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This article reviews U.S. metric conversion efforts, particularly as they have affected education. Education system benefits and costs are estimated for three possible measurement system conversion plans. Of the three, the soft-conversion-to-metric plan, in which all inch-pound instruction is dropped, appears to provide the largest net benefits. The primary benefit is class time saved by teaching just one measurement system. These net benefits appear to be many times larger than the costs anticipated for the controversial plan to convert all U.S. highway signs to metric or dual measures.

EDUCATION SYSTEM BENEFITS OF U.S. METRIC CONVERSION

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INTRODUCTION

Any more, the news is familiar and expected. Whereas U.S. elementary and high school students perform well in comparison with their foreign counterparts on international tests of reading achievement, they perform poorly on international tests of mathematics and science achievement.

Several explanations have been posed to explain the poor U.S. performance in math and science, such as a relatively shorter school year in the United States, fewer required math and science courses in U.S. high schools, subpopulations taking the exams that differ from country to country in the proportions of students at each grade level represented, and inferior school systems. The full explanation for the relatively poor U.S. performance in math and science is certainly multifaceted.

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Ironically counterpoised to this image of low U.S. achievement in math and science are National Education Goals 4 and 5 that posit, respectively, that U.S. students will be first in the world in math and science, and that every adult American will possess the knowledge and skills necessary to compete in a global economy (National Education Goals Panel 1994). The goals underscore the important role our society believes math and science proficiency play on the modern global economic stage.

Another possible, albeit only partial, explanation for the poor U.S. achievement in math and science is posed here. The United States, almost alone in the world, does not use a single system of measurement. We use two systems of measurement: the metric system and the inch-pound system. And, we teach both of these systems of measurement in the schools. Along with the possible confusion from learning two systems, there is a cost associated with the time spent teaching two systems. A half year of instruction or more may be spent in this duplication of effort.

Our schools spend one to several weeks a year teaching two measurement systems when teaching just one could be done in less time. Elementary school mathematics textbooks generally give equal weight to the two systems, as do the curriculum standards of the National Council of Teachers of Mathematics (1989). Educators feel forced to teach both systems because, even though Americans still primarily use the inch-pound system in our daily lives, the metric system is used in many professions (e.g., medicine, science, and engineering) and now in much of industry. High school science courses now use the metric system exclusively.

The object of this article is to test some of the arguments that could be used to make valid education's case for conversion to a single system. This will be done by developing quantitative measures of the benefits and costs of three possible measurement system conversion strategies available to the United States currently, calculating the net benefits of each, and comparing them.

The three conversion strategies presented here are hardly the only ones possible; many others could fall within the realm of possibility. The object here is simply to propose three reasonable strategies, with three reasonable, albeit rough, calculations of the resulting benefits and costs.

Any reasonable estimates of the benefits and costs of measurement system conversion as they pertain to education would be an improvement over what we have now, which is no estimates at all. In current debates over measurement system conversion, the potential effects of conversion on the education system are referred to in only the most general terms, when referred to at all.

BACKGROUND ON METRIC CONVERSION IN THE UNITED STATES

Along with only Liberia and the isolated, reclusive Myanmar (the former Union of Burma), the United States retains an adherence to a version of the Imperial British system of measurement (a.k.a. the inch-pound or "customary" system, hereafter referred to as the inch-pound system). The other 100-plus nations of our planet have already embraced the *système internationale d'unités*, the metric system. The British themselves started to wean themselves from the Imperial British system of measurement in the late 1960s, citing the relative simplicity, internal consistency, and greater worldwide popularity of the metric system.[1] Soon after, most of the other British Commonwealth countries converted to the metric system.[2] Our northern neighbor, Canada, planned originally to convert in conjunction with the United States starting in 1975 but completed the process alone as the U.S. effort fizzled.[3]

The Metric Conversion Act of 1975 established the U.S. Metric Board and recommended complete conversion to the metric system in the United States. Conversion was not, however, made mandatory, and the board was given no powers of coercion. Conversion efforts throughout the United States in the ensuing years were scattered, uncoordinated, and often unsuccessful. Elite opinion was almost unanimously in favor of metric conversion; scientists, engineers, educators, and political leaders all seemed to be for it. Even most business leaders, while anticipating confusion and cost in converting their operations, acknowledged a larger good they believed metric conversion would effect.

Public sentiment, which had early on favored metric conversion, was turning against it by 1978 when Congress got around to fully funding the U.S. Metric Board, 3 years behind schedule (Schmidt and Gwin 1988). Ultimately, the most profound criticism of metric conversion came from Congress' own research agency, the General Accounting Office (GAO). The lengthy GAO report suggested that the United States should either convert quickly, which its authors thought impossible under a voluntary program, or forget about conversion entirely and embrace the inch-pound system (U.S. GAO 1978).

The GAO did not attempt to measure the benefits and costs of conversion. It merely asked firms in various industries how they felt about conversion, and the responses were more unfavorable than favorable. The intervening years have shown, however, that metric conversion in industry, when it is done as part of the normal product replacement cycle, is far less expensive and disruptive than had been feared under forced conversion (e.g., see the statements of Andrew Naves or Andrew Kenopensky, U.S. Congress 1982).

The GAO study did not attempt, in particular, to estimate the savings in classroom time that a metric conversion would effect, nor did it anticipate that our schools would be stuck with both systems of measurement in their curriculum and not just the inch-pound system. Neither did the GAO study consider the possibility of a soft conversion plan, which is described here.

As a result of the criticisms from the GAO and elsewhere, and the public's skepticism of the value of metric conversion, public conversion efforts were cut back. The chief federal government spokespersons for metric programs in the Commerce Department's Office of Metric Programs were careful to point out that no one was now being forced to convert to metric. They even euphemized the phrase "metric conversion" to the less threatening "metric transition." And, they accepted the notion that U.S. society would be "bilingual in measurement" for some time to come (Underwood 1990; Schmidt and Gwin 1988).

In industry, however, metric conversion continued at a deliberate pace. By 1990, some U.S. industries had gone completely metric. Others were in the process of changing, while still others had no plans to change. One survey found that, as early as 1982, 62% of Fortune 1000 firms made at least one metric product, 34% of new products used metric designs, 32% of total net sales were in metric-designed products, 16% of firms reported some loss in sales because of a failure to use metric in product design, 68% felt that metric would become predominant in their industry, and over 50% favored mandatory conversion within 20 years ("Shift to Metric" 1982; D. Gorin, personal communication, July 1990).

Tucked into Congress' 1988 Omnibus Trade and Competitiveness Act, moreover, lay the Metric Usage Act, an amended version of the earlier, failed Metric Conversion Act. The Metric Usage Act designates the metric system as the preferred measurement system for trade and commerce and requires government agencies to start buying metric whenever practical. By 1993, government agencies were to "use the metric system . . . in procurements, grants and other business-related activities, except to the extent that such use is impractical or is likely to cause significant inefficiency or loss of markets to U.S. firms" (U.S. GAO 1990, 8).

A major stimulus for a renewed effort at metric conversion in general and the U.S. government's metric procurement provision in particular came from the 12-nation European Community (EC).[4] In 1992, the EC became a single free-trade zone and trading bloc with unitary customs regulations. As of 1992, the EC no longer allowed importation of goods sized in nonmetric units. Other nations had started turning away non-metric-sized imports even earlier.[5] The U.S. government is attempting to use its purchasing leverage to encourage U.S. industry to convert for U.S. industry's own sake and the long-run benefit of our country's export trade.

A 1990 GAO report, however, asserted that, as of early 1990, most federal agencies had "not advanced beyond the early stages of planning" (U.S. GAO 1990, 3). Only 1 out of 37 key federal agencies, the report continued, had even developed a plan to identify areas within its purview for review and conversion (U.S. GAO 1990).

