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Appeared in
CIB Proceedings of the Fourth International Symposium on Building Economics
Copenhagen 1987
Session A — Methods of Economic Evaluation
p. 188-201
(IRC Paper No. 1538)

Price $5.00

NRCC 29020

Canada

A Framework for Evaluating Building Codes

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Keywords: Building codes, code evaluation.

Summary

The paper proposes a framework for evaluating building codes on the basis of technical, economic and social merits. The proposed framework may be used to reationalize existing building codes and to evaluate the introduction of new codes or changes in the existing ones. An example is provided to illustrate the model.

Mots clé: code du bâtiment, évaluation des codes.

Résumé

La présente documentation propose une méthode pour évaluer les codes du bâtiments d'après leurs valeur technique, économique et sociale. La méthode proposée peut être utilisée pour rationnaliser les codes du bâtiments existants et pour évaluer l'introduction de nouveaux codes ou de modifications aux codes existants. Un example est donnée pour illustrer le modèle.

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Introduction

The Third Symposium on Building Economics included a number of papers dealing with the economic aspects of building regulations(1),(2). In addition, the Danish Model by Bonke and Pederson(3) represented a good logic for proceeding with the exploitation of such a model. The subjective nature of much of the input data makes the drawing of firm conclusions elusive. This is made more difficult still when drawing general conclusions by the fact that regulations frequently vary from one jurisdiction to another.

The present paper starts off from where the Bonke and Pederson Model left, and attempts to systematically incorporate technical, economic and social aspects of building codes. It outlines a framework that can be used to rationalize existing code structure and to evaluate the introduction of new code provisions and the changes in the existing ones. The proposed framework is illustrated with an hypothetical example.

Components of the Framework

The proposed framework will have the following components:

1. Building code goals/objectives hierarchy structure
2. Building code requirements impacts
3. Performance measures
4. Database
5. Risk analysis.

Building Code Goals/objectives Hierarchy

Developing goals/objectives hierarchy structure is needed:

(1) to break the overall goal of building codes into a series of detailed objectives, down to a level at which objectives can be directly related to the design of different building components;

(2) to identify for different requirements in the building codes;

(3) to develop an Objective Interaction Matrix for detecting duplications;

(4) to identify the type of information that may be required for the assessment of different code requirements; and

(5) to identify evaluation methodologies for assessing different code requirements.

To illustrate this hierarchial structures, goals can be identified at different levels. For example, at level 1, a goal is defined in terms of main objectives of codes, e.g., safety, health, comfort, social concerns and government policy. At level 2, a distinction is made between the objectives that relate to construction phrase and those that concern with occupancy phase (see Figs. 1 and 2). Similarly, further breakdown of the goals can be undertaken.

For the proper assessment of the code requirements, relationships between different objectives need to be identified. An Objective Interaction Matrix is developed to achieve this purpose (Fig. 3). This figure exhibits the interaction between different design objectives. It also shows that a code requirement may relate to more than one objective (e.g., room size is related to health requirements as well as comfort).

Furthermore, requirements that satisfy one objective may have some effect on the performance of the building with respect to other objectives (e.g., fire confinement vs. ventilation, air quality).

Building Code Requirements Impacts

The impacts of building code requirements can be viewed from different perspectives. The builder may be interested in building code requirements that limit his choices and increase the building cost while the owner/occupant is concerned with safety requirements. Labour may be concerned with the impact of code provisions on employment while the manufacturer is concerned with the limitations on the use of raw material, manufacturing processes and new requirements for testing and standards.

Systematic determination of these impacts requires proper identification of (i) impact groups, and (ii) field of consequences. Impact groups include those industries (the construction, manufacturing, insurance, etc.) and individuals (developer, builder, designer, supplier, regulator) that are directly or indirectly affected by building codes. The Fields of Consequence include different components of a building project as well as particular impact categories such as technical impacts, economic impacts, and social impacts (see Tables 1 and 2). Each of these impacts can be estimated on projects, developer, owner, designer, supplier, regulator and on various industries such as manufacturing, real estate, insurance, etc.

