U.S. Department of Housing and Urban Development
Office of Policy Development and Research

# A Suggested Methodology for Estimating the Cost Impact of Changes to the Model Building Codes

## FINAL REPORT
## August 1994

*Keeping the American building industry on the cutting edge of technology*

NAHB RESEARCH CENTER

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Prepared for

**The U.S. Department of Housing and Urban Development**
**Office of Policy Development and Research**
Washington, DC

Prepared by

**NAHB Research Center**
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Notice

Acknowledgements

This report was prepared by the NAHB Research Center under funding provided by the U.S. Department of Housing and Urban Development. The principal author was Phil C. Davis, with technical assistance and review provided by David Dacquisto. Special appreciation is extended to William Freeborne, U.S. Department of Housing and Urban Development, for guidance and review throughout the project.

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# 1.0 INTRODUCTION

## 1.1 Purpose and Background

The purpose of this document is to present a systematic methodology for estimating the cost impact of building code changes. Although none of the major model code organizations currently requires the submission of cost impact information as part of the code change process, access to reliable, well-documented estimates of cost impacts would assist decision makers and participants in understanding the implications of proposed changes. This document provides a simple methodology for deriving such estimates.

The methodology addresses only the impact of code changes on the cost of construction. This is an important issue that should never be overlooked, but it is not the only issue that should be considered in evaluating a proposed code change. Potential benefits, enforceability and impact on the entire system of code administration also are relevant to an ultimate determination of the appropriateness of any given proposal. Those issues may be difficult to assess and generally are beyond the scope of this methodology.

The approach is based on methods described in earlier research[1] identified in a literature search conducted in Task 1 of this project.

## 1.2 Approach and Scope

While the ultimate output of the methodology can be estimates of future and/or aggregate cost impacts on homebuyers, the methodology focuses primarily on developing estimates of per house

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[1]*Economic Impact of Building Codes*, National Bureau of Standards, U.S. Department of Commerce, Washington, DC, January 1977.

*An Economic Analysis of Building Code Impacts: A Suggested Approach*, National Bureau of Standards, U.S. Department of Commerce, Washington, DC, October 1978.

*Estimating Benefits and Costs of Building Regulations: A Step by Step Guide*, National Bureau of Standards, U.S. Department of Commerce, Washington, DC, June 1981.

*Estimating Economic Impacts of Building Codes*, National Bureau of Standards, U.S. Department of Commerce, Washington, DC, November 1981.

or per unit cost impacts on homebuyers in the immediate future. These impacts are based on the use of selected individual buildings or units termed "representative types." These types are termed representative because they exemplify buildings or units affected by a code change.

While such per unit cost impact estimates can be extended to address aggregate and/or future impacts on potential homebuyers, the basic output is useful in and of itself to decision makers. The per unit cost impact estimates carry a minimum of uncertainty and controversy, while imposing limited data demands on the user. It is hoped that this flexible approach will allow the analyst to produce usable results under a variety of conditions and constraints.

This report is organized into four sections and four appendices. Section 1.0 provides an introduction. Section 2.0 presents and discusses the methodology. Section 3.0 discusses aggregation of the per unit cost impacts and extension of the results into estimates of cost impacts in future years. Section 4.0 presents concluding remarks. Appendices A, B and C list sources of various data that can be used with the methodology in deriving cost impact estimates. Appendix D contains blank forms that can be copied and used in computing and documenting estimates of cost impacts.

The following section presents the recommended methodology. The discussion provides a brief explanation of the steps involved in the process and is followed by a more detailed discussion of each step. Examples of recently proposed or adopted code changes illustrate issues related to the methodology. Despite references to a variety of code changes, most of the discussion pertains to two code changes proposed in recent years.

The first example is a proposed modification to the seismic provisions contained in Article 11 of the 1990 Building Officials and Code Administrators International (BOCA) *National Building Code* (*NBC*). Subsequently modified before adoption, the change represented a shift in the basis of seismic requirements. While the seismic requirements in the 1990 *NBC* were based on ASCE 7, the requirements incorporated into this proposed change were based on the provisions of the National Earthquake Hazards Program (NEHRP) *Recommended Provisions for the Development of Seismic Regulations for New Buildings*. This example is referred to by the number assigned to it as a proposed change: B223-91.

The second example is a change adopted by the International Conference of Building Officials (ICBO) *Uniform Building Code* (*UBC*) and requires the installation of smoke detectors in all residential bedrooms in addition to the installation of smoke detectors in the previously required locations. The proposed change had a designation of Item 110, 1210(a)90-1. It will be referred to as ICBO Item 110 in this document.

## 2.0 METHODOLOGY

### 2.1 Steps in the Methodology

The methodology consists of the following six steps:

*1. Provide basic information* to establish the general framework for the assessment of the cost impact of a building code change. This task calls for developing a statement of the scope and time period of the assessment and explaining the rationale for the analysis.

*2. Develop a description of the code change* to explain the code change. The description is the basis for selecting representative types of residential units affected by the change, guides the development of designs that depict the impact on the structure and helps identify sources of "soft" or nonconstruction cost impacts.

*3. Select representative housing type(s)* to specify examples of buildings or units affected by the code change. The selected units must be consistent with information developed in Steps 1 and 2 as they become the basis for Step 4.

*4. Depict the physical impact* to portray the effects of the code change on the construction of the selected representative housing types. This step consists of developing designs or graphic renderings of the representative types constructed both with and without the code change. The information contained in the code change description is augmented with a description of the change in the structure(s) specified and the techniques and practices necessary to accomplish the changes.

*5. Estimate cost impacts* based on the results of Steps 2 through 4. Information on potential sources of soft costs identified in Step 2 are combined with data on the changes in construction illustrated in the designs developed in Step 4 to produce estimated cost impacts for the representative housing types.

*6. Perform sensitivity analysis* to test the impact of varying the input data that produced the cost estimates in Step 5.

## 2.2 Examination of Each Step

A more detailed discussion of each step follows.

### *2.2.1 Step 1: Provide Basic Information*

The first step in the development of the cost estimates establishes the general framework of the analysis. It involves identifying the code change to be analyzed and explaining the rationale for the assessment. The scope of the analysis should be clearly stated and include the time frame of the analysis and the geographic region for which the costs are to be developed. Finally, any further constraints or qualifications to those basic assumptions should be clearly stated.

The time frame of the analysis is the period during which the units whose costs are subject to estimation are assumed to be constructed. In its most basic form, this period will be the near future, i.e., the period immediately following adoption of the code change. If the analyst's intent is not to develop aggregate cost estimates, the use of current cost data eliminates the need for projected rates of inflation. If the analyst's intent is to develop aggregate cost estimates, the coming year might be the logical time frame for the analysis, assuming that construction activity for the period can be estimated or that data on the average levels of construction can be used. Of course, if the ultimate aim is to develop estimates over some extended time frame, appropriate data will be required. In any case, the analyst should clearly state the time period for which the estimates are to be developed.

The geographic region used in the analysis can be an entire model code region, a specific state or a particular locality. The geographic unit may affect costs as well as requirements that vary geographically (e.g., seismic protection).

The information provided in this step helps focus the study at the outset and aids the ultimate user in understanding the basis for the estimates.

### 2.2.2 *Step 2: Develop a Description of the Code Change*

This is the first step in turning what is often a technically worded code change into a description of the impact on the design and construction of selected residential buildings. The description provides the basis for developing graphic mock-ups for subsequent material, labor and equipment take-offs. It also identifies potential nonconstruction impacts and may explain the assumptions and processes needed to develop the cost estimates. The inclusion of a description of parts or all of the unamended requirements may also be required to serve as background in the development of the cost impact estimate.

At this stage, the description of some changes may be stated in general terms. For example, further details about specific impacts on design and construction of changes to provisions relating performance standards may be delayed until Steps 3 and 4.

A simple example of a description of ICBO Item 110, delineating the new smoke detector requirement and providing required background information, reads as follows:

> Section 1210 (a) 4 of the ICBO *UBC* which governs the installation of smoke detectors in dwelling units has been amended to require a smoke detector in each sleeping room in addition to those required before adoption of this requirement.
>
> The requirements prior to the adoption of this change are as follows: One detector must be centrally installed in the hall or area providing access to each sleeping room. For multistory buildings or buildings with basements, one detector must be installed on each story and in the basement. Further, if a story or basement is split into two or more levels, a smoke detector must be installed on the upper level and when a sleeping area is located on the lower level, a smoke detector must be installed on each level. When the bedrooms are on the upper level, the detector must be installed at the ceiling close to the stairway. Additionally, if the hall connects to an open room with a ceiling height exceeding that of the hall by 24 inches or more, smoke detectors must be installed in both the hall and the adjacent room. Finally, the alarm must be audible in all sleeping areas.

Obviously, this change does not represent a major modification to the original requirements governing smoke detector installation. Rather, it simply requires the installation of additional smoke detectors. Nevertheless, some interpretation of the requirements is needed. Accordingly, the following statement would be added to the description:

> The requirement that the alarm be audible in all sleeping areas means that the actuation of any of the smoke detector alarms should activate the alarms in every bedroom.

The magnitude, complexity and impact of code changes can vary greatly and have implications for the development of the description. The adoption of BOCA's B223-91, unamended, would have resulted in the deletion of 56 numbered sections, tables or figures and the insertion of 88 new sections, tables or figures. Other changes—B213-92, B214-92 and B215-92—on the other hand, proposed only to change single tables or numbered sections of the code.

B223-91 is also a complex code change. In addition to replacing most of the existing requirements, its approach to varying requirements results in the impact of the code change varying greatly among different types of structures, depending on whether a unit is multifamily or single-family, what material is used in the construction of the seismic load resisting frame and the "Seismic Performance Category" of a unit.

The experience with B223-91 helps illustrate a point. At times, a preliminary examination of a code change may suggest that the impacts will vary greatly according to some multiple set of characteristics. For example, the requirements embodied in B223-91 differ between single-family and multifamily housing and by framing material and seismic performance category (SPC). To allow an effective and efficient analysis of the impacts, the requirements for each of the performance categories might need to be separated according to category. The requirements in the provisions to be replaced would then need to be organized into like categories for comparison. A first step might be the development of comparative lists of the requirements under both the old and new provisions that would affect different types of housing (see Table 1).

| Table 1<br>COMPARISON OF SEISMIC REQUIREMENTS | | |
|---|---|---|
| **Category** | **1990 NBC** | **B223-91** |
| | **R-3 Buildings** | |
| $A_v < 0.15$ | Exempt | Exempt |
| $0.15 \le A_v < 0.20$ | | |
| ≤ 35 feet and light wood-frame seismic load-resisting system | Exempt | Comply with Section 1113.3.6.1 |
| > 35 feet and light wood-frame seismic load-resisting system | Exempt | Comply with requirements for SPC C buildings |
| Masonry constructed seismic load-resisting system | Exempt | Comply with requirements for SPC C buildings |
| $0.20 \le A_v$ | | |
| ≤ 35 feet and light wood-frame seismic load-resisting system | Comply with requirements in Section 1113.0 | Comply with Section 1113.3.6.1 |
| > 35 feet and light wood-frame seismic load-resisting system | Comply with requirements in Section 1113.0 | Comply with requirements for SPC D buildings |
| Masonry constructed seismic load-resisting system | Comply with requirements in Section 1113.0 | Comply with requirements for SPC D buildings |
| | **R-2 Buildings** | |
| $A_v < 0.05$ | Comply with Sections 1113.11.1 and 1113.11.2 | Comply with Section 1113.3.6.1 |
| $0.05 \le A_v < 0.10$ | | |
| light wood-frame seismic load-resisting system | Comply with Sections 1113.11.1 and 1113.11.2 | Comply with Section 1113.3.6.1 |
| Masonry constructed seismic load-resisting system | Comply with Sections 1113.11.1 and 1113.11.2 | Comply with requirements for SPC B buildings |
| $0.10 \le A_v < 0.15$ | Comply with requirements in Section 1113.0 | Comply with requirements for SPC C buildings |
| $0.15 \le A_v < 0.20$ | Comply with requirements in Section 1113.0 | Comply with requirements for SPC C buildings |
| $0.20 \le A_v$ | Comply with requirements in Section 1113.0 | Comply with requirements for SPC D buildings |

Table 1 presents separate comparative requirements for single-family (R-3) and multifamily (R-2) dwelling types. The term $A_v$ refers to the effective peak velocity-related rate of acceleration—a measure of seismicity—taken from maps included in the code. The reference to the requirements for a specific SPC (seismic performance category) refer to the provisions in B223-91 which regulate the design and construction of residential buildings classified into each seismic performance category. It should be noted that this analysis does not address any differences between the seismic maps contained in the 1990 edition of the BOCA *NBC* and B223-91.

