V. Friday Morning Papers

SUBSTITUTION –SOME PRACTICAL CONSIDERATIONS

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"Substitution" is a term and a concept which has been much overworked in recent years. It has been, directly or subliminally, the subject of many papers, of conferences, and of studies by both Government and industry. It has been blessed by Congress, encouraged by the Administration, and will be thoroughly assessed by OTA in coming months. But in the context of future constraints on the supplies of materials, substitution is not a unique solution; it is only part of a larger response. Typically, the replies to threats of shortages are "conservation" and "substitution." Both of these require substantial changes in social attitudes and in technology. If our experience with the energy "crisis" is a precedent, the latter will be more easily achieved than the former, And yet real growth in technology also requires modification of the prevalent community attitudes on science and technology, so one might argue that the initial burden is on the social scientist rather than the technologist.

Further, I'm not comfortable with the popular implications of the terms; "conservation" seems to infer sacrifice and deprivation, and "substitution" suggests to many the use of less satisfactory or ersatz materials. The objective, in my view, is the "Intelligent Use of Material Resources," the equitable sharing of a finite (although theoreticall_y inexhaustible') body of resources among a steadily growing quantity and variety of demands. Goeller and Weinberg[2] foresee an "Age of Substitutability," an era in which we have solved all the necessary technical problems to permit essentially infinite interchangeability of materials. I am persuaded by their arguments, but underline their observation

1 Although I subscribe to the Frascheian view that total exhaustion of any mineral resource will never occur (see D. F. Frasche. NAS-NRC Publication 1OOO-C, p. 18 (1963),) at any given time, the availability of a resource is 1 imited by the current technology; hence. at any given time the usable resource is finite.

2 H. E. Goeller and Alvin M. Weinberg, The Age of Substitutability, Science, Volume 191. No. 4228, pp 683-689, February 20, 1976.

that achievement of that ideal circumstance and accessibility of the essentially inexhaustible natural resources of our planet depend on timely development of the necessary technologies. The ultimate burden is, indeed, on the technologist.

James Boyd, Materials Policy-Maker Emeritus, prefers to use the term "interchangeability of materials." But this expression, too, has implications of the ideal world, of technological Nirvana. In the Goeller-Weinbergian Stage 3, interchangeability will be the order of the day; but in our age the process is impeded by the realities of a pragmatic society.

Lacking semantic innovation, I am thus resigned to accept for the moment the term "substitution" to describe one of the basic processes in the Intelligent Use of Materials Resources. The fundamental philosophy of substitution has been well reasoned. In their excellent appendix to the COMRATE Report, Chynoweth, Huddle, and Speer[3] examined the concept of substitution and provide, in my judgment, the definitive statement of the subject. Their study addresses the practical considerations in response to shortages by replacement of critical materials. They provide a very realistic introduction to the substitution issue.

Rather than attempt to construct heady forecasts or Newtonian hypotheses, I'd like to expand a bit on the CHS (Chynoweth/Huddle/Speer) concept of substitution. The following discussion is based primarily on a recent Battelle report to the Office of Technology Assessment as part of the Assessment on Materials Information Systems.[4] Battelle's study examines the information systems implications of substitution analyses. I'll not go into the information requirements in detail, but address the motivations for and nature of substitution analyses.

Defining Terms

Let's begin at the beginning—with a definition of "materials." As you will already have recognized, there is some debate about the limits of the term. For the purpose of this review, we're defining "materials" very broadly—to include all substances used by mankind, except food and drugs, It is useful to classify materials,

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[3] A. G. Chynoweth, F. P. Huddle, and F. Speer, Materials Conservation Through Substitutes and Product Design. Appendix to Section 1, Report of Panel on Materials Conservation Through Technology, Mineral Resources and the Environment (COMRATE Report), NAS, PB 239580, February. 1975.

[4] J. L. McCall, H. D. Moran, and W. L. Swager, Materials Substitutability and Information Systems Implications, Volume IV, Assessment of Materials Information Systems, Office of Technology Assessment, U.S. Congress, February, 1976.

however, both in accordance with their intended use and relative to their state of manufacture, as done in table 1.