To further strengthen the federal agencies' metric conversion efforts, President Bush signed an executive order in 1991 (U.S. GAO 1994) that

1. designated the Department of Commerce as a "lead" agency and required the commerce secretary to report annually to the president regarding metrication progress;
2. required all executive branch departments and agencies to submit two documents—a metric transition plan and an assessment of agency progress, problems, and recommendations for solving them;
3. made each department and agency responsible for providing the requisite resources necessary to meet the stipulated metric conversion goals.

A 1992 report by the Congressional Research Service (CRS), another congressional research agency, asserted that, as of early 1992, most federal agencies were still behind schedule. Only 10 of 25 agencies surveyed predicted they would complete their metric conversion by the September 1992 deadline of the Metric Usage Act ("Going Slow on Metric" 1992). The deadline for agency conversion has since been extended to 1996.

In keeping with its responsibilities under the Metric Usage Act, the Federal Highway Administration (FHWA) intimated that it would change signs on all federal highways and roads built with federal aid (Fehr 1992). Much as it did in the late 1970s, this prospect aroused a flurry of protest, some of it hyperbolic (see Will 1992; "Going Metric" 1992).

THE STATUS OF THE METRIC SYSTEM IN THE UNITED STATES TODAY

If left to their own devices, then, in a natural evolutionary metric transition, would all U.S. firms eventually convert to metric? Some experts say no, thinking that industries dominated by small firms and relatively untouched by international trade and competition, such as construction, will not change unless the whole society changes (U.S. Congress 1982).

Some readers would probably be surprised, however, by how much our consumer economy has already converted. In September 1995 the author gathered a convenience sample of products, consisting of all the items in his kitchen and linen closets. This sample comprised all the food and cleaning products, medicines, and personal hygiene products in a fairly average home with two residents. The sample contained 377 items, none of which was purchased deliberately because of its measurement labeling.

It was a surprise to this author to find that only 67 items in the sample were *not* dual-labeled in both inch-pound and metric measures. Three hundred ten, or 82% of the items, were dual-labeled. Thirty-nine, or 10% of the items, were uniquely inch-pound labeled, whereas 28, or 7% of the items, were uniquely metric labeled.

It appears that some types of products tend to be labeled uniquely in one or other measurement system. For example, wine and liquor, medicines, and foreign goods tend to be metric. By contrast, locally labeled goods (e.g., individually cut and weighed deli foods), goods produced just for the local market, goods that we purchased a long time ago, and ironically, foreign goods that are labeled in the United States tend to be sold uniquely in inch-pound measures.

The U.S. Federal Trade Commission issued rules for consumer products, under the Fair Packaging and Labelling Act, that took effect in early 1994, requiring that metric as well as inch-pound measures be written on all product labels. Manufacturers were allowed to use up their old supplies of labels, however (Federal Trade Commission 1993).

So, it would appear that most of our economy has already become bilingual in measurement. But our federal, state, and local governments have not. We still see highway signs in most states that list miles exclusively. Public signs of other sorts, for the most part, still use inch-pound measures.

It is likely that the next skirmish in the ongoing metric conversion struggle will take place over highway signs. In keeping with the mandate of the Metric Conversion Act, the Omnibus Trade and Competitiveness Act, and President Bush's executive order, the Department of Transportation developed a metric conversion plan in 1990. It established policy and administrative procedures for changing to the metric system and a timetable for completing the changeover.

To date, all steps short of actually changing the signs have been taken. The FHWA developed a metric conversion plan; initiated revision of all pertinent laws and regulations; converted their manuals, documents, and publications to include metric measures; converted their data collection and reporting systems to include metric measures; and authorized construction contracts to include metric measures. In August 1993 the FHWA issued a notice of its intent to convert all signs on federal highways by September 1996 (U.S. GAO 1995, 3-4).

The notice received enough negative comments that Congress decided to postpone the conversion. For the time being, Congress has specifically prohibited the use of federal aid funds for placing metric signs on federal highways and has removed requirements that states convert highway signs to metric (U.S. GAO 1995, 4-5).

STATUS OF METRIC CONVERSION IN EDUCATION

Meanwhile, educators sit in limbo. Mostly in the late 1970s and early 1980s, metric content was added to math and science curricula and textbooks. Now, most science textbooks use metric measures exclusively, but elementary math textbooks include separate sections on measurement: one in inch-pound, one in metric. The sections are equally comprehensive and of equivalent length (V. Antoine, personal communication, July 1990; personal communications with state math curriculum coordinators 1990;[6] personal communications with math textbook editors 1992[7]).

Several years ago, the National Council of Teachers of Mathematics (NCTM) completed a multiyear effort to develop national standards for mathematics instruction in the United States (NCTM 1989). The NCTM standards, however, do not choose between metric and inch-pound. In the book that the NCTM's effort produced, measurement concepts are explained alternately using each measurement system, thus giving each measurement system equal treatment.

To prepare students for science, medicine, engineering, and design fields—to be good producers—teachers need to teach metric. To prepare students to be wise consumers, teachers feel they need to teach the inch-pound system. Our society has settled into an equilibrium state in which both systems are provided roughly equal status.

The 1978 GAO assumption that U.S. society could just choose to use the inch-pound system exclusively, then, has proven false. At least it is no more true that we can become exclusively inch-pound than it is that we can become exclusively metric without the government forcing the issue either way. The scientists, health care workers, and manufacturing firms that have converted to metric out of self-interest will not volunteer to reconvert.

STATUS OF METRIC CONVERSION IN THE FEDERAL GOVERNMENT

In 1994, the GAO issued yet another report, another update on federal agency metrication activities. In this most recent report, the GAO pointed to substantial progress made on the part of most federal agencies in developing transition plans, issuing guidelines to contractors and suppliers, and providing progress reports to the Congress or secretary of commerce. The Education Department (ED), however, seemed to be moving more slowly than the other agencies, according to the GAO. Part of the ED's problem has been that in the one area one might think it could have the greatest impact—curriculum—it is statutorily prohibited. The Department of Education Organization Act restricts ED from either prescribing or mandating any area of curriculum. ED also sensed that seeming to propose metric conversion would meet some stiff opposition and deplete the precious political capital it needed to pursue other department objectives (U.S. GAO 1994).

Nonetheless, the Metrication Operating Committee (MOC), a coordinating committee made up of representatives from every major federal agency or department, suggested two objectives for ED (U.S. GAO 1994, 24-25):

1. a plan and recommendations for a comprehensive public affairs strategy for conversion;
2. initiation of an outreach effort to the educational community that would include model curricula.

In general, the most recent GAO report recommended metric conversion a "subsystem" at a time, more public dialogue, and more public-private coordination of metrication efforts.

STRUCTURE OF ANALYSIS

The object of this article is to test some of the arguments that the Education Department could use to make education's case for measurement system conversion. This will be done by developing quantitative measures of the benefits and costs of three possible education-oriented measurement system conversion strategies available to the United States now, calculating the net benefits of each, and comparing them.

The three measurement system conversion strategies are as follows: (a) the status quo (i.e., no conversion), (b) a "soft" (i.e., unforced) conversion to metric, and (c) a "soft" conversion to inch-pound.

Benefits are calculated for the classroom time saved by teaching just one system of measurement rather than two; possibly dropping some instruction in fractions; and by, in the case of metric, an alleged quality and efficiency advantage. In the GAO nomenclature, school curriculum could be considered one "subsystem" in the measurement system conversion process.

Costs are calculated by using government estimates for the length of time needed for teacher training in measurement.

Again, the three conversion strategies presented here are hardly the only ones possible. Many others could fall within the realm of possibility. The object here is simply to propose three reasonable strategies, with three reasonable, albeit rough, calculations of the resulting benefits and costs.

Any reasonable estimates of the benefits and costs of measurement system conversion as they pertain to education would be an improvement over what we have now, which is no estimates at all. In current debates over measurement system conversion, the potential effects of conversion on the education system are referred to in only the most general terms.

"HARD" AND "SOFT" CONVERSION

The difference between hard and soft conversions refers to the degree to which the conversion is forced. The two terms do not have fixed definitions but are, rather, relative terms. An example of a conversion that could be considered relatively hard is one that mandates, with only a brief conversion period, public use of only one system; product "sizing" in the mandated system; and retrofitting of equipment, procedures, and systems to the mandated system.

