depth of water accumulated in one hour caused by a rainfall with an intensity of 10 mm/h. The mass of a nickel is approximately 5 grams, and this recognition point can be used to relate other masses (weights). For example, international airmail weight cut-off points for letters, in multiples of 10 g, when these are introduced.

The principal quantities used in everyday activities are length, area, volume and capacity, mass (weight), and temperature. A series of recognition points for each of these quantities--based upon familiar objects--is shown in Table 9.1. Where approximations have been used, the maximum variation from the exact equivalent is 2 percent.

Many activities involve "guesses" of magnitudes--such as approximate lengths, distances, masses, or volumes. The basis for such guesses is the mental data bank of recognition points. This data bank is fallible. It is desirable to demonstrate in a metric training program how fallible estimates made in familiar units can be. A good example is to ask people to indicate on a sheet of paper, their estimate of the length of the U.S. dollar bills, all of which are the same size. With a large enough sample, a normal distribution is obtained, where the standard deviation is about 1 inch.

C. Abstract Recognition Factors

Whereas length, area, volume, mass, and temperature can be measured by scales or other measuring devices, many of the quantities used in design are "abstract values," derived from formulas, standards, or codes of practice. Reference values are part of the mental data bank, but they are assimilated in relation to concepts rather than actual physical measurement. A compressive strength of concrete of a certain magnitude evokes an image, but can rarely be related to an actual physical characteristic, other than a pressure gauge in a

Table 9.1: Some Metric Recognition Points

1. Linear Measurement	1 mm	=	approximate diameter of a paper clip wire
	2 mm	=	thickness of a nickel [5¢ coin]
	10 mm	=	height of a stack of 5 nickels [5¢ coins] or 7 pennies [1¢ coins]
	25 mm	=	vertical dimension of an ordinary U.S. postage stamp; nearest equivalent to 1 inch
	60 mm	=	height of the printed frame on the front of U.S. paper currency
	100 mm	=	international cigarette length; basic metric building module; nearest metric preferred dimension to 4 inches (1.6% less)
	200 mm	=	vertical height of three U.S. one dollar bills, laid edge-to-edge
	600 mm	=	height of three courses of concrete blocks including mortar joints
	1 m [1000 mm]	=	1 meter is the basic unit of length in the metric system and SI. [If you do not know its length--a little over 39 inches--it is best to acquire a metric tape to measure it.] 1 meter is the approximate length of a baseball bat or height of a laboratory bench
	2 m	=	approximate height of a standard door opening
	10 m	=	height of the diving tower high board in olympic swimming pools
	50 m	=	length of an olympic size swimming pool basin
	100 m	=	olympic and international sprint distance in athletics
	1 km	=	1000 m = approximate equivalent of 5 furlongs in horse racing
2. Area Measurement	500 mm^2	=	face area of an ordinary U.S. postage stamp [20 mm x 25 mm]
	10 000 mm^2	=	approximate area of notes in U.S. paper currency
	60 000 mm^2	=	[0.06 m^2] = area of American quarto paper [215 mm x 280 mm]
	1 m^2	=	1 square meter: approximate area of four 20-inch square furnace filters; approximate area of a shower base
	100 m^2	=	floor area of a small house (a little less than 11 squares)
	1000 m^2	=	a building allotment of approximately 1/4 acre; surface area of an olympic size swimming pool [20 m x 50 m]
	2 ha	=	[20 000 m^2] = approximate equivalent of a 5-acre property
3. Volume Measurement	30 mL	=	nearest equivalent to 1 fluid ounce in prescriptions or perfume
	1 L	=	1 liter: 5.7% more than a U.S. quart; new soft drink bottle size
	200 L	=	[0.2 m^2] = capacity of a 55-gallon drum
4. Mass [Weight]	1 g	=	approximate weight of a paper clip or a dollar bill; artificial sweetener package size
	5 g	=	mass [weight] of a nickel [5¢ coin]
	50 g	=	mass [weight] of a golf ball
	100 g	=	chocolate bar size (approximately 3 1/2 ounces)
	1 kg	=	1 kilogram: the base unit of mass in SI; mass of water in a cube with 100 mm sides (approximately 2.2 pounds)
	20 kg	=	luggage allowance in economy class international air travel (44 lb)
	100 kg	=	a heavyweight man (220 pounds)

5. Temperature	0°C	= freezing point of water		25°C	=	warm
	5°C	= cold		30°C	=	hot
	10°C	= cool		35°C	=	very hot
	15°C	= mild		37°C	=	normal body temperature
	20°C	= comfortable [thermostat setting in winter-- 68°F]		100°C	=	boiling point of water

compressive strength testing machine in a laboratory. The change to metric units requires the substitution of new abstract reference values. Direct conversion of the customary data bank will merely become a "conversion crutch" and yield little benefit. The customary data bank will need to be blanked out, and the simplest and quickest way to do this is to associate simple and preferred metric values with technical concepts or benchmarks.

Common design factors, expressed in SI, need to be rationalized to preferred values. For example, a uniformly distributed floor load of 40 lbf/ft^2 would be easier to memorize as 2 kPa (kilopascals) than as 1.9 kPa or even 1.915 kPa. Similarly, a compressive strength for concrete of 20 MPa (megapascals) seems to be a better value than 20.7 MPa or 20.68 MPa. It is even preferable to work from a rationalized metric data bank in the transitional period, and to use values such as 20 MPa, with a rounded customary equivalent of 2900 lbf/in^2 where customary units are used.

D. Metric Visual Aids

The most useful aids in the transition to a metric measurement environment are metric posters, wallcharts, displays, cutouts, and other articles in preferred dimensions and sizes. These items are visual reminders that provide mental images and recognition points for people during the transitional period, and thus form an important link in the adaptation process to "think metric."

Therefore it is critical that the information presented is convincing, concise, and correct.

Metric posters are one of the best means of "metric" visual communication, provided that their message and design evoke interest. Posters, in general, can only be used for simple messages, and if used, should be changed from time to time.