TABLE I.—Definition of Materials

By Use Category	By State of Manufacture
Physical/Structural	Raw, Semifinished and Finished
Reagents and Intermediates	Components/Applications
Energy/Fuels	Systems

The terms used in table 1 may be further defined as follows:

- Physical/Structural materials include all substances in raw, semifinished, and finished form used in the manufacture of goods, which remain in identifiable form during a period of use, They include metallic minerals, metais, construction minerals, wood, paper, cotton, wool, plastics, and ceramics.
- Reagents and Intermediates include all substances which are used in the manufacture of a finished product but do not remain as part of it. Such substances generally include chemicals, fertilizers, abrasives, solvents, and industrial gases.
- Energy/Fuels materials include the various mineral fuels and products refined from them. They include petroleum coal, natural gas, natural gasoline and liquified petroleum gases.
- Raw, Semifinished, and Finished materials include ores, concentrates, and basic metals and alloys. Also included are agricultural and wood products.
- Components/Applications include all parts of consumer and industrial durables. Also included are pesticides, pharmaceuticals and household cleaners, as well as finished grades of petroleum products.
- Systems include all finished household and industrial durables. The term "systems," as applied to energy/fuels and reagents and intermediates, usually refers to the method by which these classes of materials are used.

The reasons for this little classification system are made clearer by the examples in table 2. Using both classifications, we can begin to categorize substitution in order to separate the concept into manageable elements. The nature of substitution analyses vary according to classifications of this sort.

But then we also need to agree on a definition of "substitution," It is obvious, and CHS have told us, that the concept of substitution cannot be limited to the simple replacement of one material with another, It also involves the replacement of one process with another or changing the functional characteristics of a material or part, Further, these three classes of substitution—material, process, and function—can occur at any of the steps in the resource, processing, and manufacturing cycle, from raw materials through primary products, parts manufacture and components, to final system desigfi and assembly. Table 3 offers some illustrative examples of these classes:

In proposing these three classes of substitution, we've departed slightly from Chynoweth, Huddle, and Speer in that we've separated process from material-for-material replacement, Since the objective—presumably — is conservation of essential materials, processes which offer reduced wastage (and/or reduced energy consumption) may achieve the same purposes more efficiently than introduction of an alternative material. And CHS included the additional category of "System Substitution," wherein an entire system may be replaced, with concomitant changes in materials utilization. Examples would be mass transit to replace personal automobiles, optical communications replacing electronics, or solar power alternatives to fossil fueled systems. I would contend, however, that such overwhelming developments are not in themselves initiated for the purposes of conservation of engineering materials and, hence, are beyond the context of this discussion, They may alter or eliminate the demand for essential materials, but as an effect rather than a cause.

A glance at table 3 reveals the obvious: that the distinctions between these classifications are tenuous, They overlap in many instances; for example, replacement of a basic material will, in perhaps a majority of instances, require process changes; process changes may affect the design; design changes almost inevitably mean new material requirements. Nonetheless, each analysis begins with an initial objective falling into one of these classifications,

Those of our colleagues who are diligently pursuing the difficult goal of metrication refer to the process of conversion as "hard" or "soft"–development of completely new metric standards versus conversion of English units to metric in existing

TABLE 2.—Examples of Substitution Involving Various Classes of Materials

Category of Material, by State of Manufacture	CLASS OF MATERIAL—BY USE		
	Physical/Structural	**Reagents and Intermediates**	**Energy/Fuels**
Raw, Semifinished, and Finished Materials	Alunite for bauxite	Recovered sulfur for Frasch sulfur	Western coal for Eastern coal
	Raw polyester for raw cotton	Natural brines for rock salt	Gasified coal for natural gas
	Alcoa's chlorlde alumlnum reduction process for the Hall process	Mining of natural soda ash for Solvay process soda ash	Fuel 011 for natural gas
	Basic oxygen furnaces for open hearth steel-making	Phosphoric acid from furnace phosphorus for wet process acid	Formed coke for metallurgical coke
Components/Applications	New copper alloy for present alloy in auto radiator	Hydrochloric acid pickllng for sulfurlc acid pickling	Lead-free gasollne for regular
	Aluminum alloy for copper alloy In auto radiator	Direct application to soil of anhydrous ammonia for liquld application of ammonim salts	Propane for fuel 011
Systems	Air-cooled auto engine for water-cooled engine	Not applicable	Geothermal for coal-fired steam boiler
	Mass Transit for automobiles		Solar heating system for natural gas system
	Video phone communications for business transportation		

TABLE 3.—Examples of Three Broad Classes of Substitution

One Material for Another

- Aluminum for Copper in a Bus Bar
- No. 2 Yellow Pine for No. 1 in Woodwork for Home
- Mica-Based for Asbestos-Based Insulation
- Polyester Fabric for Cotton
- Painted Plain Carbon Steel for Stainless Steel
- Aluminum Building Wall Studs for Wooden
- Graphite Golf Club Shafts for Steel/Hickory
- Copper Laminate Coin for Silver