The analyst can formulate and examine lists of specific sections of the code that include the requirements for buildings constructed in each SPC and then perform a preliminary comparison of the requirements. Table 2 illustrates such a list of design and construction requirements for one subset of housing identified in Table 1 and presents a brief discussion of the referenced sections. The process of separating requirements at this point in the analysis allows the analyst the choice of developing more detailed descriptions of selected building types or addressing the entire set of regulated residential building types.

## Table 2
## REQUIREMENTS FOR SPC B R-2 USE GROUP BUILDINGS

Buildings in Seismic Performance Category B must comply with the following requirements:

Table 1113.3.3—Structural Systems
Table 1113.3.4.2—Vertical Structural Irregularities
Section 1113.3.5.2—Seismic Performance Category B and C (Analysis procedure)
Section 1113.3.6.1—Seismic Performance Category A (Design, detailing requirements and structural component loads)
- Section 1113.3.6.1.1—Ties and continuity
- Section 1113.3.6.1.2—Concrete and masonry wall anchorage

Plus
Section 1113.3.6.2—Seismic Performance Category B (Design, detailing requirements and structural component loads)
- Section 1113.3.6.2.1 Materials
- Section 1113.3.6.2.2 Openings
- Section 1113.3.6.2.3 Orthogonal effects
- Section 1113.3.6.2.4 Discontinuities in vertical system
- Section 1113.3.6.2.5 Nonredundant systems
- Section 1113.3.6.2.6 Collector elements
- Section 1113.3.6.2.7 Diaphragms
- Section 1113.3.6.2.8 Bearing Walls
- Section 1113.3.6.2.9 Inverted pendulum-type structures

and
Section 1113.4 Equivalent Lateral Force Procedure

Buildings in Seismic Performance Category B must comply with the design, detailing requirements and structural component load effects for buildings in Seismic Performance Category A, plus the structural design requirements of Section 1113.3.3, the building configuration requirements of Section 1113.3.4, the analysis procedure of Section 1113.5 and the additional design, detailing requirements and structural component load effects of Section 1113.3.6 for Category B. The sections and tables listed above reflect that combination of requirements.

Section 1113.3.3 requires all buildings of Seismic Performance Category B to comply with the building height and structural system limitations in Table 1113.3 for the selected base structural system. The most common building systems found in residential construction are bearing wall systems and building frame systems. This table presents no building height limitations for those systems for SPC B. Section 1113.3.4 states that buildings will be classified as regular or irregular based on plan and vertical configuration. Type 5 vertical irregularity (weak story) in Table 1113.3.4.2 of that section is the only building irregularity relevant to Seismic Performance Category B. The item refers the user to the requirements in Section 1113.3.6.2.4.

Finally, according to Section 1113.3.5.2, both regular and irregular buildings must be analyzed according to Section 1113.4.

Other factors can complicate the development of code change descriptions. In the case of prescriptive requirements, which are explicit statements of what the builder is required to do, the analyst may be able to convert a code change directly into a general description of the change in construction practices—all with little interpretation. For example, the general implications for the design and construction of a building that complies with the requirements in ICBO Item 110 is readily apparent. On the other hand, performance requirements provide a functionality standard that some material or component must meet. For example, the seismic requirements in both Article 11 of the 1990 *NBC* and B223-91 include methods of computing "base shear."

Typically, performance requirements are more abstract than prescriptive requirements and frequently require substantial work to translate them into specific changes in design and construction practices.

As noted earlier, the description of the code change provides the basis for developing graphic mock-ups for subsequent material, labor and equipment take-offs; identifying potential nonconstruction impacts; and documenting the process used to develop the cost estimates.

### *2.2.3 Step 3: Selection of Representative Types*

The term "representative type" denotes a building selected to typify housing affected by a change in code requirements. The representative type is the basis for developing the "before" and "after" designs that illustrate the impact of the code change.

The impact of many code changes on the construction of residential structures will be most apparent through the modification of existing practices. The modified practices must be isolated before assessing a code change's cost impact. To isolate a change, the new requirements must be applied to the design of some appropriate residential structure(s). First, however, appropriate residential structure(s) must be identified. These structures are termed "representative types."

To allow the accurate portrayal of the impact of a code change, a representative type must:

- typify the residential units or some subset of those residential units affected by the change; and,

- characterize the residential construction occurring in the region governed by the code change.

The term "representative type" should not be taken as merely suggesting some common type of construction. The selection process must extend to a careful examination of the description of the code change to identify significant factors for various housing types. Such factors can vary greatly. The exceptions granted in B223-91, for example, consider the materials used in constructing seismic load-resisting systems, whereas the exceptions in the 1990 *NBC* requirements do not. Factors influencing the impact of the code change are not limited to the physical characteristics of the building. For example, the requirements of B223-91 also vary by the building's "seismic performance category." For any given type of building, these categories represent measures of seismic risk as depicted on a map of the United States. Thus, the requirements embody a clear geographical component.

The rationale for the analysis should guide both the consideration of the description and choice of a representative building or unit. If the code change's potential impact on the cost of "affordable", entry-level housing prompted the analysis, it would be inappropriate to select for analysis an upscale, detached, 4,000-square-foot single-family house. This is not to say that all cost-impact analyses must address affordable housing. For example, concerns about the overall impact of a proposed code change would suggest careful selection of the representative type(s) to ensure that the estimate can be generalized. In such cases, the selection of the representative types(s) would depend on the prevalence of each house type affected by the code change. If the assessment is prompted by concerns over a code change's potential impact on a given category of residential units within a code area, the representative type must reflect the characteristics of the affected buildings of that kind within that region.

Although the predominant construction techniques and characteristics of residential units constructed in the different regions of the country may be well-known, the analyst may wish to apply statistical analysis when deciding between candidates for representative types. For example, suppose the rationale for examining the requirement for smoke detectors in all bedrooms is a concern over the cost impact on typical new single-family detached residences, the following type of statistical information would aid in defining a representative type.

> A recent analysis of data contained in the *Annual Builder Practices Survey* (*ABPS*) database indicates that about 51 percent of single-family detached houses constructed in 1992 with 4,000 or less square feet of living space in states that adopt the *UBC* were two-story structures. The average number of bedrooms in these residences was 3.71; the average amount of living space on the second story was 1,043 square feet.

This information indicates that one viable representative type would be a 35-foot by 30-foot, two-story, single-family detached house with four bedrooms. The *ABPS* is not the only source of data on housing characteristics. Appendix A lists currently available sources of data on housing characteristics.

If the goal of the analysis is to extend the cost-impact estimates for the representative types into aggregate estimates, then the analyst will require information on either the number or percent of each representative type. In such cases, the data can be developed as part of the identification of representative types. In some instances, detailed statistical data may not be required. For example, it is conceivable that consideration of a code change could indicate that a clearly defined subset of housing would be impacted and the analyst does not intend to develop aggregate estimates. In some cases, reliable relevant statistical data may not be available.

If the analysis calls for multiple representative types, the analyst should organize the information to be developed for each type. For example, Table 3 illustrates the selection of two representative types for analysis of B223-91. The table provides a numeric designation and a brief description of each representative type.

**Table 3**
**DESCRIPTION OF REPRESENTATIVE TYPES 1 & 2**

| Representative Type 1 | Representative Type 2 |
|---|---|
| Three-story wood-framed multifamily building in area where $0.10 \leq A_v < 0.15$ | Three-story masonry-framed multifamily building where $0.05 \leq A_v < 0.10$. |

### *2.2.4 Step 4: Depict Physical Impact*

The purpose of this step is to translate the requirements as described in Step 2 into specific construction practices that would be applied to the representative types selected in Step 3. Step 4 usually requires the development of some form of graphic mock-up such as floorplans for each representative type both with and without the code change. These plans or designs serve two purposes: they provide the basis for developing estimates of the change in the use of labor and materials as inputs to the cost analysis in Step 5, and they provide visual documentation of the impact of the code change for submission along with the cost estimate data.

Figures 1 and 2 illustrate designs portraying the effects of the requirement for additional smoke detectors in the bedrooms contained in ICBO Item 110. Figure 1 is the layout of the second story of the representative unit under the old requirement. A single smoke detector (denoted by "X") is centrally located in the hall ceiling adjacent to the stairs and bedrooms. Figure 2 presents the design under the new requirement and includes an additional smoke detector in each