Imagine, for example, an extreme version of a hard conversion to the metric system: The government mandates that within 3 years only the metric system can be used. All products must not only be uniquely labeled in metric units, but sized in metric units. Thus it would no longer be acceptable for a producer to sell soup in a 1-pound, 16-ounce can that is dual-labeled as 453 grams. They would have to resize their cans to a convenient metric size, such as 500 grams (or, 5 centigrams).

An extremely hard conversion to the metric system might mandate metric conversion in all aspects of our lives. Baseball diamonds, football fields, sheets of paper, nuts and bolts, cake pans, and measuring spoons would all have to be resized to similar metric units.

Moreover, an extremely hard conversion to the metric system might mandate retrofitting of a plant's equipment into metric sizes long before the expected end of the equipment's life. But, not *everything* could be made in metric measures retroactively in any kind of feasible program. Imagine the prospect of tearing down all buildings or tearing up all roads, railroad tracks, and dams because they are currently sized in inch-pound measures, and starting over.

For purposes of this discussion, two aspects of hard conversions bear relevance. First, this extreme form of hard conversion is assumed in some of the more vitriolic essays and op-ed pieces written in opposition to metric conversion. Images of jack-booted police breaking into people's homes and arresting them for the use of inch-pound measuring cups are not beyond the realm of the subject matter employed in some of these writings (see Will 1992; Schillinger 1976).

Second, hard conversions are clearly unrealistic. Even if it were constitutionally permissible for the federal government to enforce product sizing (of domestic products) and the retrofitting of equipment, it would clearly not be politically possible. In this current period of widespread anti–federal government sentiment, it would be difficult for the federal government to muster the votes in Congress for such a severe imposition of standards. Moreover, the financial costs of a conversion plan involving the resizing of products and the retrofitting of equipment could be prohibitive.

By contrast, any government mandates involved in a soft conversion could be minimal, just enough to allow an unforced conversion to occur naturally. Instead of mandating that products be "sized" in certain units, for example, the federal government could mandate that, within some reasonable period of time, all products be labeled in the chosen units or simply dual-labeled in both the old and new measurement units. That way citizens could refer to or make their calculations and comparisons in the units of their choice. A soft conversion can also allow for generous exceptions to the conversion, such as for football fields, baseball diamonds, and nuts and bolts.

THREE MEASUREMENT SYSTEM CONVERSION STRATEGIES

This analysis will develop quantitative measures of the benefits and costs of three measurement system conversion strategies possible for the United States currently, calculating the net benefits of each, and comparing them.

THE STATUS QUO

In this conversion plan, it is assumed that the United States will continue to convert to the metric system in its production of goods, as more and more companies and industries convert to metric and none deconvert from metric to inch-pound. Companies and industries that anticipate positive net benefits from converting to metric will do so, regardless of what the government does. Short some deliberate government mandate, however, U.S. consumers would continue to use the inch-pound system primarily. The only explicit conversion program would be the federal government's current buy-metric and metrication programs in federal agencies. All would continue as at present, then, with both measurement systems taught in the schools for the foreseeable future. One could reasonably describe the status quo as an extremely mild form of soft conversion to metric.

A PLAN FOR A SOFT CONVERSION TO METRIC

This plan assumes that firms will continue to change to metric in production as they see fit, just as they do now. Federal government conversion programs would also proceed at the same pace and in the same character as at present, with provisions for government purchases of metric-sized products and government assistance to citizens and firms who wish to convert. Our schools, however, would drop the teaching of inch-pound measures entirely.

This plan assumes that an ordinary citizen, schooled only in metric measures, could live as a fully functioning member of society without having to learn the inch-pound system. At the same time, older citizens without metric schooling could continue to function fully well in society without having to learn the metric system.

There would have to be some exceptions, however. In some specialized positions—in firms or professions that employ only inch-pound measures (e.g., home construction)—some individuals will have to learn the system in which they have not been schooled.

Industrial conversion benefits and costs are not included in this plan because firm-level metric conversions are voluntary and it is assumed they would not be undertaken unless thought to be beneficial.

Through this soft conversion plan, the United States would be dual-measured in consumption and in its public life, inch-pound or metric in production (according to each firm's own choice), and metric-only in the schools.

A PLAN FOR SOFT CONVERSION TO AN INCH-POUND MEASUREMENT SYSTEM

This plan would be the mirror image of the previous plan. It would involve dropping all metric instruction in mathematics *and* science courses in the schools. In the case of science courses, however, textbooks and curricula would have to be rewritten, since they now use the metric system virtually exclusively.

Thus there is a cost implied here that would not exist in the previous plan. In the previous soft-conversion-to-metric plan, teachers could simply quit teaching the inch-pound material that is currently included in their textbooks, while continuing to teach the metric material that is also currently included in those same texts.

Under the soft-conversion-to-inch-pound plan, however, it would not be that easy. Most science textbooks now contain only metric material, so the inch-pound material would have to be added. Moreover, most high school science teachers have been trained to teach in metric measures and so would have to be retrained to teach in inch-pound measures.

There are two ways to handle the cost of rewriting the science books for this analysis: Consider that all schools will be required to replace their science books as soon as possible; or consider that schools will replace their science books as soon as is practical. The first way, requiring schools to convert soon, is almost certainly not possible politically. The second way, letting them convert in the normal course of their textbook replacement cycle, would put the benefits of conversion off for several years. By the most conservative estimate, textbook publishers would take 3 years before getting their new metric and inch-pound, or exclusively inch-pound, science books on the market (personal communications 1992 [see Note 7].) The duration of the normal textbook replacement cycle in our schools has been estimated at 3 to 6 years (U.S. Department of Commerce 1971, 105).

Adding the two durations together, one arrives at a delay of about 8 years before the benefits of inch-pound conversion could start to be realized.

As with the soft-conversion-to-metric plan, this soft-conversion-to-inch-pound plan would have to allow for exceptions. In some specialized positions—in firms or professions that employ only metric measures (e.g., in hospitals or export manufacturing industries)—some individuals will have to learn the system in which they have not been schooled.

MEASURING THE BENEFITS AND COSTS

I will now put some specific time and dollar figures on the benefits and costs of the three hypothetical measurement system conversion plans. There is no pretense that these estimates are anything but rough. The plans themselves are only hypothetical, and each includes many assumptions. Precise estimates simply do not exist for some of the activities included in the estimates.

These estimates, however, are reasonable given the assumptions and the best estimates available. Moreover, as will be demonstrated later, the differences in net benefits among the three plans are so robust that the allowable margin of error for each estimate is very large.

The benefit and cost estimates are summarized in Table 1a in terms of annual classroom hours saved and time lost to teacher training, and in Table 1b in net present value terms. Detailed benefit and cost calculations that correspond to the estimates in Table 1 are to be found in Appendix A.

THE BENEFITS—CLASSROOM TIME SAVED

I chose to use the Addison-Wesley *Mathematics* series teacher pacing charts for class time calculations because their curriculum was well organized for making time-itemized calculations and because the proportion of mathematics instruction that is included uniquely for the sake of teaching the inch-pound system is clearly designated, separate from other instruction in fractions (Eicholz et al. 1987). Moreover, the amount of instructional time that Addison-Wesley designates for teaching measurement seems to be average for the industry.

The elementary mathematics textbook editors at four other publishers (Silver-Burdett/Ginn, D.C. Heath, Macmillan/McGraw-Hill, and Houghton Mifflin) provided estimates for the amount of instructional time devoted to teaching each measurement system. All claimed that the two systems were given equal time in their textbook series. Their estimates for the percentage of the school year devoted to teaching a second measurement system were, respectively, 5.3, 9, 7, and 3.5, which makes the Addison-Wesley series, with a percentage of 5.8, the median case (see Note 7).