One Process for Another

- Friction Welding of Metal Parts for Butt Welding
- Rolled Threads on Screws for Cut Ones
- Castings for Forgings
- Float Glass for Ground Plate Glass
- Continuous Melt Extraction of Wire for Drawing
- ‘Net Shape’ Processes

One Function or Level of Functlon for Another

- Bulk Distribution of Oil Products in Place of Unit Containers
- Elimination of Chrome on Automobiles
- Air-Cooled Engine as a Substitute for Radiators in Water-Cooled Engines

standards. Similarly, a substitution action may be “soft” or “hard.” Although perhaps trite, the distinction is one of economic significance, as illustrated in table 4. And this comparison reminds us of what might_be termed the Law of the Obvious: The Simpler the Application, the Easier the Substitution.

Decisions and Decision Makers

With something of a framework for categorizing substitution decisions, let’s consider who is concerned with such decisions, and why. Although in some manner literally every one of us makes materials substitution choices (viz., the housewife who must choose between plastic wrap and aluminum foil), those whose actions will have a significant effect on the utilization of essential materials fall into two general categories: the Materials User and the National Policy maker (table 5).

TABLE 4.—’Hard’ Versus ‘Soft’ Substitution

Soft Substitution:
Introduction of a replacement material without significant changes in tooling, processes, or design.
Example: Steel number plates for aluminum; minimal impact on costs
Hard Substitution:
Introduction of replacement material requiring changes in design and processes
Example: Aluminum baseball bats for hickory; substantial changes in tooling, processing, and labor costs

Table S.—The Decision Makers

Materials Users	National Policy-Makers
R&D Personnel	Government Administrators
Designers/Engineers	Congress/Executive Branch
Management/Entrepreneurs	Public Interest Groups
	Labor

The Materials User category includes literally anyone in the entire cycle, from raw material producer to scrap processor. Even producers of raw materials are users of materials in a less refined state, e.g., the alumina producer is a user of bauxite. Policy-makers are a more austere classification, including only those who define, implement, or influence public policy.

But why consider substitution in the first place? Four primary reasons, from the viewpoint of the National Policy maker, were spelled out in the COMRATE Report:

Ž Environmental and safety controls, which have introduced a whole new set of social specifications, creating a need to deal with shortages resulting from prohibited facilities, materials and processes

- Government intervention in the industrial system to overcome large dislocations such as the combined shortage of electric power and petroleum fuels
- Future prospects of dislocations in the flow of materials from sources in developing countries and unstable sources
- The need to reduce reliance on materials of rising cost from foreign sources to balance U.S. payments abroad and control inflation at home

Motivations for Substitution

On the other hand, the Materials User is motivated to consider substitution for one (or more) of three fundamental reasons: to reduce costs, to improve performance, or to replace a scarce material or component. His motivations are less ethereal, more pragmatic, and every bit as important to the maintenance of the free enterprise system. A variety of more subtle incentives derive from those basic motivations. Some examples are given in table 6:

Although our Materials User is an honest, dues-paying patriotic American citizen, we must recognize that there may exist, from time to time, a dichotomy between his pragmatic, profit-oriented purposes and those objectives deemed by the Policy maker to be in the National interest. It may be incumbent upon the Policy maker, then, to offer some incentives for substitution, when that action is necessitated by gross societal or political pressures, This is an aspect of the substitution issue which has received insufficient attention to date and which demands early consideration. Substitution, by the Materials User, may be voluntary — in response to motivations such as cited in table 6; or it may be enforced –by price controls, rationing, regulation, or decree, Surely all of us who are reasonable Policy makers eschew arbitrary enforcement. We must offer, then, suitable acceptable incentives to the Materials User, such as those listed below:

- Capital Investment Credits,
- Simplified and/or Relaxed Government Specifications and Standards,
- Subsidies,
- Tax Incentives,
- Low-Interest Loans,

TABLE 6.—Examples of Materials User Motivations for Substitution

Material Shortage/Potential Shortage
Price/Cost Advantage-Uncertain Future Cost
Higher/Better Performance
Increased Reliability/Decreased Maintenance/Increased Life
Increased Marketability
Skilled Labor Shortages
Fabrication/Production Facility Shortages
Poor Performance of Present Materials
Regulatory Actions
Development of Self-Sufficiency
Elimination of Single Source Dependency
Use of Internal Materials
Risk Minimization
Political Advantages of Domestic Industries
Follow Competition

- Protective Tariffs,
- Preferential Shipping Rates,
- Relaxed Regulations, and
- Appreciation

Other examples might include:

- Relaxed anti-trust regulations to encourage cooperative research and development,
- Modification of Patent Law to provide protection with earlier disclosure and protection beyond the development period–which often may exceed 17 years, and
- Some form of liability deferment in instances where the consumer should share the risks as well as the benefits.

