Study S-209

NUCLEAR BLAST EFFECTS ON A METROPOLITAN ECONOMY

William C. Truppner

INSTITUTE FOR DEFENSE ANALYSES
ECONOMIC AND POLITICAL STUDIES DIVISION

September 1965

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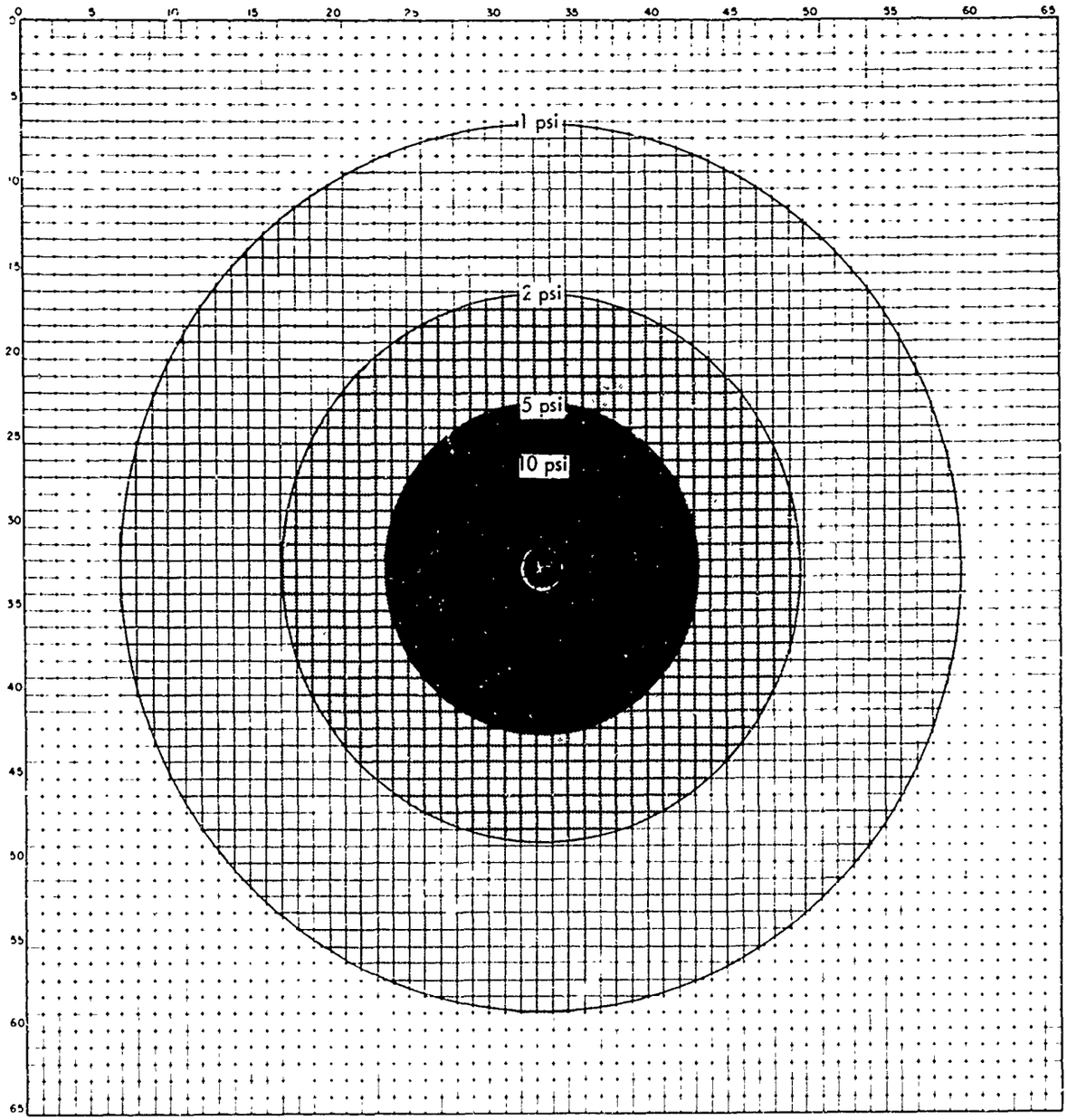

Ten Megaton Weapon Blast Effects on a 65 x 65 Matrix of Kilometer Squares

FOREWORD

The work reported in this Study is part of a continuing effort in the analyses of alternative civil defense systems by the Institute for Defense Analyses under Contract No. OCD OS-63-134 (dated June 28, 1963) with the Office of Civil Defense, Department of the Army. The studies are being performed in the Economic and Political Studies Division of IDA under the direction of Mr. Samuel Ewer Eastman, Project Leader, and Mr. W. C. Truppner, Deputy Project Leader.

This Study is a detailed treatment of material summarized in IDA Research Report R-113, The Effects of Nuclear Weapons on a Single City: A Pilot Study of Houston, Texas, September 1965. It assesses weapon effects on economic resources and considers the post-attack relationships between surviving population and resources. It emphasizes the method for assessing damage in a single city rather than the statistical results obtained from the pilot study.

The tables on loss of property values and economic output, as well as much of their analysis, were developed by Mrs. Jane-Ring Crane and Miss Elizabeth Johnston working with data prepared (under subcontract) by Jack Faucett Associates. Miss Judith Crumlish was responsible for the preparation of the statistical material dealing with the characteristics of the surviving population. Miss Dorothy Harris undertook the bulk of the work necessary to allocate property values to each of the cells of the 65 x 65 kilometer square grid used in damage assessment computations. Mr. Charles Lerner was responsible for editing the entire Study.

At the Office of Civil Defense, Department of the Army, contract liaison was provided by Mr. George Divine under the supervision of Mr. John Devaney, Systems Evaluation Division, Research Directorate.

W. C. Truppner

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SUMMARY AND CONCLUSIONS

This Study summarizes the work done to develop a method for measuring the effects of nuclear weapons on the economic resources of a single city. The method developed was applied to data describing the Houston, Texas, Standard Metropolitan Statistical Area, and the results were presented in terms of weapon effects on economic output, property values, and population characteristics including the experienced labor force.

The material contained in this document essentially reflects the results of a pilot study. The Study was designed with the limited objective of testing the feasibility of distributing measures of economic resources to a 1-kilometer square grid, so that estimates could be made of nuclear blast effects on the local economy. It is planned to conduct additional research to develop more sophisticated methods to take account of the internal viability of a single city after an attack as well as its economic relationship to the nation. In the meantime, it is hoped that publication of a study containing an appraisal of data sources, methods employed, and results obtained will prove useful to those conducting research on local areas in general, and contractors working on the OCD's Five-City Study in particular.

The first major problem in developing a measure of weapon effects on economic resources was the difficulty in obtaining reliable input data for property values. Houston tax records were used as a basis for developing an estimate of the market value of property. The complete or partial exclusion of certain types of property from taxation created gaps which had to be filled by various estimating procedures. For the property values which were initially included, difficulties were met in establishing the true relationship between assessed value and market value.

A related problem was encountered in developing reliable measures of economic output for Houston. A large variety of sources and methods had to be employed for this purpose. As a result, it was not possible to establish an orderly and integrated industrial classification system for aggregating data for individual business establishments. Moreover, the accuracy of damage assessment depends on the accuracy with which each facility producing a good or service is located in the area under study. The use of a variety of lists prepared for other purposes sometimes presented serious problems in establishing the distance between ground zero and the producing establishment. The Houston experience supports a recommendation that the Bureau of the Census establish a central data bank for economic statistics without disclosing confidential company data.

The assessment of property damage described in detail in this Study produced the following results of special interest: Approximately 90 percent of the total pre-attack property value remained undamaged after a 0.1-Mt attack, 75 percent after a 1-Mt attack, about 50 percent after a 7-Mt attack, and about 10 percent after a 100-Mt attack. No substantial differences appeared in the proportion of total property values accounted for by each of the classes of property analyzed.

The assessment of damage to economic resources produced the following important results: after a 0.5-Mt attack, undamaged facilities represented about 30 percent of pre-attack output, after a 3.0-Mt attack about 15 percent, and after a 10.0-Mt attack about 7 percent. For the same attacks, facilities damaged beyond repair represented 30 percent, 45 percent, and 60 percent of pre-attack output, respectively. The relatively greater degree of damage suffered by facilities contributing directly to industrial activity is partly explained by the fact that ground zero was located near the central city business district while an important component of property value was accounted for by residential property which is widely dispersed throughout the metropolitan area.

The percentages of total pre-attack output accounted for by facilities in various damage classes were calculated as a function of weapon yield. As the weapon yield increased, the amount of heavy damage inflicted increased at a rate equivalent to that at which the no-damage class declined. The combination of light damage and moderate damage did not show a pronounced change in terms of pre-attack relationship.

If all facilities in the no-damage and light-damage categories are regarded as available for use at some time after an attack, then almost two-thirds of the total economic capacity in all sectors would be available after a 0.5-Mt attack, almost half after a 3.0-Mt attack and only one-third after a 10.0-Mt attack.

A closer examination of the structure of Houston's post-attack manufacturing industry yielded some disturbing results. The analysis was based on a postulated detonation of a 10-Mt weapon at the at-home population centroid.[1] Damage to manufacturing facilities was measured in terms of three digit Standard Industrial Classifications except where a four digit classification was necessary to distinguish industries of different vulnerability within a three digit group.

Out of the 127 industries listed, only a half dozen registered 20 percent or more of their output in the no-damage category. The entire output of over 100 was classified in the light-to-heavy damage category.

Of the total pre-attack capacity, 14 percent fell in the no-damage class and more than half in the light-damage category, the combined capacity in the no-damage and light-damage classes was 70 percent of the pre-attack level. However, the degree of vulnerability, as well as differences in geographic distribution resulted in wide variations (0 to 100) in the percentage of capacity remaining for individual industries. In other words, the Houston economic structure was severely distorted.

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1. i.e., the population distribution in the evenings and on weekends.

This is vividly illustrated when the industries are grouped by deciles according to the percentage of capacity falling into the combined light-damage and no-damage classes. Forty of the total number of 127 listed industries had less than 10 percent of total capacity included in these two damage classes and twenty-five had over 90 percent in these classes. Thus, a total of 65 industries, or slightly more than half the total number of SIC classifications in Houston, were at the extremes of under 10 percent or over 90 percent usable. In other words, slightly less than half had between 10 and 90 percent of the capacity lost to the community.

The magnitude of this destruction is so great, that even if perfect data were available, the general picture would change little, if at all. Assuming that such a situation would be characteristic of every target city in a nuclear attack, it would appear that important tears in the fabric of the nation's industrial strength are obscured by analyses that employ only nationwide aggregation.

This finding has obvious implications for judgments based on estimates of post-attack economic output developed from statistics reflecting national totals. It might also be observed that any study of the adequacy of transportation facilities in a post-attack period should be based on an analysis of nuclear weapon effects on individual target cities expressed in terms of their production and consumption functions for individual industries.

The same attack (a 10-Mt weapon delivered to the at-home population centroid) was postulated to measure its effects on the characteristics of the Houston population. Two postures were considered: First, one in which the population of Houston was assumed to be at home and unsheltered (the no-special-shelter case), and second, one in which the residents of Houston were permitted to seek and occupy only fallout shelters in the census tract in which they live (the National Fallout Shelter Survey-Extended case--NFSS-X).[1]

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1. For a complete description, see S. E. Eastman, The Effects of Nuclear Weapons on a Single City, IDA Report R-113, Institute for Defense Analyses, Economic and Political Studies Division (Arlington, Va., September 1965).

In the no-special-shelter case, 10 percent of the population survived; in the NFSS-X case, 30 percent survived. In both cases, the general characteristics of the population, expressed in broad terms such as age groups and employment status, showed little significant change from pre-attack proportions.

The analysis of survivors both by industry in which employed and by occupational skill has important implications for the value of a shelter system. The data clearly indicate that the shelter program not only reduced the total number of fatalities, but substantially reduced post-attack distortions in the distribution of groups of workers by industrial classification and occupational skill. To the extent that the viability of a post-attack society depends on retaining some reasonable relationship between the post-attack and pre-attack distribution of skills among the experienced labor force, this result reinforces the life-saving argument for shelters: Efforts to protect people automatically increase the economic viability of the population protected.

INTRODUCTION

The ultimate purpose of any civil defense system is to save the lives of as many citizens as possible. Evaluation of a shelter system must, therefore, deal with the life-saving effects of various shelter configurations, expressed in terms of fatalities inflicted by various attacks upon a population protected by shelter programs of various sizes. But any unified program for the protection of as complex an organism as a large urban population must consider what happens "when they come out of the shelters."

Long-term survival of human society, clearly depends on how much and what kinds of economic resources survive and on how effectively they can be used to further the welfare of the surviving population. This Study is a first attempt to deal analytically with these questions.

The data presented here concern the effects of a nuclear attack on property, economic capacity,[1] and occupational skills in a large urban community, in this case Houston, Texas. Data on these effects are essential to any analysis of post-attack viability. But they are also useful in at least three other respects: First, and most obvious, any well-developed society will be concerned with measuring the economic loss resulting from an assumed nuclear attack. Second,

1. In this Study, pre-attack and post-attack comparisons of aggregate dollar output data are made in terms of "capacity" and "output." These terms are used interchangeably to denote the value of the goods and services produced by the group of facilities that accounted for specified dollar output in 1960, expressed as either undamaged, damaged, or destroyed in the post-attack period.

loss in property value is a useful measure of the economic cost of replacement, which is necessary for any study dealing with recuperation problems and long and short-term competing demands for resources. Finally, data on potential economic loss are useful in considering the relative effectiveness of alternative defense systems, which may vary widely in this respect. However, the structuring of this particular Study did not include this last application.

1.1 SOME PROBLEMS IN DEVELOPING MEASURES OF PROPERTY VALUE

For some purposes, it is necessary to try to express property value in terms of post-attack utility. The objective of this Study, however, was to develop a measure of (1) the value of the accumulated pre-attack wealth of a community, and (2) the proportions lost as a result of a series of hypothetical nuclear attacks.

While the development of a set of pre-attack property values is conceptually simple, data are not available in a form which makes them immediately usable for this purpose. In Houston, an effort was made to develop the value of physical property, defined as all structures and other above-grade improvements,together with durable property consisting of machinery, equipment, household furnishings and inventories of goods. The most comprehensive source of data relevant to this evaluation was the file of tax assessments in the Houston tax office. These records contain the assessed value of all property taxable under local, city, or county tax laws. This approach presented a number of problems.

First, certain types of property are exempt from taxation. Public buildings, streets and highways, schools, hospitals, churches, and airports are examples of the most important exemptions. Further, certain types of property were not uniformly included on the tax rolls. Thus, household furnishings and automobiles were assessed in some localities, although the records seemed incomplete in others.