Textbooks tend to choose one measurement system—metric or inch-pound—as primary and the other as secondary. In each grade level's mathematics textbook, then, measures are introduced in the primary measurement system. When each measure comes up again in the secondary system, then, it needs less explaining because it has already been introduced once. Metric happens to be the primary system in the Addison-Wesley series on which I focus. But, some other publishers make the inch-pound system primary.

Itemizing the days of instruction in measurement during any one student's elementary and secondary school career, the numbers break down in the following manner (see detailed breakdown in Appendix B):

TABLE 1A: Benefit/Cost Summary Table

Benefit or Cost	*Status Quo*	*Soft Conversion to Metric*	*Soft Conversion to Inch-Pound*
1. Classroom time saved (by teaching just one system)		+71 days of math class annually, starting with 1996-97 school year	+71 days of math class annually, starting with 2003-4 school year
2. Classroom time saved (by dropping that proportion of instruction in fractions tied to learning inch-pound measures)		+11 days of math class annually, starting with 1996-97 school year	
3. Quality and efficiency disadvantage of the inch-pound system (measured for students only)			–60 days of math class annually, starting with 2003-4 school year
4. Train science teachers to teach with inch-pound measures			–2 weeks training for over 110,000 science teachers (1-time-only cost)

NOTE: Measured in units of time.

98	days on primary measurement system (includes tests)
22	days on time measurement and the concept of measurement
71	days on secondary measurement system (includes tests)
+11	days on fractions (only that part of instruction in fractions that is embedded within measurement chapters)
202	days (a "day" signifies a day's math class).

THE BENEFITS—CLASSROOM TIME SAVED BY TEACHING JUST ONE SYSTEM

If only the primary system, either metric or inch-pound, would be taught in elementary schools, 71 days of mathematics classes would be saved for every U.S. student into the foreseeable future. It is assumed in the case of conversion to metric that inch-pound instruction could be dropped starting next year. It is assumed in the case of conversion to inch-pound that metric instruction could be dropped starting 8 years from now, after science textbooks have been rewritten with inch-pound content and replaced.

TABLE 1B: Benefit/Cost Summary Table (measured in net present value [NPV])

Benefit or Cost	*Status Quo*	*Soft Conversion to Metric*	*Soft Conversion to Inch-Pound*
1. Classroom time saved (by teaching just one system)		+$15,285 million	+$7,674 million
2. Classroom time saved (by dropping that proportion of instruction in fractions tied to learning inch-pound measures)		+$2,368 million	
3. Quality and efficiency disadvantage of the inch-pound system (measured for students only)			–$6,485 million
4. Train science teachers to teach with inch-pound measures			–$203 million
Total	0	+$17,653 million	+$986 million

Although a few states have required a metric curriculum in mathematics (e.g., New York and Michigan), most states have no rigid curriculum requirements for the local school districts. Some states run "textbook adoption" programs, under various levels of public and local school district influence, that generate lists of textbooks approved for "adoption" by local districts. The approved lists tend to include the offerings of the most well-known textbook publishers. Some states do not have even that much influence over local schools' textbook purchases.

I spoke by telephone with the state education department mathematics curriculum coordinators of 12 of the largest states in the United States (in terms of population; see Note 6). All agreed that short of state curriculum requirements, which most states do not have, teachers tend to follow the curricula of the textbooks they use. All the major U.S. mathematics textbooks include chapters on metric and on inch-pound measures. Some teach metric first and inch-pound second, and vice versa. Most high school science texts now use metric measures exclusively.

Most state education agencies and textbook publishers have now adopted to some degree the National Council of Teachers of Mathematics (NCTM) content standards for mathematics instruction. But, again, the NCTM standards deliberately give the metric and inch-pound system equal attention.

By this analysis, 71 days of mathematics instruction annually (or counted over the course of each student's school career) could be saved by teaching just one measurement system.

CLASSROOM TIME SAVED BY DROPPING INSTRUCTION IN FRACTIONS THAT IS EMBEDDED IN MEASUREMENT INSTRUCTION

If it was decided to convert to the metric system and to drop the inch-pound system, there would be less reason to teach fractions. The analysis here, however, uses a very conservative figure for the amount of time teaching fractions that might be dropped due to metric conversion, counting only that portion of instruction in fractions that is embedded within chapters on measurement. In the Addison-Wesley series, that eliminates a small amount of study in fractions in the primary grades, but retains the larger number of days devoted to fractions in the higher grades.

Some curriculum experts have asserted that no instruction in fractions would be necessary if the metric system were adopted exclusively in the curriculum, and that the total amount of time spent teaching arithmetic could be reduced by 25% if inch-pound and fractions instruction were dropped (U.S. Department of Commerce 1971). Teachers from countries using the metric system for generations have remarked on the amount of time spent teaching fractions in inch-pound countries (Shaw 1971). The time that had been devoted to teaching fractions in Great Britain before that country converted to the metric system was much reduced after conversion (Chalupsky, Crawford, and Carr 1974, 108).

According to this analysis' conservative estimate, reducing the time devoted to fractions within measurement lessons would free up 11 class hours of math annually (or over the course of a student's elementary school career).

THE QUALITY AND EFFICIENCY DISADVANTAGE OF THE INCH-POUND SYSTEM

After considering the instructional time devoted just to introducing the concept of each measure, about equal time seems to be devoted to both the metric system and the inch-pound system in elementary school textbooks. If a day is devoted to the topic of area in metric units in Grade 2, then a day is also devoted to teaching area in inch-pound units in Grade 2.

Does this mean, then, that what is learned in equal amounts of time is of equivalent quality? Perhaps not. Some concepts of equivalent importance or power can take less explaining than others, or are easier to grasp, or to remember, or to use. As an example, think of teaching a high school math student how to use a hand calculator versus teaching her how to use a slide rule. Both instruments can be used for the same purpose, but computation on the calculator is easier to teach, to learn, and to use. Moreover, calculator use is more efficient because it is simpler (causing fewer mistakes) and it is faster.

There is some experimental evidence that the metric system offers such a quality and efficiency advantage over the inch-pound system. E. James Tew, the director for quality assurance at Texas Instruments, conducted two controlled studies to compare the ease of calculation across the two measurement systems. He chose a sample of students who had been schooled in both metric and inch-pound measures. In a 1984 study, he randomly divided his sample into two groups to take measurements using laboratory instruments, one with metric equipment, the other with inch-pound equipment. He found that the metric equipment could be used more quickly, in 17.7% less time (Tew 1984).

In a 1985 study, Tew had two equivalent groups perform some paper-and-pencil computations, one using metric measures, the other using inch-pound measures. He found that the metric computations could be completed more quickly, in 44.9% less time (Tew 1985).

How large is the quality and efficiency advantage of metric over inch-pound? That question would be extremely difficult to answer precisely. It would probably take years of study, at great expense, with many more controlled studies, surveys, and tests.

It is far easier to come up with a rough estimate. Think of the two measurement systems as languages and then dissemble them into their essential linguistic components. Those essential components are of two types: names of measures and conversion ratios between measures. If one wishes to know and use (i.e., compute in) one of these measurement systems, it is necessary to know the names of some measures and to know the conversion ratios among the measures.

Examining the measurement systems in this manner, it is easy to see why proponents claim that the metric system is more concise, internally consistent, and easier to use (see Tables 2a and 2b). Tables 2a and 2b contain the same amount of information: three measures (length, capacity, and weight), the names of seven units of each measure, and the conversion ratios between each unit and its neighboring units. Observation alone will reveal that the metric system conveys the same total amount of information more concisely than does the inch-pound system. A few simple calculations (in Table 2c) will demonstrate the difference as well.