Two examples of metric posters from Britain and Australia are provided in Section 8 of this publication, entitled "New Measures in Graphics Design and Publications - The Advance of the Metric System." The British poster is an excellent example of a "single impact" poster. Designed by the British Construction Industries Training Board, it shows the underside of a human foot with a two-line message: "This is not a foot it's 300 mm" and a further line with the words "think metric."

By contrast, the Australian Metric Conversion Board poster on "Metric Units for Real Estate" has correct information, but so much of it that it suffers from visual indigestion. The data presented provide sufficient material for four or five posters.

While most of the early metric posters designed in the United States are interesting designs with good visual impact, many of them suffer from technical inaccuracies, poor examples, and the use of non-preferred units and prefixes. Typically, some posters show superseded or non-SI units; soft conversions rather than preferred sizes; incorrect symbols; incorrect presentation of numbers smaller than "one," which should always be prefixed by a zero before the decimal point; and non-preferred prefixes such as "hecto," "deka," and "deci."

Where posters are purchased for the purpose of providing a metric impact, their contents should be carefully checked as to technical accuracy; otherwise, an incorrect poster may undo a lot of the teaching undertaken in a metric training program.

Wallcharts also are useful adjuncts to present metric information. For example, wallcharts might show the metric conversion timetable for the construction industries or an individual organization, or relationships within the metric system.

One of the best visual aids is one that can be touched, measured, and compared, as well as seen:

- A modular cube with 100 mm sides in a metric display will evoke a much better mental image than the area of one of its faces shown on a poster.
- Materials in new sizes or packages can be displayed and appropriately labeled (for example, a new metric modular brick of 290 mm x 90 mm x 90 mm size, with an indication of its mass, say 4 kg).
- A panel of one square meter of area, painted brightly and identified suitably, can be hung in the office to function as a metric display board.
- Items which provide personal reference points for the judgment of metric measurement, such as a metric scale on which individuals can establish their weight (mass) in kilograms, or a vertical wallscale to measure height, can be displayed.

E. Marking of Offices in Metric Measurement

Designers and other groups are encouraged to use their ingenuity in designing horizontal and vertical scales or markers, dimension markers for objects, modular men, etc., dimensioned exclusively in metric units. Such items will create a metric environment in the rooms or buildings in which they work.

The best results will probably be achieved spontaneously, combining education (familiarization) with humor or entertainment. The change to metric could become an interesting theme for an office or Christmas party.

F. Calculations in Metric (SI) Units

Because of their internal coherence and decimal nature, the use of metric units will result in greater simplicity, speed, and accuracy in calculations; particularly where compound units or formulas are used. Metric calculations generally involve no more than in-line multiplication, as the only possible divisors are powers of ten, compared with complex multiplications and divisions in customary calculations. A number of example calculations are shown in Appendix A.

The use of side by side calculations in metric and customary units during a training program will convincingly demonstrate the advantages of a decimally based measurement system in terms of speed and accuracy; more so than any lengthy discussion of metric virtues.

Studies conducted in other countries that have changed from English units to metric units have shown that metric calculations can be made with approximately twice the speed of customary calculations, but with five times the accuracy. Some mistakes can cost a lot of money; and therefore, the greater likelihood to avoid mistakes can save a lot of unnecessary costs.

There is an unlimited number of variations on the sample calculations shown in the Appendix and special worked examples can be constructed for any training situation.

CONCLUDING REMARKS

A significant part of metrication is metric education. It is highly desirable for any formal training or familiarization program to be presented with ingenuity and humor, rather than with dull routine. The modern metric system is a live system, despite the fact that it does not relate directly to human "feet" or other measurements. In everyday use, the metric system is a natural ally of two systems that all people use continually--the decimal system of numbers, and the decimal system of currency.

It is a fair challenge for the metric trainer to take the myths and the mystery out of metric. This requires a detailed knowledge of the system, its application, its history and development, and its practical use in a metric world.

Most importantly, metric training should be a "fun exercise" with direct personal involvement during the learning process. Innovative approaches can reinforce the program. For example, metric information--displayed in building lobbies and/or corridors and suitably illuminated--will attract the curious; metric dimensional markers or measuring devices placed in waiting rooms, or restrooms will help to familiarize. The net result is that metric information is processed and absorbed without compulsion.

Metric training is a creative challenge!

APPENDIX A

COMPARISON OF CALCULATIONS IN CUSTOMARY UNITS AND IN METRIC (SI) UNITS

1. Addition of Linear Measurement

Find the overall dimension of a room for which the following dimensions have been established with a measuring tape:

5'-9 3/4" + 4'-7" + 3'-10 1/2"

Find the overall dimension of a room for which the following dimensions have been established with a metric tape:

1770 mm + 1400 mm + 1180 mm

Note: The example may be modified to use actual room dimensions.

For comparison purposes, it is desirable to check the time taken for calculations in customary units and in metric units, as well as the percentage of incorrect answers. This or similar examples will demonstrate how much quicker and more accurate it is to calculate in metric units.

2. Addition of Linear Measurement

You want to frame a painting which measures 2'-5" by 1'-9 1/2" with a 2" wide bevelled frame. An allowance must be made for cutting to waste at the corners. What is the total length of framing required?

You want to frame a painting which measures 735 mm by 550 mm with a 50 mm wide bevelled frame. An allowance must be made for cutting to waste at the corners. What is the total length of framing required?

3. Division of a Linear Dimension into Equal Parts

A detailed drawing shows a height of 8'-10" between two floors connected by a stair with 14 risers, but not the height of each riser. What is the target height of risers so that none of them varies by more than 1/16"?

A detail drawing shows a height of 2690 mm between two floors connected by a stair with 14 risers, but not the height of each riser. What is the target height of risers so that none of them varies by more than 1 mm?