A second serious problem was the difficulty of establishing the true relationship of the assessed value to the market value of various types of property. The reliability of assessed values

depends importantly on the type of property, its age, and the basis for reaching judgments. Judgments which have to be based on data reported by the owners (e.g., business machinery and equipment) may be subject to a substantial understatement leading to a consistent bias in the aggregate estimate. In Houston, the official assessment rate was 20 percent. In estimating market values by multiplying actual assessments by a factor of five, differences from the official rate were, of course, multiplied five times in dollar magnitudes. Some evidence exists to suggest that assessment values were less than 90 percent of the "official" level.

The effects of these difficulties are more severe in terms of the reliability of property-loss data for Houston as developed by the methodology used in this study. This results from the allocation of property values to one-kilometer squares and the subsequent calculation of property loss based on the distance between each square kilometer and ground zero. Since any errors in the aggregate data for Houston are multiplied in the process of allocating property values to square kilometers, the reliability of property-loss estimate becomes subject to deviations of unknown magnitude.

1.2 SOME PROBLEMS IN DEVELOPING MEASURES OF ECONOMIC OUTPUT

As was true for property values, considerable difficulties were faced in measuring the reduction in economic output resulting from the destruction of or serious damage to production units. The post-attack economic output of a metropolitan area can be measured with a number of objectives in mind: The degree to which the city is self-sustaining, the degree to which it can contribute to the rest of the nation, and the degree to which it is dependent on the rest of the nation for its viability. Difficulty in obtaining data restricted the work reported here to the first of these objectives only. The second two goals remain as subjects of future research.

Loss of output in a metropolitan area is analyzed in this Study by identifying the location of producing units, developing information on the type and quantity of products or services produced by

each, and establishing similar measures of the kind and quantity of requirements needed for continued operation. Also useful, are measures of finished goods inventories in producing plants as well as in retail and wholesale establishments, and of the level of raw material inventories on a plant basis. The last of these permits some estimate of "run-out" time for undamaged producing units in the event that new supply is not available after an attack.

In developing measures of economic output for Houston, a wide variety of sources and methods had to be employed. This necessarily imposed certain severe and inherent limitations on the usefulness and reliability of the data. Because they are inherent in the approach, such limitations would be characteristic (in varying degree) of the results obtained for any metropolitan area where the same or a similar approach was employed.

Such a variety of sources almost precludes an orderly and integrated classification system. Classifying establishments in an integrated way such as by the U.S. Government Standard Industrial Classification system is a difficult job even when data on the products and service produced by each establishment are available. When privately produced directories and tax records are used, industrial classification methods are severely handicapped, while the resulting aggregates may or may not be compatible with summary data from other sources.

Location problems give rise to another serious deficiency in the use of various sources for damage assessment. In damage assessment, emphasis must be given to the location of the particular facility that produces the good or service. Lists compiled for other purposes may reflect a greater interest in the location of corporate headquarters, administrative offices, and the like. As a result, applying a technique of damage assessment that depends importantly on the distance between a producing establishment and ground zero can produce unreliable results in the aggregate data if the source data were not compiled specifically to locate the producing facility.

The Houston experience should provide some useful guidelines in developing a data base for use in estimating economic output for other metropolitan areas. The Bureau of the Census conducted 1963 Censuses of Manufacturing, Retail Trade, Wholesale Trade, Services Industries, Mineral Industries and Transportation. The establishments included in these censuses account for a very large proportion of the economic output measure being sought. The Census returns carefully identify the location of the facility or establishment producing the goods or services, show detailed output information, and, when appropriate, detailed inventory and materials purchase data. In short, each reporting establishment can be looked at as a functioning entity in terms of its output of goods and services and its input requirements of labor and materials.

While the Census returns represent almost the precise data being sought, both in terms of coverage and content, the data on individual establishments are confidential and cannot be revealed to anyone other than Census employees. This precludes developing economic data aggregates for small areas such as one-kilometer squares. The same is true, and to only a slightly lesser degree, for larger areas such as census tracts. It would appear to be highly desirable to endeavor to work out an arrangement with the Bureau of the Census to permit the establishment of a central data bank for economic statistics based on Census data.

1.3 THE DATA FOR HOUSTON

The sections that follow present the data on property values, economic output, and occupational characteristics for Houston together with the methods used for their development. In the tables, the aggregate data are used as though no limitations with respect to their reliability exist. It seemed desirable to illustrate the way in which such data could be used to turn future research efforts to improving the quality of the input statistics.

One special word of caution is in order. Since no inter-industry relationships were used, the economic output figures essentially reflect the proportion of capacity that is lost, and the proportion that survives. In short, there is a tacit assumption that the necessary inputs of labor, capital, and materials are available to the degree needed to produce the economic output shown.

2

PROPERTY VALUES

This section presents estimates of the value of the following items in the Houston Standard Metropolitan Area: (1) all structures and other above-grade improvements; (2) durable property such as machinery, equipment, household furnishings; and (3) inventories of perishable and nonperishable goods. The value of land, grading, sodding and drainage improvements is excluded on the assumption that a nuclear attack would not significantly reduce the value of land and these improvements.

2.1 PROCEDURES USED TO ESTIMATE PROPERTY VALUES

Physical property values were subdivided into four categories reflecting the organization of data sources: (1) taxable real-estate improvements; (2) taxable machinery, equipment, and inventories; (3) nontaxable property; and, (4) household furnishings, automobiles and miscellaneous nontaxable property.

Of the total estimated physical property value of $11,277 million for Houston in 1963, 77 percent was based on values from the Houston tax-assessment file. This file includes assessed values for taxable real-estate improvements and nongovernment machinery, equipment and inventories which, when inflated to market value, total $8,647 million. Values for property owned by organizations which are not taxed (11 percent of total) were derived from estimates of market value made by government agencies and other owners. The remaining 12 percent of the value, household furnishings and automobiles was based on housing values.

The final estimates of the value of physical property (except land) in Houston in 1963 are summarized in Table 1. These are

compared with national estimates for 1958 from a recent National Bureau of Economic Research Study,[1] for which an estimated adjustment was made to eliminate the value of land.

2.1.1 Real-Estate Improvements

Tax-assessment values of real-estate improvements were the basis for estimates of the value of real-estate improvements in Table 1. The assessed values were obtained from the Houston tax file by real-estate subdivision and block or by acreage tract number. Specific locations were established for all subdivisions, blocks and acreage tracts with an assessed aggregate value in excess of $50,000. These accounted for 95 percent of the total value. To adjust for the 5 percent undercoverage, the located values were inflated by dividing by 0.95. Since the tax-assessed value of real-estate improvements represents 17.7 percent[2] of their market value, it was again necessary to inflate the values by this factor in order to convert to estimated market values.

2.1.2 Machinery, Equipment, and Inventories

The tax-assessment values of machinery, equipment, and inventories shown in Table 1 were given for each location of each company. A selection was made of all firms with a tax assessment in excess of $10,000. The list accounted for about 10 percent of the entries but covered approximately 85 percent of the total value of the file.

Owing to possible company reporting bias and to the difficulty of verifying the actual amounts of machinery, equipment, and inventories held by each business firm, the tax-assessment estimates are believed to be considerably understated: 60 percent by value

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1. R. Goldsmith, R. Lipsey, and M. Mendelson, Studies in the National Balance Sheet of the United States: Basic Data (Princeton, New Jersey: Princeton University Press, 1963) Vol. II.

2. This ratio was developed by the Tax Research Association, an independent research group in Houston.

Table 1

ESTIMATED PHYSICAL PROPERTY VALUES FOR THE STANDARD METROPOLITAN AREA OF HOUSTON AND FOR THE UNITED STATES

Property Class	Value, billions of $		Percentage of total[a]		Per Capita Value, thousands of $	
	Houston (1963)	United States (1958)	Houston	United States	Houston (1963)	United States (1958)
Total physical property	11.28	1350	100.0	100.0	9.20	7.76
Real estate improvements (except government)	6.27	668	55.6	49.5	5.11	3.84
Machinery, equipment and inventories (except government)	2.37	317	21.0	23.5	1.94	1.82
Government and other non-taxable real estate improvements and equipment	1.23	186	10.9	13.7	1.00	1.07
Household furnishings, automobiles and miscellaneous non-taxable property	1.40	179	12.4	13.3	1.14	1.03

[a]Detail may not total to 100% due to independent rounding.

was estimated to be included in tax-assessment data.[1] With the use of this percentage, the values were adjusted to the estimated value shown in Table 1.[2] The remaining 15 percent of the values (under $10,000) were distributed in the Houston area in the same proportion as the over-$10,000 values. The estimate of full market value for machinery, equipment, and inventories was obtained by dividing the assessed value by the 20-percent assessment rate used in Houston.

2.1.3 Nontaxable Property

To derive the value of physical property owned in Houston by government units, churches, and other nontaxed organizations, (such as public buildings, schools and colleges, hospitals, airports and docks, streets and highways, water and sewerage systems) it was necessary to obtain estimates of market value from the Federal, county and city agencies, as well as private organizations having cognizance over the property.

Estimates of the current value of Federal buildings were obtained from data on the original costs and dates of construction by adjusting for depreciation, the increase in construction costs and the value of furnishings and equipment in each of the buildings. Individual values were obtained for airports and equipment, for buildings and equipment owned by colleges and universities, for large churches, for stadiums, for the NASA Manned Spaceflight Center, and for non-taxable hospitals; it was necessary to estimate average values for high schools, junior high schools, and elementary schools. For county and city buildings and furnishings, navigation docks, freeways, highways, city streets, water and sewer mains and pumping stations, on the other hand, only aggregate values were obtainable.

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1. This adjustment (although probably conservative) is somewhat arbitrary due to lack of data.

2. The use of this factor increases the total value of Houston physical property by 9.4 percent.

2.1.4 Household Furnishings and Miscellaneous Nontaxable Property

Household furnishings and personal household property values, including automobiles, were estimated as a 40 percent proportion of housing values in the Houston area. The values of miscellaneous nontaxable property included in this category are those for small churches which were not individually located. These values were distributed in proportion to Houston housing values.

2.2 ALLOCATION OF PROPERTY VALUES TO TARGET VALUE ELEMENTS

In order to estimate losses in physical property values in Houston, it was necessary to establish the specific location of the economic facilities so that values could be allocated by geographical area. Facilities in all categories were located on a grid consisting of 65 x 65 kilometer-square "target value elements" (TVE's), superimposed on maps of Houston.

Tax data on real estate assessments are entered on the Houston file by school district, real estate subdivision, block number within each subdivision, and individual property ownership. Using the map designations the individual values of real-estate improvements were allocated directly to the matrix. The distribution was made with the use of real-estate maps from the Zingery Map Company in Houston. This set of approximately 150 maps of the Houston Standard Metropolitan Area had indices of the various subdivisions and large individual acreage listings.

Only subdivisions with aggregate values of $50,000 or more were assigned to specific locations. Such subdivisions were found in the map index and the area which they included located on the appropriate map. The TVE matrix was overlaid and the values of blocks and lots within the subdivisions assigned to the TVE's in which they fell. The values of subdivisions, blocks and lots located in more than one TVE cell were assigned arbitrarily to one cell. In order to minimize the distortion imposed by this arbitrary assignment of values on the boundaries, an attempt was made to equalize the number of values displaced north and south (and east and west) of their actual location.

Only values of acreage groupings whose total values were $50,000 and over were allocated to a TVE. No attempt was made to separately identify individual lots within an acreage grouping on the Zingery maps. Instead, the total value of each grouping was distributed equally to all kilometer squares in which the property was located.

Approximately 5 percent of the total value of all real-estate improvements could not be distributed by means of these procedures. This remainder, which included all aggregate listings under $50,000 and those values located within the area included by the matrix grid but not identified on the maps, was distributed to the matrix in the same proportion as the values specifically allocated.

Values of machinery, equipment, and inventories were distributed to TVE's on the basis of locations of the business firms given in the local business-property tax records. The Houston tax-assessment file lists each business firm, the assessed value of its machinery, equipment, and inventories at each location, and the street address. All values on the file in excess of $10,000 were allocated with a TVE matrix overlaid on the 1963 industrial map of Houston from the Bank of the Southwest. Values in all sectors were located on the map with a street address index and then assigned to the appropriate TVE. The map lists and identifies all manufacturing plants with more than twenty-five employees, simplifying the location of all machinery, equipment and inventories in the manufacturing sector.

The allocation of nontaxable property values to the matrix required a combination of procedures. The values of major facilities were located individually on the Bank of the Southwest map and then on the TVE matrix in accordance with map designations and street addresses obtained from local sources.

Values of Federal buildings were distributed to TVE's based on map locations of the specific street address of each building. Individual values of airports and equipment, buildings and equipment owned by colleges and universities, large churches, stadiums, the NASA Manned Spaceflight Center, and nontaxable hospitals were first

located on the Bank of the Southwest map and then assigned to the appropriate TVE's. Aggregate values for county and city buildings and furnishings and navigation docks were assigned to principal facilities in the category and distributed to TVE based on street addresses of these locations. Values for high schools, junior high schools and elementary schools were assigned to all schools within the Houston SMSA. These schools were identified on the Southwest map by street address and then given TVE designations.

Aggregate values for freeways and highways were distributed evenly over the TVE's among which they run, with double weight given to major interchanges. City street values and the values of all city water and sewerage mains and pumping stations were allocated to all TVE's in built-up areas in the same proportion as the Houston population is distributed in these areas, with the exception that facilities in the central business district were given a triple weight.

Values of household furnishings and personal property, including automobiles and small churches not specifically located, were assigned to TVE's based on the distribution of housing values to census tract and the further distribution of these values to the TVE matrix.

The use of the procedures described for city street, water, sewerage, household furnishings, personal property and small church values is based on the assumption that these values represent neighborhood facilities which in the aggregate are distributed over the map in a relatively even manner. Although this assumption is not valid when one TVE is considered alone, it seems reasonably accurate for a number of TVE's taken together.

2.3 PROCEDURES USED TO ESTIMATE LOSS IN PROPERTY VALUES

Loss in property values was determined for a range of sixteen nuclear attacks representing eight weapon yields, each detonated at ground level against both the at-home and at-work population centroids.[1] The population centroid is the single TVE at the center of the 35-psi contour which includes largest number of people for each yield.[2]

The method used is similar to that used to obtain population fatalities.[3] Damage assessments were made using the TVE matrix. The procedure used to distribute the estimated property values of real-estate improvements; machinery, equipment, and inventories; nontaxable property; and household furnishings, automobiles, and miscellaneous nontaxable property to the TVE's of the Houston matrix is described in Section 2.2.