The last suggestion is not entirely facetious. Hundreds of corporations and labor groups have been proud to fly the “E” for Effort/Efficiency/Energy banner originated in World War II. A letter of thanks from the White House might not do much for the Finance Committee, but it can do wonders in explaining a two point drop in dividends to the stockholders.

If we are serious about planning for future constraints on essential materials—and I hope we are—policy development must include consideration of practical and positive incentives to industry for the implementation of conservation measures.

The Process of Substitution Analysis

Our two classes of substitution decision makers differ not only in their motivation but also in their approach to the analysis of alternatives. The Policy maker enjoys broader horizons and more flexible prerogatives, but because the impact of his actions may affect the entire society, his justifications must be significantly more persuasive, The Materials-User, on the other hand, must balance technical and fiscal considerations in assuring that revised designs will not compromise the profitability of his organization.

The Battelle study develops DELTA charts–logical networks of Decisions, Events, Logic, Time sequence, and Activity—for the two categories of substitution analysis. We include those charts here without detailed explanation,[5] merely to illustrate the differing nature of the decision processes and yet the relative complexity of any substitution analysis. We also wish to introduce a consideration on which we'll elaborate below—the requirement for an extensive variety of reliable information and data, much of which are not adequately available, especially to the Policymaker.

In both instances, the trigger is recognition that prevailing or prospective conditions are such that a substitution must be considered, The Policy maker must examine all present use patterns of the original material. He must consider the direct effects —economic, performance, and social —of the introduction of alternatives. And he must determine whether substitution of Material B for Material A will generate shortages of Material B, then necessitating the substitution of C for B—and so on—the so-called "ripple effect." The Policy maker must have sufficient knowledge (and understanding) of the state-of-the-art to deter-

[5] For detailed discussion see: J. L. McCal 1, H. D. Moran, and W. L. Swager, Materials Substitutability and Information Systems Implications. Volume IV, Assessment of Materials Information Systems, Office of Technology Assessment. U.S. Congress. February 1976.

mine the facility with which a substitution can be introduced. He has to consider available capacities, capital resources, and raw material supplies. He must contemplate the possible requirements for R&D investment to develop the alternative applications, He must especially consider the international and social impacts of dramatic changes in consumption patterns. And then he must be clever enough to frame suitable legislation or other policy actions to encourage and implement the change. Each of these decisions is depicted in figure 1,

Many of the same considerations—perhaps on a less macroscopic level— must occur to the Materials User, However, his analysis examines the design aspects for given applications. He is concerned with performance, cost trade-offs, and assurance of supplies of needed materials or components. He must take into account his present facility commitments, labor resources, and time lost in the market place, He must look into the applicable environmental and safety regulations and assure avoidance of conflict. Proprietary aspects are important, New capital requirements must be examined, And will he expose his organization to new liabilities? Ultimately, the question is simply, are the incentives sufficient to justify the change? Figure 2 displays the logic pattern for a manufacturing industry; similar DELTA charts can be developed for other Materials Users, e.g., process industries,

A moment's reflection on this logic process of the Materials User reveals a significant conclusion: from the standpoint of the Materials User, substitution is nothing more than a special case of materials selection, one in which one given material must be omitted from the candidates for a particular application. The decision procedure otherwise is identical to that followed in the original selection of a material for that application. And the information and data requirements, therefore, are the same. Materials selection takes place with a particular set of criteria; when those criteria are revised, another selection takes place— this time called substitution.

Information Requirements for Substitution Analyses

The DELTA Chart is particularly helpful in defining the separate—and common—requirements of the Policy maker and the Materials User for information and data. Although the Policy-maker may operate in a larger universe, enjoying a loftier and perhaps more detached viewpoint, he requires much of the same pragmatic background for his comparison of alternatives. And the Materials User, especially under today's social constraints, must consider his actions in the light of community impact. In