In the inch-pound system every unit has a unique name, so there are 21 unit names that one must remember if one is to know this three-measure system in inch-pound units completely. The conversion ratios between neighboring units are also unique: 12 inches in a foot, 3 feet in a yard, 5 and 1/2 yards in a rod; and so on. True, there is some duplication—for example, 16 ounces in a pound and 16 drams in an ounce—but there is no order to the

TABLE 2A: The Inch-Pound System

Length	*Weight*	*Capacity*
1 mile = 8 furlongs	1 long ton = 2,240 pounds	1 barrel = 31.5 gallons
1 furlong = 40 rods	1 short ton = 20 hundredweights	gallon (standard)
1 rod = 5 1/2 yards	1 hundredweight = 100 pounds	1 quart = 1/4 gallon
yard (standard)	pound (standard)	1 pint = 1/2 quart
1 foot = 1/3 yard	1 ounce = 1/16 pound	1 ounce = 1/16 pint
1 inch = 1/12 foot	1 dram = 1/16 ounce	1 tablespoon = 1/2 ounce
1 ounce = 1/64 inch	1 grain = 1/27 dram	1 teaspoon = 1/3 tablespoon

TABLE 2B: The Metric System

Factor	*Prefix*	
1,000	kilo-	
100	hecto-	
10	deka-	meter (length)
1	(standard) →	gram (mass)
.1	deci-	liter (capacity)
.01	centi-	
.001	milli-	

TABLE 2C: Comparing the Two Systems

With 3 Measures	*With 6 Measures*	*With 9 Measures*
Inch-Pound		
7 unit names	7 unit names	7 unit names
× 3 measures	× 6 measures	× 9 measures
21 names	42 names	63 names
+	+	+
18 conversion ratios	36 conversion ratios	54 conversion ratios
Metric		
6 prefixes	6 prefixes	6 prefixes
+ 3 unit names	+ 6 unit names	+ 9 unit names
9 names	12 names	15 names
+	+	+
2 conversion ratios	2 conversion ratios	2 conversion ratios

duplication. In order to "know" the system completely one must memorize each and every conversion ratio.

In summary, to know our three-measure inch-pound measurement system, one must remember 21 names and 18 conversion ratios. If one was to expand the system to include three more measures, such as those for force, pressure, and frequency, one would need to remember 42 names and 36 conversion ratios. Add three more measures, such as those for area, energy, and power, and one would need to remember 63 names and 54 conversion ratios.

In the metric system, by contrast, every measure has one unique standard unit name, such as meter for length, gram for weight, and liter for capacity. All other units within measures bear one of these standard unit names plus one of six prefixes. The prefixes are common to all measures. A thousand meters is a kilometer, a thousand grams is a kilogram, and a thousand liters is a kiloliter. So, all told, there are only nine names to remember in our three-measure metric system. The conversion ratios are even simpler: There are only two (between neighboring units). Each and every unit is one tenth the size of the neighboring lower unit and ten times the size of the neighboring higher unit. Expand our system to include other measures and there is little more information to remember—just the names of the standard units for the additional measures.

Comparing nine-measure systems, one can see that the inch-pound system requires that one memorize 63 unit names and 54 conversion ratios while the metric system contains only 15 different names and 2 conversion ratios. Because the metric system is more concise, one can know more of it more easily. Because all of its conversion ratios are decimal, one should make fewer calculation errors. (See Appendix C for an extended discussion of the conciseness of the metric system.)

Nine measures represent the fullest extent of the measurement systems that are taught in the regular math and science curriculum of our elementary and secondary schools. Only in very advanced high school science courses would students be exposed to a larger system.

My calculations in Table 2c offer a very rough calculation of the difference in conciseness of the two measurement systems. In order to know a nine-measure inch-pound system with complete fluency, a student would have to memorize 63 names (either unit names or names of measures) and 54 conversion ratios. In order to know a nine-measure metric system with complete fluency, a student would have to memorize 15 names and 2 conversion ratios. That comes out to 117 names and ratios for complete command of the nine-measure inch-pound system and 17 names and ratios for complete command of the nine-measure metric system.

The metric system is just as powerful and practical to use as the inch-pound system, but requires only 15% of the factual recall or can be learned in 15% of the time that it takes to learn the inch-pound system.

The student using the inch-pound system may compensate for its complexity by forgetting some of its information (perhaps the conversion ratios for furlongs, drams, and hundredweights, for example). But then her use of the system is crippled—she is only using part of it. In fact, the difference in quality and efficiency across the two systems could show up in several ways: metric learners may learn measurement better and faster, know more measures and more conversion ratios between units, use measures with greater facility, or make calculations employing measures more quickly.

Thus the cost counted in row 3 of Tables 1a and 1b represents the extra time it takes a student to learn a nine-measure inch-pound system by comparison with a nine-measure metric system. It is assumed that the metric system can be learned to an equivalent level of mastery in 15% of the time it takes to learn the inch-pound system.[8] This amounts to a savings of 60 days of mathematics instruction annually (or over the course of a student's school career).

CONVERT SCIENCE TEXTS AND CURRICULA TO INCH-POUND OR BOTH METRIC AND INCH-POUND

Under the soft-conversion-to-inch-pound plan, inch-pound instructional content would have to be added to science textbooks that now contain only metric material. Moreover, because most high school science teachers have been trained to teach only in metric measures, they would have to be retrained to teach in inch-pound measures.

It is assumed here that the science textbooks would have to be rewritten (which would take a minimum of 3 years),[9] that schools would replace their textbooks in the normal cycle (which would take 3 to 6 years; see U.S. Department of Commerce 1971, 105), and that teachers would have to be retrained.

Adding the two durations together, one arrives at a delay of about 8 years before the benefits of inch-pound conversion could start to be realized.

The cost counted in row 4 of Table 1a and 1b assumes that all high school science teachers would need 2 weeks of retraining, and would be paid at their regular salary for those 2 weeks[10] (see U.S. Department of Commerce 1971).

SUMMARY OF THE PLAN RESULTS

If the assumptions of this analysis are correct, choosing the soft-conversion-to-metric plan over the status quo would give every American school student into the foreseeable future an extra 82 classes over the course of their elementary-secondary school careers, probably, though not necessarily, in mathematics. That amounts to almost a semester of additional instructional time for students to learn more than they do currently (see Table 1a).

Choosing the soft-conversion-to-inch-pound plan over the status quo, by contrast, would give every student into the foreseeable future an extra 11 classes over the course of their elementary-secondary school careers, probably in mathematics. This gain would come with some cost, however; that of retraining high school science teachers in inch-pound instruction (see Table 1a).

Because all the benefits to the soft-conversion-to-metric plan counted here derive from savings in classroom time, one may be tempted to propose that changes be made in the school alone and that suggestions of dual-labeling in the rest of society be dropped. Doing that, however, would introduce two new costs. First, the students would not learn the metric system as well, and the quality of their learning would be embedded in the benefits calculated.

In a doctoral dissertation written in 1978, Richard Lee Williams tested the metric knowledge of students in Spokane, Washington and Calgary, Alberta. Even controlling for all school, ability, family background, and metric education factors, the U.S. students' metric skills were still significantly worse. Williams surmised that the variation in the social background—Canada had mostly converted to metric by then while the United States had not begun—accounted for the difference (Williams 1978). Generalizing to the populace as a whole, Americans' measurement abilities may remain inferior as long as our society remains inch-pound in public.

SUMMARY OF PLAN RESULTS, MEASURED IN NET PRESENT VALUE

The education system benefits and costs of the three measurement system conversion plans have been converted to a common metric—dollars—through present value calculations. These calculations, and the assumptions upon which they are based, are included in Appendix A. The results of these calculations are included in Table 1b.[11]

According to these present value calculations, choosing the soft-conversion-to-metric plan over the status quo would provide our society a $17,653 million net benefit. Choosing the soft-conversion-to-inch-pound plan over the status quo, by contrast, would provide our society a $986 million net benefit.

There is no pretending that these estimates have been or could have been made with great precision. These are rough estimates. But, they are illuminating nonetheless, and they are robust. Because the estimates are so robust, their margins of error can be very wide; the relative result would still be the same even with large estimation errors. Even if the net benefit estimates were off by 80%, the soft-conversion-to-metric plan would still be the winner, at least as far as our education system is concerned. The assumptions made in this analysis would have to be grossly erroneous for the relative result to be different.