Overpressure levels for the particular weapon were calculated for the center of every cell of the TVE matrix. These computations were based on approximations to the peak static overpressure curve in The Effects of Nuclear Weapons[4] which gives levels of overpressure at various distances from a ground zero for a weapon of 0.1-kt yield. To obtain overpressure levels for the other weapon yields, a cube root scaling factor[5] was employed. Physical property which had been

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1. Yields used were 0.1, 0.5, 1, 3, 5, 7, 10 and 100-Mt. These yields were selected because they were used in the computation of population fatalities.

2. It might be desirable in further calculations of damage to physical property to find optimum property targets which maximize property value destroyed.

3. See S. E. Eastman, The Effects of Nuclear Weapons on a Single City, IDA Report R-113, Institute for Defense Analyses, Economic and Political Studies Division (Arlington, Va., September 1965).

4. The Effects of Nuclear Weapons, ed. S. Glasstone (Washington, D.C.: U.S. Atomic Energy Commission, 2nd Edition April 1962) Figure 3.66, p. 135.

5. Ibid., p. 134.

distributed to any given TVE was considered to be in the center of that cell so that overpressure levels applying to these points would also apply to the property value.

The vulnerability to blast damage from any of the weapons was defined by a step function which describes the percent of value surviving different levels of peak static overpressure. This function, shown in Table 2, is applicable to multi-story concrete or steel-frame buildings with lightweight curtain or panel walls and steel sash, the predominant type of building construction in Houston. It is based on data from the Stanford Research Institute[1] and from the Dikewood report.[2]

A post-attack value was calculated for each physical property facility in all TVE's. For a given ground zero and a given weapon yield, physical property was assumed to be subjected to the level of peak static overpressure computed under these conditions for the TVE in which it was located. Using the step function, this overpressure level determined the percent of pre-attack value remaining after the attack. For example, Table 2 shows that a TVE which sustains an overpressure level of 4.7 psi would retain 10 percent of its value post-attack. Thus, a property in that TVE valued at $1,000 before the attack would contribute $100 to the total physical property value post-attack and to the total value of its physical property category.

For each weapon yield, the calculated post-attack values were summed over all TVE's in a given physical property category, and a grand total value of all post-attack physical property was computed.

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1. J. Crain, C. Bigelow and D. Andrews, Montgomery County Civil Defense Study: Transportation and Transportation Support Functions from Warning to Emergence, (Stanford Research Institute, Working Paper, Menlo Park, California, June 1963), p. 50.

2. L. Wayne Davis, et al., Prediction of Urban Casualties from the Immediate Effects of a Nuclear Attack (U) CONFIDENTIAL, (Dikewood Corporation, DC-FR-1028, Albuquerque, New Mexico, April 1963).

Table 2

ASSUMED RELATIONSHIP BETWEEN OVERPRESSURE AND PROPERTY SURVIVAL

Overpressure, psi		Property Surviving, %
More Than	Less Than or Equal To	
0	3.0	100
3.0	3.5	75
3.5	4.0	70
4.0	4.5	15
4.5	5.0	10
5.0		0

Post-attack property value for each category was then expressed as a percentage of pre-attack value (for the same category) and as a proportion of the value of all physical property surviving the attack.

2.4 ESTIMATES OF PROPERTY VALUE

Table 3 presents 1963 pre-attack and post-attack physical property values for Houston. Estimates of post-attack property values are shown for two different ground zeros for each of eight hypothetical weapon yields. The at-home and at-work population centroids were used as ground zeros for surface bursts in the two attacks.

As shown in the table, the total 1963 pre-attack value of physical property in Houston was estimated to be $11,277 million. Real estate improvements accounted for 56 percent of the total ($6,274 million), machinery, equipment, and inventories 21 percent ($2,373 million), nontaxable property 11 percent ($1,229 million) and household furnishings, automobiles and miscellaneous nontaxable property 12 percent ($1,402 million).

Similar data are presented for each of the sixteen hypothetical attacks considered. In general, the proportion of total property value accounted for by each of the four classes of property remains fairly constant. Of some interest is the tendency for the proportion accounted for by real-estate improvements to increase with the size of the weapon.

Table 3 also shows the percentage of the pre-attack value of total physical property and each of the four classes of property remaining after the sixteen hypothetical attacks. Approximately 90 percent of the total pre-attack value remains after a 0.1-Mt attack. This percentage drops to 75 percent after a 1-Mt attack About one-half of the total value survives a 7-Mt attack, and a 100-Mt attack destroys all but 10 percent of the total pre-attack value.

Table 3

ESTIMATED PRE- AND POST-ATTACK PHYSICAL PROPERTY VALUES FOR HOUSTON, 1963

Property Class	Population Centroid Targeted[a]	Value[b], millions of $ (percentages in parentheses)								
		Pre-Attack	Post-Attack: Weapon Yield of n Mt							
			n=0.1	n=0.5	n=1	n=3	n=5	n=7	n=10	n=100
Total value of all physical property	H	11277	10641	9230	8405	7028	6317	5829	5134	1208
	W	11277	9969	9197	8498	7125	6441	5913	5274	1156
Percent of pre-attack value	H	(100.0)	(94.4)	(82.0)	(74.5)	(62.3)	(56.0)	(51.7)	(45.5)	(10.7)
	W	(100.0)	(88.4)	(81.6)	(75.4)	(63.2)	(57.1)	(52.4)	(46.8)	(10.3)
Real-estate improvements	H	6274	5972	5314	5006	4198	3816	3551	3141	764
	W	6274	5619	5302	5016	4308	3916	3621	3229	745
Percent of pre-attack value	H	(100.0)	(95.2)	(84.7)	(79.8)	(66.9)	(60.8)	(56.6)	(50.1)	(12.2)
	W	(100.0)	(89.6)	(84.5)	(80.0)	(68.7)	(62.4)	(57.7)	(51.5)	(11.9)
Percent of all physical property	H	(55.6)	(56.1)	(57.4)	(59.6)	(59.7)	(60.4)	(60.9)	(61.2)	(63.2)
	W	(55.6)	(56.4)	(57.6)	(59.0)	(60.5)	(60.8)	(61.2)	(61.2)	(64.4)
Machinery, equipment, and inventories	H	2373	2198	1693	1457	1213	1081	979	876	241
	W	2373	1883	1639	1439	1206	1078	967	879	229
Percent of pre-attack value	H	(100.0)	(92.6)	(71.3)	(61.4)	(51.1)	(45.6)	(41.3)	(36.9)	(10.2)
	W	(100.0)	(79.4)	(69.1)	(60.7)	(50.8)	(45.4)	(40.8)	(37.0)	(9.7)
Percent of all physical property	H	(21.0)	(20.7)	(18.3)	(17.3)	(17.3)	(17.1)	(16.8)	(17.1)	(20.0)
	W	(21.0)	(18.9)	(17.8)	(16.9)	(16.9)	(16.7)	(16.4)	(16.7)	(19.8)
Nontaxable property	H	1229	1155	997	817	716	651	606	549	143
	W	1229	1116	1025	923	691	640	606	556	126
Percent of pre-attack value	H	(100.0)	(94.0)	(81.1)	(66.5)	(58.3)	(53.0)	(49.3)	(44.7)	(11.6)
	W	(100.0)	(90.1)	(83.4)	(75.1)	(56.2)	(52.1)	(49.3)	(45.2)	(10.3)
Percent of all physical property	H	(10.9)	(10.9)	(10.8)	(9.7)	(10.2)	(10.3)	(10.4)	(10.7)	(11.8)
	W	(10.9)	(11.2)	(11.1)	(10.9)	(9.7)	(9.9)	(10.2)	(10.5)	(10.9)
Homefurnishing, automobiles, and miscellaneous nontaxable property	H	1402	1317	1226	1125	901	768	693	568	60
	W	1402	1351	1232	1120	920	807	719	610	57
Percent of pre-attack value	H	(100.0)	(94.0)	(87.4)	(80.2)	(64.3)	(54.8)	(49.4)	(40.5)	(4.3)
	W	(100.0)	(96.4)	(87.9)	(79.9)	(65.6)	(57.6)	(51.3)	(43.5)	(4.0)
Percent of all physical property	H	(12.4)	(12.4)	(13.3)	(13.4)	(12.8)	(12.2)	(11.9)	(11.1)	(5.0)
	W	(12.4)	(13.6)	(13.4)	(13.2)	(12.9)	(12.5)	(12.2)	(11.6)	(4.9)

a. H = at-home population centroid, W = at-work population centroid.
b. Detail may not add to total due to independent rounding.

Differences in the property survival rates attributable to the location of the two ground zeros are minimal for each weapon except the 0.1-Mt. This is not surprising since the at-home and at-work population centroids are not far apart. The difference in the case of the smallest weapon considered is directly traceable to the difference in damage done to real-estate improvements. If the weapon is detonated at the at-work centroid, the loss suffered is double th · inflicted when the at-home centroid is ground zero. This reflects the substantial difference in property damage that results when ground zero is shifted within a general area of large concentrated real-estate improvement values for a weapon with relatively small contours.

Figure 1 shows the effect of the size of attack on property survival. Percentage of property survival values are plotted against weapon yield. If all categories of physical property were destroyed equally, a single line, sloping downward as yield increases, would be expected. But the data show the four categories are not equally affected. Machinery, equipment, and inventories suffer extensive destruction; real-estate improvements suffer less. This inequality is explained by the geographic distribution of values relative to ground zero. Machinery, equipment, and inventories are concentrated in the center of town; real-estate improvements are more dispersed with more than half of the total being accounted for by residential property.

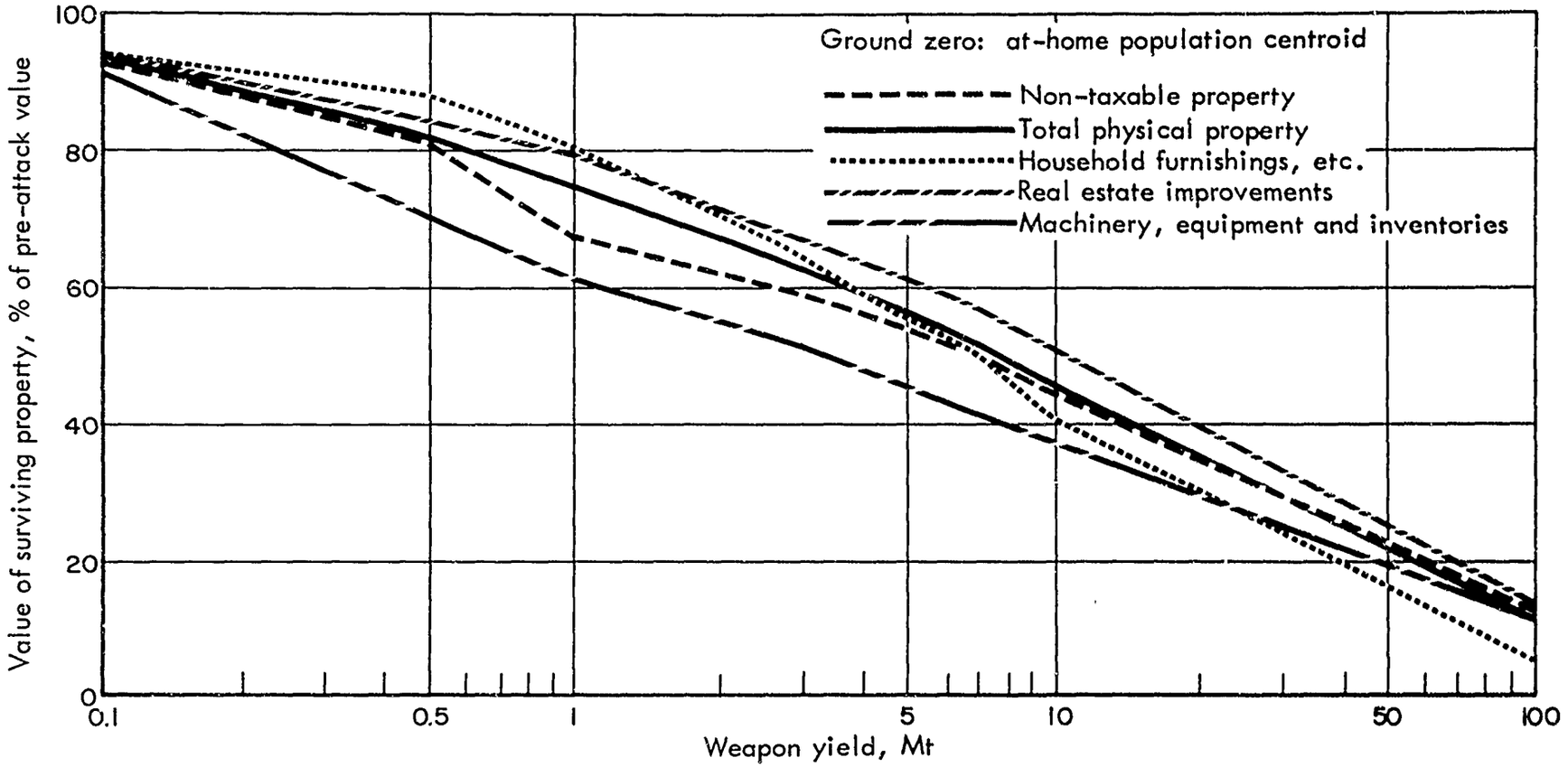

FIGURE 1 The Effect of Attack Size on Houston Property Survival

3

ECONOMIC OUTPUT

A measure of economic output that would be useful for this Study is one reflecting the final contribution of industries or sectors to the output of the Houston economy as a whole in terms of economic resources employed. Gross product was selected as an appropriate measure of the final economic importance of each sector. It includes factor payments of wages and salaries, interest, income taxes and profits, indirect business taxes, and depreciation allowances.[1]

3.1 PROCEDURES USED TO ESTIMATE ECONOMIC OUTPUT

The general methodology employed for estimating total gross product for Houston was to develop measures of value added for the manufacturing and mining sector and measures of wages and salaries for the other sectors. These measures were updated to 1960 based

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1. Other possible measures of economic output are value of shipments or receipts, value added by manufacture, and income originating. The value of shipments or receipts provides the most useful statistics on product flows. However, it is an inadequate measure of the final contribution of each sector, since the relationship between work performed and the value of receipts varies widely among sectors (and among industry groupings within some sectors). Value added differs from gross product by the exclusion of most indirect business taxes (except property taxes and license fees paid by businesses) and the inclusion of purchased business services. The latter item is a cost of operation and thus not a proper component of the measure of economic output desired. In addition, value added is normally calculated only for the manufacturing and mining sectors. For this reason it is not the most suitable single measure to provide comparability among sectors. Like gross product, income originating includes the factor payments of wages and salaries, interest, income taxes and profits; but it excludes indirect business taxes and depreciation allowances. Of the two measures, gross product is believed to be the better measure of the contribution of each sector to the economy's total output.

on the annual average increase in wages and salaries from the year for which the measures were calculated to 1960. They were then converted to an estimated total gross product for each sector by applying the appropriate national ratios.