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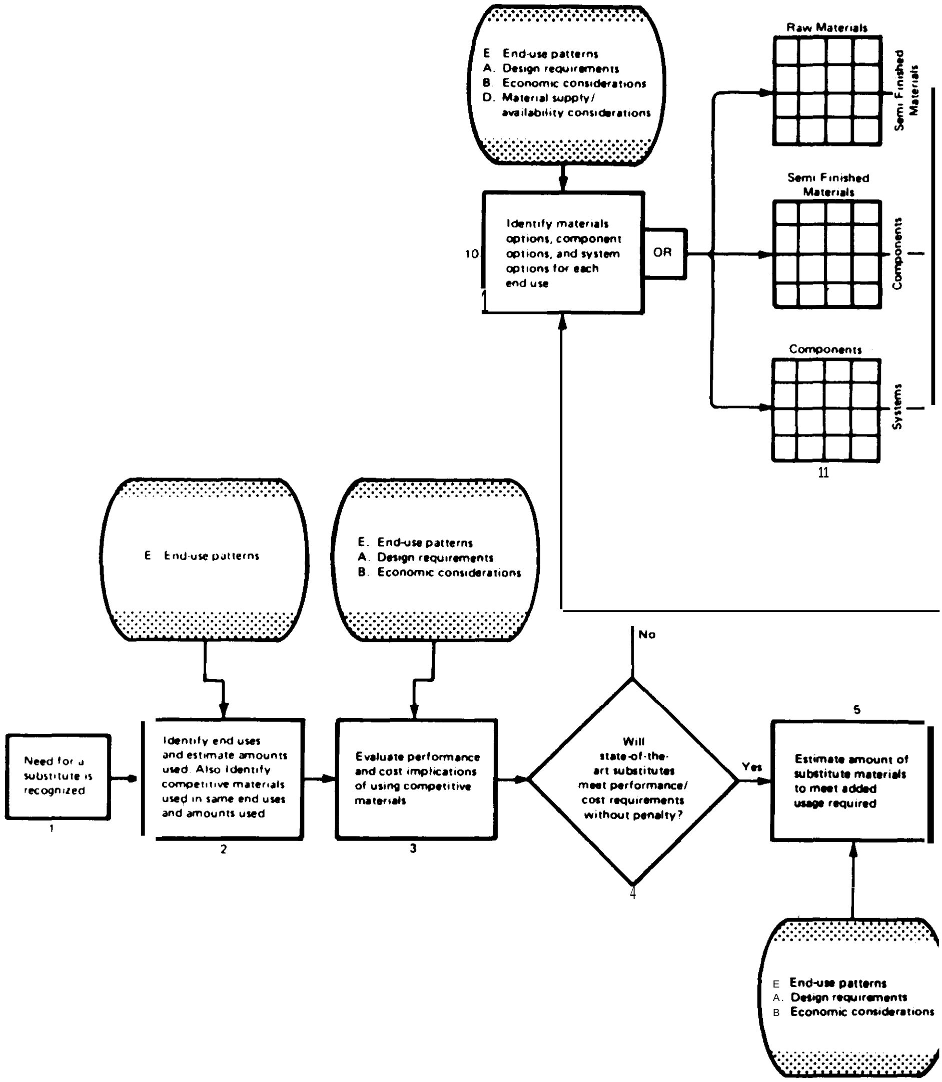
FIGURE 1—Substitution Analysis by National Policy Makers