**Figure 1**
**PROPOSED CHANGE - ITEM 110**
**REPRESENTATIVE TYPE 1 - "BEFORE" DESIGN**

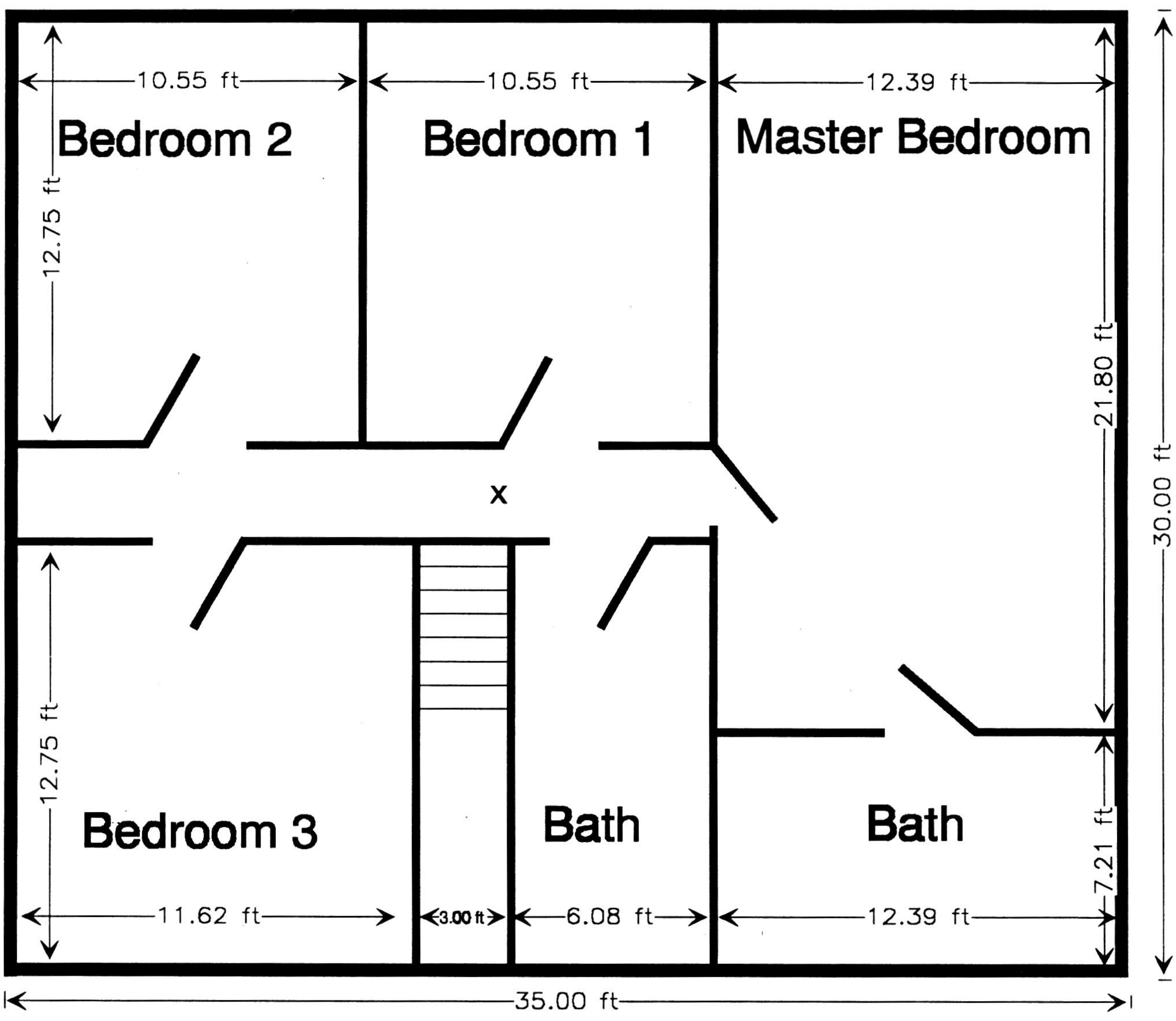
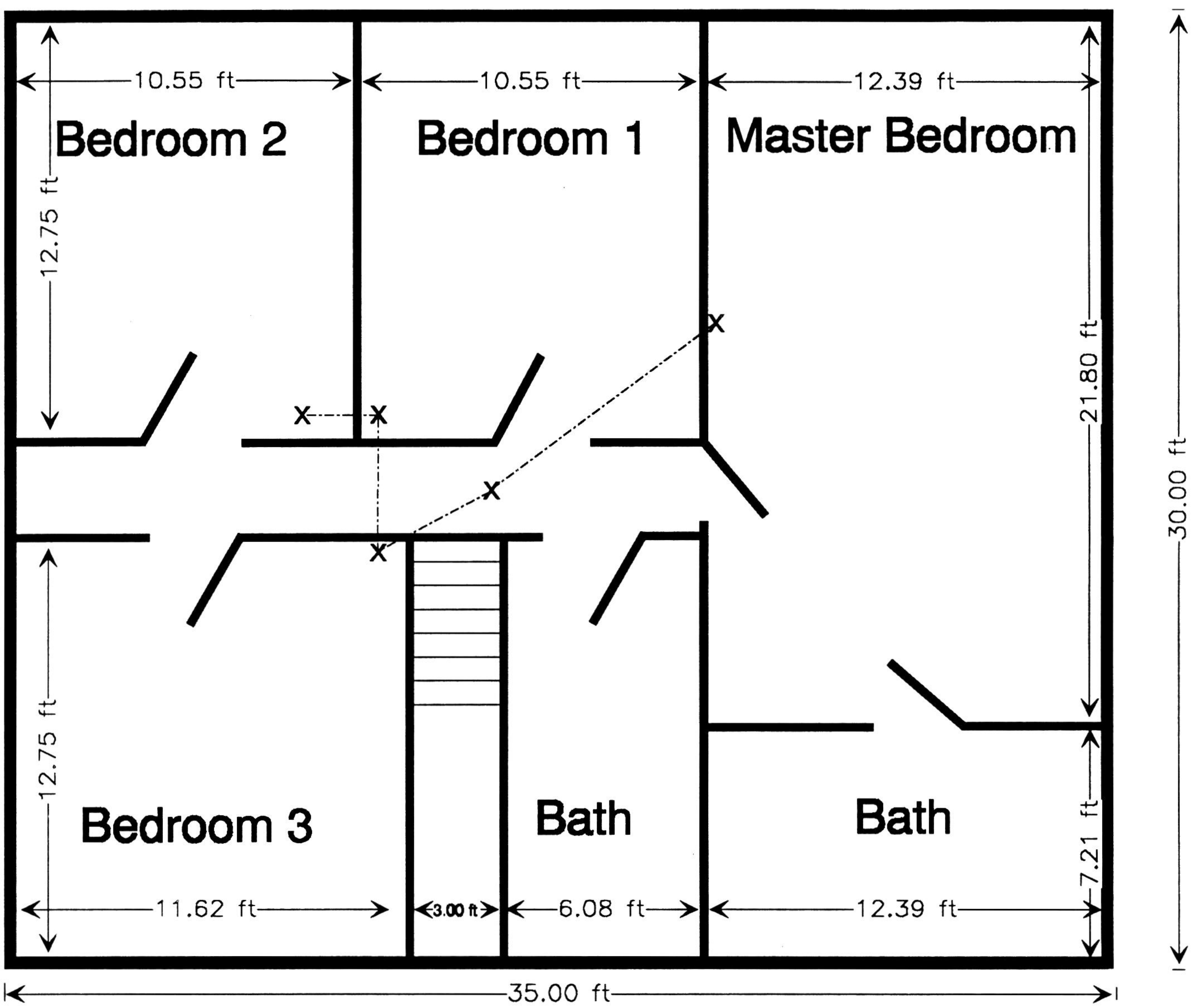


**Figure 2**
**PROPOSED CHANGE - ITEM 110**
**REPRESENTATIVE TYPE 1 - "AFTER" DESIGN**




bedroom. The locations of the additional units were selected to minimize installation costs. The dashed line indicates the path of the wiring that interconnects the smoke detectors. The layout presumes that the wiring is split at the hall smoke detector to run to the bedroom detectors. Further, three-conductor wire is required so that the actuation of the detectors will be signaled to the other detectors via the third wire and thus prompt activation of their alarms.

#### 2.2.4.1 *Issues in the Development of Designs*

The development of designs requires the translation of the information produced up to this point in the analysis into representations of methods of complying with both the old and new requirements. In developing the designs, the analyst frequently faces several choices. Without the use of some common set of conventions, different analysts may develop dissimilar "before" and "after" designs, even when proceeding from the same representative type. An unsuitable selection may yield distorted results stemming from an improper basis of comparison or consideration of impacts that do not reflect a "real world" situation. The following discussion addresses issues involved in the development of designs and provides some guidelines in the choices involved in the design process.

*Minimum requirements and industry practices.* The combined effects of "before" and "after" designs must accurately reflect the true impact of the code change on the representative type. In general, the "before" design must comply with the existing or unchanged code requirements and must also illustrate "real world" builder practices. Of course, it is appropriate to assume that all units constructed under the old provisions of the code comply with the minimum requirements; the issue arises because new homes often exceed minimum requirements in the code. Thus, the use of designs that exhibit strict adherence to the minimum requirements can be unrealistic and may not portray the true impact of a code change. For example, the 1991 edition of the *UBC* contains no minimum requirements for the number of sleeping areas in a dwelling unit. Accordingly, a minimalist design might contain just one bedroom while, in reality, most detached houses feature more than one bedroom. The designs presented in Figures 1 and 2 are based on a statistical analysis of the characteristics that are likely to be relevant to the impact of the change. These characteristics include the number of stories and bedrooms and the area of second-floor living space. Even in the absence of such definite statistical evidence, it would be unrealistic to presume the existence of just one bedroom for the analysis, at least if there is any desire to draw conclusions about the cost impacts on more typical homes or to generalize about the total cost impact on new homes considered as a group.

It is not the contention here that the minimum requirements should not be used as the baseline. For some aspects of design, the use of minimum standards is justified in that they reflect how the representative type is constructed. The point is that any decision to desert the minimum requirements in favor of an alternative baseline should be based on evidence or sound professional judgement that the alternative more realistically reflects actual construction. In such a case, the analyst should carefully document the circumstances and assumptions involved in departing from the minimum requirements. Otherwise, the old minimum requirements should be used in the "before" design.

Certain circumstances can dictate the use of minimum standards. It may be very difficult to ascertain the relative distribution of specific builder practices when no statistical data exist and other evidence is unconvincing. In such cases, the analyst should use the unchanged code requirements in specifying the critical characteristics of the "before" design. For example, suppose a proposed code change would increase the insulation required in the exterior walls of residential structures. In the absence of convincing evidence that builders systematically exceed the minimum values mandated by the old requirement, the analyst should use the old minimum requirements for a baseline in the "before" design.

At times, the purpose of a specific analysis may dictate which "before" design to use. For example, suppose the purpose of an analysis is to illustrate the impact on units of the representative type that are currently built to minimum requirements contained in the provisions that are the subject of the change, and that the analyst does not intend to develop aggregate impact estimates. The baseline is, of course, the old requirements. As long as the analyst explicitly states his or her goal and explains the process and assumptions, this approach is legitimate.

*Optional routes to compliance.* Occasionally, the approach to be adopted in a design is not obvious in the code change. Traditionally, a code change is commonly thought of as the replacement of some provision(s) that compels some specific practice(s) by another provision(s) that compels a new practice. Such a change provides clear direction to the selection of designs. The same can be said of changes that add a specific requirement. For example, the "before" design in the analysis of ICBO Item 110 must depict the installation of a smoke detector in an appropriate central second-story location. The "after" design must reflect the new mandated installations in all bedrooms. While the code may accord some latitude in the choice of locations within bedrooms, it permits no latitude with regard to the presence of a smoke detector in each bedroom.

The choice of designs for use in the analysis of other code changes can be more open-ended. For example, some code changes either delete or add **alternative** methods of achieving compliance. The baseline to be used in a "before" design for a code change that **deletes** one of multiple-alternative approaches to compliance is clear: it is the deleted option. The choice of a "before" design is not anywhere near as clear with a change that **adds** a new but **optional** means of compliance. An examination of the change will not indicate which of the pre-existing alternatives is most commonly used for the representative type. One approach would be to develop a "before" design for each alternative. If budget or time constraints preclude this approach, either statistical analysis of the available data or, in the absence of data, professional judgment must be used to select the appropriate alternative(s) for the "before" design(s).

Changes that **delete** one of multiple alternative paths to compliance can make the selection of "after" designs difficult. The "after" design must represent a reasonable response to the new requirements. That is, the builder must select a design that both complies with the requirement and produces a marketable building at reasonable cost. As with the "before" design for changes that add an alternative, the choice of an "after" design representing the alternative that will most likely be adopted by builders in lieu of the deleted alternative will not be indicated in the change. Optimally, if more than one alternative exists, the analyst can develop an "after" design to represent each option for comparison against the "before" design representing the deleted alternative. Failing that, statistical analysis or professional judgment can be assist the selection of the appropriate alternative.

*Comparability.* "Before" and "after" designs must be truly analogous. In other words, there should be no change in the functionality of the building except that compelled by the code change. For example, assuming that house size remains constant, a requirement for shallower stair dimensions would decrease the usable amount of living space devoted to other purposes. This loss of functionality presents a problem—for potential homebuyers, the resultant house will not be comparable to the "before" design. Furthermore, since the change in functionality was not mandated by the code change, this loss of functionality is unnecessary. There can be further complications depending on the nature of the "after" design. For example, a redesign that eliminates a powder room to accommodate the stairs within the existing building envelope leads not only to a diminished functionality of the house, but also makes a direct comparison of construction costs misleading. The redesign would eliminate the total expense related to the construction of the powder room, thus potentially reducing overall costs. The impact of the loss of the functionality of the powder room would remain unaccounted for in a conventional computation of costs and benefits. Thus, a comparison based on this design would be flawed.