Gross national product is routinely derived for each major sector of the economy. Since it is comprised largely of wages and salaries, there is a stable relationship between the two measures for each sector. Thus, gross product by economic sector was estimated for the Houston Metropolitan Area by applying a fixed percentage of wages and salaries to each sector other than manufacturing and mining using these national ratios.

A value-added measure of economic output was calculated for the mining and manufacturing sectors in Houston. For these two sectors, Houston SMSA gross product was derived from Houston value-added totals instead of wages and salaries by applying the national ratios.

The data used to derive these measures were taken from the US economic censuses and employment surveys and supplemented by information from local Houston sources. Also found in the economic censuses were the appropriate value added or wage and salary data for the mining, manufacturing, wholesale trade, retail trade, business and personal services, and government sectors, which account for approximately two-thirds of the gross product of the Houston SMSA.[1] The data were updated to 1960 based on the annual percentage increase in wages and salaries between 1959 and 1962 as reported in County Business Patterns.[2] Estimates of wages and salaries for the other

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1. 1958 Census of Mineral Industries, 1958 Census of Manufactures, 1960 Annual Survey of Manufactures, 1957 Census of Governments, 1958 Census of Business (for wholesale trade, retail trade and services). The data for the services sector found in the Census of Business excludes medical and professional services.

2. Employment, wages, and salaries data are available at the county level for each sector except government. The data, collected by establishments and tabulated by SIC code from BOASI reports, are generally comparable to the coverage in the economic censuses.

sectors[1] were developed from the County Business Patterns data for 1959 and were updated to 1960 following the procedure described above. Table 4 gives a summary of the methodology for obtaining total values for each sector. The final estimates, with corresponding national totals, are presented in Table 5.

3.2 ALLOCATION OF ECONOMIC OUTPUT TO TARGET VALUE ELEMENTS

The loss of economic output for Houston was calculated on the basis of the location of producing units in the TVE matrix relative to ground zero. It was therefore necessary to distribute sector values to the individual kilometer-square cells. Since the availability of data varied widely among the sectors, different procedures had to be used to complete the distribution of output for all elements of the Houston economy.

In the case of the manufacturing, mining, utilities, communications, transportation, and banking and insurance sectors, relatively few establishments accounted for a very large proportion of total output and employment. Over 90 percent of manufacturing employment (by gross product) was identified by specific location on the Bank of Southwest map and then assigned to TVE (by 3-digit SIC code) on the basis of employment data provided by a directory of manufacturing firms published by the Houston Chamber of Commerce.[2] Large establishments in the remaining sectors mentioned above were similarly located on the basis of a variety of directories and assigned employment totals with the help of local sources.

For each of the foregoing sectors, the total employment specifically located was compared with the aggregate Houston employment estimates for the sector to establish the percentage of gross

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1. Contract construction, medical and professional services, transportation (except railroads), communications, public utilities, and finance, insurance and real estate.

2. Houston Gulf Cost Area Manufacturers' Directory, ed. Howard N. Martin and B. Wayne Carroll (Houston: Houston Chamber of Commerce, Manufacturing Division, Research Committee, 1963).

Table 4

DERIVATION OF HOUSTON STANDARD METROPOLITAN AREA GROSS PRODUCT BY SECTOR

Sector	Elements of Gross-Product Calculation
MINING	Value of Shipments, Houston, (1958 Census of Mineral Industries) X Ratio of Value Added to Value of Shipments for Texas 1958 → 1958 Estimated Value Added, Houston X U. S. Ratio of Gross Product to Value Added 1958 → 1958 Estimated Gross Product, Minerals Production, Houston X 1958 Estimated Gross Product Mining Services, Houston → Total Estimated Houston Gross Product 1960[a]
CONSTRUCTION	Estimate of Houston Wages and Salaries 1960, Interpolation Btwn 1959 and 1962 (County Business Patterns Data) X U. S. Ratio of Gross Product to Wages and Salaries, 1958 → Total, Estimated Houston Gross Product, 1960
MANUFACTURING	1958 Value Added by 3-Digit SIC, Houston (Census of Manufactures) → 1960 Value Added, Based on Change in 2-Digit Data in Period for Houston (Annual Survey of Manufactures) X U. S. Ratio Gross Product to Value Added for all Manufacturing Combined, 1958 → Total, Estimated Houston Gross Product, 1960
WHOLESALE TRADE	1958 Wages and Salaries, Houston (Census of Business) → 1960 Wages, Applying Annual % Increase in Salaries (County Business Pattern, 1959 & 1962) to 1958 Figures for Houston X 1958 U.S. Ratio Gross Product to Wages and Salaries → Total, Estimated Houston Gross Product, 1960
RETAIL TRADE	1958 Wages and Salaries, Houston (Census of Business) → 1960 Wages, Applying Annual % Increase in Salaries (County Business Pattern, 1959 & 1962) to 1958 Figures for Houston X 1958 U.S. Ratio Gross Product to Wages and Salaries for Wholesale Trade → Total, Estimated Houston Gross Product, 1960
SERVICES	1958 Wages and Salaries Excluding Medical and Professional Services, Houston (Census of Business) X [Wages and Salaries of all Service Industries, Houston / Wages and Salaries for all Services Excluding Medical and Professional, Houston] County Business Patterns, 1959 → Estimated Wages and Salaries 1960, Houston, Based on Average Annual Increase Btwn 1959 and 1962 X 1958 U.S. Ratio Gross Product to Wages and Salaries → Total, Estimated Houston Gross Product, 1960
TRANSPORTATION, COMMUNICATION & UTILITIES	1960 Wages and Salaries for Houston Based on 1959 & 1962 (County Business Patterns Data) + Wages and Salaries of Houston Railroad Workers Not Covered by Preceding Data X 1960 U.S. Ratio Gross Product to Wages and Salaries → Total, Estimated Houston Gross Product, 1960
FINANCE, INSURANCE AND REAL ESTATE	1960 Wages and Salaries, Houston, from Interpolation Btwn 1958 & 1960 Figures (County Business Patterns) X 1960 U.S. Ratio Gross Product to Wages and Salaries → Total, Estimated Houston Gross Product, 1960
GOVERNMENT	1957 Wages and Salaries for State, County, City and School Employment, Houston, (Census of Governments) + 1960 Wages and Salaries for Individual Federal Facilities, Houston X Inflation Factor for Increase in Wages and Salaries Btwn 1957 & 1960 Based on 1960 Texas Employment Commission Employment Estimates X 1960 U.S. Ratio Gross Product to Wages and Salaries → Total, Estimated Houston Gross Product, 1960

a. Since changes in mining output and employment between 1958 and 1960 appear to be insignificant, the 1958 total gross product estimate is used to represent 1960.

Table 5

GROSS PRODUCT BY ECONOMIC SECTOR
FOR HOUSTON[a] AND THE UNITED STATES

Sector	Gross Product[b]				
	Harris County		United States		
	Millions of 1960 Dollars	Percent of Total	Millions of 1960 Dollars	Percent of Total	Harris County as Percent of U.S. Total
Mining	130	3.6	11,400	2.4	1.1
Construction	240	6.7	23,700	5.0	1.0
Manufacturing	1,119	31.1	139,900	29.2	0.8
Transportation Communication, and Utilities	410	11.4	45,600	9.5	0.9
Wholesale Trade	347	9.6	89,000	18.6	0.8
Retail Trade	356	9.9			
Finance, Insurance and Real Estate	489	13.6	61,300	12.8	0.8
Services	339	9.4	54,300	11.4	0.6
Government	166	4.6	52,900	11.1	0.3
TOTAL[c]	3,596	100.0	478,100	100.0	0.8

a Standard Metropolitan Area (Harris County)

b Detail may not total to 100% due to independent rounding.

c Excluding agriculture, households, institutions, and rest of world.

product not distributed on an individual facility basis. When necessary, this residual was distributed in the TVE matrix for each sector on the basis of the tax file for machinery, equipment, and inventories. The file was analyzed, smaller firms were coded by sector and located by street address, and the assessment value was then distributed by sector to TVE's. The residual employment mentioned above was then allocated by TVE on the basis of the small firm percentage distribution from the tax file. The gross product used in the damage calculations was prepared from the sum of the two components.

Gross-product values for wholesale trade, retail trade and construction were distributed to firms in each sector listed on the tax file based on the distribution of the assessed values of machinery, equipment and inventories of these firms over the matrix. The small firms not included were assumed to be distributed over one-kilometer squares in the same proportion as the allocation of firms included.[1]

Service establishments were inadequately represented in the list of firms obtained from the tax file due to their generally small size. These establishments were assumed to be distributed over the Houston area in the same manner as retail trade facilities. Thus, gross product for this sector was distributed to locations on the Southwest map and then to TVE's in the same proportions as those for the allocation of gross product values for retail trade.

Gross product for the government sector was distributed separately for Federal government, local government, and schools. The separate estimates of gross product for Federal government and local government were distributed to individual locations on the map based on employment estimates of each. These values were then assigned to the

1. It is estimated that firms actually included on the tax file made up the following percentages of total value in each sector: wholesale trade, 70%; retail trade, 55%; construction, 55%.

appropriate TVE's. Specific estimates of employment by location accounted for all federal employment and two-thirds of local government employment; the residual was implicitly prorated with the totals specifically located. Gross product for schools was distributed to TVE's based on the distribution of physical values of school facilities.

3.3 PROCEDURES USED TO ESTIMATE LOSS IN ECONOMIC OUTPUT

The method used for estimating loss in economic output was similar to that employed for property value destruction. The targets and weapon yields chosen were the same as those used for hypothetical attacks on physical property. Thus, loss of economic output was computed for eight weapon yields, each detonated at ground level at both the at-home and at-work population centroids. As in the case of physical property, the TVE matrix was employed to make all damage assessments.

Approximations to the peak static overpressure curve in The Effects of Nuclear Weapons were used to obtain overpressure levels for the TVE matrix. The cube-root yield factor was used to give overpressure levels for weapon yields other than 0.1-kt.[1] Just as the level of overpressure of a TVE for a given weapon yield was determined by the distance between the center of the TVE cell and ground zero, all economic output values distributed to a TVE were assumed to be located at its center.

For the manufacturing sector susceptibility to damage was determined from a set of physical vulnerability codes developed by the National Resource Evaluation Center, Office of Emergency Planning (NREC). Three-or four-digit Standard Industrial Classification groups were assigned vulnerability codes based on the

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1. The Effects of Nuclear Weapons, ed. S. Glasstone (Washington, D.C.: U.S. Atomic Energy Commission, 2nd Edition April 1962) p. 134, 135.

structural type considered typical for the industrial class. Through a conversion table, three damage categories (light, moderate and severe) were related to three different levels of overpressure received from surface bursts for each industrial class. NREC gives the following definitions for these three levels of damage:

> (1) Severe Structural Damage. At least that degree of structural damage which precludes further use of a structure for the purpose for which it is intended without essentially complete reconstruction, and requires extensive reconstruction effort for use for any purpose.
>
> (2) Moderate Structural Damage. At least that degree of structural damage which precludes effective use of a structure for the purpose for which it is intended until major repairs are made to principal load-carrying members (trusses, columns, load-bearing walls, beams).
>
> (3) Light Damage. That degree of damage which permits effective use of a structure for its intended purpose, but which, if not repaired, will cause deterioration and eventual loss of the structure for its intended use; e.g., loss of windows, damage to doors and roof.

The mining sector was assigned the SIC code for petroleum refineries and then treated accordingly under the NREC procedure for this code. This reflected the heavy preponderance of petroleum and gas extraction in the total Houston mining output.

For all other sectors, a single vulnerability code was chosen (4.8 psi overpressure = severe damage, 3 psi overpressure = moderate damage, and 1 psi overpressure = light damage) based on the step function used for property value damage calculations.[1] For these sectors the code describes the vulnerability to blast damage of multi-story, concrete, or steel-frame buildings with lightweight curtain or panel walls, and steel sash. This is the predominant type of building construction in Houston.

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1. See Table 2, p. 16.

The pre-attack economic output value of an industry in a TVE was assigned to some damage category for every weapon and every ground zero. For a given weapon yield, an industry located in a particular TVE was assumed to suffer overpressure equal to the overpressure level for the center of its TVE based on the distance of this point from the specified ground zero. By means of a conversion table, the vulnerability code was translated to psi to give the three levels at which structures of its industrial class are vulnerable to light, moderate, and heavy damage.

Damage was computed by comparing the overpressure received in the TVE due to weapon blast effects with these three industrial psi vulnerability levels. Industries were classified as having received light, moderate, heavy or no damage according to the overpressure received in their TVE. In general, values for industries in TVE's whose overpressure levels were between those for two damage categories were assigned to the category of lesser damage. All industries in grid elements which received lower overpressure than that inflicting light damage were considered undamaged.[1]

There are several differences between the NREC method used to assess damage to the manufacturing and mining sectors and the one described above, which was used to assess damage to the other sectors. Of major importance is the difference in the overpressure levels used to define the boundaries of light, moderate, and heavy damage.

Thus, the building vulnerability levels for the three damage levels were 1.0, 3.0, and 4.8 psi[2] as applied to all sectors except manufacturing and mining. With respect to these two sectors, a

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1. For all industries within the manufacturing sector and for all other sectors, this level was 1 psi.

2. See Table 3, p. 18.

variety of vulnerability levels were applied, depending on the particular industry being considered. In only one case (lumber and wood products) were the vulnerability levels lower than those used for buildings: 1.0, 2.5, and 3.0 psi for the three damage levels. For all remaining industries, the lower level of light damage is the same in both procedures, 1.0 psi. For most remaining industries, the lower level of moderate damage is over 10 psi, while that for heavy damage, over 14 psi.

This accounts for the difference in the damage level calculated for the machinery, equipment, and inventory property file (1.0, 3.0, and 5.0 psi for the three damage levels) and the related data on manufacturing output as shown in the tables that follow. The SRI vulnerability criteria were used for all physical property files, although the NREC criteria might have been more applicable to the machinery, equipment, and inventory data. It did not seem feasible to prepare an industrial coding for this file that would be reliable enough to warrant a finer-grain analysis. Moreover, the proportion of the value accounted for by each of the three components of the total was unknown. With the more detailed classifications available for the output data, on the other hand, use of the NREC procedure was indicated for the manufacturing sector.

3.4 ESTIMATES OF ECONOMIC OUTPUT

Table 6 presents values of estimated pre-attack and post-attack economic output for Houston for a 0.5-, 3.0- and 10.0-Mt weapon detonated at the at-home population centroid. Measures are expressed in terms of gross product for major sectors of its economy. The pre-attack output value for all sectors of the Houston economy was estimated at $3,595 million (1960 dollars), with manufacturing accounting for almost one-third of the total.