4. Area Calculations to Determine Order Quantity

A broken window pane needs to be replaced. The area of glass required measures 2'-9 1/2" by 4'-4 3/4". How many square feet of glass should you pay for if the glazier charges to the nearest square foot?

A broken window pane needs to be replaced. The area of glass required measures 850 mm by 1340 mm. How many square meters of glass should you pay for if the glazier charges to the nearest tenth of a square meter?

5. Area and Volume Calculations to Determine Order Quantity

A flat concrete slab for an industrial structure has the following dimensions:
Length: 25'-0"; width: 26'-6"; and thickness: 5".
Determine the order quantity of concrete to the nearest half of a cubic yard.

A flat concrete slab for an industrial structure has the following dimensions:
Length: 7.5 m; width: 8.4 m; and thickness: 125 mm (0.125 m).
Determine the order quantity of concrete to the nearest half of a cubic meter.

6. Volume and Capacity Calculations

You have a small rectangular swimming pool with the following dimensions:
Length: 16'-6"; width: 10'-6"; and average depth 4'-3" (to water line).
How much water, in gallons, will it take to fill the pool?

You have a rectangular swimming pool with the following dimensions:
Length: 5.0 m; width: 3.2 m; and average depth: 1.3 m (to water line).
How much water, in liters, will it take to fill the pool?

7. Runoff Calculations

A parking area measures 5 acres. How much runoff, in gallons of water, will result from a rainfall of 1 inch?

A parking area measures 2 hectares. How much runoff, in liters of water, will result from a rainfall of 25 mm?

Note: A similar calculation would be necessary to determine the quantity of water needed to irrigate a property of 5 acres (2 hectares) to the equivalent of a rainfall of 1 inch (25 mm).

CALCULATIONS AND COMMENTARY

	Customary Units	Metric [SI] Units
1.	5'-9 3/4" 4'-7" 3'-10 1/2" 15'-3 1/4"	1770 mm 1400 mm 1180 mm 4350 mm

Commentary: The calculation in customary units requires the separate addition of fractions, inches, and feet. This increases both the use of time and the likelihood of error.

	Customary Units	Metric [SI] Units
2.	2 × (2'-5") = 4'-10" 2 × (1'-9 1/2") = 3'-7" 8 × 2" = 16" = 1'-4" (mitre offcuts) 9'-9" Order: 10 feet	2 × 735 mm = 1470 mm 2 × 550 mm = 1100 mm 8 × 50 mm = 400 mm 2970 mm Order: 3 m [3000 mm]

Commentary: The calculations in customary units are similar to those in Example 1, but also involve multiplication.

	Customary Units	Metric [SI] Units
3.	8'-10" = 106" 106 ÷ 14 = 7.57" 7.57" ≃ 7 9/16" (Check) 7 9/16" × 14 = 105 7/8" (- 1/8") Target height of riser: 7 9/16" with 2 risers at 7 5/8" (+ 1/16" each)	2690 ÷ 14 = 192.1 mm (Check) 192 × 14 = 2688 mm (-2 mm) Target height of riser: 192 mm with 2 risers at 193 mm each.

Commentary: Division of measurement in customary units requires decimalization and change to and from decimal fractions.

	Customary Units	Metric [SI] Units
4.	2'-9 1/2" = 2.79' 4'-4 3/4" = 4.40' 2.79' × 4.4' = 12.28 ft^2 Pay for: 13 ft^2	[850 mm = 0.85 m] [1340 mm = 1.34 m] 0.85 m × 1.34 m = 1.14 m^2 Pay for: 1.2 m^2

Commentary: Linear dimensions in customary units need to be decimalized for area or volume calculations. Millimeters are converted to meters simply by dividing by 1000, and moving the decimal point three places.

	Customary Units	Metric [SI] Units
5.	$\frac{25 \times 26.5 \times 5}{12}$ = 276 ft^3 276 ÷ 27 = 10.22 yd^3 Order: 10 1/2 yd^3	7.5 × 8.4 × 0.125 = 7.85 m^3 Order: 8 m^3

Commentary: Customary units need to be decimalized, and factors are required with inches and conversion of cubic feet to cubic yards. Metric volume is derived directly by multiplication of dimensions.

	Customary Units	Metric [SI] Units
6.	16.5 × 10.5 × 4.25 × 7.48 = 5508 gallons Water required: 5510 gallons	5 × 3.2 × 1.3 × 1000 = 20 800 L Water required: 20 800 liters

Commentary: In customary units, feet and inches are decimalized; 1 cubic foot has a capacity of approx. 7.48 gallons. 1 cubic meter has a capacity of 1000 liters.

	Customary Units	Metric [SI] Units
7.	$\frac{5 \times 43\ 560 \times 1 \times 7.48}{12}$ = 135 760 gallons Runoff: [say] 135 000 gallons	2 × 10 000 × 25 = 500 000 L Runoff: 500 000 liters (or 500 m^3)

Commentary: Factors need to be known: 1 acre = 43,560 ft^2; 1 ft^3 = 7.48 gallons; 1 hectare = 10 000 m^2; 1 m^3 = 1000 L; 1 mm × 1 m^2 = 1 L.

SECTION 10

Guidelines for the Metric Transitional Period in Building Design and Construction

Material prepared as basis for a section in the "AIA Metric Building and Construction Guide," at present under development within the American Institute of Architects.

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INTRODUCTION

The transition period in metrication is the time from the commencement of planned metric activity--when the bulk of industrial activity still is conducted in customary units of measurement, to substantial accomplishment of metrication--when work in non-metric units of measurement is the exception. Precedent has shown that the transition to metric building design and construction can be accomplished in the space of three years or less (South Africa, Australia) to five years or more (Britain). In general, the quicker the transition, the less traumatic will be the metric change. However, this does not mean that the change should be a "soft conversion," that is, a change in description only. The metric change should be approached with the purpose to effect changes to new and preferred values and sizes, wherever practicable and desirable.