At the preliminary stages, one may identify positive and negative impacts of a particular requirement. The positive impacts represent the benefits (improvements in safety/health, reduction in cost, increase in productivity, etc.) while, the negative impacts represent the costs (increase in risk of death/injury/damage, increase in cost, decrease in productivity, etc.).

FIELD OF CONSEQUENCE	TECHNICAL CONSEQUENCES	
BUILDING PROCESS	PLANNING/PROJECTION	- Limitation of choice
	DESIGN	- Enginering design - Architectural design
	CONSTRUCTION	- Productivity - Equipment - Material - Safety/protection
	OPERATION/ MAINTENANCE	- Energy consumption - Operating policy - Maintenance policy - Safety - Health - Comfort
MATERIAL/ EQUIPMENT	RAW MATERIALS	- Material limitation - Availability
	MANUFACTURING	- Standards - Performance
	DISTRIBUTION	- Availability - Design information
QUALITY/ SAFETY ASSURANCE	WARRANTY	- Demand for new warranties
	CERTIFICATION	- Demand for standards - Demand for testing procedure
	CODE ENFORCEMENT	- Demand for inspection policy

TABLE 1 - Technical Consequence Breakdown

FIELD OF CONSEQUENCE	SOCIO - ECONOMIC CONSEQUENCE	
ECONOMIC	DESIGN PHASE	- Design fee - Plan approval cost (Gov.) - Plan approval cost (Ower)
	CONSTRUCTION PHASE	- Material cost - Labour cost - Equipment cost - Building inspection cost - Certification cost - Financing cost - Administration cost
	OCCUPANCY PHASE	- Operating cost - Maintenance cost - Upgrading cost - Insurance cost - Taxes
SOCIAL		- Environment - Employment - Distribution impact - Accessability - Energy conservation

TABLE 2 - Socio - Economic Consequence Breakdown

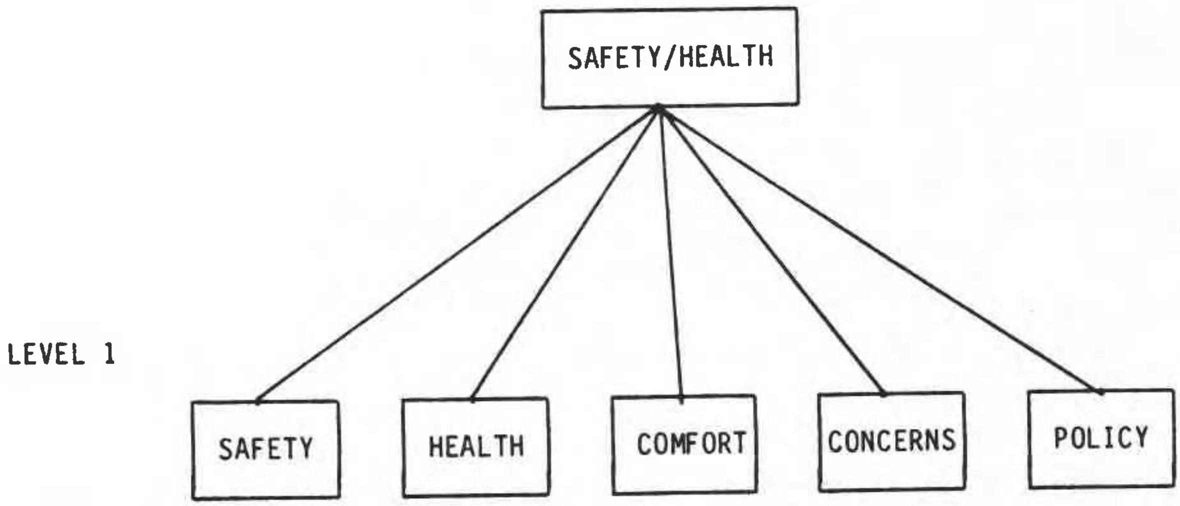

Fig. 1 Hierarchy of Overall Building Code Goal (Level 1)