To emphasize a previous observation, applying pre-attack output measures to damage classes does not give a true measure of post-attack output. These values should be interpreted as measures of maximum possible output given all necessary inputs (such as raw materials and labor) and thus as post-attack capacity.

Table 6

PRE- AND POST-ATTACK HOUSTON OUTPUT BY SECTOR FOR THREE WEAPON YIELDS[a]

Sector	Weapon Yield, Mt	Pre-attack Output Value[b]	No Damage		Light Damage		No & Light Damage		Moderate Damage		No, Light & Moderate Damage		Heavy Damage	
			Output Value[b]	Percent of Pre-attack	Output Value[b]	Percent of Pre-attack	Output Value[b]	Percent of Pre-attack	Output Value[b]	Percent of Pre-attack	Output Value[b]	Percent of Pre-attack	Output Value[b]	Percent of Pre-attack
Mining	0.5	129,715	53,704	41.4	41,568	32.0	95,272	73.4	0	.1	95,272	73.4	34,443	26.6
	3.0	129,715	45,122	34.8	45,472	35.1	90,594	69.8	369	.3	90,963	70.1	38,752	29.9
	10.0	129,715	35,944	27.7	52,881	40.8	88,825	68.5	872	.7	89,697	69.1	40,018	30.9
Construction	0.5	240,000	89,440	37.3	98,336	41.0	187,776	78.2	19,592	8.2	207,368	86.4	32,632	13.6
	3.0	240,000	12,528	5.2	88,528	36.9	101,056	42.1	37,976	15.8	139,032	57.9	100,968	42.1
	10.0	240,000	9,816	4.1	24,528	10.2	34,344	14.3	56,368	23.5	90,712	37.8	149,288	62.2
Manufacturing	0.5	1,118,857	558,279	49.9	486,674	43.5	1,044,953	93.4	21,535	1.9	1,066,488	95.3	52,369	4.7
	3.0	1,118,857	347,764	31.1	621,594	55.6	969,358	86.6	20,707	1.9	990,065	88.5	128,792	11.5
	10.0	1,118,857	156,403	14.0	632,205	56.5	788,608	70.5	51,446	4.6	840,054	75.1	278,803	24.9
Transport, etc.	0.5	409,744	104,675	25.5	127,749	31.2	232,424	56.7	7,216	1.8	239,640	58.5	170,104	41.5
	3.0	409,744	34,491	8.4	124,261	30.3	158,752	38.7	48,167	11.8	206,919	50.5	202,825	49.5
	10.0	409,744	14,232	3.5	56,405	13.8	70,637	17.2	51,364	12.5	122,001	29.8	287,743	70.2
Wholesale Trade	0.5	347,000	62,639	18.1	143,908	41.5	206,547	59.5	17,366	5.0	223,913	64.5	123,087	35.5
	3.0	347,000	32,921	9.5	46,299	13.3	79,210	22.8	83,979	24.2	163,187	47.0	183,811	53.0
	10.0	347,000	13,667	3.9	53,136	10.1	48,803	14.1	24,202	7.0	73,005	21.0	273,995	78.9
Retail Trade	0.5	356,000	93,480	26.3	86,642	24.3	180,122	50.6	14,547	4.1	194,669	54.7	161,331	45.3
	3.0	356,000	28,516	8.0	78,107	21.9	106,623	30.0	38,559	10.8	145,182	40.8	210,818	59.2
	10.0	356,000	13,496	3.8	37,987	10.7	51,483	14.5	38,244	10.7	89,727	25.2	266,273	74.8
Finance, etc.	0.5	488,530	51,548	10.6	58,947	12.1	110,495	22.6	97,755	20.0	208,250	42.6	280,280	57.4
	3.0	488,530	12,642	2.6	44,786	9.2	57,428	11.8	11,221	2.3	68,649	14.1	419,881	85.9
	10.0	488,530	5,390	1.1	29,792	6.1	35,182	7.2	13,769	2.8	48,951	10.0	439,579	90.0
Services	0.5	338,908	63,203	18.6	60,969	18.0	124,172	36.6	67,703	20.0	191,875	56.6	147,033	43.4
	3.0	338,908	29,141	8.6	41,164	12.1	70,305	20.7	22,453	6.6	92,758	27.4	246,150	72.6
	10.0	338,908	5,781	1.7	37,303	11.0	43,084	12.7	18,633	5.5	61,717	18.2	277,191	81.8
Government	0.5	166,310	42,122	25.3	32,566	19.6	74,688	44.9	6,832	4.1	81,520	49.0	84,790	60.0
	3.0	166,310	14,508	8.7	33,149	19.9	47,657	28.7	6,108	3.7	53,765	32.3	112,545	67.7
	10.0	166,310	2,931	1.8	25,425	15.3	28,356	17.1	14,554	8.8	42,910	25.8	123,400	74.2
Total	0.5	3,595,064	1,119,090	31.1	1,137,359	31.6	2,256,449	62.8	252,546	7.0	2,508,995	69.8	1,086,069	30.2
	3.0	3,595,064	557,633	15.5	1,123,350	31.2	1,680,983	46.8	269,539	7.5	1,950,522	54.3	1,644,542	45.7
	10.0	3,595,064	257,660	7.2	931,662	25.9	1,189,322	33.1	269,452	7.5	1,458,774	40.6	2,136,290	59.4

a. Ground zero: at-home population centroid.
b. Output values in thousands of 1960 dollars.

Figure 2 shows the percentage of total pre-attack output falling into each damage class as a function of weapon yield. As the weapon yield increases, the rate of heavy damage received increases, largely by the transfer of equivalent output from the no-damage class. The combination of light damage and moderate damage does not show a pronounced change from their pre-attack relationship.

The proportions of pre-attack output of major sectors by type of damage received for the 0.5-, 3.0-, and 10.0-Mt weapons are shown in Figures 3, 4, and 5. With the exception of mining and manufacturing, the sector differences in the degree of damage suffered is the result of geographic distribution relative to ground zero. While this factor influences the results for the mining and manufacturing sectors as well, the use of different vulnerability codes introduces an additional variable.

For the 0.5-Mt weapon (Figure 3) some damage is suffered by facilities accounting for a range of 75 to 90 percent of the output of transportation and communication, wholesale trade, retail trade, finance, insurance, real estate, services, and government sectors. About one-half of the output of the finance, government, and retail trade sectors is heavily damaged by the same weapon. In particular, the finance sector with firms located in the center of Houston is hard-hit, with nearly 80 percent of its pre-attack output value moderately or heavily damaged. On the other hand, at least 50 percent of all sectors but finance, services, and government receive either no damage or light damage and three-quarters of mining and construction, as well as over 90 percent of manufacturing output, is in these two categories for the same weapon.

Under the 3.0-Mt weapon attack (Figure 4), only in the mining, construction and manufacturing sectors does less than one-half of the output receive heavy damage. On the other hand, about 40 percent of transportation and construction output, 70 percent of mining, and almost 90 percent of manufacturing output values were in the no-damage and light-damage categories.

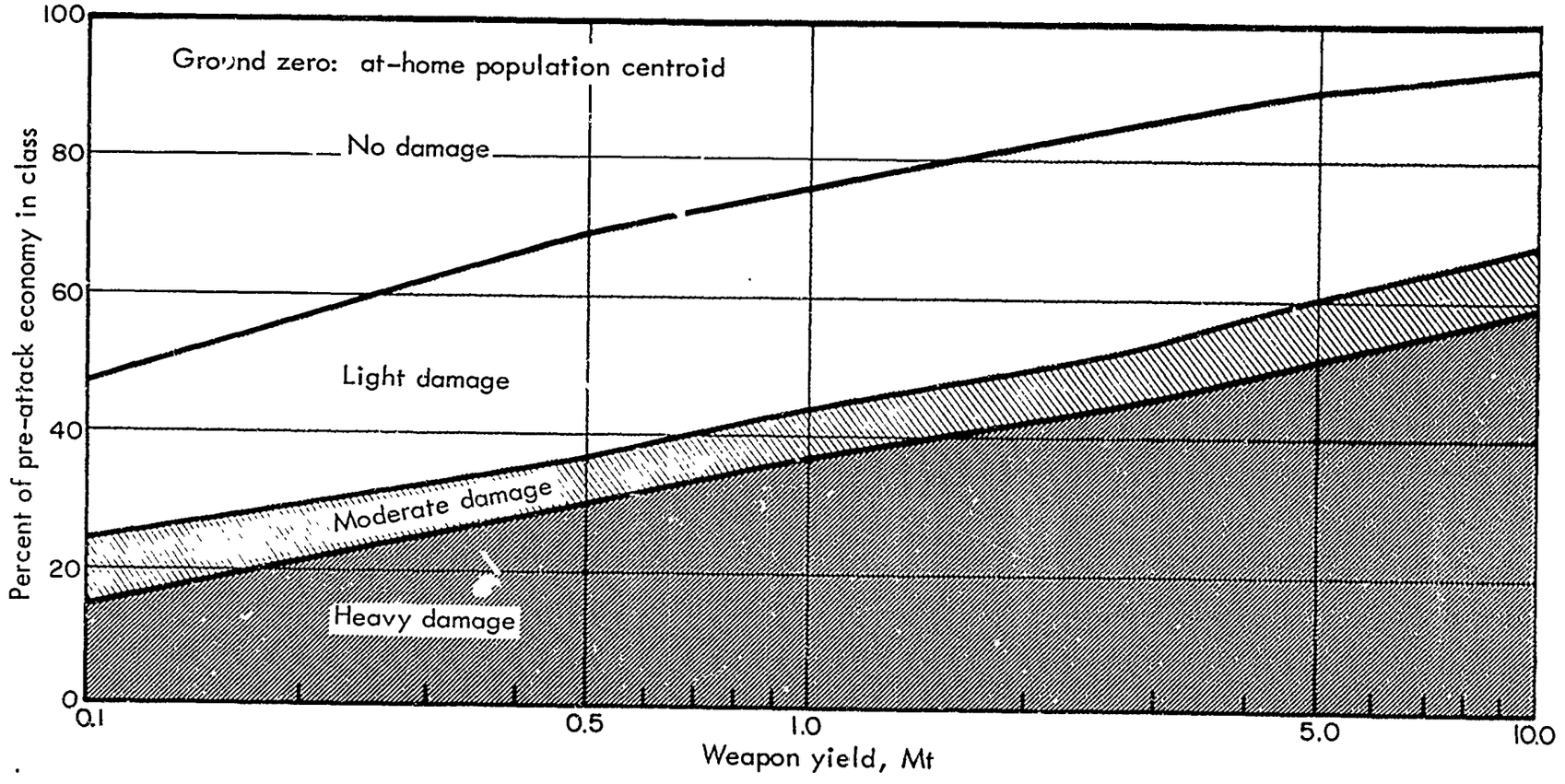

FIGURE 2 Distribution of Total Houston Economic Output by Damage Class as a Function of Weapon Yield

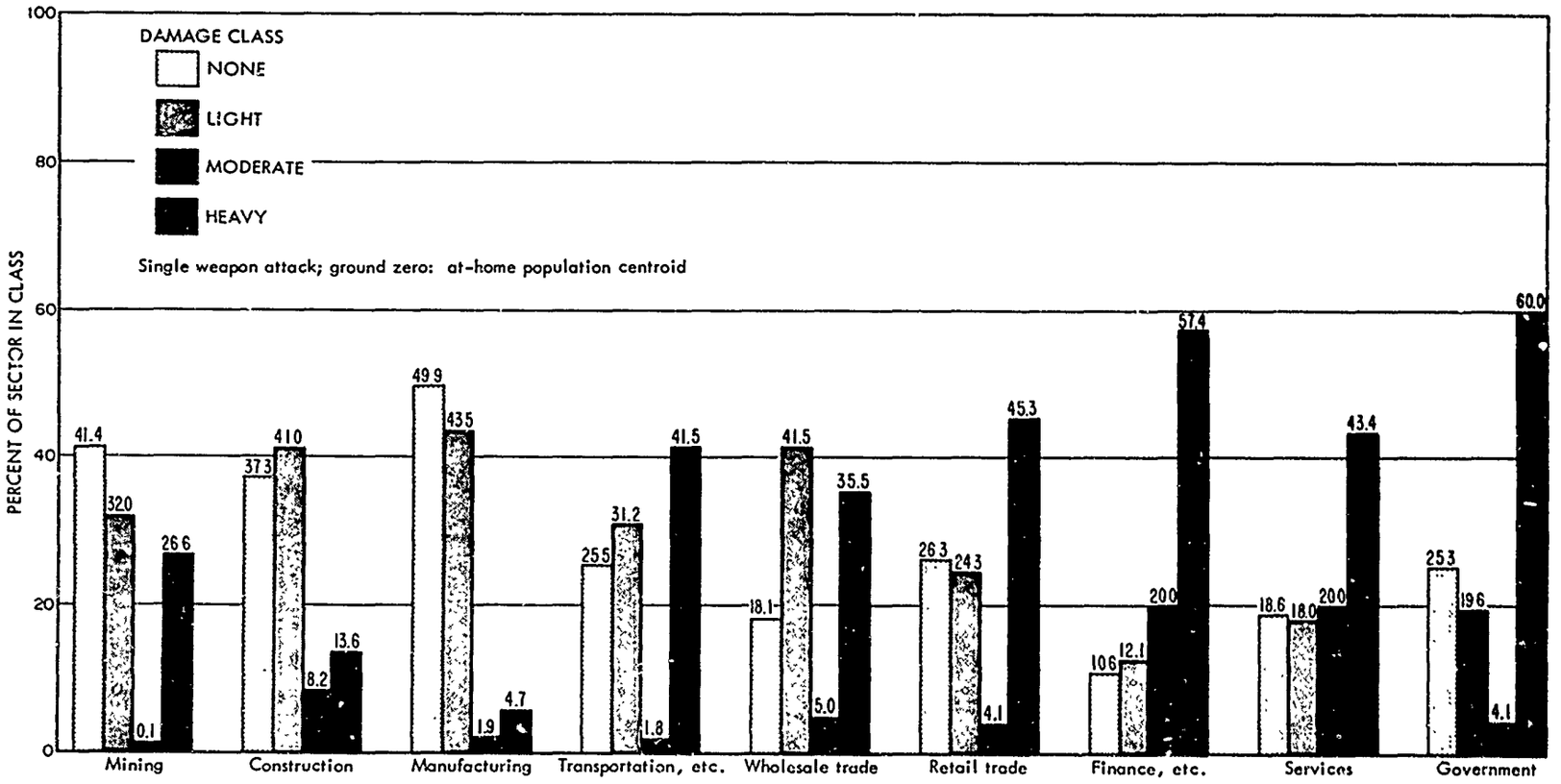

FIGURE 3 Distribution of Houston Economic Output by Sector among Damage Classes: 0.5-Mt Attack