Why is there such a difference among the three plans after all the calculations are complete? One reason is that U.S. metric conversion is already occurring to a large extent. The soft-conversion-to-inch-pound plan is costly because our nation's science classes have already converted entirely to metric. The soft-conversion-to-metric plan is feasible only because so much in our society is already metric or, at least, dual-labeled. As a society, we may have already passed the breakeven point, where it has now become more costly to revert to inch-pound than to convert to metric.

Another reason the net benefit numbers turned out the way they did has to do with the difference between savings into perpetuity and one-time-only costs. Classroom time is a large investment when one adds up the numbers because it affects so many people year after year. The one-time-only cost of retraining science teachers appears minuscule by comparison.

IMPLICATIONS

CONVERTING U.S. HIGHWAY SIGNS

The next skirmish in the ongoing metric conversion struggle in the United States will take place over highway signs. To date, all steps short of actually changing the signs have been undertaken.[12] The U.S. Congress has prevented the changeover itself due to a vocal opposition. Although dual-labeling consumer products arouses little opposition, dual-labeling highway signs arouses vitriol.

Estimates have been made for the cost—in time and in dollars—of changing all signs on federal, state, and local roads. The estimates are based on the metric conversion experience in Canada and on a study conducted by the state of Alabama, and are included in the most recent GAO report.[13] These ballpark estimates are $334 million (based on Canada) and $420 million (based on Alabama; see U.S. GAO 1995, 7).

Canada completed the changeover within a period of 2 months; the U.S. FHWA has proposed 6 months to a year. Either of these time periods, and even longer time periods, would be consistent with a soft-conversion-to-metric plan that would drop all inch-pound instruction in the schools starting next year. Even the oldest of the students now attending elementary school will not be driving on our roads for another 3 years.

Would a soft-conversion-to-metric plan be worth the cost of highway sign conversion? Judging by the calculations in Appendix A, freeing up just 2 days of math class (from now into perpetuity) would be worth about $430 million.[14] Those 2 days alone would more than pay for the conversion of all highway signs in the United States. If estimates in this analysis are reliable, the education benefits of the soft-conversion-to-metric plan would pay for the highway sign change 44 times over.

THE POLITICAL USE OF THIS INFORMATION

Currently, the debate over metric or dual-labeled highway signs revolves around U.S. entry into the global economy (for the proponents of the changeover) and the federal government's alleged arrogance of power and arbitrary usurpation of the rights and preferences of the states and their citizens (for the opponents of the changeover). In this author's opinion, the proponents of the change do not have a politically strong argument. It would probably seem a stretch to most voters to tie what is written on our domestic highway signs to our export companies' global competitiveness.

The analysis here offers changeover proponents what might be a stronger and more compelling argument: We may be harming our children, hindering their futures, and stunting our country's economic growth by miseducating our children. What U.S. citizens might not be willing to do to please the federal government or multinational corporations, they might be willing to do for their own children and their children's future prosperity.

USE OF THE ADDITIONAL INSTRUCTIONAL TIME

It is not certain that the entire windfall of additional instructional time would be applied solely to mathematics instruction or to adding additional subjects to the math curriculum.

The savings in instructional time to be gained by dropping inch-pound measures from the curriculum would accumulate over several grade levels, one to a few weeks each year. Converting the disparate pieces of time into a discrete lump would require deliberate effort. But, such effort would be necessary if one wished to convert the instructional time savings into a semester of a particular subject, such as algebra 2, analytical geometry, statistics, or calculus.

Otherwise, the instructional time savings would stretch out the time table of each year's math course, mostly in the elementary grades. Our students could spend more time on their current curriculum and could learn more math. Or, they could delve into the chapters they do not ordinarily get to at the back of their textbooks. Even better still, they could add new topics taken from the National Council of Teachers of Mathematics' (NCTM) *Curriculum and Evaluation Standards for School Mathematics* (1989).

It is possible, moreover, that schools might choose to apply the windfall in instructional time to subject areas other than mathematics. But, I think that that is unlikely. There has been interest in *increasing* mathematics curricular offerings in recent years, and most states have also been increasing the number of mathematics courses required for students' graduation from high school (see U.S. Education Department 1993, 133, table 135). Besides, because the time savings would occur entirely within existing math courses, they would never be available to teachers in other subject areas. They would be "captive" to the math teachers.

Even if schools were to apply the instructional time windfall to other subject areas, however, it is still a benefit.

RELATIONSHIP BETWEEN INCREASED INSTRUCTIONAL TIME AND MATHEMATICS ACHIEVEMENT

It seems logical that if students are granted more instructional time on a certain subject matter, all other factors being held equal, they are likely to more aptly learn the subject matter. This intuitively sensible conclusion was questioned in the seminal analysis of the data from the Second International Mathematics and Science Study (SIMSS). This 1982 cross-country mathematics assessment tested 13-year-old students in many participating countries on their math and science knowledge.

The seminal analysis of the data from SIMSS was published in a report titled *The Underachieving Curriculum* (see International Association for the Evaluation of Educational Achievement 1989). In it, the authors claimed that they could not find a relationship between the amount of time spent in mathematics instruction and country-level student achievement in mathematics.

In a more recent article, however, Lewis and Seidman (1994) examined the data from *The Underachieving Curriculum* very closely. They noted, among other things, that the authors of the original study used as their figure for the amount of time spent in mathematics instruction only the amount for the school year of the tested group of students. For the high-scoring Japanese students, this was 7th grade, coincidentally a grade level with a relatively small amount of math instruction in the Japanese curriculum.

Lewis and Seidman (1994) recalculated the "math time" variable to include the "cumulative stock" of time in math classes in both primary and lower secondary school; the time spent in after-school programs, such as Japanese *jukus* and summer programs; and time doing math homework. They calculated this math-time factor for all the countries that participated in the SIMSS. Whereas the amount of instructional time in mathematics in the 8th grade for U.S. 13-year-olds exceeded that in the 7th grade for Japanese 13-year-olds (144 hours vs. 101 hours), according to Lewis and Seidman's "net stock" of "cumulated math-time," the Japanese 13-year-olds easily bested the U.S. 13-year-olds (1,370 hours vs. 1,054 hours).

When Lewis and Seidman (1994) ranked the participating countries according to their 13-year-olds' net stock of math time, the Japanese ranked first, the Scots second, the French third, the Belgians fourth, and the Dutch fifth. At the bottom were the Finns, the Swedes, the Israelis, the Thais, the Canadians, and the Americans.

Lewis and Seidman (1994) employed the net stock of math-time variable in simple and multiple regressions and found that, contrary to the conclusions in *The Underachieving Curriculum*, it is a significant and robust predictor of mathematics achievement. How much does math achievement improve with increased math time? Lewis and Seidman find that a 100-hour increase in math-time accumulation by 8th grade would have increased the United States' SIMSS score by 7% or 8% and moved it up five places in the rankings, from 13th place (out of 17 places) to 8th place in the world, past Finland, England and Wales, Scotland, Canada (Ontario), and Hong Kong.

Dropping all inch-pound instruction in the schools and using the time windfall to teach more mathematics would have moved the United States up six notches in the rankings among the 17 participating SIMSS countries on math-time accumulation. Furthermore, it would have increased the U.S. math score by 5.3% and moved the United States up two notches in the rankings based on average achievement score, past Finland and England and Wales.

In an even more recent analysis by the U.S. Education Department's National Center for Education Statistics (NCES), students who took more math and science courses did better on achievement tests in those subjects (gender, racial or ethnic background, and socioeconomic status were held constant; see U.S. Education Department 1995).

IMPLEMENTING A SOFT METRIC CONVERSION IN THE SCHOOLS

To imagine how educators might react to a mandate for metric conversion one need only study their behavior in the late 1970s and early 1980s. Educators supported the effort virtually universally. No groups of educators in science or math at the elementary and secondary level or at the college level spoke against it. Most publicly supported the effort. Math and science educators believed metric to be the superior system and its adoption in the United States to be inevitable (U.S. Congress 1982, 1987; Boyer 1979; Bright 1973; Elwell 1976; Fischer 1973; Helgren 1973; Paige 1978; Viets 1973).