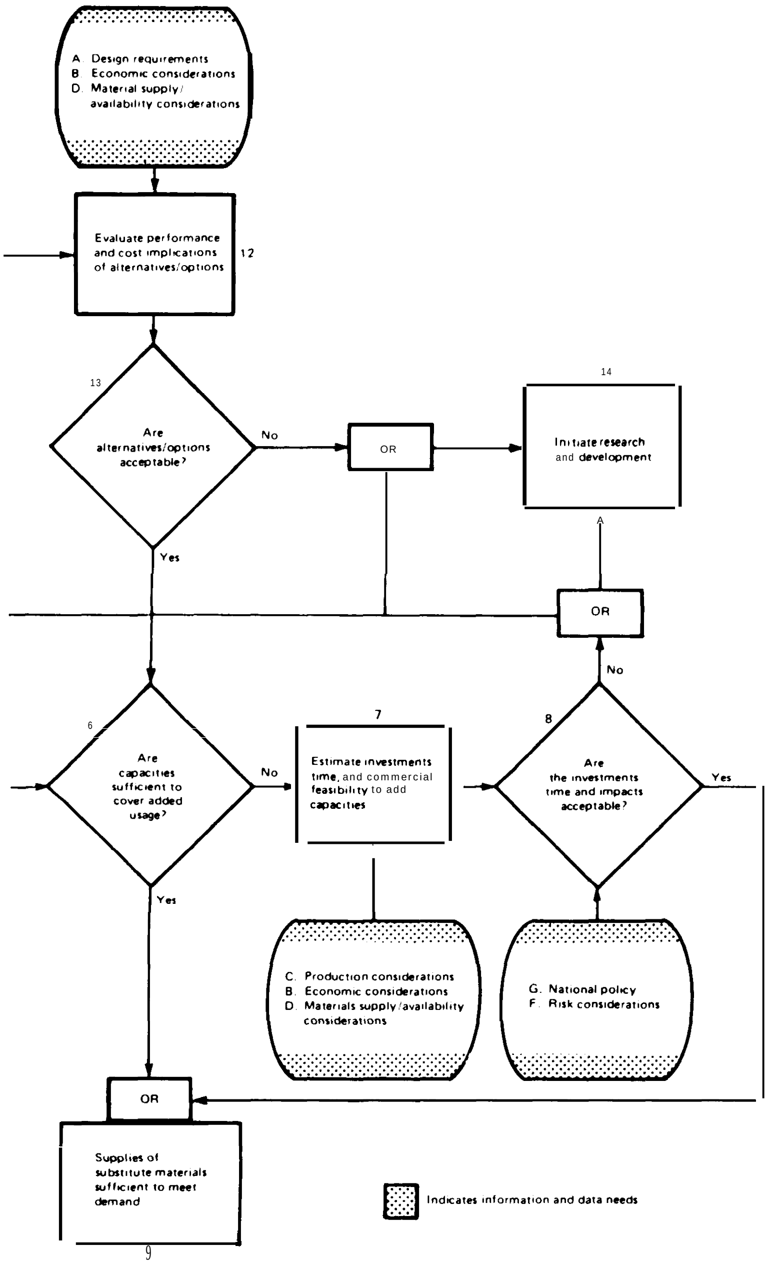

A. Design requirements
B. Economic considerations
D. Material supply/availability considerations
Evaluate performance and cost implications of alternatives/options
12
13
Are alternatives/options acceptable?
No
OR
14
Initiate research and development
A
Yes
OR
No
6
Are capacities sufficient to cover added usage?
No
7
Estimate investments time, and commercial feasibility to add capacities
8
Are the investments time and impacts acceptable?
Yes
Yes
C. Production considerations
B. Economic considerations
D. Materials supply/availability considerations
G. National policy
F. Risk considerations
OR
Supplies of substitute materials sufficient to meet demand
9
Indicates information and data needs