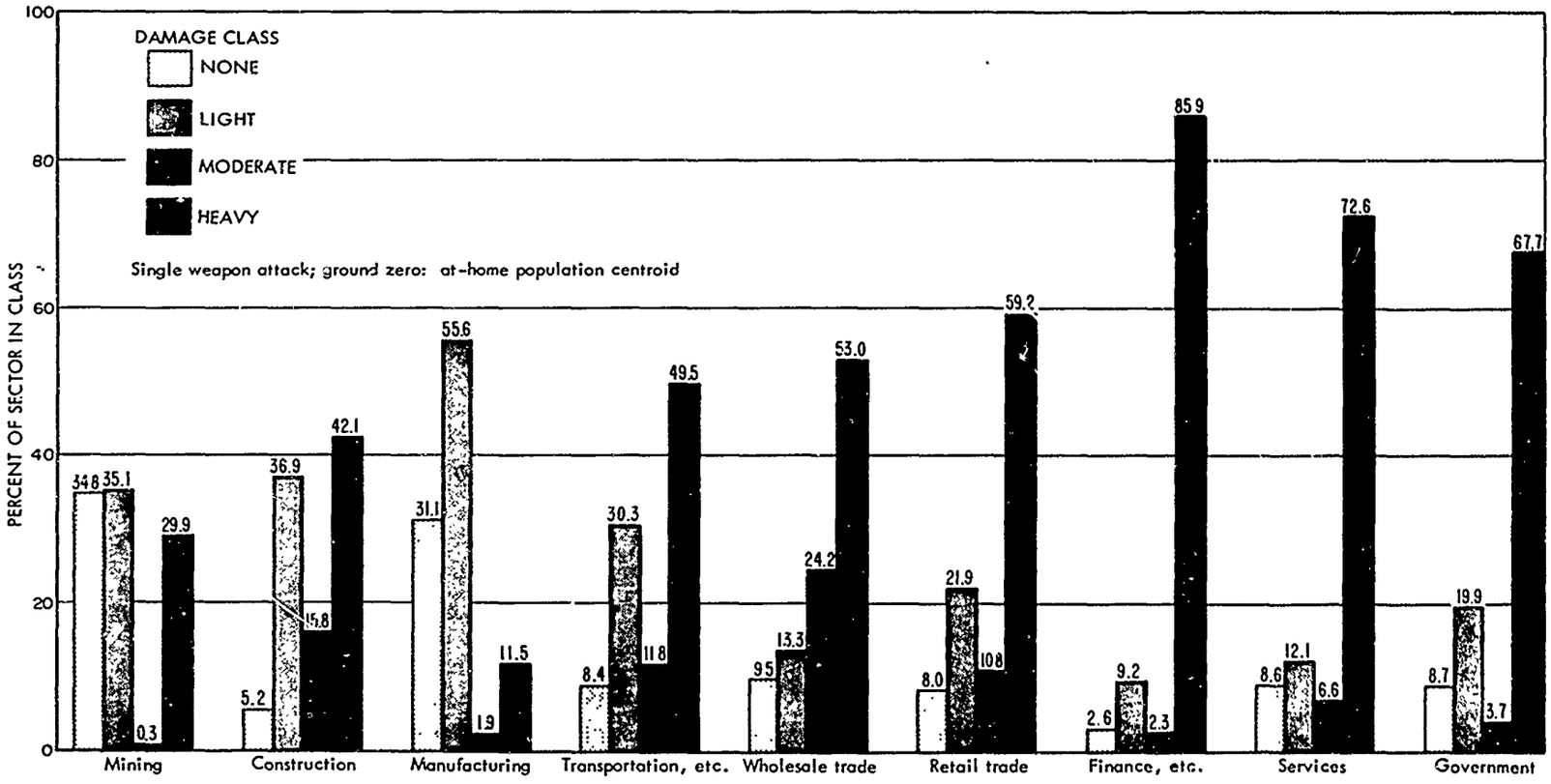

FIGURE 4 Distribution of Houston Economic Output by Sector among Damage Classes: 3.0-Mt Attack

For a 10.0-Mt attack (Figure 5), output values with damage limited to none or light, account for less than 20 percent of the total value for every sector except mining and manufacturing (70 percent each). Heavy damage is sustained by facilities accounting for a range of 70 to 90 percent of the value of the transportation and communication, wholesale trade, retail trade, finance, services, and government sectors. Eighty-five percent of the pre-attack output of the construction sector receives either moderate or heavy damage. Fifteen percent of manufacturing and 30 percent of mining gross product is still undamaged.

The fact that for all three weapons a larger percent of the output of the construction, wholesale trade, retail trade, and the transportation and communication sectors is assigned to moderate damage than for the other sectors suggests that values for these sectors are widely dispersed throughout the Houston SMSA. The economic output of mining, on the other hand, was allocated partially to oil and gas fields surrounding Houston and partially to central offices of oil companies in the inner city. Therefore, for the 0.5-Mt weapon, for example, approximately one-fourth is heavily damaged, three-fourths receives no or light damage, and none is in the moderate damage category. Construction follows a pattern reflecting substantial dispersion on the outskirts of the metropolitan area. Almost 40 percent receives no damage for the 0.5-Mt yield, while over 40 percent is heavily damaged by a weapon of 3.0-Mt and 85 percent is moderately or heavily damaged by the 10.0-Mt attack.

To summarize, if all output in the no-damage and light-damage categories is thought of as total capacity available in Houston at a given time post-attack, then almost two-thirds of the total pre-attack economic capacity in all sectors is available after a 0.5-Mt attack, almost half after a 3.0-Mt attack, and only one-third after a 10.0-Mt attack.

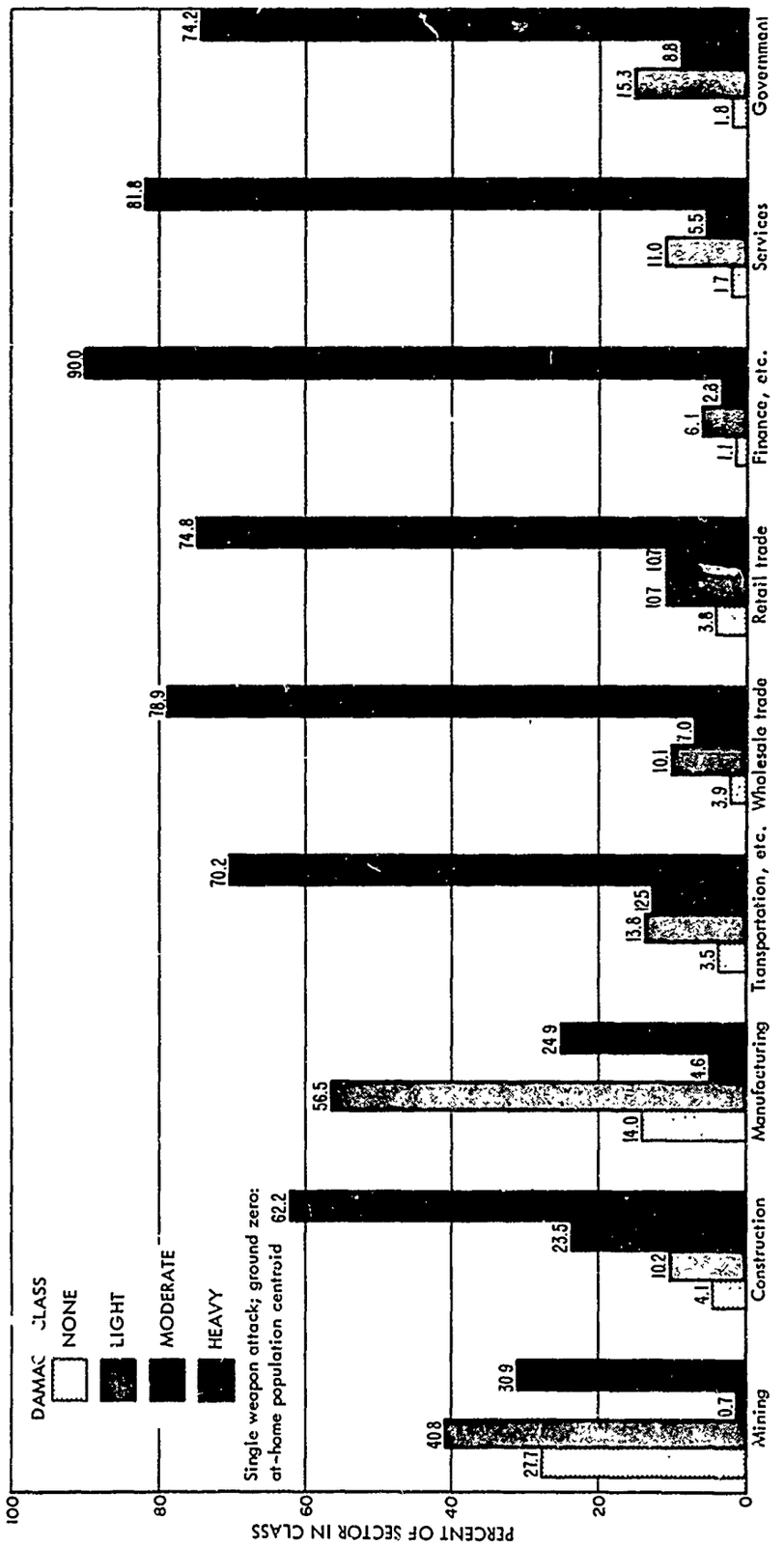

FIGURE 5 Distribution of Houston Economic Output by Sector among Damage Classes: 10.0-Mt Attack

Tables 7, 8, and 9 examine these totals more closely by comparing, for the same three weapons, the pre-attack percentage distribution of economic output among the major sectors with the distribution of post-attack output within various damage categories. Shortly after weapon delivery, post-attack available capacity in the Houston economy might be described by that proportion of each sector receiving no damage. At a later period, depending on the time necessary for repair, capacity would be approximated by that proportion of each sector with either no damage or light damage. Given further time for repair, the proportion of each sector suffering no, light, or moderate damage might reflect productive facilities more closely. Thus, these tables are intended to provide some insight into the degree of distortion that might exist in intersectoral relationships.

For all sectors except mining and manufacturing, and for all weapons, the post-attack ratio of sector output to total output decreases from the pre-attack ratio. The output of the finance sector falls from 14 percent of the pre-attack total to 5 percent (no and light damage) after a 0.5-Mt attack and 4 percent after a 10.0-Mt attack. On the same basis, output of the manufacturing sector increases from a little less than a third of the pre-attack proportion to almost half of the new total with a 0.5-Mt weapon, 60 percent with a 3.0-Mt weapon and about two-thirds with a 10.0-Mt weapon.

Nine industries accounted for some two-thirds of the estimated 1960 manufacturing output of Houston. Post-attack output for each of these industries is expressed as a percent of total output by damage class in Table 10. Pre-attack and post-attack output data by damage class are presented for those industries which individually contributed over 2 percent of the estimated 1960 manufacturing output of Houston.

Four of these industries--SIC 2810, Industrial Inorganic and Organic Chemicals; SIC 2820, Plastic Materials and Synthetic Rubber and Other Man-Made Fibers Except Glass; SIC 2910, Petroleum Refining;

Table 7

POST-ATTACK HOUSTON OUTPUT OF MAJOR SECTORS
BY DAMAGE CLASS: 0.5-MT ATTACK[a]

Sector	Output, % of total[b]						
		Post-Attack					
	Pre-Attack	No Damage	Light Damage	No & Light Damage	Moderate Damage	No, Light & Moderate Damage	Heavy Damage
Mining	3.6	4.8	3.7	4.2	0	3.8	3.2
Construction	6.7	8.0	8.6	8.3	7.8	8.3	3.0
Manufacturing	31.1	49.9	42.8	46.3	8.5	42.5	4.8
Transportation, Communication and Utilities	11.4	9.4	11.2	10.3	2.9	9.6	15.7
Wholesale Trade	9.7	5.6	12.7	9.2	6.9	8.9	11.3
Retail Trade	9.9	8.4	7.6	8.0	5.8	7.8	14.9
Finance, Insurance and Real Estate	13.6	4.6	5.2	4.9	38.7	8.3	25.8
Services	9.4	5.6	5.4	5.5	26.8	7.6	13.5
Government	4.6	3.8	2.9	3.3	2.7	3.2	7.8
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0
OUTPUT	3.595[c]	1.119	1.137	2.256	0.253	2.509	1.086

a. Single-weapon attack; ground zero: at-home population centroid.
b. Detail may not total to 100% due to independent rounding.
c. Millions of 1960 dollars.

Table 8

POST-ATTACK HOUSTON OUTPUT OF MAJOR SECTORS
BY DAMAGE CLASS: 3.0-MT ATTACK[a]

Sector	Output, % of Total[b]						
		Post-Attack					
	Pre-Attack	No Damage	Light Damage	No & Light Damage	Moderate Damage	No, Light & Moderate Damage	Heavy Damage
Mining	3.6	8.1	4.0	5.4	0.1	4.7	2.4
Construction	6.7	2.2	7.9	6.0	14.1	7.1	6.1
Manufacturing	31.1	62.4	55.3	57.7	7.7	50.8	7.8
Transportation, Communication, and Utilities	11.4	6.2	11.1	9.4	17.9	10.6	12.3
Wholesale Trade	9.7	5.9	4.1	4.7	31.2	8.4	11.1
Retail Trade	9.9	5.1	7.0	6.3	14.3	7.4	12.8
Finance, Insurance and Real Estate	13.6	2.3	4.0	3.4	4.2	3.5	25.5
Services	9.4	5.2	3.7	4.2	8.3	4.8	15.0
Government	4.6	2.6	3.0	2.8	2.3	2.8	6.8
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0
OUTPUT	3.595[c]	0.558	1.123	1.681	0.270	1.951	1.645

a. Single-weapon attack; ground zero: at-home population centroid.
b. Detail may not total to 100% due to independent rounding.
c. Millions of 1960 dollars.