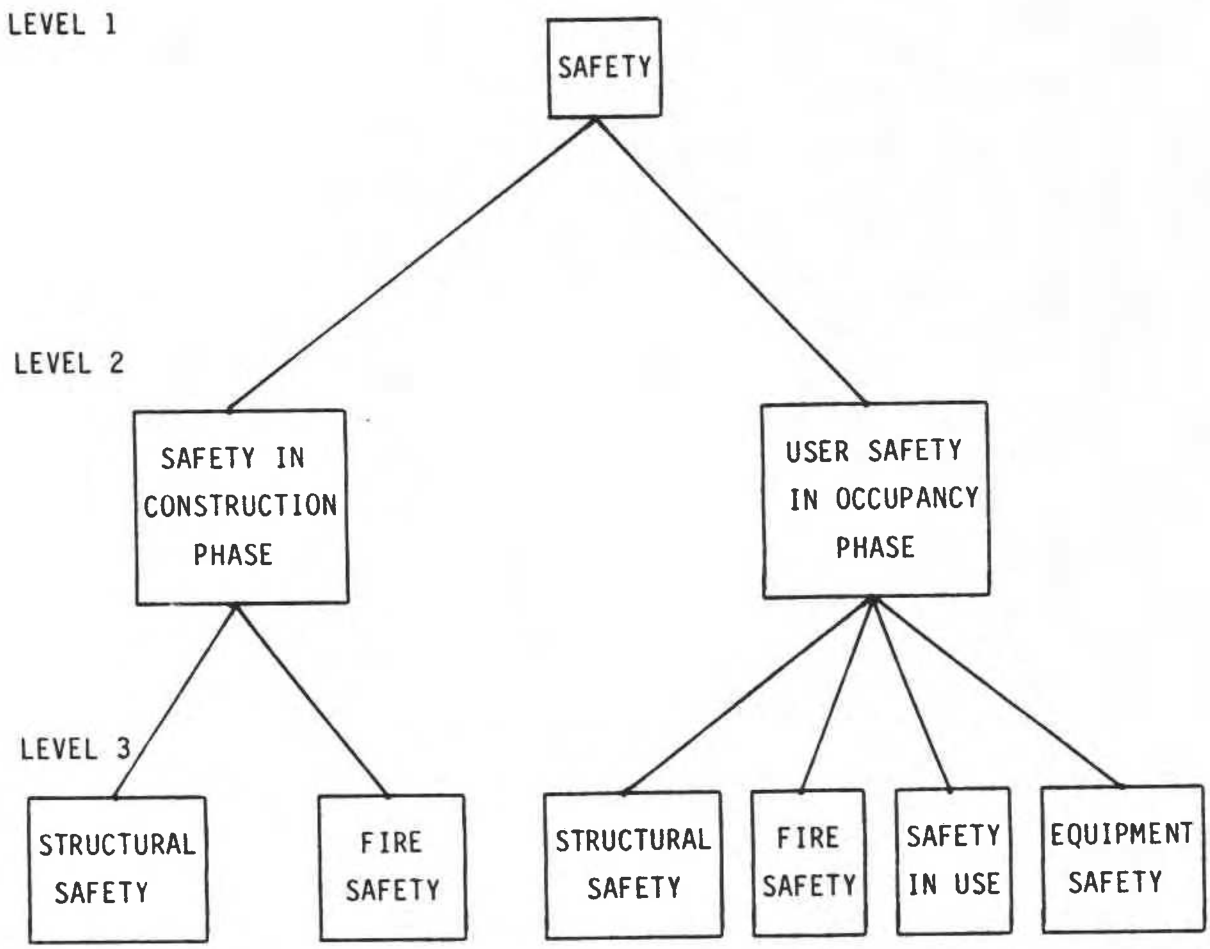

Fig. 2 Safety Objective (Levels 2,3)