Largely through support from federal grants, school districts throughout the country developed and tried new curricula and methods for teaching the metric system (see “Federal Funds” 1976; U.S. Congress 1982, 1987). These many reports presumably still exist and could be resurrected, eliminating the need for any such exploratory or preparatory studies again. Besides, at this point, teachers do not need to learn how to teach the metric system. They have been teaching the metric system for over a decade. This time around, metric conversion could consist quite simply of dropping a chapter a year out of the study plans. Nothing new pertaining to the metric system would need to be learned.

The early attempts at metric conversion in the schools taught educators one important lesson. It was better to teach the metric system on its own from scratch or to teach it through rough, convenient equivalencies with inch-pound measures. When educators tried to teach metric through memorization of conversion ratios from inch-pound measures, students rebelled, learned poorly, and usually resented the metric system for the confusing complexity (even though the inch-pound system was the real culprit) (V. Antoine, personal communication, July 1990; Paige 1978; U.S. Congress 1982, 1987).

It should be noted that, although a federal metric conversion program could provide aid, encouragement, and advice, states are free to act on their own. They can drop the inch-pound system (or the metric system, for that matter) from their curriculum whenever they wish. In sympathy with its all-metric auto industry, the state of Michigan did just that, eliminating inch-pound instruction in its schools.

APPENDIX A
Calculations of Benefits and Costs

First-Order Conditions

- Discount rate equals current inflation rate (≈3%) plus federal funds rate (≈5%), or 9%.
- Student time is valued at the average U.S. expenditure per student found in U.S. Education Department statistical reports, $5,600 per student.
- Teacher time is valued at the average U.S. teacher salary found in U.S. Education Department statistical reports.
- PV = present value; NPV = net present value.

Soft Conversion to Metric—Table 1, Row 1—Classroom Time Saved by Teaching Just One System

Assumptions

- 71 days of math class saved annually (from Appendix B)
- current expenditure per pupil = $5,600 (U.S. Education Department 1993, tables 43, 159)
- 180 days in a school year
- 1/6 of school day is devoted to math class
- 30 million elementary school students (U.S. Education Department 1993, tables 44, 62)
- 8 grade levels in elementary school, ∴ 30/8 = 3.75 million students per grade level
- $5,600 per year per student/180 days = $31 per student per day

Calculations

71 days per year × 3.75 million students per year × 1/6 school day × $31 day expenditure = $1,376 million in instructional time saved annually.

NPV = PV(to perpetuity) = $1,376/9% discount rate = $15,285 million.

Soft Conversion to Metric—Table 1, Row 2—Classroom Time Saved by Dropping Some Instruction in Fractions

Assumptions

- 11 days of math class saved annually (from Appendix B)
- current expenditure per pupil = $5,600 (U.S. Education Department 1993, tables 43, 159)
- 180 days in a school year
- 1/6 of school day is devoted to math class

- 30 million elementary school students (U.S. Education Department 1993, tables 44, 62)
- 8 grade levels in elementary school, ∴ 30/8 = 3.75 million students per grade level
- \$5,600 per year per student/180 days = \$31 per student per day

Calculations

11 days per year × 3.75 million students per year × 1/6 school day × \$31 day expenditure = \$213 million in instructional time saved annually.

NPV = PV(to perpetuity) = \$213/9% discount rate = \$2,368 million.

Soft Conversion to Inch-Pound—Table 1, Row 1—Classroom Time Saved by Teaching Just One System

Assumptions

- metric instruction would be dropped starting 8 years from now (in 2004)
- 71 days of math class saved annually (from Appendix B)
- current expenditure per pupil = \$5,600 (U.S. Education Department 1993, tables 43, 159)
- 180 days in a school year
- 1/6 of school day is devoted to math class
- 30 million elementary school students (U.S. Education Department 1993, tables 44, 62)
- 8 grade levels in elementary school, ∴ 30/8 = 3.75 million students per grade level
- \$5,600 per year per student/180 days = \$31 per student per day

Calculations

71 days per year × 3.75 million students per year × 1/6 school day × \$31 day expenditure = \$1,376 million in instructional time saved annually.

$$\begin{aligned} \text{NPV} &= \text{PV(to perpetuity)} - \text{PV(next year)} - \text{PV(year} + 1) - \\ &\quad \text{PV(year} + 2) \ldots \text{PV(year} + 8) \\ &= (\$1{,}376/9\%) - (\$1{,}376/1.09) - (\$1{,}376/1.09^2) - (\$1{,}376/1.09^3) \ldots \\ &\quad (\$1{,}376/1.09^8) = \$15{,}289 - 1{,}262 - 1{,}158 - 1{,}063 - 974 - \\ &\quad 894 - 820 - 753 - 691 \\ &= \$7{,}674. \end{aligned}$$

(continued)

Soft Conversion to Inch-Pound—Table 1, Row 3—Classroom Time Lost Due to Quality and Efficiency Disadvantage

Assumptions

- metric instruction would be dropped starting 8 years from now (in 2004)
- 71 days of math class saved annually (from Appendix B)
- current expenditure per pupil = \$5,600 (U.S. Education Department 1993, tables 43, 159)
- 180 days in a school year
- 1/6 of school day is devoted to math class
- 30 million elementary school students (U.S. Education Department 1993, tables 44, 62)
- 8 grade levels in elementary school, ∴ 30/8 = 3.75 million students per grade level
- \$5,600 per year per student/180 days = \$31 per student per day

Calculations

60 days per year × 3.75 million students per year × 1/6 school day × \$31 day expenditure = \$1,163 million in instructional time lost annually.

$$\begin{aligned} \text{NPV} &= -\text{PV(to perpetuity)} + \text{PV(next year)} + \text{PV(year} + 1) + \\ &\quad \text{PV(year} + 2) \ldots \text{PV(year} + 8) \\ &= -(\$1{,}163/9\%) + (\$1{,}163/1.09) + (\$1{,}163/1.09^2) + (\$1{,}163/1.09^3) \ldots \\ &+ (\$1{,}163/1.09^8) \\ &= -\$12{,}922 + 1{,}067 + 979 + 898 + 824 + 756 + 693 + 636 + 584 \\ &= -\$6{,}485. \end{aligned}$$

Soft Conversion to Inch-Pound—Table 1, Row 4—Retraining Science Teachers

Assumptions

- courses in science make up 12% of high school coursework (U.S. Education Department 1993, table 134)
- number of secondary school teachers = 917,103 (U.S. Education Department 1993, table 64)
- number of secondary school science teachers = number of secondary school teachers × 12% = 917,103 × .12 = 110,052
- average secondary school teacher salary = \$36,059 (U.S. Education Department 1993, table 76)
- teachers work 9-month school year, or 39 weeks
- average secondary school weekly salary = \$36,059/39 weeks = \$925 per week
- retraining in inch-pound measures for teaching science would take 2 weeks

NPV = \$925 × 2 weeks × 110,052 teachers = \$203 million (1 time only cost).

APPENDIX B
Breakdown of the Number of Classroom Days Devoted to Teaching Each Measurement System

Grades 1-8, text series *Mathematics* Management Guide—Complete Daily Plans (Eicholz et al. 1987).

1st Grade

Chapter 12: Measurement—Metric Units. Total of 9 days (length, capacity, weight, temperature)—6 days on metric measures, 2 days on the concept of measurement, 1 day is a test (2 days are listed as optional).

Chapter 14: Fractions and Customary Measurement. Total of 9 days—3 days on customary measures, 5 days on fractions alone, 1 day is a test (2 days are listed as optional).

2nd Grade

Chapter 9: Measurement—Metric Units. Total of 10 days (length, area, capacity, weight, temperature)—8 days on metric measures, 1 day on the concept of measurement, 1 day is a test.