Table 9

POST-ATTACK HOUSTON OUTPUT OF MAJOR SECTORS
BY DAMAGE CLASS: 10.0-MT ATTACK[a]

Sector	Output, % of Total[b]						
		Post-Attack					
	Pre-attack	No Damage	Light Damage	No & Light Damage	Moderate Damage	No, Light & Moderate Damage	Heavy Damage
Mining	3.6	14.0	5.7	7.5	0.3	6.1	1.9
Construction	6.7	3.8	2.6	2.9	20.9	6.2	7.0
Manufacturing	31.1	60.7	67.9	66.3	19.1	57.6	13.1
Transportation, Communication, and Utilities	11.4	5.5	6.1	5.9	19.1	8.4	13.5
Wholesale Trade	9.7	5.3	3.8	4.1	9.0	5.0	12.8
Retail Trade	9.9	5.2	4.1	4.3	14.2	6.2	12.5
Finance, Insurance and Real Estate	13.6	2.1	3.2	3.0	5.1	3.3	20.6
Services	9.4	2.2	4.0	3.6	6.9	4.2	13.0
Government	4.6	1.1	2.7	2.4	5.4	2.9	5.8
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0
OUTPUT	3.595[c]	0.288	0.932	1.189	0.296	1.459	2.136

a. Single-weapon attack; ground zero: at-home population centroid.
b. Detail may not total to 100% due to independent rounding.
c. Millions of 1960 dollars.

and SIC 3310, Blast Furnaces, Steel Works, and Rolling and Finishing Mills--accounted for a little less than 40 percent of pre-attack manufacturing output. The relative contribution of these four industries increases consistently with weapon yield; with a 10-Mt weapon, more than half the manufacturing output sustains no damage or light damage.

Table 11 is included to indicate the kind of detailed analysis that can be made of the manufacturing sector for a single city. For reasons set forth in the Introduction to this Study, the reliability of the data set forth in this degree of detail remains open to question.[1]

The data on post-attack output shown in Table 11 are based on damage caused by a 10-Mt weapon detonated at the at-home population centroid. Damage was generally measured in terms of three-digit SIC codes. Where four-digit SIC codes are shown, they were necessary to account for variation in physical vulnerability within a three-digit industry group.

Despite the limitations mentioned above, a few observations are of interest. All the facilities accounting for the output of 23 industries fell into the heavy-damage category. These were primarily in two major industry groups--SIC 23, Apparel ; and SIC 27, Printing, Publishing, and Allied Industries. Of special note is the fact that facilities accounting for four-fifths of the output of SIC 20, Food and Kindred Products, fell into the heavy-damage category.

Only a half-dozen industries out of the 127 listed, registered a significant (20 percent or more) proportion of their output in the no-damage category. The entire output of over one hundred was classified in the light-to-heavy damage category.

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1. The degree of detail presented in Table 11 in terms of the percentage of each industry by damage class does not reflect confidence in the precision of the data; these are merely the actual figures produced by the computer.

Table 10

POST-ATTACK HOUSTON OUTPUT OF MAJOR MANUFACTURING INDUSTRIES AS PERCENT OF TOTAL BY DAMAGE CLASS[a]

Industry	Output, % of Total						
	Pre-Attack	Post-Attack					
		No and Light Damage			No, Light & Moderate Damage		
		0.5[b]	3.0	10.0	0.5	3.0	10.0
Bakery Products	2.7	2.4	2.2	0.2	2.4	2.2	0.4
Miscellaneous Food Prep.	4.4	4.1	4.3	0.6	4.0	4.3	1.1
Industrial Inorganic and Organic Chemicals	15.5	16.6	17.9	20.9	16.4	17.5	20.5
Plastic Materials and Synthetic Rubber and Other Man-Made Fibers Except Glass	3.2	3.3	3.6	4.4	3.4	3.6	4.2
Agricultural Chemicals	3.8	4.0	4.0	4.2	3.9	3.9	4.4
Petroleum Refining	15.9	17.1	18.4	22.6	16.8	18.1	21.3
Blast Furnaces, Steel Works, and Rolling and Finishing Mills	4.6	4.9	5.2	6.4	4.8	5.1	6.0
Fabricated Structural Metal Products	4.1	4.3	4.0	2.2	4.3	4.1	2.6
Construction, Mining and Materials Handling Machinery and Equipment	13.2	14.2	14.9	14.4	13.9	14.7	15.1
All Others	32.6	29.1	25.5	24.1	30.1	26.5	24.4
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

a. Ground zero: at-home population centroid.
b. Weapon yield in megatons.

Table 11

PRE-ATTACK AND POST-ATTACK GROSS PRODUCT VALUES FOR HOUSTON, TEXAS, 1960: MANUFACTURING

Values (percentage in parentheses, all other numbers in thousands of dollars)								
SIC Code (1a)	Industry (1b)	Pre-attack (2)	Post-attack					
			No Damage (3)	Light Damage (4)	3 + 4 (5)	Moderate Damage (6)	5 + 6 (7)	Heavy Damage (8)
2010	Meat Products	6662 (100.00)	20 (0.300)	1811 (27.184)	1831 (27.484)	1306 (19.604)	3137 (47.088)	3525 (52.912)
2020	Dairy Products	20383 (100.00)	0 (0.000)	1112 (5.456)	1112 (5.456)	0 (0.000)	1112 (5.456)	19271 (94.544)
2030	Canning and Preserving Fruits, Vegetables and Sea Foods	3747 (100.00)	787 (21.003)	1199 (31.999)	1986 (53.002)	412 (10.995)	2396 (63.998)	1349 (36.002)
2040	Grain Mill Products	19794 (100.00)	0 (0.000)	4420 (22.330)	4420 (22.330)	198 (1.000)	4618 (23.330)	15176 (76.670)
2050	Bakery Products	30301 (100.00)	0 (0.000)	1863 (6.148)	1863 (6.148)	1237 (4.082)	3100 (10.231)	27201 (89.769)
2070	Confectionery and Related Products	186 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	186 (100.000)
2080	Beverage Industries	9532 (100.00)	0 (0.000)	1973 (20.699)	1973 (20.699)	1471 (15.432)	3444 (36.131)	6088 (63.869)
2090	Miscellaneous Food Preparations and Kindred Products	49371 (100.00)	0 (0.000)	5251 (10.636)	5251 (10.636)	4003 (8.108)	9254 (18.744)	40117 (81.256)
2210	Broad Woven Fabric Mills, Cotton	1576 (100.00)	0 (0.000)	1576 (100.000)	1576 (100.000)	0 (0.000)	1576 (100.000)	0 (0.000)
2290	Miscellaneous Textile Goods	1007 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	1007 (100.000)
2310	Men's, Youths', and Boys' Suits, Coats, and Overcoats	122 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	122 (100.000)
2320	Men's, Youths', and Boys' Furnishings, Work Clothing and Allied Garments	200 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	200 (100.000)
2330	Women's, Misses', and Juniors' Outerwear	1638 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	1638 (100.000)
2350	Hats, Caps, and Millinery	14 (100.00)	0 (0.000)	0 (0.000)	0 0.000)	0 (0.000)	0 (0.000)	14 (100.000)
2380	Miscellaneous Apparel and Accessories	14 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	14 (100.000)
2390	Miscellaneous Fabricated Textile Products	6203 (100.00)	0 (0.000)	3038 (48.976)	3038 (48.976)	125 (2.015)	3163 (50.991)	3040 (49.009)
2420	Sawmills and Planing Mills	212 (100.00)	110 (51.887)	51 (24.057)	161 (75.943)	0 (0.000)	161 (75.943)	51 (24.057)
2430	Millwork, Veneer, Plywood, and Prefabricated Structural Wood Products	2804 (100.00)	0 (0.000)	171 (6.098)	171 (6.098)	118 (4.208)	289 (10.307)	2515 (89.693)
2440	Wooden Containers	1415 (100.00	0 (0.000)	14 (0.989)	14 (0.989)	0 (0.000)	14 (0.989)	1401 (99.011)

Table 11 (Continued)

Values (percentage in parentheses, all other numbers in thousands of dollars)								
SIC Code (1a)	Industry (1b)	Pre-attack (2)	Post-attack					
			No Damage (3)	Light Damage (4)	3 + 4 (5)	Moderate Damage (6)	5 + 6 (7)	Heavy Damage (8)
2490	Miscellaneous Wood Products	2069 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	62 (2.997)	62 (2.997)	2007 (97.003)
2510	Household Furniture	7275 (100.00)	0 (0.000)	3979 (54.694)	3979 (54.694)	73 (1.003)	4052 (55.698)	3223 (44.302)
2520	Office Furniture	58 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	15 (25.862)	15 (25.862)	43 (74.138)
2530	Public Building and Related Furniture	289 (100.00)	0 (0.000)	194 (67.128)	194 (67.128)	0 (0.000)	194 (67.128)	95 (32.872)
2540	Partitions, Shelving, Lockers, and Office and Store Fixtures	2715 (100.00)	0 (0.000)	2090 (76.980)	2090 (76.980)	0 (0.000)	2090 (76.980)	625 (23.020)
2590	Miscellaneous Furniture and Fixtures	231 (100.00)	0 (0.000)	126 (54.545)	126 (54.545)	0 (0.000)	126 (54.545)	105 (45.455)
2620	Paper Mills, Except Building Paper Mills	17019 (100.00)	0 (0.000)	17019 (100.000)	17019 (100.000)	0 (0.000)	17019 (100.000)	0 (0.000)
2640	Converted Paper and Paperboard Products, Except Containers and Boxes	15350 (100.00)	0 (0.000)	10898 (70.997)	10898 (70.997)	0 (0.000)	10898 (70.997)	4452 (29.003)
2650	Paperboard Containers and Boxes	3354 (100.00)	134 (3.995)	2684 (80.024)	2818 (84.019)	0 (0.000)	2818 (84.019)	536 (15.981)
2660	Building Paper and Building Board Mills	1000 (100.00)	0 (0.000)	1000 (100.000)	1000 (100.000)	0 (0.000)	1000 (100.000)	0 (0.000)
2710	Newspapers: Publishing, Publishing and Printing	16872 (100.00)	504 (2.987)	507 (3.005)	1011 (5.992)	0 (0.000)	1011 (5.992)	15861 (94.008)
2720	Periodicals: Publishing, Publishing and Printing	1258 (100.00)	0 (0.000)	327 (25.994)	327 (25.994)	0 (0.000)	327 (25.994)	931 (74.006)
2740	Miscellaneous Publishing	755 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	755 (100.000)
2750	Commercial Printing	9791 (100.00)	113 (1.154)	1672 (17.077)	1785 (18.231)	30 (0.306)	1815 (18.537)	7976 (81.463)
2760	Manifold Business Forms Manufacturing	502 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	502 (100.000)
2780	Bookbinding and Related Industries	900 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	900 (100.000)
2790	Service Industries for the Printing Trade	1710 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	1710 (100.000)
2810	Industrial Inorganic and Organic Chemicals	174426 (100.00)	47451 (27.204)	117386 (67.298)	164837 (94.503)	7674 (4.400)	172511 (98.902)	1915 (1.098)
2820	Plastics Materials and Synthetic Resins, Synthetic Rubber, Synthetic and Other Man-Made Fibers, Except Glass	36439 (100.00)	18220 (50.001)	17126 (46.999)	35346 (97.000)	0 (0.000)	35346 (97.000)	1093 (3.000)
2830	Drugs	1365 (100.00)	0 (0.000)	832 (60.952)	832 (60.952)	0 (0.000)	832 (60.952)	533 (39.048)

Table 11 (Continued)

Values (percentage in parentheses, all other numbers in thousands of dollars)								
SIC Code (1a)	Industry (1b)	Pre-attack (2)	Post-attack					
			No Damage (3)	Light Damage (4)	3 + 4 (5)	Moderate Damage (6)	5 + 6 (7)	Heavy Damage (8)
2840	Soap, Detergents and Cleaning Preparations, Perfumes, Cosmetics, and Other Toilet Preparations	3034 (100.00)	0 (0.000)	1064 (35.069)	1064 (35.069)	874 (28.807)	1938 (63.876)	1096 (36.124)
2850	Paints, Varnishes, Lacquers, Enamels, and Allied Products	10618 (100.00)	1339 (12.611)	5712 (53.795)	7051 (66.406)	0 (0.000)	7051 (66.406)	3567 (33.594)
2860	Gum and Wood Chemicals	151 (100.00)	39 (25.828)	0 (0.000)	39 (25.828)	0 (0.000)	39 (25.828)	112 (74.172)
2870	Agricultural Chemicals	42645 (100.00)	0 (0.000)	33263 (78.000)	33263 (78.000)	3838 (9.000)	37101 (87.000)	5544 (13.000)
2890	Miscellaneous Chemical Products	15681 (100.00)	1788 (11.402)	4110 (26.210)	5898 (37.612)	0 (0.000)	5898 (37.612)	9783 (62.388)
2910	Petroleum Refining	178909 (100.00)	84884 (47.445)	94025 (52.555)	178909 (100.000)	0 (0.000)	178909 (100.000)	0 (0.000)
2950	Paving and Roofing Materials	2265 (100.00)	0 (0.000)	1556 (68.698)	1556 (68.698)	709 (31.302)	2265 (100.000)	0 (0.000)
2990	Miscellaneous Products of Petroleum and Coal	386 (100.00)	0 (0.000)	135 (34.974)	135 (34.974)	216 (55.959)	351 (90.933)	35 (9.067)
3010	Tires and Inner Tubes	30 (100.00)	0 (0.000)	30 (100.000)	30 (100.000)	0 (0.000)	30 (100.000)	0 (0.000)
3060	Fabricated Rubber Products, Not Elsewhere Classified	5852 (100.00)	0 (0.000)	2808 (47.984)	2808 (47.984)	29 (0.496)	2837 (48.479)	3015 (51.521)
3070	Miscellaneous Plastics Products	2950 (100.00)	59 (2.000)	2214 (75.051)	2273 (77.051)	0 (0.000)	2273 (77.051)	677 (22.949)
3140	Footwear, Except Rubber	122 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	122 (100.000)
3190	Leather Goods, Not Elsewhere Classified	122 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	122 (100.000)
3220	Glass and Glassware, Pressed or Blown	243 (100.00)	0 (0.000)	197 (81.070)	197 (81.070)	39 (16.049)	236 (97.119)	7 (2.881)
3230	Glass Products, Made of Purchased Glass	167 (100.00)	0 (0.000)	14 (8.383)	14 (8.383)	0 (0.000)	14 (8.383)	153 (91.617)
3240	Cement, Hydraulic	9410 (100.00)	0 (0.000)	5752 (61.126)	5752 (61.126)	0 (0.000)	5752 (61.126)	3658 (38.874)
3250	Structural Clay Products	1060 (100.00)	0 (0.000)	1060 (100.000)	1060 (100.000)	0 (0.000)	1060 (100.000)	0 (0.000)
3270	Concrete, Gypsum, and Plaster Products	15510 (100.00)	395 (2.547)	7355 (47.421)	7750 (49.968)	1286 (8.291)	9036 (58.259)	6474 (41.741)
3280	Cut Stone and Stone Products	251 (100.00)	0 (0.000)	171 (68.127)	171 (68.127)	0 (0.000)	171 (68.127)	80 (31.873)
3292	Asbestos Products	4398 (100.00)	0 (0.000)	2796 (63.574)	2796 (63.574)	1540 (35.016)	4336 (98.590)	62 (1.410)

Table 11 (Continued)