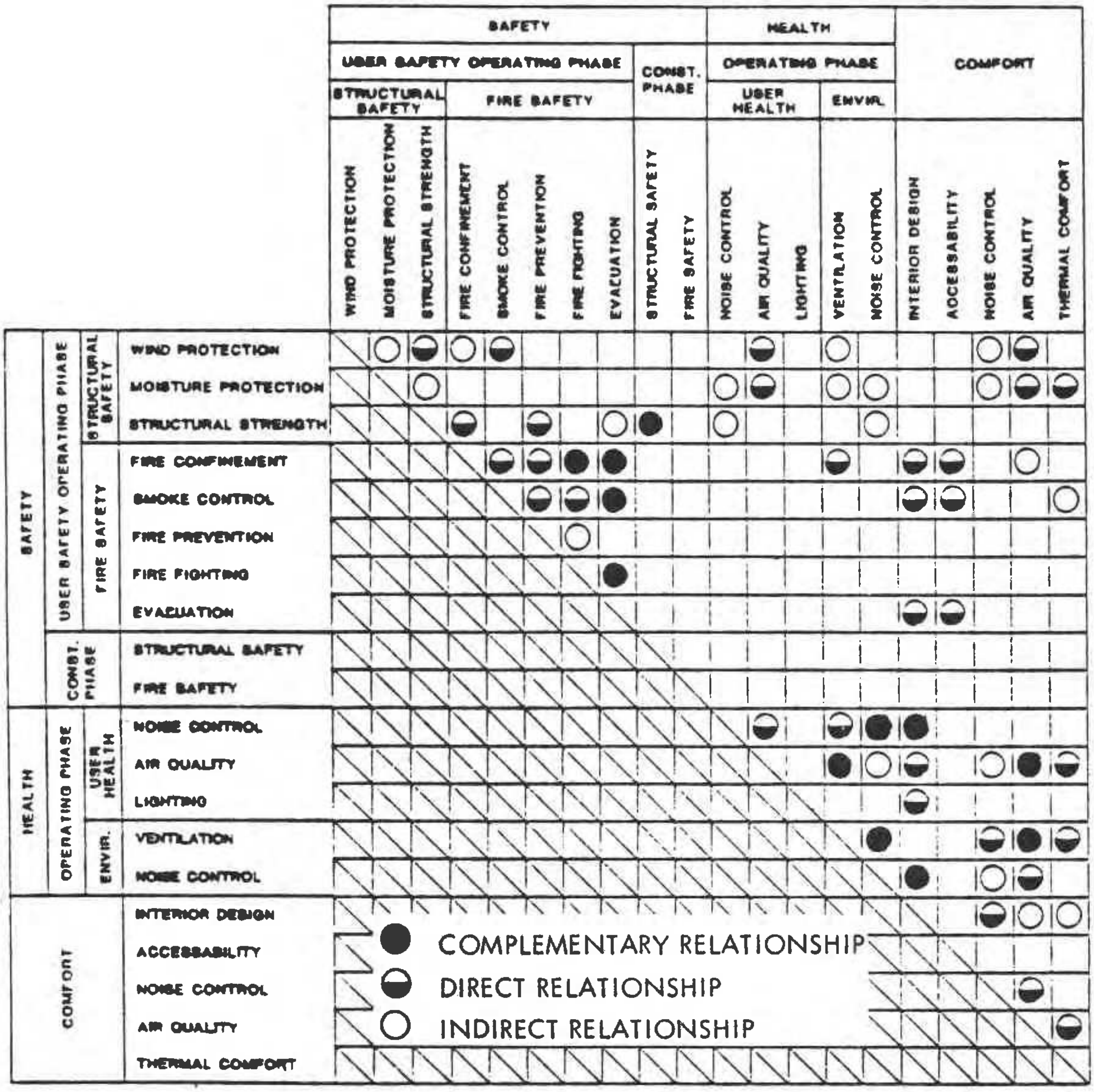

FIGURE 3

CODE OBJECTIVES INTERACTION MATRIX

Performance Measures

An appropriate set of performance measures that reflect the code objectives used to define in order to measure the impact of code requirements. These performance measures can be classified into three types:

(i) Technical performance measures,

(ii) Economic performance measures, and

(iii) Social performance measures.

The technical performance measures are required for evaluating the impact of code requirements on the technical performance of buildings; the economic performance measures for measurig the economic impact of code requirements on the impact groups; and the social performance measures will be needed to address the issue of code requirements impacts on the environment, people and other sectors of the society. The performance measures include qualitative measures such as accessibility and user comfort as well as quantitative measures such as energy consumption and probability of a fire-related injuries. Since the useful life of buildings (or their components) extend beyond their construction period, it is essential to consider the impact over a long period of time (e.g., 15-20 years); and, in doing so, to consider the time related factors such as inflation or effects of aging on buildings.

The following is a sample of the performance measures that may be used in the model.