FIGURE 2.—Substitution Analysis by Materials Users

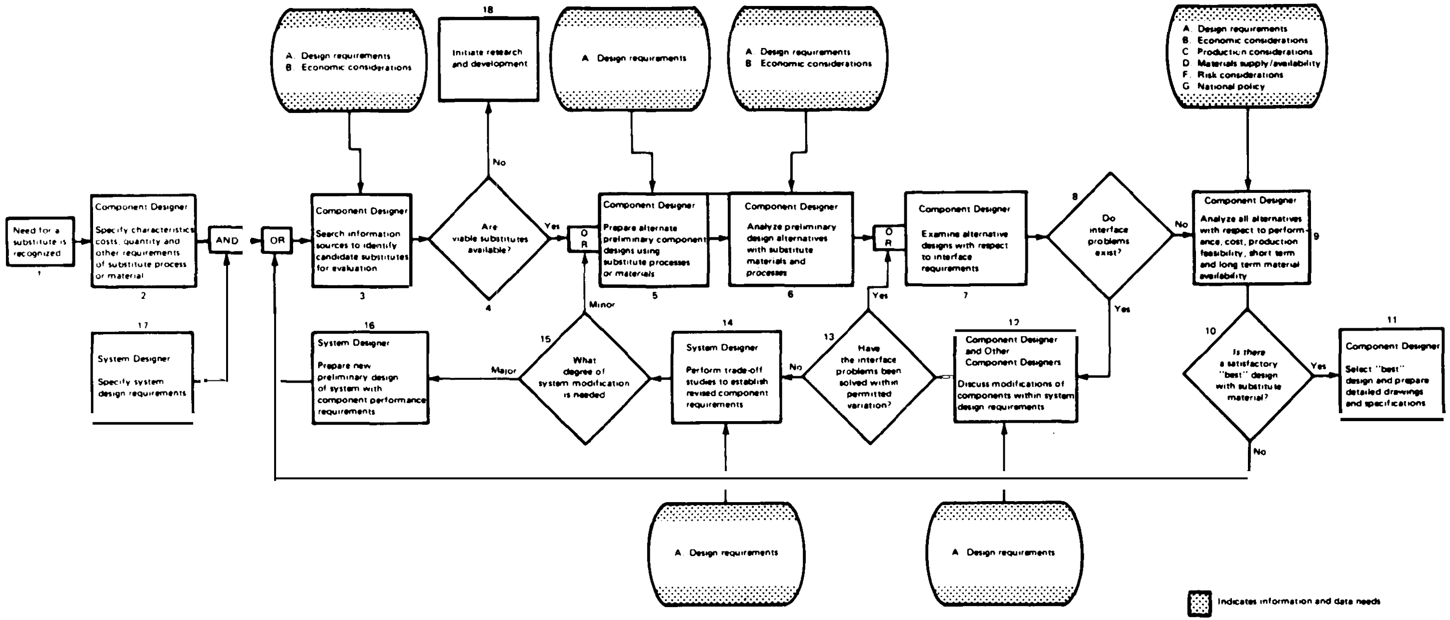


table 7, we endeavor to summarize those mutual requirements for information to support substitution analyses, in particular distinguishing between information required by one user group versus that required by the other, Since this table was extracted from the Battelle study, a word of explanation is necessary. Part of the objective was to define those quantitative data currently available, and those needed but not accessible to the particular user group, Further, the table indicates those types of subjective information needed in the decision processes, but not amenable to centralized collection and dissemination, i.e., those coded "O,"

These information requirements are restated in tables 8 and 9, identifying separately the needs of the two user groups, These tabulations certainly are not exhaustive, and many of the suggested items could be argued. However, the intent is to initiate the formulation of criteria for a National Materials Information System.

A morphology of the concept of Substitution is beginning to emerge, The important benefit is not in the academic exercise, but in the opportunity it provides for identification of those tools which are essential to the decision makers in Government and industry who are responsible for the intelligent use of our materials resources.

TABLE 7.—Information Requirements for Substitution Analysis

	Materials Users	National Policy-makers
A. DESIGN REQUIREMENTS		
Customer Acceptance		
Esthetics	0	N
Personal Bias	0	N
Market Acceptability	0	N
Performance Criteria	0	0
Materials Performance		
Mechanical Properties	I	N
Chemical Properties	I	N
Physical Properties	I	N
Fabricability	I	N
Machinability	I	N
Toxicity	I	N
Ease of Joining	I	N
Corrosion, Oxidation, and Fire Resistance	I	N
Compliance with Specifications and Codes	I	N
Protection Against Misuse	0	N
Vandalism Protection	0	N
Reuse/Recyclability/Disposal	1 0	1-0
Compliance with Specifications and Codes	1-0	10
Reliability and Maintainability	1 0	1-0
B. ECONOMIC CONSIDERATIONS		
Material Cost	I	I
Cost/Price Stability	I	I
Transportation Costs	10	10
Marketing Costs (to use substitute)	0	N
Production Costs	O	10
Investment Required to Incorporate	O	1 0
Life-Cycle Costs	0	0
Tariffs and Taxes	1-0	I
C. PRODUCTION CONSIDERATIONS		
Availability of Fabrication Facilities	10	I
Availability of Labor (specific skills)	10	I
Production Rates Achievable	0	I
Time Required to Incorporate Substitute	0	10
Use of Existing Facilities and Labor		1 0
Energy Requirements	I '0	I
Inspectability	0	N

	Materials Users	National Policy-makers
D. MATERIALS SUPPLY/AVAILABILITY CONSIDERATIONS		
Supply - Present and Future, Current and Potential		
Resources/Reserve$	10	I
Stockpile Level	10	I
Imports/Exports	1 0	I
Defense Allocation	10	I
Inventories	10	I
Supply Assurance (including trade agreement)	0	10
Identity and Location of Supplies	I	I
Forms of Materials Available	I	I
Delivery Time (Lead Time)	I -o	I
E. END-USE PATTERNS - Historical and Projected	I -0	I
F. RISK CONSIDERATIONS		
Legal Liability	0	N
Technical/Professional	0	N
Business	0	0
Political	0	0
G. NATIONAL POLICY CONSIDERATIONS		
Regulatory Agency Compliance (Federal, State, local)		
Environmental	1-0	I
Health/Safety	1-0	I
Energy	1-0	I
Economic Impacts of Using Substitutes	I -O-N	I
Political Impacts of Using Substitutes	O - N	0

1 = required and possible m system (hard data either technical or economic)

O = required but obtained outside system

N = generally not required by user group

TABLE 8.—Information Requirements for Substitution Analysis: Those Specifically Required by Materials Users are Underlined