An alternative approach is to expand the building envelope to retain not only the powder room, but also all other space that would be otherwise lost. There are two possible variations of this approach. One is to expand the envelope to recapture the lost space. Measuring the value of lost space becomes a nonissue, and the cost of the new requirement is the change in cost of producing the representative type with this alternative design relative to the "before" design. This solution may not, however, be feasible in some cases, therefore another possible approach is to expand the envelope even further. A comparison based on this alternative can be questioned because it represents an increase in living space over the "before" design and, therefore, is fundamentally different. Additionally, a direct comparison would reflect the costs associated with space not included in the "before" design. Wherever possible, designs should be formulated to avoid introducing such difficulties into the analysis.

The development of designs that are truly comparable and reflect approaches that home builders actually use or are likely to use can help ensure a firm basis for the subsequent analysis.

#### *2.2.4.2 Nature of the Graphic Designs*

Changes in construction should be readily apparent in all graphic representations. A side-by-side comparison of floorplans—with and without the new requirement—should allow any user to discern the nature of the change easily. Marking changed areas or including a legend may aid the interpretation of the drawings. The drawings should also portray construction in sufficient detail to allow the analyst to develop a reliable understanding of the changes in labor, material and equipment used as inputs to the development of cost estimates in the next step.

Although traditional graphic renderings of residential buildings take the form of sets of floorplans and elevations, other mock-ups—in addition to, or in place of, traditional graphics—may be required. For example, designs for a new frost-protected shallow foundation might include cross-sectional drawings of footings. In addition, some code changes, such as new material requirements, may not lend themselves to graphic representation at all.

#### *2.2.4.3 Other Products of Step 4*

Step 4 should also produce a narrative describing the designs and documenting their development. The commentary should relate the relevant technical aspects of the designs that result from the code change, indicate the reasons for selection of the approaches depicted and discuss any assumptions that the analyst adopted in developing the designs. As with the description of the code change, the amount of information and the effort involved can vary.

The technical details in this commentary set the stage for the development of cost estimates in Step 5. Table 4 illustrates such details in presenting information on the location of the bedroom smoke detectors as mandated in ICBO Item 110 and presented in Figure 2. Based on these locations, Table 5 presents the distance between the detectors wired as presented in Figure 2. The specifications for the wiring needed for the installation are presented following the tables.

| Table 4<br>SMOKE DETECTOR LOCATION | |
|---|---|
| **Room** | **Location*** |
| Master Bedroom | 12" from surface of left interior wall, 42" from door opening |
| Bedroom 1 | 12" from surface of wall of adjoining hall, 6" from surface of left interior wall |
| Bedroom 2 | 12" from surface of wall of adjoining hall, 12" from surface of interior right wall |
| Bedroom 3 | 12" from surface of wall of adjoining hall, 6" from surface of interior left wall |

* all detectors are ceiling-mounted

| Table 5<br>DISTANCES BETWEEN DETECTOR LOCATIONS | | | |
|---|---|---|---|
| **Smoke Detector Located** | **From** | **To** | **Distance** |
| Master Bedroom | Hall detector | Master Bedroom | 103.0" |
| Bedroom 1 | Bedroom 3 | Bedroom 1 | 69.0" |
| Bedroom 2 | Bedroom 1 | Bedroom 2 | 22.5" |
| Bedroom 3 | Hall detector | Bedroom 3 | 58.5" |

No. 14 AWG three-conductor nonmetallic-sheathed 600 volt wire with a ground will be used for power and signaling among the smoke detectors.

### *2.2.5 Step 5: Estimate Costs*

Step 5 produces an estimate of the cost impact of the subject code change within the framework presented in Step 1 as based on the information and designs developed in Steps 2 through 4. The output of Step 5 is a detailed estimate of the difference in cost to the homebuyer of the representative type constructed under the new requirement. It includes the impact on the direct cost of construction for such items as labor, material and equipment and, to the extent possible, addresses other less direct costs at the individual building or unit level. The resulting estimate also includes overhead and profit that subcontractors and builders typically add to labor, material and equipment cost in determining the price the homebuyer eventually pays.

### *2.2.5.1 Hard Costs*

The most significant source of cost impacts arises from what are termed "hard costs"—expenditures on labor, material and equipment required for the construction of the unit. The various alternative approaches to deriving estimates of hard costs have their advantages and disadvantages. The more common alternatives are described below.

*Observing the actual construction of buildings.* Observing the construction of buildings according to the designs developed in Step 4 permits the collection of data on labor, material and equipment use. This approach can be expensive and subject to conditions specific to individual job sites. It calls for the use of accepted time-and-motion study techniques to derive estimates of time use. Data on material use are gathered at the site. Unit-level cost data for both labor and material are then acquired from appropriate sources and applied to the use data to derive estimates for each design. This approach has the advantage of producing estimates of cost impacts based on the construction of actual units.

*Using a professional cost estimator.* This method does not constitute a technique for deriving cost-impact estimates, but rather identifies a person who has experience and/or access to the appropriate materials that would allow the development of cost estimates. The advisability of using this approach depends on the estimator's ability to produce reliable results and to explain the results to others.

*Using estimation manuals.* Cost estimation manuals are frequently used to develop construction cost estimates. They help in formulating estimates of the required amount and cost of labor, material and equipment based on an examination of the designs of representative types. The manuals offer the advantage of allowing the development of fairly detailed construction cost estimates with minimum resources. They, however, have their shortcomings. Although such manuals generally contain data pertaining to a wide variety of construction processes, they do not always contain the data needed to assess a particular code change. Thus, they are at times inadequate such that the analyst must rely on his/her professional judgment.

*Discussion of estimation manuals.* Although cost estimation manuals may have their drawbacks, they are widely used. There is some variation in content and format among the various manuals. Some are general in scope while others focus on specific construction market segments. Appendix B lists some currently available manuals.

The *MEANS Residential Cost Data* (*RCD*) manual is described in detail to illustrate the use of similar manuals. The manual contains separate sections that present three different approaches to cost estimating. The first approach develops cost estimates by square foot of living space for typical residential buildings based on building class, size and other general characteristics. In addition, it presents data that allow the adjustment of those estimates based on selected options. It also disaggregates cost for selected structure types into ten component areas: site work; foundation; framing; exterior walls; roofing; interiors; specialties; mechanical; electrical; and overhead. Per square foot data in terms of personhours of labor, material cost, labor cost and total cost are presented for each component area.

The second section is called "systems costs" and is more detailed. It allows the development of estimates of the cost of the assemblies that constitute residential buildings. For example, under the foundation category, data are detailed separately for footings, block walls, concrete walls, wood foundation walls and floor slabs. Within the footings section, the appropriate data on labor use and costs for labor, material and total are presented for the concrete, forms, reinforcing, keyways and dowels. The accompanying data allow for selected variations of techniques and materials. Information on the quantity of each material needed, the personhours of labor required, material and installation costs and the total installed cost for a standard unit of measure is also included.

The third section uses an approach termed "unit costing" in which data, organized according to the MASTERFORMAT system, are presented in separate divisions devoted to general requirements; site work; concrete; masonry; metals; wood and plastics; thermal and moisture protection; doors and windows; finishes; specialties; equipment; furnishings; special construction; conveying systems; mechanical; and electrical. Each division is further subdivided into more narrowly defined subjects. Data in this section of the manual include: a code to denote the type of work crew that is reflected in the data; the crew's expected daily output; the personhours required for production of one standard unit; the standard unit of measurement; bare cost for labor, material, equipment and total for one standard unit of output; and a total cost that includes overhead and profit. Using data in this section would allow the analyst to develop a cost estimate for an assembly by costing out the labor and materials of the assembly's constituent parts.

The analyst can use the data in the manuals in two alternative ways. With some code changes the cost of labor, materials and equipment required for the construction of both the "before" and "after" designs must be determined separately. The hard cost impact would then be the difference between the cost of the two designs. With other code changes, the analyst may be able to isolate the change in material use prompted by the change, determine the required labor and equipment and, using the appropriate costing data, directly compute the costs associated with the change in labor, material and equipment. The change to the *UBC* smoke detector requirements—ICBO Item 110—is an example of the latter. An illustrative estimation of the cost impact of that change on the selected representative type follows.

*Illustrative use of estimation manual.* This example illustrates the use of another well-known manual entitled the *1993 Craftsman Electrical Construction Estimator* as applied to the design developed for ICBO Item 110. The discussion and tables below trace the development of the cost impact of the requirement for the additional smoke detectors based on the design developed for the selected representative type. Table 6 presents information on the amount of material and labor required for the four additional detectors. Material includes wiring and fiberglass ceiling boxes needed to install the additional smoke detectors on the ceilings of the four bedrooms.

| Table 6<br>MATERIAL REQUIREMENTS | |
|---|---|
| **Wiring** | |
| **Location** | **Amount** |
| Up 4" from hall detector, 103" across and 4" down to master bedroom detector, with an additional 8" at each end for stripping and fitting | 127.0" |
| Up 4" from hall detector, 58.5" to bedroom 3 and 4" down to detector, with an additional 8" at each end for stripping and fitting | 82.5" |
| Up 4" from bedroom 3 detector, 69" to bedroom 1 and 4" down to detector, with an additional 8" at each end for stripping and fitting | 93.0" |
| Up 4" from bedroom 1 detector, 22.5" to bedroom 2 and 4" down to detector, with an additional 8" at each end for stripping and fitting | 46.5" |
| Total | 349.0" |
| Smoke Detectors | 4 |
| Fiberglass Ceiling Boxes | 4 |

Table 6 illustrates the amount of wire required is 349 inches or 11 inches short of 30 feet. For purposes of this analysis, the amount is rounded up to 30 feet. The wire required is No. 14 AWG three-conductor Romex with ground. The third wire is used to transmit signals between the alarms to activate all upstairs smoke detectors when one of the units is activated. In addition to the wire, four smoke detectors and four fiberglass ceiling boxes are required for the installation.

Table 7 presents the basic assumptions on unit costs taken from the *1993 Craftsman Electrical Construction Estimator* used to produce materials cost estimates.

| Table 7<br>UNIT COST DATA | |
|---|---|
| **Materials** | **Cost** |
| Cable | $0.2543/linear ft. |
| Smoke Detector | $11.30 each |
| Fiberglass box | $1.66 each |

Table 8 presents a computation of the cost of the material required for the installation. These results represent the cost of the materials as cited in the estimation manual but does not include sales tax on the material or the electrical subcontractor's, general contractor's or builder's mark-up for overhead and profit. Adjustments to account for such mark-ups follow discussion of the use and cost of labor in the smoke detector installation.

**Table 8**
**MATERIAL COST TO THE CONTRACTOR**

| Material | Units Needed | Unit Cost | Material Cost |
|---|---|---|---|
| Cabling | 300 ft. | $0.2543 | $7.63 |
| Fiberglass Boxes | 4 | 1.66 | 6.64 |
| Smoke Detectors | 4 | 11.30 | 45.20 |
| Total | - | - | $59.47 |

Labor is the other component of the cost impact. The estimation manual uses a labor wage rate of $28.63/hour which assumes a journeyman electrician base wage of $21.65/hour, fringe benefits at 14 percent of the base wage and taxes and insurance at 18.23 percent of the base wage.