Technical Performance Measures

- Probability of structural failure
- Probability of fire
- Probability of health hazards
- Energy consumption level
- Flexibility in use

Economic Performance Measures

- Life cycle costs
- Costs and benefits
- Productivity (labour, equipment, material)

Social Performance Measures

- Accessibility
- Comfort and user satisfaction

- Environmental pollution.

Date Base

The availability of a reliable data base for testing or working with any framework is as important as the framework itself. For evaluation purposes, information about the technical performance of buildings and other health and safety related requirements can be obtained from various sources.

Sources of the required data

Basically, there are three situations:

(i) Published information exists (e.g., fire-related statistics) and they only need re-structuring or refinement;

(ii) The information exists in different organizations, but in unorganized and unpublished forms. In this case, efforts will be made to investigate, collect and develop a data base. Also, as part of this exercise, a permanent system of data collection will be established; and

(iii) Technical information exists but is not available. In this case, a bank of technical experts, in different code related subjects, will be developed. The information will be collected through questionnaire or through other feasible means such as Delphi method.

Risk Analysis

One of the main objectives of developing the Code Assessment Framework is to enable the decision makers in the code advisory committees to make better-informed decisions by providing them with additional information about the impact of building code requirements, especially where the assessment is subjective. The final outcome of impact analysis would not be certain. The uncertainty will creep into the analysis because of varius assumptions made regarding certain parameters and insufficient or unreliable data used.

There are other uncertainties regarding the scope or quantity of things (e.g, number of bricks, pounds of steel, man hours) and the unit cost of things at the time when these costs are actually incurred. There are also uncertainties regarding the timing of actual occurrence of these costs. The risk analysis will expose the significance of uncertainties associated with various assumptions and quantities and costs of impacts.

The two leading approaches to uncertainty assessment are: the sensitivity approach and the probabilistic approach.

Sensitivity analysis, in the sense of response to variations, can be of two types: quantitative and qualitative. Quantitative sensitivity is defined as the numerical measures of changes in output to variations of input (parameters). The qualitative aspect of sensitivity analysis deals with model design. It refers to the capability of a model to respond to dynamic changes in the subject being modeled.

The sensitivity analysis is performed by varying different values of inputs (or parameters) and thereby obtaining different values for corresponding outputs. In this way, upper and lower bounds of output can be established.

Probability analysis relies on the use of probabilities rather than the repetition of the evaluation process (as is the case in sensitivity analysis). It is useful when (1) there is more than one possible condition or "state of nature" that can occur; (2) the outcome of the project may differ depending on the state that occurs; and (3) the probability or the relative frequency with which each possible state is expected to occur can be used to calculate the average, or "expected", value of possible outcomes weighted according to their frequency of occurrence. With the help of probability analysis, different alternatives with different states and probabilities can be compared to each other.

An Illustrated Example

This section provides an hypothetical illustration of how the assessment model might be applied in a practical situation. For this purpose, the general area of fire safety requirements has been chosen. This is one of the most comprehensive and fast-growing sections of building codes. Unfortunately, this growth is mainly a reactive (and possibly unreasoned) response to fire accidents. In general, it is not the result of well-directed research regarding fire safety nor is it the strategic accumulation of informative statistics regarding fires, e.g., configuration of the building, type of construction, level of compliance with the code, facilities that were useful in limiting or extinguishing the fire, etc. As a result, there is a general feeling that requirements have increased on ad hoc basis without proper justification.

As an example, consider the case of the requirement for "fire hose cabinets" in large buildings. They cost hundreds of thousands of dollars to install and equip. But are they effective? Do occupants use them? Do they cause accidents and damage? Do fire fighters use them? Do they create a false sense of security? In short, are they worthwhile or are they wasteful?

The problem is complex. Many issues must be considered and much data assembled. In the first place, the issue must be looked at in the whole context. In this case, this means a reviw of the "fire confinement" area of the code in which the provision of fire hose cabinets is one of the requirements. How do fire hose cabinets contribute to fire safety objectives? What is their marginal contribution to the cumulative impact of the combined requirements? Are other requirements more effective or more cost/effective?