A. DESIGN REQUIREMENTS

- Customer Acceptance
  - Esthetics
  - Personal Bias
  - Market Acceptability
- Performance Criteria
- <u>Materials Performance</u>
  - <u>Mechanical Properties</u>
  - <u>Chemical Propertles</u>
  - <u>Physical Properties</u>
  - <u>Fabricability</u>
  - <u>Machineabilltу</u>
  - <u>Toxicity</u>
  - <u>Ease of Joining</u>
  - <u>Corrosion, Oxidation and Fire Resistance</u>
  - <u>Compliance with Specifications and Codes</u>
- Protection Against Misuse
- Vandalism Protection
- <u>Reuse/Recyclablllty/DIsposal</u>
- <u>Compliance with Specifications and Codes</u>
- <u>Reliance and Maintainability</u>

B. ECONOMIC CONSIDERATIONS

- <u>Material Cost</u>
- <u>Cost/Price Stability</u>
- <u>Transportation Cost</u>
- Marketing Costs (to use substitute)
- Production Costs'
- Investment Required to Incorporate
- Life-Cycle Costs
- <u>Tariffs and Taxes</u>

C. Production CONSIDERATfONS

- <u>Availability of Fabrication Facilities</u>
- <u>Availability of Labor (specific skillsj</u>
- Production Rates Achievable
- Time Required to Incorporate Substitute
- <u>Use of Existing Facilities and Labor</u>
- <u>Energ y Requirements</u>
- Inspectability

D. MATERIALS SUPPLY/AVAILABILITY CONSIDERATIONS

- <u>Supply Present and Future, Current and Potential</u>
  - <u>Resources/Reserves</u>
  - <u>Stockpile Level</u>
  - <u>Imports/Exports</u>
  - <u>Defense Allocations</u>
  - <u>Inventories</u>
- Supply Assurance (including trade agreements)
- <u>Identify and Location of Supplies</u>
- <u>Forms of Materials Available</u>
- <u>Delivery Time (Lead Time)</u>

<u>E. END-USE PATTERNS & Historical and Projected</u>

F. RISK CONSIDERATIONS

- Legal Liability
- Technical/Professional
- Business
- Political

G. NATIONAL POLICY CONSIDERATIONS

- <u>Regulatory Agency Compliance (Federal, State, local)</u>
- <u>Environmental</u>
- <u>Health/Safety</u>
- <u>Energy</u>
- <u>Economic Impacts of Using Substitutes</u>
- political Impact of Using Substitutes

TABLE 9.—Information Requirements for Substitution Analysis: Those Specifically Required by Policy Makers are Underlined

A. DESIGN REOUIREMENTS

- Customer Acceptance
  - Esthetics
  - Personal Bias
  - Market Acceptability
- Performance Criteria
- Materials Performance
  - Mechanical Properties
  - Chemical Properties
  - Physical Properties
  - Fabricability
  - Machineabllity
  - Toxicity
  - Ease of Joining
  - Corrosion. Oxidation, and Fire Resistance
  - Compliance with Specifications and Code
- Protection Against Misuse
- Vandalism Protection
- Reuse/Recvclabilitv/Diaoosal
- Compliance with Soedifications and Codes
- Reliability and Maintainability

B. ECONOMIC CONSIDERATIONS

- Material Cost
- Cost/Price Stabllity
- Transportation Cost
- Marketing Costs (to use substitute)
- Productlon Cost>
- Investment Reqlured to Incorporate
- Life-Cvcle Costs
- Tariffs and Taxes

C. PRODUCTION CONSIDERATIONS

- Avallabllity of Fabrlcation Facllltles
- Avallabllty of Labor (speclflc skills)
- Production Rates Achievable
- Time Reqlured to Incorporate Substitute
- Use of Exlsting Facllltles and Labor
- Energy Requirements

D. MATERiALS SUPPLY/AVALASILtTY CONSIDERATIONS

- Supply—Present and Future, Current and Potential
  - Resources/Reserves
  - Stockpile Level
  - Imports/Exports
  - Defense Allocation
  - Inventories
- Supply Assurance (Including Trade Agreement~
  - Identity and Location of Supplies
  - Forms of Materials Available
  - Delivery Time (Lead Time)

E. END-USE PATTERN--Historical and Projected

- Supply--Present and Future, Current and Potential
  - Resources/Reserves
  - Stockpile Level
  - Imports/Exports
  - Defense Allocation
  - Inventories
- Supply Assurance (Including Trade Agreement)
  - Identity and Location of Supplies
  - Forms of Materials Available
  - Delivery Time (Lead Time)

F. RISK CONSIDERATIONS

- Regulatory Agency Compliance (Federal, State, Local)
  - Environmental
  - Health/Safety
  - Energy
- Economic Impacts of Using Substitute