Chapter 13: Fractions and Customary Measurement. Total of 11 days (length, area, capacity, weight, temperature)—5 days on customary measures, 5 days on fractions alone, 1 day is a test.

3rd Grade

Chapter 5: Measurement—Metric Units. Total of 18 days (time, length, area, volume, capacity, weight, temperature)—13 days on metric measures, 4 days on time (clock and calendar), 1 day is a test.

Chapter 14: Measurement—Customary Units. Total of 6 days—5 days on customary measures, 1 day is a test.

4th Grade

Chapter 6: Measurement—Metric Units. Total of 17 days (time, length, area, volume, capacity, weight, temperature)—10 days on metric measures, 6 days on time, 1 day is a test (1 day is listed as optional).

Chapter 15: Measurement—Customary Units. Total of 9 days (length, volume, weight, capacity, temperature)—7 days on customary measures, 1 day on fractions, 1 day is a test.

(continued)

5th Grade

Chapter 8: Measurement. Total of 21 days (length, area, volume, capacity, weight, time, temperature)—16 days on metric measures, 4 days on time, 1 day is a test.

Chapter 16: Measurement: Customary Units. Total of 16 days (length, area, volume, capacity, weight, temperature; fractions are in other chapters)—15 days on customary measures, 1 day is a test.

6th Grade

Chapter 7: Measurement. Total of 17 days (length, volume, capacity, weight, time, temperature)—12 days on metric measures, 3 days on time, 1 day is a test (1 day is listed as optional).

Chapter 16: Measurement—Customary Units. Total of 12 days (length, capacity, weight, temperature)—11 days on customary measures, 1 day is a test.

7th Grade

Chapter 10: Measurement—Metric Units. Total of 16 days (length, area, volume, weight, liquid measure, temperature)—15 days on metric measures, 1 day is a test.

Chapter 16: Measurement—Customary Units. Total of 9 days (length, area, volume, weight, liquid measure, temperature)—6 days on customary measures, 1 day is a test (2 days are listed as optional).

8th Grade

Chapter 7: Measurement—Metric Units. Total of 12 days (length, capacity, weight, time, temperature)—8 days on metric measures, 2 days on time, 1 day is a test (1 day is listed as optional).

Chapter 16: Measurement—Customary Units. Total of 10 days (length, area, volume, weight, liquid measure, temperature)—9 days on customary measures, 1 day is a test.

Breakdown of School Days Devoted to Teaching Measurement

98 days on primary measurement system (includes tests)
22 days on time measures or the concept of measurement
71 days on secondary measurement system (includes tests)
+ 11 days on fractions alone

202 days total

APPENDIX C
More on the Conciseness of the Metric System

As the inch-pound system enlarges, the amount of information necessary to know it completely expands roughly at a geometric rate. As the metric system enlarges, however, the amount of information necessary to know it completely expands roughly at an arithmetic rate. It is no wonder that scientists and engineers, who need to use enlarged measurement systems, prefer metric.

The difference in conciseness between the two systems is even greater than illustrated thus far because thus far I have considered conversion ratios only between neighboring units. In the metric system, each unit is one hundredth the value of the unit two units higher and a hundred times the value of the unit two units lower. In the inch-pound system, there is no such uniformity. The same is true for conversions between units three units apart or four units apart, and so on.

The difference in conciseness between the two systems is larger still if one expands the systems to include factors above a thousand and below a thousandth. The more of a system one uses, the greater is metric's advantage. Consider an enlarged measurement system, such as a research scientist might use, with 12 measures, using factors up to a million and down to a millionth, and count all conversion ratios within a measure, not just those between neighboring units. One can see from the calculations in the table below that an enlarged metric system consists of 36 pieces of information while the enlarged inch-pound system consists of 1,092 pieces of information.

Comparing the Two Enlarged Systems

Inch-Pound	*Metric*
13 unit names	12 prefixes
× 12 measures	+ 12 measures
156 names	24 names
78 ratios within a measure	
× 12 measures	
936 conversion ratios	12 conversion ratios
156 + 936 = 1092	24 + 12 = 36

The enlarged metric system is more concise than the enlarged inch-pound system by a factor of 30.

Americans have adapted to the complexity of the inch-pound system by knowing only an abbreviated system. We do not bother remembering furlongs, rods, barrels, hundredweights, or drams. And we do not bother remembering all the conversion ratios, even of the units with which we are familiar.

(continued)

Indeed, it is doubtful that many Americans even know measures as an integrated system. Instead, most are familiar with a hodgepodge collection of the more familiar units and conversion ratios, to which some metric units have now been added, as with millimeters for camera lens sizes; liters for soft drink, water bottle, and car engine sizes; milligrams for pills and the nutritional content of packaged foods; and meters for track and swimming competitions. Students using the metric system, however, do not have to make such accommodations.

NOTES

1. The United Kingdom has just this year completed its conversion to metric. Groceries and most consumer goods have been labeled in metric measures for years, but highway signs and some other items were still marked in Imperial measures until this year.

2. New Zealand and Australia, among others, are completely converted.

3. Canada is mostly converted but metric is not strictly enforced in some marginal markets such as those for bulk and fresh foods.

4. The EC nations consist of Belgium, Denmark, France, Netherlands, Germany, Greece, Ireland, Italy, Luxembourg, Portugal, Spain, and the United Kingdom. Nations of the European Free Trade Association, which include Austria, Finland, Iceland, Norway, Sweden, and Switzerland, are now negotiating a merger with the EC.

5. The most celebrated case is that of Saudi Arabia and some of its neighboring states.

6. Conversations with the mathematics curriculum coordinators in the 12 largest states in terms of population: Massachusetts, New York, Pennsylvania, Illinois, Michigan, Georgia, Florida, California, Washington, Arizona, Colorado, and Minnesota.

7. Conversations with four math textbook editors: Valerie Levenberg at Silver Burdett/Ginn, Morristown, NJ; Kathy Anderson at Houghton Mifflin, Boston, MA; Barbara Carrell at D.C. Heath, Lexington, MA; and Laura Ganjevic at Macmillan/McGraw-Hill, New York. These editors' surveys, feedback, and observations conclude that teachers teach both systems, giving roughly equal attention to each.

8. There is some reason to believe, however, that the row 3 figures may be underestimated. So far, I have only counted conversion ratios between neighboring units. Extend the count to nonneighboring units and the gap in efficiency between metric and inch-pound yawns wider. Moreover, I have only counted measurement within a range of magnitude of 10^6—between a thousand and thousandths of a base unit. Enlarging the system would only widen the gap in efficiency between the two systems. Furthermore, I have not tried to account for the advantage metric has due to its decimal base.

9. In the author's conversations with several mathematics textbook editors, they estimated that it has become possible in recent years to produce a new textbook in 3 years. Three years is on the low end of the range of estimates.

10. In the original metric conversion studies conducted by the U.S. Department of Commerce in the 1960s and 1970s, detailed estimates were made of the amount of time, money, and effort needed to retrain all the country's teachers in metric measures. Two weeks was on the conservative end of the range of estimates.

11. To calculate the value of student time or teacher time, average expenditure-per-pupil and teacher salary figures are multiplied by the time estimates. The author acknowledges that these

should more precisely be regarded as measures of investment than as the real values that result from those investments. But, the author also acknowledges that those resultant values could not be estimated by any method much better than speculation given the paucity of information on the subject. The estimates contained herein are rough enough, and they will have to do.

12. Highway mileage signs that are dual-labeled would probably have to have metric measures written on a different-color background (yellow has been suggested) or in a different script to clearly distinguish them from inch-pound measures.

13. The changeover in Canada was done with overlays at first, rather than with completely new signs.

14. Assumptions include 3.75 million students per grade level, $31 per day in expenditures per student, one sixth of each school day devoted to math, and a discount rate of 9% (see Appendix A). Thus each day of math class saved is worth $19,375 million annually. PV (into perpetuity) = $19,375/9% = $215 million for each day of math class saved.

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