Table 9 below presents a breakdown of labor required for the installation of the four additional smoke detectors. The labor data on the installation of the Romex cable as presented on Page 99 of the estimation manual indicate that one electrician working for 6.75 hours could install 1,000 feet of wire at a cost of $193.25. By dividing that cost by 1,000 to produce a per foot cost and multiplying the results by 30, the amount of cable needed for the additional smoke detectors, yields a cost of $5.80. Dividing that amount by the wage rate of $28.63 yields an estimated 0.2025 personhours required for the installation of the cable. A similar approach was used with the fiberglass ceiling boxes and smoke detectors. Although the amount of the labor cost impact can be derived without determining the number of required personhours, the computation and presentation of that measure allow for a better evaluation of the results and assumptions.

| Table 9<br>LABOR COSTS | | |
|---|---|---|
| **Installation Activity** | **Personhours Required** | **Labor Cost** |
| 30 Feet of Wire at $28.63/hour | 0.2025 hours | $5.80 |
| 4 Fiberglass Ceiling Boxes | 1.0 hour | 28.63 |
| 4 Detectors | 2.0 hours | 57.26 |
| Total Labor Costs | | $91.69 |

As with material cost, the wage rate of $28.63/hour does not reflect a complete mark-up for the electrical subcontractor's, general contractor's or builder's overhead and profit. In discussing the electrical contractor and overhead, the manual advises the user (assumed to be a contractor) to add his/her own overhead and expected profit. It continues by saying:

> Many contractors feel that adding 10 percent for profit yields an acceptable return on the money invested in the business. But there's no profit percentage that fits all jobs and all contractors.
>
> For some electrical contractors, overhead may add as little as 10 percent to the labor and material cost. But routinely adding 10 percent for overhead is poor estimating practice. It's the estimator's responsibility to identify all overhead costs and include them in the estimate, either as a lump sum or as a percentage of the total labor and material cost.

For purposes of this illustrative exercise, conservative mark-ups of 10 percent will be adopted for the electrical contractor's overhead and profit.

If the installation were performed by employees of the builder, this mark-up would be sufficient to reflect the cost impact to the home buyer. It is likely that this work would be subcontracted to an electrical contractor. An additional mark-up is needed to reflect the expense to the general contractor/builder of coordinating the subcontractor's work. *MEANS RCD* addresses this additional mark-up by saying:

> In most cases, if the work is to be subcontracted, it is best for a general contractor to add an additional 10% to the figures found in the column title **'TOTAL INCL. O&P'.**

Although this mark-up is intended for use with estimates derived from the MEANS manual, the 10 percent mark-up will be assumed for the present example. Used for illustration only, both this mark-up and that for the subcontractor are conservative estimates and may understate the cost impact of the change. If the user has a bona fide reason to suspect that the mark-ups are inappropriate for a particular code change, he/she should use alternative specifications and document the rate of mark-up and the rationale.

Table 10 portrays the impact of both subcontractor and contractor mark-ups on the labor and material cost estimates derived earlier, along with the impact of a 5 percent sales tax on material. Again, if that tax rate is inappropriate for use with a specific code change, the analyst should use the relevant mark-up These computations assume that the builder is the general contractor.

**Table 10**
**DERIVATION OF TOTAL COST**

| Cost Category | Material | Labor | Total |
|---|---|---|---|
| Unadjusted Amount | $59.47 | $91.69 | $151.16 |
| Sales Tax | 2.97 | NA | 2.97 |
| Overhead | 5.95 | 9.17 | 15.12 |
| Profit | 5.95 | 9.17 | 15.12 |
| Contractor Mark-up | 7.43 | 11.00 | 18.43 |
| Total | $81.77 | $121.03 | $202.80 |

Based on these data, the total estimated cost impact on labor and materials is $202.80.

*2.2.5.2 Other Costs*

Code changes can produce costs not directly associated with construction activities. Such costs, which can include expenses for redesign necessitated by the code change, additional fees required by the code change and delays for inspections, approvals or certification, must be addressed. The effects of delays can take the form of increased direct costs for idle labor and additional construction loan interest charges. Some costs are incurred at the per unit level and, thus, can be added directly to the construction costs in deriving total direct costs. Other costs, such as the expense of redesigning a unit to bring it into compliance with a new requirement, are incurred for some aggregate level of units, and must therefore be apportioned over the number of units of that design scheduled for production. Other costs are not as easily quantified but must at least be identified for discussion. Information on costs that do not lend themselves to quantification or apportionment should be noted in the documentation.

Once the analyst has developed the cost data for each design, computed the per unit cost impact estimates for each representative type, and documented the process that produced those estimates, the next step is to test the results.

### *2.2.6 Step 6: Perform Sensitivity Analysis*

The author of *Estimating the Economic Impacts of Building Codes* suggests the performance of sensitivity analysis to examine the effects of assumptions and values used in the cost analysis. This technique allows the analyst to determine how changes in assumptions or data affect the final outcome when the values of selected parameters are varied and the cost impact recomputed. Sensitivity analysis can serve two purposes. First, it helps determine if an estimate needs refinement. If a small variation in the value of an input variable produces a significant impact on the results, then a small error would likely have serious implications for the cost analysis. Second, it aids in assessing the impact of conflicting sets of assumptions or estimates. If two sets of markedly different values produce only a small impact on the results, then the disagreement may be rendered moot. The recommended steps in performing sensitivity analysis are:

- identify the variables to be tested;
- decide on the approach;
- select the values to be used;
- recompute the cost impacts; and,
- record the results.

*Identify variables to be tested.* The analyst should select specific parameters as the subject of the analysis. If variation in the value of some parameter is likely to have a major impact on the cost analysis, it is a likely candidate. Likewise, if a variable is the subject of contention, the study would benefit from its inclusion in the sensitivity analysis.

*Decide on the approach.* The analyst may choose to vary individually the value of each selected parameter or to vary the values of groups of variables. The latter approach can produce the results of "likely," "optimistic" and "pessimistic" scenarios. In such a case, the "likely" scenario would be the computation of the cost impact given the initial assumptions. The "pessimistic" scenario would entail the use of values that would increase the cost impact relative to the "likely" results, while the "optimistic" scenario would be one based on values that would decrease the cost impact. In formulating a "pessimistic" (or "optimistic") scenario, the analyst may feel that it is unrealistic to assume that all of the selected variables will simultaneously assume their "pessimistic" (or "optimistic") values. Accordingly, the analyst may perform several "pessimistic" (or "optimistic") studies to assess the impact of several sets of assumptions.

*Select the values to be used.* The analyst must choose alternative values for the variables that represent some reasonable set of assumptions.

*Recompute the cost impacts.* Once the variables and their range of values are selected, the analyst changes the values of selected variables(s) to determine the impact of the change on costs. The nature and magnitude of the required recomputations depend on the variable(s) selected and the nature of the code change.

*Record the results.* The analyst should document the results of the sensitivity analysis for each representative type. The information should include the variables selected for the study, the range of variation and the reason for their selection.

Although the above steps are presented sequentially, as in the referenced literature, the identification of a variable to be tested and the choice of values to be used may occur simultaneously, for example when controversy revolves around the choice between two alternative wage rates. In using sensitivity analysis, the analyst should submit each representative type to the process to identify the impact on each.

This technique can be used to check the impact of the assumptions of the estimated cost of the smoke detector installation used in the analysis of ICBO Item 110. The earlier analysis assumed an electrician's base wage rate of $21.65/hour, whereas the 1994 edition of the *RCD* manual lists an electrician's base wage rate as $17.60/hour. This latter figure reflects open shop wages and includes the cost of such benefits as vacation pay and employer-paid health costs. The earlier analysis also assumed an overhead mark-up rate of 10 percent. Some may feel that the mark-up is low. *RCD*, on the other hand, provides a 30 percent overhead mark-up rate for electricians.

Sensitivity analysis can be used to examine the impact varying the base wage and overhead rates. Given that the impact of the two variations will be in opposite directions, it makes sense to assess the impacts separately. The resulting estimates can then serve as possible lower and upper bounds for the estimate or "optimistic" and "pessimistic" scenarios, respectively. The values for each of the variables to be tested are as follows:

Scenario 1: wage rate = $17.60/hour
overhead = 10%

Scenario 2: wage rate = $21.65/hour
overhead = 30%

First, in Scenario 1, the impact of a base wage rate of $17.60/hour is tested. Marking up that salary to reflect taxes and insurance at 18.23 percent of the base wage yields $20.81. Table 11 recomputes the impact on labor costs, thereby pushing the labor costs down to $66.64.

**Table 11**
**ALTERNATIVE LABOR COSTS (BASE WAGE = $17.60/Hour)**

| Installation Activity | Personhours Required | Labor Cost |
|---|---|---|
| 30 Feet of Wire at $20.81/hour | 0.2025 hours | $4.21 |
| 4 Fiberglass Ceiling Boxes | 1 hour | 20.81 |
| 4 Smoke Detectors | 2 hours | 41.62 |
| Total Labor Costs | | $66.64 |

Table 12 reflects a recomputation of the total loaded costs based on the revised total labor costs. As can be seen, total costs now equal $169.73.

| Table 12<br>ALTERNATIVE TOTAL COST (BASE WAGE = $17.60/Hour) | | | |
|---|---|---|---|
| **Cost Category** | **Material** | **Labor** | **Total** |
| Unadjusted Amount | $59.47 | $66.64 | $126.11 |
| Sales Tax | 2.97 | NA | 2.97 |
| Overhead | 5.95 | 6.66 | 12.61 |
| Profit | 5.95 | 6.66 | 12.61 |
| Contractor Mark-up | 7.43 | 8.00 | 15.43 |
| Total | $81.77 | $87.96 | $169.73 |

Alternatively, in Scenario 2, the original wage rate of $28.63/hour could be assumed with a higher overhead rate of 30 percent. As displayed in Table 13, the total cost impact increases to $236.06.

| Table 13<br>ALTERNATIVE TOTAL COSTS (OVERHEAD = 30%) | | | |
|---|---|---|---|
| **Cost Category** | **Material** | **Labor** | **Total** |
| Unadjusted Amount | $59.47 | $91.69 | $151.16 |
| Sales Tax | 2.97 | NA | 2.97 |
| Overhead | 17.84 | 27.51 | 45.35 |
| Profit | 5.95 | 9.17 | 15.12 |
| Contractor Mark-up | 8.62 | 12.84 | 21.46 |
| Total | $94.85 | $141.21 | $236.06 |

Consolidating the results of the varying assumptions into a single summary table can make presentation of the results more readily understandable. Table 14 presents such a consolidation and characterizes the cost impact that results from using the lower wage rate as the lower bound of the estimate and the impact of a 30 percent overhead rate as the upper bound along with the initial estimate.

| Table 14<br>IMPACTS OF VARYING ASSUMPTIONS | | | |
|---|---|---|---|
| | **Initial Estimate** | **Scenario 1—Lower Bound** | **Scenario 2—Upper Bound** |
| Wage Rate Per Hour with Fringe Benefits | $28.63 | $20.81 | $28.63 |
| Overhead Rate | 10% | 10% | 30% |
| Total Cost | $202.80 | $169.73 | $236.06 |

## 3.0 AGGREGATING AND EXTENDING THE RESULTS

The primary purpose of this methodology is to provide a means of deriving reliable estimates of per-unit cost impacts of individual code changes. The steps outlined above produce those estimates. Those results can be extended into estimates of the potential cost-impact on all affected housing during the base-year or for some number of subsequent years. To derive those extended estimates, the analyst must combine the per-unit cost data with additional data and assumptions about residential construction activity. Of course, since the additional data and assumptions introduce additional uncertainty, the resultant estimates may be less reliable than per-unit impact estimates. A discussion of the process of developing these extended estimates follows.

**Base year aggregation.** Once the per-unit cost impact for the base year for each representative type is derived, the analyst can, if desired, proceed to expand the results into an estimate of the impact on costs for all units of the affected types for the base year. To accomplish this, the analyst must have access to or develop estimates of the number of each type of units expected to be constructed during the base year. For each representative type, the analyst simply multiplies the number of expected starts by the cost impact. (If alternative compliance solutions have been developed, then this process must be performed for each alternative so that the lowest cost compliance alternative can be used in the aggregation.)

If the representative type is the sole proxy for some major category of housing, projections on the number of units to be constructed during the coming year may be readily available. Appendix C lists sources of housing projections.