The best transition period is one in which the necessary changes within an industry are well planned, well coordinated, and well implemented, in a "synchonized" exercise involving all activity sectors at the national, regional, and local level. The wider the involvement in the change, the more the load will be spread.

At the beginning of the change to a fully metric construction environment, there are likely to be instances where metric products specified by designers will be in short supply, or even unavailable, despite careful research of the supply situation. It would be unreasonable to expect the contractor to carry any additional costs incurred as a result of such unavailability. Similarly, the client needs to be safeguarded against the possibility of entirely "unnecessary metric extras." Towards the end of the transitional period a similar situation will arise. However, this time it applies to the remaining contracts still carried out in customary units at a time when non-metric products have become scarce or unavailable. Again, firm understandings are needed to protect all parties to a building contract.

Some commentators on metrication have predicted "problems" in the retrofit of existing buildings, and in the interfacing of metric components with non-metric components. Precedent and experience in other countries have shown that "imagined problems" rarely materialize in practice.

This paper discusses possible strategies in the adaptation of building materials and components during the transitional period; outlines considerations in the interfacing of existing non-metric buildings with metric building components or systems; and, deals with some of the legal and contractual issues that should be resolved prior to the transitional period.

Part I

ADAPTATION OF BUILDING MATERIALS AND COMPONENTS DURING THE TRANSITIONAL PERIOD

A. General

The principal influence on the rate of growth in metric construction will be decisions made by building clients, designers, and manufacturers.

Early in the transitional period there is bound to be some reluctance on the part of some manufacturers to change to metric production. This may cause some temporary difficulties in obtaining a full range of metric building products in preferred sizes. As the change accelerates, the demand for metric products will increase rapidly, and thus the supply. At the end of the change a second transition will occur. This will be when the demand for products sized in customary dimensions declines and supply evaporates, except for those items that find continued use in maintenance and renovation.

The basic "metric problem" clearly is how to effect the least disruptive and most economical transition to a metric building environment. To play their part in the transition, designers will have to prepare metric documents in good faith that metric components will be available when needed in construction. In turn, manufacturers are expected to produce metric products in time for their incorporation into a rapidly growing number of metric projects without the burden of having to maintain dual or slow-moving inventories. Such synchronization will not be easy--for reasons ranging from a lack of communication, through inadequate coordination, to a reluctance to change. Generally, a lack of action will be masked by the excuse that "the time for a change is not appropriate for economic reasons." But, without a commitment to the change by all parties, a vicious circle could eventuate which will increase costs for all parties. The most likely losers in a building environment with unbalanced demand and supply are the clients who have to pay for inefficiencies in one way or another, and the contractor who has to deal with a hybrid situation.

B. Adaptation Strategies in Design and Construction

Precedent has shown that metric design and construction can proceed, even before manufacturers have available a comprehensive range of building materials and components in rationalized and preferred metric sizes. Although only a few of the building products currently in use in the construction community convert directly to acceptable metric sizes, there are many instances where it is possible over the next few years to develop "new" products in preferred metric sizes. Such products can then be sold in both market segments: under "nominal" descriptions in the declining market for customary items, and in "actual" preferred dimensions in the growing and, ultimately, exclusively metric market. Similarly, other properties such as strength grades, can be assigned in preferred metric values where new grades are developed.

The key to metric transition in the building industry lies in the very nature of construction itself. In most buildings and structures, there is a preponderance of "fluid dimensions" for work carried out in concrete, bricks, or blocks, whose dimensions can be adjusted to accept any range of preferred component and assembly sizes. Some building components have always been readily adaptable to design or construction dimensions, either because of their small size, or because of the techniques of jointing and fitting. Such components can be integrated without much trouble into building projects designed in preferred metric dimensions, even though initially they may not have been manufactured in rationalized metric sizes. Many other components and assemblies are normally purpose-made rather than standardized. This is especially true in large or highly repetitive projects. These items can be produced in preferred metric sizes just as easily as in customary sizes. In fact, with circumspect decision-making and insistence on preferred metric dimensions, the designer frequently can achieve greater standardization of purpose-made items to obtain the benefits of maximum repetition of a minimum number of sizes.

With proper planning, the construction of metric buildings in preferred dimensions with components in preferred sizes will involve fewer complications and greater savings than the use of uncoordinated sizes in the customary system. However, until there is an ample supply of metric products, this will not totally overcome the need for adaptive action in design and/or construction. To avoid long delays and to minimize the need for last minute substitutions, the early and careful planning of metric material orders is essential.

Table 10.1 was prepared to indicate the various types of adaptive action in design and construction that may be taken to integrate different categories of dimensionally sensitive building products into metric projects. A general distinction has been made between items <u>not requiring</u> dimensional coordination, and those <u>requiring</u> it. Short-term problems caused by the unavailability of genuine metric sizes can nearly always be overcome by a clear and early appreciation of the various adaptation possibilities in relation to geometric requirements. After all, the construction community has a long legacy of adaptive ingenuity in its work as unavailability of particular items is not an unusual occurrence.

The design sector can simplify the transition by employing restraint in the selection of building materials and components. The variety of products often can be trimmed, and the specification of special non-metric items avoided altogether. Reduced variety will ensure longer production runs, better inventories and availability, and fewer instances where adaption or substitution is needed. These factors would provide greater efficiency throughout the industry. The change to metric production is likely to create economic conditions which will prevent designers from arbitrarily rejecting standarized metric sizes, especially if such products are functionally and aesthetically acceptable. This could be a very positive outcome of the change to metric measurement.