In this example, the complementary code requirements with respect to fire confinement are: (i) fire resistance ratings; (ii) fire separation ratings; (iii) fire spread ratings; (iv) sprinklers (regular/fast response); (v) hose cabinets; (vi) stand pipe water supplies; (vii) portable extinguishers.

Obviously, several carefully selected evaluation criteria are required. In our hypothetical example, we have used the following:

- Probability of fire
- Probability of death per fire
- Probability of injury per fire
- Probability of damage per fire
- Probability of safe evacuation
- Average damage cost per fire
- Life cycle cost (20 years) (owner)
- Life cycle cost (industry)

Obviously, other criteria could be used as well, such as cost to provincial governments or to regulatory agencies.

One may obtain a grasp of how the model requires the analysis is to be carried out by examining Table 3. This Table shows the type of information that would be required for the analysis and how it would be used to derive decision-making results. The Table is a matrix of quantified evaluation criteria versus cumulative code requirements. It provides the supporting data for subsequent steps in the analysis process. If an analyst wished to obtain the probable cost of a fire in a particular type of building, he would multiply the probability of fire by the average damage cost/fire. If he wished the total expected fire costs for this type of building, he would multiply the previous result by the number of buildings of this type.

The information in the table is not factual but is reasonably realistic.

CODE REQUIREMENTS

	(1) FIRE RESISTANCE RATINGS	(2) (1)+FIRE SEPARATION RATINGS	(3) (2)+FLAME SPREAD RATINGS	(4) (3)+ SPRINKLERS	(5) (4)+HOSE CABINETS	(6) (5)+ STANDPIPE WATER SUPPLIES	(7) (6)+INTERIOR DESIGN REQUIREMENTS
PROBABILITY OF FIRE	0.008	0.008	0.008	0.006	0.006	0.006	0.006
PROBABILITY OF DEATH/FIRE	0.007	0.006	0.004	0.002	0.0018	0.001	0.0008
PROBABILITY OF INJURY/FIRE	0.04	0.037	0.03	0.02	0.025	0.018	0.015
PROBABILITY DAMAGE/FIRE	0.3	0.3	0.3	0.3	0.3	0.3	0.3
PROBABILITY OF SAFE EVACUATION	0.8	0.9	0.95	0.98	0.98	0.99	0.998
AVERAGE DAMAGE COST/FIRE	?	?	?	?	?	?	?
COST TO OWNER (OVER 20 YRS)	?	?	?	?	?	?	?
COST TO INDUSTRY	?	?	?	?	?	?	?

Table 3 - Cumulative Impact of Fire Confinement Requirements Contained in the Building Code.

Since there is no existing data bank of cost or technical information, it is not possible even to speculate as to the total economic impact of the requirements (note many question marks). These question marks dramatically demonstrate the need for the development of a complete and comprehensive data base. Reliable decision making is directly dependent on the input of adequate supporting information. A large amount of information must be assembled to carry out a complete analysis. Some of the input data required for this example are:

- Total number of buildings that are (will be) affected by a code requirement
- Total number of reported fires in this building category
- Number of deaths and injuries in these fires
- Type of construction, and fire-safety features in buildings with fire accidents
- Marginal impacts of the complementary code requirements
- Increasing costs and reducing the risk of fire/death/injury/damage.

As a matter of interest, Fig. 4 which depicts the data for the first criteria in bar-chart form, has been prepared. It shows how each additional code requirement reduces the risk of hazard in buildings. Note, however, that it indicates that the addition of requirement "5" decreases the risk of fire or death but that it increases the risk of injury. An injury could result from the improper use of such a facility in a panic situation. Even at this stage, our hypothetical example implies that the provision of fire hose cabinets results in no significant increase in fire safety and that their cost is unwarranted in this particular case.

The next step in the analysis would be to examine alternate combinations of requirements. In one of these combinations, fire hose cabinets might prove to be cost/effective. The essential point is that no individual requirement should ever be considered in isolation. The overall cumulative impact of any combination of requirements must always be determined.

The full analysis of the fire hose cabinet requirement would require the completion of an impact analysis as outlined earlier. The impact of fire hose cabinet requirements on various actors could be negative or positive.

The next step would be to convert these qualitative symbols to quantitative figures wherever possible. It is this total information package that decision makers will consider, in conjunction with associated risk analysis data, to come to a reasoned conclusion.