When a representative type is a surrogate for some smaller subset of housing, the analyst will likely need to derive projections for the representative type by using additional information and/or by formulating assumptions. Suppose that an analyst wants to develop aggregate estimates of the cost-impact of B223-91 on low-rise multifamily housing slated for construction in areas where effective peak velocity-related rate of acceleration is greater than or equal to 0.05 but less than 0.10. In such a case, the analyst would probably select a representative type for low-rise multifamily buildings with a seismic load-resisting system fabricated of wood-frame construction and another based on an entirely masonry constructed system, both to be constructed in an area with the above described seismicity. In the likely event that the analyst does not have access to projections for low-rise multifamily buildings disaggregated by framing type and seismicity, he/she may be able to use statistical analysis to develop such projections by extending more general projections.

First, the analyst may have projections only of the number of multifamily **units** that will be constructed during the coming year which he/she must convert into projections of the number of multifamily **buildings** for a single state. In turn, if the analyst has access to, or has developed projections of the number of buildings to be constructed, he/she must derive the percent of low-rise multifamily buildings built in the appropriate seismic regions as well as the percent of those buildings with each type of seismic load-resisting frames noted above. Estimates of these proportions can be derived through statistical analysis of the available historical data on the characteristics of residential construction and from an examination of appropriate maps delineating areas by seismicity. Appendix A lists sources of historical data. By superimposing results of the statistical analysis on the more general projections, the analyst will be able to derive projections for the number of low-rise multifamily buildings with the two specified framing systems in the affected area. The projected number of each representative type is then multiplied by its per unit cost impact and the results summed to derive an estimate of the potential cost impact on all affected units in the base year. Table 15 illustrates a format that could be used for presenting the aggregate cost impact estimates. The details of the entire statistical analysis and other procedures used to develop the aggregate-level estimates should be documented.

| Table 15<br>PROPOSED CHANGE B223-91<br>REPRESENTATIVE TYPES I & II<br>BASE YEAR AGGREGATE COST IMPACTS | | | |
|---|---|---|---|
| **Representative Type** | **Per-Unit Cost-Impact** | **Number of Units Projects** | **Aggregate Cost-Impact** |
| I | | | |
| II | | | |
| Total | | | |

The credibility of the results depends greatly on the quality and quantity of the statistical data used to produce the aggregate estimates. Nonetheless, budgetary constraints may preclude detailed statistical analysis. Further, data of sufficient quality and quantity may not exist for the building type and geographic region that need to be studied. In such instances, the analyst may be forced to make certain assumptions about the available data. The analyst should be careful to document his/her assumptions. In addition, the analyst should examine the influence of suspect statistics through sensitivity analysis.

**Extension of the results beyond the base year**. The per-unit cost impact estimates can also be used as the basis of projections of cost impacts in future years. Access to data that will allow the development of the number of relevant starts projected in those years analogous to that discussed immediately above will be required, along with assumptions on cost escalation rates. As with aggregate-level estimates, the analyst should meticulously document sources of data, statistical techniques and assumptions used in the production of such estimates.

The general approach to developing these extended estimates is to: decide on the number of subsequent years that the results will be extended; develop the estimates of the per-unit cost impact for each representative type for each year by escalating the base year costs appropriately; multiply the results by the projected number of starts for each representative type for that year; discount the results for each year to present value for each type as of the base year; and add the result for all of the representative types to produce an estimated total cost impact for the analysis period. This derivation of the total aggregated cost impact for one representative type over a period of "n" years can be represented mathematically as:

$$PVAGTC_1 = \sum_{i=0}^{n-1} \left(\frac{S_i * TC_i}{1+D}\right)^i$$

Where:

| | | |
|---|---|---|
| $PVAGTC_1$ | = | the present value of the aggregated total cost impacts for representative type 1 |
| $S_i$ | = | the number of starts for representative type 1 in year i |
| $TC_i$ | = | the total per unit cost impact for representative type 1 in year i |
| D | = | the discount rate |

The formula used in that computation is based on the economic concept of "present value", a detailed explanation of which is beyond the scope of this methodology. More in-depth discussions of appropriate computational methods for deriving present value and dealing with cost escalation in a construction context can be found in published sources including *Building Economics*[2] and in the compilation *ASTM Standards on Building Economics*.[3]

Like the aggregated estimates for the base year, the results of a multiyear cost estimation can be presented in table format, as in illustrative Table 16.

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[2] *Building Economics - Theory and Practice*, Ruegg, R. and Marshall, H.,Van Nostrand Reinhold, New York, NY, 1990 .

[3] *ASTM Standards on Building Economics*, ASTM, Philadelphia, Pennsylvania, 1992.

**Table 16**
**PROPOSED CHANGE B223-91**
**REPRESENTATIVE TYPES I & II**
**AGGREGATE COST IMPACTS 1994 - 1997**

| | Number of Buildings | Per-Building Cost Impact | Aggregate Cost Impact |
|---|---|---|---|
| 1994 | | | |
| Rep. Type I | | | |
| Rep. Type II | | | |
| 1995 | | | |
| Rep. Type I | | | |
| Rep. Type II | | | |
| 1996 | | | |
| Rep. Type I | | | |
| Rep. Type II | | | |
| 1997 | | | |
| Rep. Type I | | | |
| Rep. Type II | | | |
| Total | | | |
| Rep. Type I | | | |
| Rep. Type II | | | |
| Both Types | | | |

In addition to consolidating the results in a table such as that above, the analyst should document the sources of data and assumptions used to develop projections and escalation rates.

## 4.0 CONCLUSION

**Implications of the Methodology** - The method presented in this document implies the use of certain assumptions. First, the cost estimates are based on the assumption that the unit is constructed. Second, the estimates are based on past construction practices. It must be noted that the details of the designs of representative houses, with the exception of the aspects of the construction modified by the code change, are likely based on characteristics of houses as they are currently built. Cost impact estimates for a proposed change imply that these construction practices will continue into the future. Third, there are no market adjustments to changes in cost. In producing aggregate cost impact estimates for a representative type, the per-unit cost impact estimates are multiplied by the number of units anticipated to be constructed. The number of units anticipated is apt to be based on published projections derived without consideration of market adjustment in reaction to the cost impact of the code change. This static approach was taken in order to produce a methodology that would be usable by people with no expertise in such specialized fields as econometrics.

One aspect of this approach is that it seems to suggest that code changes that prompt an increased use of labor or material can increase economic activity. The logic is that while a code change may cause a rise in costs, it also stimulates the demand for labor, material or both. Additionally, by factoring the hard cost impacts by the prevailing profit rate, the amount of profit accruing to builders rises. This would seem to indicate that increases in cost make a builder more profitable.

In fact, the impact on the housing market is not nearly this simple. Changes in the cost of production affect the supply curve; that is, the total number of units that would be produced at any given market price. Changes in features can affect the demand curve; that is, the total number of units that would be purchased at any given market price. A code change that makes houses more or less attractive to buyers will have a corresponding impact on the demand curve. The interaction of these changes in supply and demand is what ultimately determines the impact on market price, level of production and demand for labor and material and profitability. This interaction is not addressed by the methodology presented in this document.

Nonetheless, the static approach provides insight into the cost impact of code changes by enabling the user to answer the question, "What would have happened to the cost of the represented housing had they been constructed as pictured?" but, it stops short of requiring the development and maintenance of economic models of all of the markets affected.

Finally, the method presented in this document is intended to be used in assessing individual code changes. Although multiple code changes may be subjected to this method, the impact of each change is computed in isolation from other changes. The analyst should note that summing the results of each assessment presumes that the costs are additive. This would be true only in certain cases. Some code changes will have ripple effects on the impact of other code changes. For example, suppose two changes are proposed for inclusion in the code. The first change proposes to increase the minimum tread depth and to reduce the maximum riser height for residential stairs, which would result in an increase in the length of the run of the stairs. The second change proposes to increase the cross-section of the handrail. Computing the cost impact of both changes separately and adding the results would fail to capture the impact of the changed handrail cross-section for the additional length of stairway run prompted by the adoption of the first proposed code change. The reader should be aware of this aspect of the methodology if discussions of the combined impact of multiple code changes arise.

**Documenting and reporting the results** - Although much of the focus of this document has been on the activities entailed in producing estimates of the cost impact of code changes, it must be remembered that the purpose of this methodology is not to produce some single number that represents the cost impact of a change to a model building code. Such a number would not provide decision makers with any means of assessing the dependability of those results, since it offers no insight into the assumptions and methods used in deriving the results. In addition, some impacts are not quantifiable. A strictly quantitative report would ignore those issues.

If the analyst is to make a persuasive case for a set of results, the process that produced the cost impact estimates must be well-documented and presented along with the results of the analysis. This documentation should include an explanation of the process that lead to the selection of the representative types. It should contain the floor plans or other mock-ups developed for each of the designs for each of those representative types. Physical changes to the designs necessitated by the code change should be clearly indicated.

The methods used to develop the estimates of material, labor and capital usage, based on those changes and the sources of cost data to convert them into estimates of construction costs, must be explained. The methods and assumptions used in the derivation of estimates of the other direct costs and the indirect costs must also be presented. Any costs that were not readily quantifiable or apportionable must be discussed along with their implications for the cost impact. Finally, the results of the sensitivity analysis or other methods chosen to test the outcome of the estimation must be detailed.

# APPENDIX A

APPENDIX A
SOURCES OF CONSTRUCTION CHARACTERISTICS DATA

Survey of housing stock:

This survey is conducted every other year on the odd numbered years. This report presents data on: the number of single-family houses, multifamily units, mobile homes and vacant housing units. Data include age, sex and race of householders and monthly income, monthly housing costs (mortgage/rent and utilities), condition of building, neighborhood quality, size of the housing units, homeowner repairs, rent control, current rent subsidies and previous unit of recent movers and reasons for moving.

1. Bureau of the Census, *American Housing Survey*: 1991, United States, Series H150/91, U.S. Government Printing Office, Washington, DC, 1993.

Each year the survey is conducted, 11 MSA editions are published. The selected MSAs vary from year-to-year on a four-year rotating basis. In 1991, data for the following MSAs were published: Atlanta, GA; Baltimore, MD; Chicago, IL; Columbus, OH; Hartford, CT; Houston, TX; New York-Nassau-Suffolk, NY; Northern NJ; St. Louis, MO-IL; San Diego, CA; Seattle-Tacoma, WA. In 1990, data for the following MSAs were published: Anaheim-Santa Ana, CA; Cincinnati, OH-KY-IN; Denver, CO; Kansas City, MO-KS; Miami-Fort Lauderdale, FL; New Orleans, LA; Pittsburgh, PA; Portland, OR; Riverside-San Bernardino-Ontario, CA; Rochester, NY; San Antonio, TX. In 1989, data for the following MSAs were published: Boston, MA-NH; Dallas, TX; Detroit, MI; Fort Worth-Arlington, TX; Los Angeles-Long Beach, CA; Minneapolis-St. Paul, MN-WI; Philadelphia, PA-NJ; Phoenix, AZ; San Francisco-Oakland, CA; Tampa-St. Petersburg, FL; Washington, DC-MD-VA. In 1988, data for the following MSAs were published: Birmingham, AL; Buffalo, NY; Cleveland, OH; Indianapolis, IN; Memphis, TN-AR-MS; Milwaukee, WI; Norfolk-Virginia Beach-Newport News, VA; Oklahoma City, OK; Providence-Pawtucket-Warwick, RI-MA; Salt Lake City, UT; San Jose, CA.

2. Bureau of the Census, *Housing Characteristics for Selected Metropolitan Areas*, Current Housing Reports H170/91, U.S. Government Printing Office, Washington, DC, 1993.

Bureau of the Census, *Housing Characteristics for Selected Metropolitan Areas*, Current Housing Reports H170/90, U.S. Government Printing Office, Washington, DC, 1992.