Table 10.1: Materials and Components for Metric Building in the Transitional Period: Suggested Adaptation in Design and Construction for Various Product Categories

CATEGORY	COMPLEXITY OF ADAPTATION	TYPICAL EXAMPLES OF MATERIALS AND COMPONENTS	ADAPTIVE ACTION IN DESIGN	ADAPTIVE ACTIO IN CONSTRUCTIO
A. Dimensional Coordination Not Required				
A.1	No change in materials - no problems foreseen	Formless, plastic or bulk materials: water, paint, mastics, tar; sand, cement, lime, dry mortar mix, loose fill insulation; readymix concrete, premixed mortar	Specify in metric units. Develop necessary site guidelines.	Weigh or measur in metric quantities. Use metric data on coverage, mi ratios, etc.
A.2	Customary sizes usable - interim "soft conversion"	Structural steel sections, reinforcing bars, pipes, tubes, fixtures, fittings, hardware	Specify metric equivalents, or show permissible substitutions. Select preferred "free" dimensions such as length or centerlines	Order in metric lengths or cut metric lengths. Set out to metri levels and to coordinated centerlines
B. Minor Site Adjustments to Coordinate With Preferred Dimensions				
B.1	Modification needed in one direction to fit layout in preferred dimensions	a. Adjustment by trimming: lumber studs, joists, and rafters; laminates, roofing, gutters b. Adjustment by lapping: shingles, tar felt, underlay, sheathing, waterproof membranes c. Adjustment by a change in joint width: bricks, blocks, paving tiles, ceramic tiles	Specify preferred metric dimensions to expedite the transition. Indicate possible construction adjustments in the drawings or in instructions	Set out project on the basis of preferred dimensions and adjust components or product size accordingly
C. Dimensional Coordination Is Required For Best Results				
C.1	Purpose-made items - no difficulties foreseen	Precast panels and slabs, door assemblies, window assemblies, fabricated metalwork, built-in units	Specify preferred metric sizes and tolerances	Fabricate or order components in rationalized metric sizes
C.2	Reshaping of customary dimensions is possible	Glazing, plywood, gypsum wallboard, sheathing, lath, rigid insulation materials, siding	Investigate supply in rationalized metric sizes and specify	Order preferred metric sizes; or cut to size offsite or on-site
C.3	Reshaping of customary dimensions is difficult, costly, or impossible	Windows, doors, metal or cast partitions; metal roof decking, cladding panels; stainless steel sections, sinks or tubs; large ceramic panels; fluorescent fixtures; distribution boards and panels; fixed appliances and cabinets, lockers	Preorder prior to job commencement in preferred metric sizes. Discuss cost of trial production with manufacturers. Use adaptive design or details.	Adapt during the interim period until preferred metric sizes are stock items. Construct spaces or openings that allow the use of non-coordinated components or assemblies.

C. Trial Projects

Early metric projects, also referred to as "trial projects" or "pilot schemes," which precede the full flow of metric work, will fulfill an important function in the transitional period. These projects will:

- show the simplicity or difficulty of metric design and construction;
- highlight likely problem areas as well as opportunities for rationalization and simplification; and,
- provide an indication of alternative strategies which may be used to avoid complications or to capitalize on opportunities in subsequent metric projects.

It would be most desirable for any major design and/or construction organization to embark on one or a few metric trial projects of modest value. This would create a positive climate for subsequent involvement in large-scale metric work. It is far better to find out in a small project whether there is any lack of familiarity with new units, or mistakes due to misinterpretation of metric instructions, than to encounter difficulties on major projects. A task force trained in early metric work also can be made the nucleus of the team for subsequent work.

Also, it is recommended that organizations establish a formal feedback system to record significant advantages as well as disadvantages that have become apparent in metric trial projects. For management purposes, such information should include data on actual time taken versus budgeted time, actual costs incurred versus budgeted costs, and employee response before and after metric work. The information from the feedback system should be communicated to other cells within the organization and to industry at-large. Preferably, it should be communicated by those who were actually involved in the trial project or projects, so that the learning experience is shared and apprehensions are alleviated.

It is very important that any mistakes, once discovered, are not concealed, but are recorded and analyzed to ensure that similar occurrences are prevented in subsequent work.

Metric precedent from Britain, Australia, and Canada indicates that early metric projects are generally planned with a little extra care, and that this planning effort easily offsets any minor complications caused by unfamiliarity. While some work time may be lost due to the need to familiarize staff with metric measurement, the general experience elsewhere has been very positive, and shows that increased productivity soon recovers such a time commitment. In addition, much greater attention to measurement and detail has increased construction accuracy and reduced errors. As a result, construction costs have not increased because jobs were designed in metric units.

The greatest single advantage will be derived from the use of just one measurement unit for all linear dimensions in construction--the millimeter (mm)--from small tolerances to large building dimensions. While general dimensions will be in multiples of 100 mm, or at least 10 mm, the use of the millimeter as a working unit will automatically encourage more precision in setting-out and assembly operations. In part, this is because more attention and supervision will be focussed on measurement related activity. But, more importantly, accuracy will increase because approximations (such as stating dimensions to the nearest common fraction of the inch) will no longer be required. All activities involving sequential addition, subtraction, or division into a number of equal parts, will invariably be more precise when carried out in millimeters than in feet, inches and fractions. Trial projects will drive this lesson home to all participants in the building process.

Finally, a most important consideration in early metric projects is that they should be designed and constructed wholly in metric units, with direct conversions minimized as far as practicable. If metric building is interpreted simply to mean the application of a "metric veneer" to customary measurement, then this is bound to lead to a loss of productivity, considerable confusion, and no real learning experience. It will merely encourage a time consuming change back and forth between customary and metric units. Pseudo-metric construction should be avoided as far as possible.

Part II

INTERFACING WITH EXISTING BUILDINGS OR BUILDING COMPONENTS

A. General

The existing building environment represents a vast legacy of non-metric design, production, and construction. This is the reason frequently advanced as one of the potentially large problems and costs associated with the change to metric sizes. There is a great danger that an entirely false impression will be created by some people who have only superficially looked at the issues involved in the maintenance and rehabilitation of traditional building assets in a metric building world.

Many valuable lessons can be learned from current maintenance and renovation activity involving existing and historical structures. These lessons include specific data from earlier items; an appreciation of the number of instances where individual components or groups of components require replacement, as against the replacement of entire floors, walls or ceilings, and the adaptive strategies employed; and, the general interface considerations and their solution with both designer's and contractor's ingenuity, particularly in building extensions and additions.