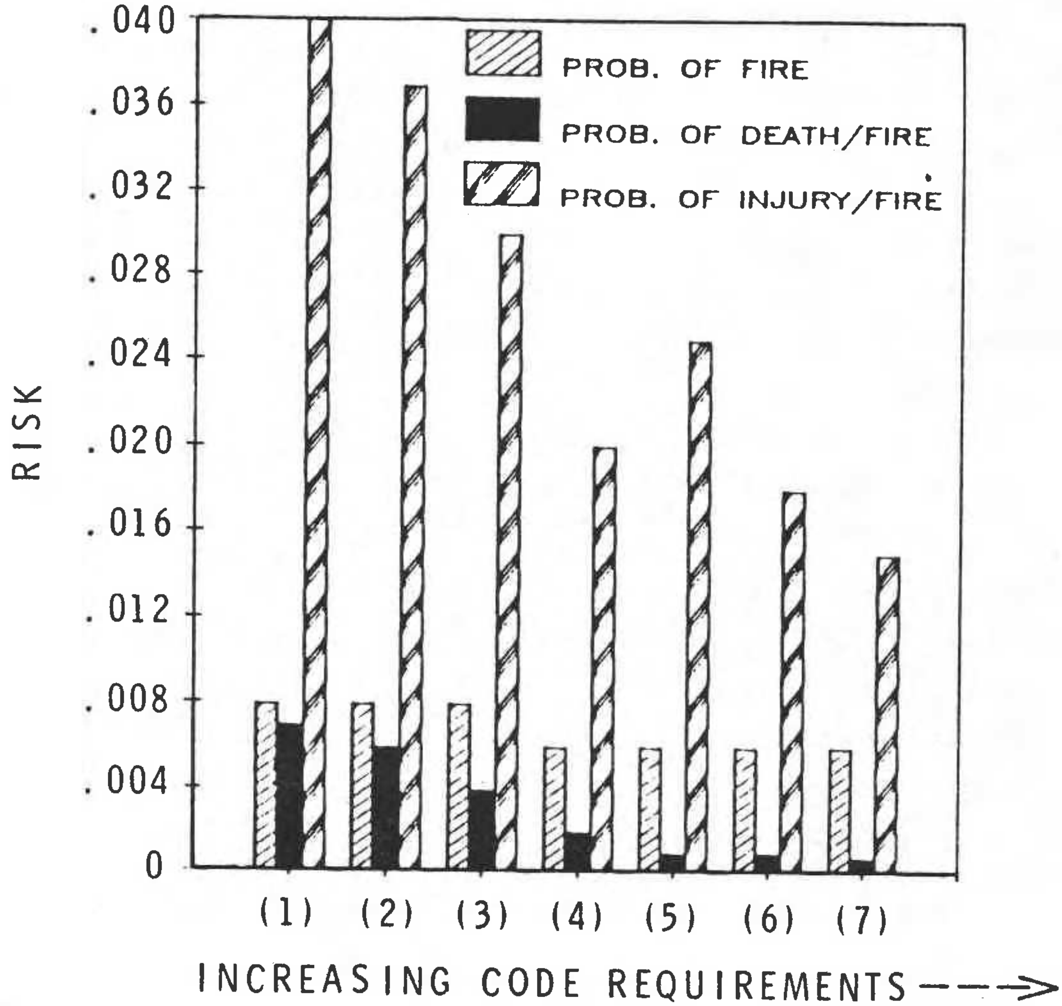

FIGURE 4

CUMULATIVE IMPACT OF FIRE CONFINEMENT REQUIREMENTS IN BUILDING CODE

Concluding Remarks

The paper has outlined the framework for technical and economic evaluation of the building codes. The proposed framework is designed to provide a practical, comprehensive decision making tool that is capable of evaluating code requirements with respect to their goals and objectives. The model is also capable of identifying different actors involved in a building project (owners, users, architects/engineers, contractors/subcontractors, governments ...etc.) and the different sectors of the industry (construction, manufacturing, real estate, insurance, etc.) that are affected by building codes. The ultimate success of the proposed framework will depend on the availability of technical and economic data.

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