Bureau of the Census, *Housing Characteristics for Selected Metropolitan Areas*, Current Housing Reports H170/89, U.S. Government Printing Office, Washington, DC, 1991.

Bureau of the Census, *Housing Characteristics for Selected Metropolitan Areas*, Current Housing Reports H170/88, U.S. Government Printing Office, Washington, DC, 1990.

Housing characteristics of new single-family homes: Monthly data include the type of structure. Annual data include the number of bedrooms, number of bathrooms, type of external wall material, foundation type, heating fuel and system, parking facilities, number of stories, square footage of floor space, number of fireplaces, availability of air conditioning and sales price.

3. Bureau of the Census, *New One-Family Houses Sold*, Series C25, Bureau of the Census, Washington, DC, published monthly.

4. Bureau of the Census, *Characteristics of New Housing*, Series C25, Bureau of the Census, Washington, DC, published annually.

Results of the 1990 Census. Housing characteristic data are available with or without population data. The "CPH" designation refers to Census of Population and Housing. The "CH" designation refers to Census of Housing. Both series offer breakdowns for certain ethnic groups, metropolitan areas and urbanized areas. The Census asked two groups of housing-related questions. The 100 percent data questions are asked of everyone. The sample housing subjects are asked of a sample of households. Data are available by U.S. total or state (including DC, Puerto Rico and U.S. Virgin Islands).

One hundred percent data include the number of rooms, number of occupants, tenure of occupancy, owner or renter, number of units in the building. Sample data include number of bedrooms, cost of utilities and mortgage/rent, condition of plumbing and kitchen facilities, presence of a telephone, water source, sewage disposal method, age of dwelling and length of occupancy.

5. Bureau of the Census, 1990 Census of Housing, *General Housing Characteristics*, Bureau of the Census, Washington, DC, 1990. (100 percent data)

6. Bureau of the Census, 1990 Census of Housing, *Detailed Housing Characteristics*, Bureau of the Census, Washington, DC, 1990.

Results of the *Annual Builder Practices Survey* conducted under the auspices of the NAHB Research Center. Reports are available on most building products used in new residential construction. In 1992, the survey contained responses from 2,207 single-family detached, 213 single-family attached and 17 multifamily low-rise builders. In 1991, the survey contained responses from 2,240 single-family detached, 172 single-family attached and 139 multifamily low-rise builders. In 1990, the survey contained responses from 1,600 single-family detached, 159 single-family attached, and 70 multifamily low-rise builders.

7. F. W. Dodge, *New Construction Report(s)*, F. W. Dodge Residential Product Demand Group, Lexington, MA, annually.
Product types included:
concrete;
lumber, framing and sheathing;
roofing;
windows and doors;
fireplaces;
gypsum (interior finish);
flooring;
HVAC equipment;
plumbing fixtures and faucets;
kitchen and vanity cabinets; and
appliances.

The *Data Book* updates and expands the previous earlier editions published by the U.S. Department of Energy in September 1986. Energy-related information is provided under the following headings: characteristics of residential buildings in the U.S.; characteristics of new single-family construction in the U.S.; characteristics of new multifamily construction in the U.S.; household appliances; residential sector energy consumption, prices, and expenditures; characteristics of U.S. commercial buildings; commercial buildings energy consumption, prices and expenditures; and additional buildings and community systems information.

8. George R. Amols, K.B. Howard, A.K. Nicholls, and T.D. Guerra, *Residential and Commercial Buildings Data Book, Third Edition*; U.S. Department of Energy, Washington, DC, 1989.

# APPENDIX B

APPENDIX B
SOURCES OF ESTIMATING DATA

## SOURCES OF GENERAL DATA ON CONSTRUCTION COST ESTIMATES:

General contractor's estimation book for all types of buildings, including residential buildings. Costs are given for economy, average, custom and luxury methods for 1-story, 1½-story, 2-story, 2½-story, 3-story, bi-level, tri-level (split-level) homes and wing and ell additions. Costs provided for post-and-beam, log and solid masonry construction methods as well as for conventional platform framing.

1. R.S. Means, *Means Square Foot Cost Data*, R.S. Means Company, Division of Southam Construction Information Network, Kingston, MA, annually.

General contractor's unit price book for estimating tasks in both residential and nonresidential construction. Material, labor, equipment and overhead costs included. Prices are for **union** work.

2. R.S. Means, *Means Building Construction Cost Data*; R.S. Means Company, Division of Southam Construction Information Network; Kingston, MA; annually.

General contractor's unit price book for estimating tasks in both residential and nonresidential construction. Material, labor, equipment and overhead costs included. Prices are for **non-union** work.

3. R.S. Means, Means Open Shop Building Construction Cost Data, R.S. Means Company, Division of Southam Construction Information Network, Kingston, MA, annually.

Contractor's estimation book for residential, commercial and industrial construction. Personhours, recommended crew and labor cost for materials and installation of common building materials. Includes "Estimate Writer," an electronic version of the book on computer diskette.

4. *National Construction Estimator* 1993, Craftsman Book Company, Carlsbad, CA, annually.

Three hundred estimating reference tables that include labor requirements for nearly every type of construction. Each section details the work to be estimated and gives the approximate crew size and equipment needed.

5. *Construction Estimating Reference Data*, Craftsman Book Company, Carlsbad, CA.

Estimating commercial building costs. Provides square footage costs for over 150 different types of commercial buildings—from farm buildings to high-rise office towers. Includes improvement costs.

6. *Marshall Valuation Service*, Marshall & Swift, Los Angeles, CA, annually.

SOURCES OF DATA ON RESIDENTIAL CONSTRUCTION COSTS

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|---|---|
| Estimator's book for residential construction costs includes over 100 illustrated complete residential square footage costs. Alternative assemblies costs are also given as well as detailed unit costs for new construction to allow easy estimation. | 7. R.S. Means, *Means Residential Cost Data*; R.S. Means Company, Division of Southam Construction Information Network, Kingston, MA, annually. |
| Home builder's estimation book includes material and installation charges for residential construction tasks. It also includes personhour projections for each task. Whole-house cost estimates are given for split-level, one-story and two-story units for average and deluxe construction for low, medium and high ranges of costs. Estimates seem in line with practical experience. | 8. *Home Builder's 1993 Costbook*, published by BNi Building News, Los Angeles and Boston, in conjunction with the Home Builder Press of the National Association of Home Builders, Washington, DC, edited by A.M. Fogarty & Associates, Hingham, MA, 1993, 1994. |
| Home builder's estimation book features three methods of calculating cost: by square foot, detailed segregated costs and comparative costs. Includes photographs, definitions and cost tables, as well as multipliers for regional cost variations in the U.S. and Canada. Provides historic multipliers to allow comparison of construction costs back to 1966. Includes costs for conventional, log homes, manufactured homes, multifamily low-rise and others. | 9. *Residential Cost Handbook*, Marshall & Swift; Los Angeles, CA, annually. |
| Estimator's book for all repair and remodeling construction tasks is designed for real estate agents, appraisers and residential contractors. Contains prices of commonly repaired and replaced items such as roofs, kitchens, bathrooms and more. Includes drawings and definitions. | 10. *The Real Estate Repair & Remodel Cost Guide*, Marshall & Swift, Los Angeles, CA, annually. |
| Estimation book for architects, adjusters, builders, contractors and real estate professionals. Provides costs for developing local repair and remodeling estimates in the U.S. and Canada. | 11. *The Dodge Repair & Remodel Cost Book*, Marshall & Swift, Los Angeles, CA, annually. |
| Estimator's book for all repair and remodeling construction tasks. Combines residential and nonresidential remodeling and provides material, labor, equipment and overhead costs. Includes HVAC, electrical and plumbing costs. | 12. R.S. Means, *Means Repair & Remodeling Cost Data*, R.S. Means Company, Division of Southam Construction Information Network; Kingston, MA, annually. |

Estimator's book for all repair and remodeling construction tasks. Provides material and labor costs for four levels of difficulty involved in the remodeling task, from easy to extremely difficult based on labor estimates of declining productivity.

13. *LSI Remodeling/Repair Construction Costs 1994*, Lee Saylor, Inc., Chatsworth, CA; annually.

SOURCES OF DATA ON SUBCONTRACTING COSTS

Developer's and excavator's estimation book for land development, excavating and landscaping. Includes costs for road work, sewage and utility construction. Costs apply to material, labor, equipment and overhead as well as to total personhours required to complete a task.

14. R.S. Means, *Means Site Work and Landscape Cost Data*, R.S. Means Company, Division of Southam Construction Information Network, Kingston, MA, annually.

HVAC contractor's estimation book includes costs for piping, heating, air conditioning, ventilation and all related construction. Excludes plumbing needed for hydronic heat.

15. R.S. Means, *Means Mechanical Cost Data*, R.S. Means Company, Division of Southam Construction Information Network, Kingston, MA, annually.

Plumber's estimation book includes costs for plumbing, irrigation systems, commercial and residential fire protection, and point-of-use water heaters.

16. R.S. Means, *Means Plumbing Cost Data*, R.S. Means Company, Division of Southam Construction Information Network, Kingston, MA, annually.

Plumber's and HVAC contractor's estimation book includes personhours, labor and material costs for common plumbing and HVAC work in residential, commercial and industrial buildings. Includes "Estimate Writer" diskette.

17. *National Plumbing & HVAC Estimator,* Craftsman Book Company, Carlsbad, CA, annually.

Electrician's estimation book includes unit and system costs with design tables and engineering guides. Specifies complete personhours, materials and labor costs.

18. R.S. Means, *Means Electrical Cost Data*, R.S. Means Company, Division of Southam Construction Information Network, Kingston, MA, annually.

Electrician's estimation book includes material and labor costs as well as material illustrations and personhour estimates. Comes with free estimating diskette.

19. *Electrical Construction Estimator 1993*, Craftsman Book Company; Carlsbad, CA, annually.

An addendum to *Means Electrical Cost Data* addresses the cost and impact of both preinstallation and postinstallation change orders. Covers productivity analysis and change order cost justifications.

20. R.S. Means, *Means Electrical Change Order Cost Data*; R.S. Means Company, Division of Southam Construction Information Network, Kingston, MA, annually.

This data book updates and expands the previous Data Book originally published by the Department of Energy in September, 1986. Energy-related information is provided under the following headings: Characteristics of Residential Buildings in the U.S.; Characteristics of New Single-Family Construction in the U.S.; Characteristics of New Multifamily Construction in the U.S.; Household Appliances; Residential Sector Energy Consumption, Prices and Expenditures; Characteristics of U.S. Commercial Buildings; Commercial Buildings Energy Consumption, Prices and Expenditures; and Additional Buildings and Community Systems Information.

21. George R. Amols, K.B. Howard, A.K. Nicholls, and T.D. Guerra, *Residential and Commercial Buildings Data Book*, Third Edition, U.S. Department of Energy, Washington, DC; 1989.

# APPENDIX C

## APPENDIX C

## SOURCES OF FORECAST DATA

### HOUSING FORECAST PUBLICATIONS

*Building & Construction Market Forecast*, Cahners Publishing Company, Division of Reed Publishing Inc., 275 Washington St., Newton, MA 02158, (708) 390-2105.

*Forecast of Housing Activity*, National Association of Home Builders, 1201 Fifteenth Street, N.W., Washington, DC, 20005, (202) 822-0245.

*U.S. Industrial Outlook*, U.S. Department of Commerce, International Trade Administration, Mail Stop: SSOP, Washington, DC 20402-9328, (202) 482-4356.

### FORECASTING SERVICES

WEFA GROUP, City Line Avenue, Bala Cynwyd, PA 19004, (610) 667-6001.

Regional Financial Associates, 1450 Boot Road, Suite 600, West Chester, PA 19360, (610) 696-8700.