To place specific issues in perspective and to correct any distorted view of the "metric interface problems" likely to be encountered, three categories of building maintenance and modification have been considered:

- Routine maintenance and repair in existing buildings or structures.
- Major renovation, alteration, and complete rehabilitation of existing buildings or structures.
- Identical horizontal or vertical extensions of and additions to existing buildings or structures.

B. Routine Maintenance and Repair Work in Existing Non-Metric Buildings

Most of the routine maintenance in existing buildings is concentrated around the preservation of surface finishes and the maintenance of fixtures, fittings, appliances, and other mechanical equipment to maintain their proper working condition.

Although caulking, patching, painting and wallpapering constitute the largest portion of the maintenance account, generally these surface finishes will constitute no problem after the change to metric measurement. Some minor difficulties may arise with surface laminates. However, approximately 90 percent of all laminated material is cut to size to suit job requirements, and it will still be possible to cut to size from metric sheets. Pattern matching is entirely dependent upon supplies available in the marketplace. It is almost impossible at present to obtain laminates whose patterns match those of ten or twenty years ago.

Repair work in existing buildings is normally occasioned by general wear and tear, breakdown of mechanical parts, accidental damage, and damage resulting from building movement or natural hazards.

No problems will be encountered where repair work necessitates full replacement of items that are cut from larger sheets, panels, or rolls--such as glass, laminates, carpet, etc.--and then fitted. Some difficulties may arise in situations where metric products in preferred dimensions have replaced traditional items that were 1.6 percent larger. While this difference in size can generally be accommodated in the joint if only one or two items are replaced, the difference in size may be functionally or aesthetically unacceptable where a large number of items are to be replaced. Blocks and bricks in preferred metric dimensions, while slightly smaller, can generally be fitted with a larger joint. Wall, floor, or ceiling tiles require more ingenious adaptive strategies where no products in customary sizes can be obtained from a dealer in replacement items. It may be necessary to transfer ceiling tiles from a concealed or minor use area to a highly visible area that has damaged tiles, and then effect any adjustments to the minor area. Broken ceramic tiles could create slightly greater problems, and may require cutting and fitting of metric replacement tiles where no replacement tiles in customary sizes can be obtained. Floor tiles, whether ceramic or plastic, require similar adaptation.

It is important to recognize that these replacement strategies are not unusual for the building repair and renovation industry. Many instances arise now where it is impossible to match products or patterns that were initially installed a good many years ago. One obvious answer for more recent buildings, or non-metric buildings now in construction, is to create a small store of possible replacement items in customary sizes for any repair contingencies, especially of products such as tiles, which are installed in a situation of dimensional fit.

As far as standard sections in metal or lumber are concerned, it is unlikely that they would be "pieced into position" in small pieces, but rather be replaced as a finite length. For example, where a baseboard has been damaged and is to be replaced, it would be common practice to take a length from a corner to a corner, or from a corner to a door frame. The use and fitting of marginally different profiles is a common occurrence now, and causes little trouble to the repair contractor. Where an exact match is required for historical or prestige purposes, a replacement item normally would be custom made.

Some people have advanced difficulties with the maintenance of customary fixtures, fittings, and equipment as a "potential problem area" in the metric building world and associated some wild estimates of increased cost with their hypotheses.

The metric reality in the experience of other countries that have made the change provides more realistic guidance. On closer examination, the issues associated with the maintenance and repair of mechanical items and the replacement of defective components will not create "new" or "unique" situations, but resemble those that are now adequately dealt with by maintenance staff and engineers.

If a suitable fastener cannot be obtained, another fastener can always be adapted, or a new thread cut. Spare parts dealers will still stock spare parts according to demand, so that a good many parts in customary sizes should remain available well into a fully metric engineering environment. Fluorescent lamps, where the bulk of production is sold in the replacement market, will continue to be available for use in customary fittings for many years. Any new, fully metric tubes produced in preferred dimensions will be shorter and are bound to be marketed with a cheap adaptor or converter for use in customary housings. Changes in electrical wiring have been made on a number of occasions in the past, and will probably be made again. Such changes have never prevented electricians from joining, splicing, or adapting electric circuits.

Similar considerations apply relative to plumbing systems. Most plumbing fixtures are in "neutral dimensions," based on anthropometric considerations, and there is no reason to expect unnecessary metric modifications. The working parts in cisterns are only likely to be changed when better designs emerge. It is expected that those manufacturers who produce pipes in rationalized metric sizes will simultaneously market connectors, to enable such pipes to be joined to existing fittings or pipes, where required. As connecting pieces would be required in the normal course of making a connection or junction, the only difference will be in the choice of a customary-to-metric connector, rather than a customary-to-customary connector. Copper and lead pipes can be flared and dressed to deal with variations in size at the connections. There is a possibility that some current pipe sizes will remain in the metric building world, so that the only consideration will be the choice of appropriate taps or dies to enable a threaded connection to be made.

Most importantly, the change to a metric building environment does not mean that non-metric tools and accessories should be discarded in the building maintenance and repair industry. There will be many instances where customary drills, taps, dies, spanners, sockets, etc. will be needed to carry out a maintenance or repair job.

C. Major Renovations, Alterations, and Rehabilitation

Major renovations, alterations, and rehabilitation are taken to mean extensive modifications to an existing building or structure, generally retaining only the structural frame and replacing all or most of the surfacing materials, components, assemblies, services systems, and equipment.

With the exception of the replacement of doors and windows in existing walls, the activities involved in major renovation of traditional buildings in a metric building world will follow the same course now in use. Work will need to be based on "actual" on-site measurements, rather than original contract drawings (should such still exist), and construction activities will follow the measure-and-fit pattern.

It is well to remember that the building renovation industry has always shown a great deal of ingenuity in dealing with the problems of matching up and/or replacement. There is no reason to suspect that this will not continue.

The replacement of entire doorsets (doors plus frames) and windowsets (window assembly including all cover strips, casings, stops, sills, and flashings, where appropriate) generally would be with purpose-made assemblies. Where standard-size windows have been used, it may be possible to adapt slightly smaller metric windows manufactured to preferred dimensions, but it may be less costly to order custom-made replacement windows. Where a change in framing material is involved, it will invariably be necessary to custom-fabricate replacement windows.

While a range of standard door sizes has been recognized for some time in the U.S. construction community, stock doors generally require some adaptation in a renovation or replacement situation. Where the opening size can be controlled, it is desirable to use metric doorsets in preferred dimensions, as this will facilitate any future replacements.

While standard windows and doors have been widely used in the past, such standards vary from region to region, and from building type to building type, so that the adaptation of existing stock items is frequently necessary in current replacement situations. Thus, the metric change imposes little or no additional burden. With respect to doors, the existing major preferences, such as the 2'-8" x 6'-8" door (which always varies a little from this call size), may continue to be produced and stocked for quite some time to service the replacement market.

Where the replacement of framing lumber is required, customary lumber sizes will show substantial differences in size according to the age of the structure. The use of framing lumber in "metric" dimensions will not impose any significant complications.

While partition units in customary dimensions are likely to be larger than those manufactured in preferred metric sizes--the difference between 8 feet and 2400 mm is 1-1/2 inches or 38 millimeters--most partition units or systems are shorter than their functional length to allow for adjustment to variations in floor-to-ceiling height. With marginal changes to coverstrips and baseboards, metric partition units would fit customary room heights.

Where extensive internal renovation of buildings is undertaken and partitions are used for the subdivision of space, these are normally custom-made to suit functional or location requirements. Thus, a metric environment would not complicate matters.

D. Extensions to Existing Buildings and Additions

For the purpose of differentiation, a distinction is made between an extension to an existing structure or building, involving a continuity of existing design and construction, and an addition to an existing structure or building, which may differ in shape and/or materials used.

In building extensions it is generally necessary to closely match the external and internal surface treatment and detailing. Therefore, the vertical or horizontal extension of customary buildings or structures predominantly becomes an exercise in applying a "metric veneer" to customary design, with metric materials and components adapted, as required.

The vertical extension can be adjusted more easily to marginal changes in product sizes, since the floor plane also provides a dividing line. Where external columns and precast panels are involved in the extension, existing sections and profiles should be followed, but specified to the nearest metric equivalent in millimeters. Similarly, windows for such vertical extensions will be required to fit into existing horizontal spaces, but may be adjusted slightly to take advantage of preferred metric vertical dimensions, where an economic benefit can be proven. Internal vertical dimensions can be adjusted to preferred metric values without undue visual disturbance; yet this would ensure vertical compatibility of metric products. All vertical connecting shafts, ducts, wells, and services systems should be matched for continuity, especially lift wells. Provided that functional requirements are not impaired, pipes and ducts in vertical extensions may be in preferred metric dimensions, with adaptors or connecting pieces to take up any differences in size. The vertical extension does not create insurmountable problems for the designer.

The horizontal extension of existing buildings or structures involves considerations of continuity similar to those encountered in the vertical extension. However, horizontal dimensions are more flexible, while vertical dimensions and heights will generally be required to continue at their existing levels, thus providing the overriding design restraint. It may sometimes be possible to change the floor level in a horizontal extension marginally to take advantage of preferred metric products in the vertical plane, by introducing a shallow ramp in connecting links. Considerations for the connection of services are similar to those for vertical services, although a horizontal extension generally imposes fewer restraints on plumbing systems.

Horizontal and vertical additions to buildings provide much greater freedom for the designer, as the principal considerations relate to the junction of the structure, materials and services. These are no different from the circumstances encountered in any addition made in customary measurement. It is the designer's challenge and responsibility to ensure proper weatherproofing and structural continuity, where required, and there are innumerable ways to properly articulate the junction. Compared with an extension of an existing building, an addition can be treated as a discrete metric project, with certain customary-metric interface considerations.

E. Measurement in Repair, Renovation, and Extension Situations

It is strongly recommended that only one measurement system be used in projects involving the interfacing of customary and metric building work. The use of metric measurement--and specifically, of the millimeter--will provide far greater precision and inherent accuracy than present activity in feet, inches and fractions. Repair and replacement work will be much better matched and more accurately set out when a millimeter rule and/or tape is used, in lieu of a tape in inches, sixteenths, or even thirty-seconds. In these activities, metric measurement is altogether superior.

Part III

LEGAL AND CONTRACTUAL IMPLICATIONS

A. Legal Implications

The issue of legal implications arising from the change to metric measurement in building design, production, and construction has been raised in some of the countries that have preceded the United States in the change. However, there have not been any instances of legal action arising out of causes partially or substantially attributable to metrication.

The implications of a design error caused by new and unfamiliar units are related to the design process and not the measurement system.

A change in regulatory requirements caused by metrication is unlikely to have a retroactive effect on existing buildings. In nearly all instances a metric minimum will fall slightly below a customary minimum, and a metric maximum will fall slightly above a customary maximum. Any changes in regulations solely attributable to new technology must not be confused with marginal changes and rounding or rationalization caused by metrication.

B. Contractual Implications

As the change to metric measurement gathers momentum in the construction community, metric sized materials and components will become more readily available, and customary sized ones less so. Most of the customary ones will eventually disappear altogether.

While designers are expected to thoroughly investigate metric material sizes and their availability, it is unavoidable that contractors will find that certain items ordered for delivery at short notice cannot be obtained in the measurement or characteristics specified in the building contract. Equally, this transitional problem will be felt in very late customary projects where certain traditional materials or equipment sizes will have been replaced by metric sizes.

Contract documents should clearly point out the effect of metric conversion on projects carried out during the transitional period.