Data Resources Inc., 24 Hartwell Avenue, Lexington, MA 02173, (617) 863-5100.

F.W. Dodge Statistics, 24 Hartwell Avenue, Lexington, MA 02173, (617) 860-6821.

## TABLE OF SERVICES

| COMPANY | HOUSE TYPES | GEOGRAPHIC UNIT | FREQUENCY of UPDATE | PUBLISHED | PROJECTION HORIZON |
|---|---|---|---|---|---|
| Cahners | Single-Family, Multifamily | 4 Census Regions | Quarterly | Annually | 2 years |
| NAHB | Single-Family, Multifamily | Major MSAs | Quarterly | Quarterly | 2 years |
| U.S. Department of Commerce | Single-Family, Multifamily | UST | Annually | Year | 1 year and 5 years |
| WEFA Group | Single-Family, Multifamily | MSAs | Quarterly | quarterly | 10 years |
| Resources Financial Associates | Single-Family, Multifamily | Counties | Monthly | Monthly | 10 years |
| Data Resources Inc. | Single-Family, Multifamily | States, 114 MSAs | Quarterly | Quarterly | 5 years and 25 years |
| F.W. Dodge | One-Family, Two-Family, Three-Family Plus | Counties | Monthly | Month | 5 years |

**APPENDIX D**

This appendix has been included for the convenience of the user and consists of blank forms that can be copied and used in the development and documentation of estimates of cost-impacts of proposed code changes. The forms are separated into six sections.

The first set of forms, found in the section entitled *Initial Documentation*, is needed for the initial steps in the analysis and provides a means of organizing the narrative associated with those steps. A separate sheet is included for: the rationale and scope of the analysis; the code change description; the discussion of any indirect (nonconstruction) costs; description of representative type(s); and description of design(s).

The next set of forms, included in the section entitled *Base Analysis*, are provided for recording data on the use and cost of material, labor and equipment and on nonconstruction costs in the base analysis. Separate forms are provided for entering data on: materials use and cost; labor use and cost; equipment use and cost; and nonconstruction costs. Additional forms are provided for consolidated entry of material, labor and equipment use and cost data, and for computing total cost including taxes and mark-ups for overhead, profit and subcontracting. This set of sheets can be used in deriving the cost impact of less complex changes.

The next group of forms are contained in the section entitled *Housing System or Component Analysis* and are provided for analyzing more complex changes. These forms are explicitly labeled for use in analysis at the housing component or system level. Forms for separate and consolidated entry of data on materials use and cost, labor use and cost and equipment use and cost are provided.

The next two sets of forms, found in sections entitled *Sensitivity Analysis* and *Housing System or Component Sensitivity Analysis*, parallel the preceding two but are for use in applying sensitivity analysis. With the exception of two forms, the sheets are identical to those in the preceding two sections but are labeled for sensitivity analysis use and provide a place for entering the scenario designation. An additional form provides for entry of information on parameters subject to the sensitivity analysis and another is provided for consolidating and comparing the cost impact of two scenarios against the base or initial estimate.

Finally, in the section entitled *Aggregation*, a single form is provided for computing aggregate cost impact by year.

# Initial Documentation

**PROPOSED CHANGE NUMBER ______**

**Rationale and Scope of Analysis**

**Page __ of __**

**PROPOSED CHANGE NUMBER ______**

**Code Change Description**

**Page __ of __**

**PROPOSED CHANGE NUMBER ______**

**Sources of Indirect Costs**

**Page __ of __**

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**PROPOSED CHANGE NUMBER ______**

**Description of Representative Type __**

**Page __ of __**

**PROPOSED CHANGE NUMBER ______**

**Description of Representative Types __ & __**

**Page __ of __**

| Representative Type __ | Representative Type __ |
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**PROPOSED CHANGE NUMBER ______**

**Description of Design __ Representative Type __**

**Page __ of __**

**PROPOSED CHANGE NUMBER ______**

**BASE ANALYSIS**

**Material Requirements and Costs**

**Representative Type ___ Design _____**

**Page __ of __**

| Item Description | Units Required | Unit Cost | Material Cost |
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**PROPOSED CHANGE NUMBER ______**

**BASE ANALYSIS**

**Labor Requirements and Costs**

**Representative Type ___ Design _____**

**Page __ of __**

| Item Description | Hours Required | Hourly Wage | Labor Cost |
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**PROPOSED CHANGE NUMBER ______**

**BASE ANALYSIS**

**Equipment Requirements and Costs**

**Representative Type ___ Design _____**

**Page __ of __**

| Equipment Description | Units Required | Unit Cost | Equipment Cost |
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**PROPOSED CHANGE NUMBER ______**

**BASE ANALYSIS**

**Consolidated Material, Labor and Equipment Requirements and Costs**

**Representative Type ___ Design _____**

**Page __ of __**

| Item Description | Unit of Measure | Units | Unit Material Cost | Total Material Cost | Unit Labor Hours | Total Labor Hours | Hourly Wage | Total Labor Cost | Unit Equipment Cost | Unit Equipment Cost | Total Equipment Cost | Total Cost |
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**PROPOSED CHANGE NUMBER ______**

**BASE ANALYSIS**

**Other Costs**

**Representative Type ___ Design _____**

**Page __ of __**

| Item Description | Unit of Measure | Unit Cost | No. of Units | Cost |
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| **Total:** | | | | |

**PROPOSED CHANGE NUMBER ______**

**BASE ANALYSIS**

**Total Cost**

**Representative Type ___ Design _____**

**Page __ of __**

| Cost Category | Material Cost | Labor Cost | Equipment Cost | Other Cost | Total Cost |
|---|---|---|---|---|---|
| Unadjusted Amount | | | | | |
| Sales Tax (if applicable) | | | | | |
| Overhead | | | | | |
| Profit | | | | | |
| Contractor Mark-up | | | | | |
| Total | | | | | |

# Housing System or Component Analysis

**PROPOSED CHANGE NUMBER ______**

**BASE ANALYSIS**

**Material Requirements and Costs**

**Representative Type ___ Design _____**

**Housing System or Component ___________ Page __ of __**

| Item Description | Units Required | Unit Cost | Material Cost |
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**PROPOSED CHANGE NUMBER ______**

**BASE ANALYSIS**

**Labor Requirements and Costs**

**Representative Type ___ Design _____**

**Housing System or Component ___________ Page __ of __**

| Item Description | Hours Required | Hourly Wage | Labor Cost |
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**PROPOSED CHANGE NUMBER ______**

**BASE ANALYSIS**

**Equipment Requirements and Costs**

**Representative Type ___ Design _____**

**Housing System or Component ___________ Page __ of __**

| Equipment Description | Units Required | Unit Cost | Equipment Cost |
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**PROPOSED CHANGE NUMBER ______**

**BASE ANALYSIS**

**Consolidated Material, Labor and Equipment Requirements and Costs**

**Representative Type ___ Design _____**

**Housing System or Component ___________ Page __ of __**

| Item Description | Unit of Measure | Units | Unit Material Cost | Total Material Cost | Unit Labor Hours | Total Labor Hours | Hourly Wage | Total Labor Cost | Unit Equipment Cost | Unit Equipment Cost | Total Equipment Cost | Total Cost |
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# Sensitivity Analysis

**PROPOSED CHANGE NUMBER ______**

**SENSITIVITY ANALYSIS**

**Parameters Varied and Values by Scenario**

**Representative Type ___ Design _____**

**Page __ of __**

| Scenario __ | Scenario __ |
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**PROPOSED CHANGE NUMBER ______**

**SENSITIVITY ANALYSIS - Scenario ___**

**Material Requirements and Costs**

**Representative Type ___ Design _____**

**Page __ of __**

| Item Description | Units Required | Unit Cost | Material Cost |
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**PROPOSED CHANGE NUMBER ______**

**SENSITIVITY ANALYSIS - Scenario ___**

**Labor Requirements and Costs**

**Representative Type ___ Design _____**

**Page __ of __**

| Item Description | Hours Required | Hourly Wage | Labor Cost |
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**PROPOSED CHANGE NUMBER ______**

**SENSITIVITY ANALYSIS - Scenario ___**

**Equipment Requirements and Costs**

**Representative Type ___ Design _____**

**Page __ of __**

| Equipment Description | Units Required | Unit Cost | Equipment Cost |
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**PROPOSED CHANGE NUMBER ______**

**SENSITIVITY ANALYSIS - Scenario ___**

**Consolidated Material and Labor Requirements and Costs**

**Representative Type ___ Design _____**

**Page __ of __**

| Item Description | Unit of Measure | Units | Unit Material Cost | Total Material Cost | Unit Labor Hours | Total Labor Hours | Hourly Wage | Total Labor Cost | Unit Equipment Cost | Unit Equipment Cost | Total Equipment Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
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**PROPOSED CHANGE NUMBER ______**

**SENSITIVITY ANALYSIS - Scenario ___**

**Other Costs**

**Representative Type ___ Design _____**

**Page __ of __**

| Item Description | Unit of Measure | Unit Cost | No. of Units | Cost |
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| **Total:** | | | | |

**PROPOSED CHANGE NUMBER ______**

**SENSITIVITY ANALYSIS - Scenario ___**

**Total Cost**

**Representative Type ___ Design _____**

**Page __ of __**

| Cost Category | Material Cost | Labor Cost | Equipment Cost | Other Cost | Total Cost |
|---|---|---|---|---|---|
| Unadjusted Amount | | | | | |
| Sales Tax (if applicable) | | | | | |
| Overhead | | | | | |
| Profit | | | | | |
| Contractor Mark-up | | | | | |
| **Total** | | | | | |

**PROPOSED CHANGE NUMBER ______**

**SENSITIVITY ANALYSIS - Scenario __**

**Impact of Varying Assumptions**

**Representative Type ___ Design _____**

**Housing System or Component ___________ Page __ of __**

| **Parameter Varied** | **Value of Parameter** | | |
|---|---|---|---|
| | **Initial Estimate** | **Scenario 1** | **Scenario 2** |
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| Total Cost | | | |

**Housing System or Component Sensitivity Analysis**

**•PROPOSED CHANGE NUMBER ______**

**SENSITIVITY ANALYSIS - Scenario ___**

**Material Requirements and Costs**

**Representative Type ___ Design _____**

**Housing System or Component ___________ Page __ of __**

| Item Description | Units Required | Unit Cost | Material Cost |
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**PROPOSED CHANGE NUMBER ______**

**SENSITIVITY ANALYSIS - Scenario ___**

**Labor Requirements and Costs**

**Representative Type ___ Design _____**

**Housing System or Component ___________ Page __ of __**

| Item Description | Hours Required | Hourly Wage | Labor Cost |
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**PROPOSED CHANGE NUMBER ______**

**SENSITIVITY ANALYSIS - Scenario __**

**Equipment Requirements and Costs**

**Representative Type ___ Design _____**

**Housing System or Component ___________ Page __ of __**

| Equipment Description | Units Required | Unit Cost | Equipment Cost |
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**PROPOSED CHANGE NUMBER ______**

**SENSITIVITY ANALYSIS - Scenario ___**

**Consolidated Material and Labor Requirements and Costs**

**Representative Type ___ Design _____**

**Housing System or Component ___________ Page __ of __**

| Item Description | Unit of Measure | Units | Unit Material Cost | Total Material Cost | Unit Labor Hours | Total Labor Hours | Hourly Wage | Total Labor Cost | Unit Equipment Cost | Unit Equipment Cost | Total Equipment Cost | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
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**PROPOSED CHANGE NUMBER ______**

**Aggregate Cost Impact - Year ____**

**Representative Types ________**

**Page __ of __**

| Representative Type | Per-Unit Cost Impact | Number of Units Projected | Aggregate Cost-Impact |
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| **Total** | | | |

**NAHB** RESEARCH CENTER
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