A condition of contract should require the contractor to give reasonable notice of items difficult to obtain as a result of the change to metric, thus enabling the designer to consider alternatives. A distinction should be made between items which are unavailable due to a shortage of supply, and items which are not yet available as anticipated in preferred metric sizes or characteristics.

The contract should provide for an adequate adjustment of contract sums--upward or downward--where substitution has to be used to meet an unforeseeable supply situation. In no case should a contractor make unilateral substitutions without advice to the designer. Such unilateral substitutions in different size or quality may well have design implications that the architect or engineer will need to consider. The designer's subsequent instructions, whether they merely authorize substitution of materials in the only size or quality available or also involve redesign, constitute a variation to the contract.

Despite the existence of an early warning system, delays may be incurred as a result of unavailability of specified items. In unusual cases, this might lead to an extension of the contract period.

C. Variation of Contract

A standard clause should be developed jointly by the American Institute of Architects, the Associated General Contractors of America, and the Construction Research Council, as representative of public and private building owners and clients. This clause should address the matter of contract variation due to the unavailability of items in early metric, as well as late customary projects.

Such a clause could set out the circumstances and procedure for variation of the contract sum in the event of unavailability of materials or equipment specified in the contract documents.

The following steps could be included:

- The contractor shall advise the authorized supervisor of the contract (the designer or the designer's representative) in writing, if he cannot obtain materials or equipment in the dimensions and characteristics specified.
- The contractor should indicate the alternatives which might be procured, together with the cost increase or cost reduction resulting from such substitution.
- The designer, or his representative shall either:
  - direct other sources of supply, or some other variations whereby the need to supply specified materials or equipment will be avoided; or,
  - authorize the contractor in writing to supply/install the materials or equipment offered in substitution, with an appropriate upward or downward adjustment to the contract sum on the production of satisfactory evidence.
- Unless specifically agreed otherwise at the time approval is given, any additional costs resulting from any substitution of materials or equipment at the contractors request, other than for reasons of unavailability, shall be at the contractor's expense.

An offer of substitute materials should be set out on an item-by-item basis, and should include details of all prices or rates for the incorporation of such alternatives into the project.

Likewise, the bidding contractor may find that materials or equipment specified in the contract documents is unlikely to be available at the construction stage, because of the timelag between the design of a project and the bid stage.

It is proposed that a contract clause be developed which permits the bidding contractor to submit alternative proposals with his bid, where he considers that he will be unable to offer materials or equipment required by the drawings and specifications. An offer of substitute materials or equipment should be set out in writing, on an item-by-item basis, and should include details of all prices and rates for the incorporation of such alternatives into the project. While this process is designed to forestall subsequent variations or substitutions, it needs to be used with discretion to permit meaningful analysis and comparison of bids.

Obviously, a negotiated contract would simplify the matter somewhat, but contractors would still wish to retain a waiver from any costs attributable to unavailability, as well as an adjustment to the contract sum where a more expensive alternative is substituted by the designer.

D. Resolution of Conflict

There is no simple answer to contractual contingencies. Precedent in other countries has shown that substitutions caused by lack of effort either to obtain the items specified or to place orders in good time, will occur just as often as genuine unavailability of items. It is also possible that some mistakes are made in the building drawings and specifications for a metric building project, which require changes or substitution at the construction stage. It would be just as unreasonable to expect the client to pay for a builder's inefficiency as it would be to pay for the designer's mistakes. To avoid unnecessary argument or costly delays in construction, it is important that all parties to a contract exercise sensible judgment in such circumstances and do not attempt to take advantage of each other.

In the Australian construction community, the experience in this area of variations and substitutions has been an excellent one. Monitoring of early metric building projects has demonstrated that much fewer variations were incurred than in a comparable project designed and built in customary units. This was due to the site representatives of the designer and contractor establishing a much closer working relationship that involved a "no-cost-solution" to many of the variations or substitutions that had to be made.

E. Design Consultants

The architect or coordinating designer should carefully check the metric expertise of design consultants before committing a client to their acceptance. It is also important to ensure that contract documents prepared by external consultants are fully coordinated on early metric projects to avoid problems of later contract variations or substitutions.

F. Subcontractors

The designer will need to be confident that any subcontractors nominated by any party involved are capable of carrying out the work in a metric construction project. Checks should be made to ensure that key operatives have had some metric pre-training. At an early stage in the design process, it may be advisable to select or agree with a contractor which firms are to be used, so that all parties can adequately prepare.

CONCLUDING REMARKS

The transitional period in metrication can be likened to a situation where the change is made from one pipeline to another newer and better pipeline with worldwide connections. As the flow is reduced in the "customary" system, the flow will be increased in the "metric" system. For some time both pipelines will be operating, one at a diminishing capacity, and the other at an increasing capacity. The objective of metrication planning and management is to ensure that any problems or bottlenecks that arise as a result of the "dual" situation are minimized and resolved before they can cause inconvenience or costs, and that the transfer from one system to the other is carried out in an optimum manner.

Once the change to metric has been initiated there is no value in reverting back to the customary system.

Subject Index

This alphabetical subject index has been prepared to allow quick access to information on specific metric topics mentioned or discussed in this compendium. Relevant page numbers indicate where a subject is mentioned, and underlined page numbers refer to a more detailed treatment of a subject. Where appropriate, subject headings have been cross-referenced.

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This publication is a compendium of ten papers prepared during 1977 by Hans J. Milton, Technical Consultant on metrication and dimensional coordination to the NBS Center for Building Technology. It may be used as an information and general reference document in the metric subject area.

International experience has enabled the author to refer to precedent in other English-speaking countries which have preceded the United States in the change to metric (SI). The papers are directed at the disciplines of building design, production, and construction. However, they contain much information which could be adapted for use in other sectors of the economy.

Some of the subject areas addressed are: management and economics of metrication; specific product metrication; public construction sector role in metrication; building standards and codes in metrication; graphic design in metrication; and, United States' opportunities in metrication.

A subject index has been included for ready reference to specific metric topics.

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