Values (percentage in parentheses, all other numbers in thousands of dollars)								
SIC Code (1a)	Industry (1b)	Pre-attack (2)	Post-attack					
			No Damage (3)	Light Damage (4)	3 - 4 (5)	Moderate Damage (6)	5 - 6 (7)	Heavy Damage (8)
3293	Steam and Other Packing, and Pipe and Boiler Covering	2690 (100.00)	0 (0.000)	472 (17.546)	472 (17.546)	1540 (57.249)	2012 (74.796)	678 (25.204)
3295	Minerals and Earths, Ground or Otherwise Treated	3060 (100.00)	205 (6.699)	2321 (75.850)	2526 (82.549)	205 (6.699)	2731 (89.248)	329 (10.752)
3296	Mineral Wool	62 (100.00)	0 (0.000)	62 (100.000)	62 (100.000)	0 (0.000)	62 (100.000)	0 (0.000)
3297	Nonclay Refractories	62 (100.00)	0 (0.000)	62 (100.000)	62 (100.000)	0 (0.000)	62 (100.000)	0 (0.000)
3312	Blast Furnaces (Including Coke Ovens), Steel Works, and Rolling Mills	41920 (100.00)	0 (0.000)	41395 (98.748)	41395 (98.748)	0 (0.000)	41395 (98.748)	525 (1.252)
3313	Electrometallurgical Products	1574 (100.00)	0 (0.000)	1574 (100.000)	1574 (100.000)	0 (0.000)	1574 (100.000)	0 (0.000)
3316	Cold Rolled Sheet, Strip, and Bars	1049 (100.00)	0 (0.000)	1049 (100.000)	1049 (100.000)	0 (0.000)	1049 (100.000)	0 (0.000)
3317	Steel Pipe and Tubes	6347 (100.00)	0 (0.000)	6295 (99.181)	6295 (99.181)	0 (0.000)	6295 (99.181)	52 (0.819)
3320	Iron and Steel Foundries	5169 (100.00)	0 (0.000)	516 (9.983)	516 (9.983)	103 (1.993)	619 (11.975)	4550 (88.025)
3340	Secondary Smelting and Refining of Nonfrerous Metals and Alloys	944 (100.00)	0 (0.000)	700 (74.153)	700 (74.153)	0 (0.000)	700 (74.153)	244 (25.847)
3350	Rolling, Drawing and Extruding of Nonferrous Metals	2784 (100.00)	0 (0.000)	1559 (55.999)	1559 (55.999)	0 (0.000)	1559 (55.999)	1225 (44.001)
3360	Nonferrous Foundries	1534 (100.00)	0 (0.000)	459 (29.922)	459 (29.922)	0 (0.000)	459 (29.922)	1075 (70.078)
3390	Miscellaneous Primary Metal Industries	3318 (100.00)	0 (0.000)	2125 (64.045)	2125 (64.045)	0 (0.000)	2125 (64.045)	1193 (35.955)
3410	Metal Cans	10387 (100.00)	0 (0.000)	10387 (100.000)	10387 (100.000)	0 (0.000)	10387 (100.000)	0 (0.000)
3420	Cutlery, Hand Tools, and General Hardware	1018 (100.00)	0 (0.000)	936 (91.945)	936 (91.945)	0 (0.000)	936 (91.945)	82 (8.055)
3430	Heating Apparatus (Except Electric) and Plumbing Fixtures	4888 (100.00)	0 (0.000)	4888 (100.000)	4888 (100.000)	0 (0.000)	4888 (100.000)	0 (0.000)
3440	Fabricated Structural Metal Products	46032 (100.00)	0 (0.000)	17767 (38.597)	17767 (38.597)	4266 (9.267)	22033 (47.865)	23999 (52.135)
3450	Screw Machine Products, and Bolts, Nuts, Screws, Rivets and Washers	1933 (100.00)	0 (0.000)	74 (4.037)	74 (4.037)	550 (30.005)	624 (34.043)	1209 (65.957)

Table 11 (Continued)

SIC Code (1a)	Industry (1b)	Pre-attack (2)	Post-attack: No Damage (3)	Light Damage (4)	3 + 4 (5)	Moderate Damage (6)	5 + 6 (7)	Heavy Damage (8)
		Values (percentage in parentheses, all other numbers in thousands of dollars)						
3460	Metal Stampings	2240 (100.00)	0 (0.000)	1613 (72.009)	1613 (72.009)	515 (22.991)	2128 (95.000)	112 (5.000)
3470	Coating, Engraving, and Allied Services	4630 (100.00)	0 (0.000)	2619 (56.566)	2619 (56.566)	92 (1.987)	2711 (58.553)	1919 (41.447)
3480	Miscellaneous Fabricated Wire Products	5052 (100.00)	0 (0.000)	3281 (64.945)	3281 (64.945)	1213 (24.010)	4494 (88.955)	558 (11.045)
3490	Miscellaneous Fabricated Metal Products	20216 (100.00)	0 (0.000)	16422 (81.233)	16422 (81.233)	714 (3.532)	17136 (84.765)	3080 (15.235)
3494	Valves and Pipe Fittings, Except Plumbers' Brass Goods	48 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	48 (100.000)	48 (100.000)	0 (0.000)
3510	Engines and Turbines	320 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	320 (100.000)
3522	Farm Machinery and Equipment	132 (100.00)	0 (0.000)	35 (26.515)	35 (26.515)	0 (0.000)	35 (26.515)	97 (73.485)
3530	Construction, Mining, and Materials Handling Machinery and Equipment	148784 (100.00)	0 (0.000)	113931 (76.575)	113931 (76.575)	12759 (8.576)	126690 (85.150)	22094 (14.850)
3537	Industrial Trucks, Tractors, Trailers, and Stackers	3 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	3 (100.000)
3540	Metalworking Machinery and Equipment	2954 (100.00)	0 (0.000)	2699 (91.990)	2699 (91.990)	0 (0.000)	2699 (91.990)	235 (8.010)
3551	Food Products Machinery	448 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	448 (100.000)	448 (100.000)	0 (0.000)
3553	Woodworking Machinery	107 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	107 (100.000)
3559	Special Industry Machinery, Not Elsewhere Classified	1580 (100.00)	0 (0.000)	488 (28.354)	488 (28.354)	918 (58.101)	1366 (86.456)	214 (13.544)
3561	Pumps, Air and Gas Compressors, and Pumping Equipment	5255 (100.00)	0 (0.000)	3954 (75.243)	3954 (75.243)	241 (4.586)	4195 (79.829)	1060 (20.171)
3564	Blowers, Exhaust and Ventilating Fans	482 (100.00)	0 (0.000)	96 (19.917)	96 (19.917)	0 (0.000)	96 (19.917)	386 (80.083)
3565	Industrial Patterns	288 (100.00)	0 (0.000)	192 (66.667)	192 (66.667)	96 (33.333)	288 (100.000)	0 (0.000)
3566	Mechanical Power Transmission Equipment, Except Ball and Roller Bearings	674 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	674 (100.000)
3567	Industrial Process Furnaces and Ovens	193 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	193 (100.000)

Table 11 (Continued)

Values (percentage in parentheses, all other numbers in thousands of dollars)								
SIC Code (1a)	Industry (1b)	Pre-attack (2)	Post-attack					
			No Damage (3)	Light Damage (4)	3 + 4 (5)	Moderate Damage (6)	5 + 6 (7)	Heavy Damage (8)
3569	General Industrial Machinery and Equipment, Not Elsewhere Classified	2554 (100.00)	0 (0.000)	1639 (64.174)	1639 (64.174)	241 (9.436)	1880 (73.610)	674 (26.390)
3570	Office, Computing, and Accounting Machines	254 (100.00)	0 (0.000)	254 (100.000)	254 (100.000)	0 (0.000)	254 (100.000)	0 (0.000)
3580	Service Industry Machines	1171 (100.00)	0 (0.000)	525 (44.833)	525 (44.833)	59 (5.038)	584 (49.872)	587 (50.128)
3590	Miscellaneous Machinery, Except Electrical	8095 (100.00)	0 (0.000)	6262 (77.356)	6262 (77.356)	778 (9.611)	7040 (86.967)	1055 (13.033)
3591	Machine Shops, Jobbing and Repair	65 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	48 (73.846)	48 (73.846)	17 (26.154)
3610	Electric Transmission and Distribution Equipment	5102 (100.00)	0 (0.000)	4031 (79.008)	4031 (79.008)	408 (7.997)	4439 (87.005)	663 (12.995)
3621	Motors and Generators	386 (100.00)	0 (0.000)	353 (91.451)	353 (91.451)	0 (0.000)	353 (91.451)	33 (8.549)
3622	Industrial Controls	673 (100.00)	0 (0.000)	66 (9.807)	66 (9.807)	0 (0.000)	66 (9.807)	607 (90.193)
3629	Electrical Industrial Apparatus, Not Elsewhere Classified	44 (100.00)	0 (0.000)	44 (100.000)	44 (100.000)	0 (0.000)	44 (100.000)	0 (0.000)
3640	Electric Lighting and Wiring Equipment	2097 (100.00)	0 (0.000)	923 (44.015)	923 (44.015)	84 (4.006)	1007 (48.021)	1090 (51.979)
3644	Noncurrent Carrying Wiring Devices	96 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	96 (100.000)
3650	Radio and Television Receiving Sets, Except Communication Types	26 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	26 (100.000)
3662	Radio and Television Transmitting, Signaling, and Detection Equipment and Apparatus	13 (100.00)	0 (0.000)	13 (100.000)	13 (100.000)	0 (0.000)	13 (100.000)	0 (0.000)
3670	Electronic Components and Accessories	171 (100.00)	0 (0.000)	15 (8.772)	15 (8.772)	40 (23.392)	55 (32.164)	116 (67.836)
3690	Miscellaneous Electrical Machinery, Equipment, and Supplies	1108 (100.00)	0 (0.000)	842 (75.993)	842 (75.993)	0 (0.000)	842 (75.993)	266 (24.007)
3710	Motor Vehicles and Motor Vehicle Equipment	221 (100.00)	0 (0.000)	99 (44.796)	99 (44.796)	44 (19.910)	143 (64.706)	78 (35.294)
3720	Aircraft and Parts	86 (100.00)	0 (0.000)	86 (100.000)	86 (100.000)	0 (0.000)	86 (100.000)	0 (0.000)
3731	Ship Building and Repairing	6070 (100.00)	0 (0.000)	6070 (100.000)	6070 (100.000)	0 (0.000)	6070 (100.000)	0 (0.000)

Table 11 (Continued)

Values (percentage in parentheses, all other numbers in thousands of dollars)								
SIC Code (1a)	Industry (1b)	Pre-attack (2)	Post-attack					
			No Damage (3)	Light Damage (4)	3 + 4 (5)	Moderate Damage (6)	5 + 6 (7)	Heavy Damage (8)
3732	Boat Building and Repairing	2793 (100.00)	355 (12.710)	1906 (68.242)	2261 (80.952)	177 (6.337)	2438 (87.290)	355 (12.710)
3740	Railroad Equipment	884 (100.00)	0 (0.000)	80 (9.050)	80 (9.050)	0 (0.000)	80 (9.050)	804 (90.950)
3790	Miscellaneous Transportation Equipment	37 (100.00)	0 (0.000)	37 (100.000)	37 (100.000)	0 (0.000)	37 (100.000)	0 (0.000)
3810	Engineering, Laboratory, and Scientific and Research Instruments and Associated Equipment	10103 (100.00)	0 (0.000)	7719 (76.403)	7719 (76.403)	0 (0.000)	7719 (76.403)	2384 (23.597)
3820	Instruments for Measuring, Controlling, and Indicating Physical Characteristics	2377 (100.00)	0 (0.000)	2020 (84.981)	2020 (84.981)	0 (0.000)	2020 (84.981)	357 (15.019)
3840	Surgical, Medical, and Dental Instruments and Supplies	111 (100.00)	0 (0.000)	49 (44.144)	49 (44.144)	0 (0.000)	49 (44.144)	62 (55.856)
3850	Ophthalmic Goods	28 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	28 (100.000)
3860	Photographic Equipment and Supplies	248 (100.00)	0 (0.000)	203 (81.855)	203 (81.855)	0 (0.000)	203 (81.855)	45 (18.145)
3910	Jewelry, Silverware, and Plated Ware	218 (100.00)	0 (0.000)	13 (5.963)	13 (5.963)	0 (0.000)	13 (5.963)	205 (94.037)
3940	Toys, Amusement, Sporting and Athletic Goods	326 (100.00)	0 (0.000)	170 (52.147)	170 (52.147)	0 (0.000)	170 (52.147)	156 (47.853)
3950	Pens, Pencils, and Other Office and Artists' Materials	362 (100.00)	0 (0.000)	80 (22.099)	80 (22.099)	0 (0.000)	80 (22.099)	282 (77.901)
3960	Costume Jewelry, Costume Novelties, Buttons, and Miscellaneous Notions, Except Precious Metal	72 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	72 (100.000)
3980	Miscellaneous Manufacturing Industries	979 (100.00)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	0 (0.000)	979 (100.000)
3990	Miscellaneous Manufacturing Industries	1667 (100.00)	0 (0.000)	194 (11.638)	194 (11.638)	604 (36.233)	798 (47.870)	869 (52.130)
TOTAL		1118857 (100.00)	156403 (13.979)	632205 (56.505)	788608 (70.483)	51446 (4.598)	840054 (75.081	278803 (24.919)

Fourteen percent of the total pre-attack capacity fell in the no-damage class. More than half of the pre-attack total was classified in the light-damage category, bringing the combined classes to 70 percent of pre-attack capacity. However, the degree of vulnerability as well as differences in geographic distribution resulted in wide variations in the percentage of capacity included for individual industries. Percentages ran the gamut from 0 to 100, thus creating substantial distortions in the Houston economic structure.

This is vividly illustrated in Figure 6, where the industries are grouped by deciles reflecting the percentage of capacity falling into the light-damage and no-damage classes combined. Forty of the total number of 127 listed industries had less than 10 percent of total capacity included in these two damage classes. Twenty-five industries had over 90 percent in these classes. Thus, the number of industries in the two extreme ranges (under 10 percent and over 90 percent) was 65, or more than half of the total number of industries. That is, slightly less than half had between 10 and 90 percent of their capacity lost to the community.

The magnitude of this distortion is so great that the limitations in the accuracy of the input data can be disregarded. If perfect data were available the general picture would change little, if at all. Assuming that such a situation would be characteristic of every target city in a nuclear attack, it would appear that important tears in the national industrial fabric are obscured by analyses relying on nationwide aggregation.

This finding has obvious implication for judgments based on estimates of post-attack economic output developed from statistics reflecting national totals. It might also be observed that any study of the adequacy of transportation facilities in a post-attack period should be based on an analysis of nuclear weapon effects on individual target cities expressed in terms of their production and consumption functions for individual industries.

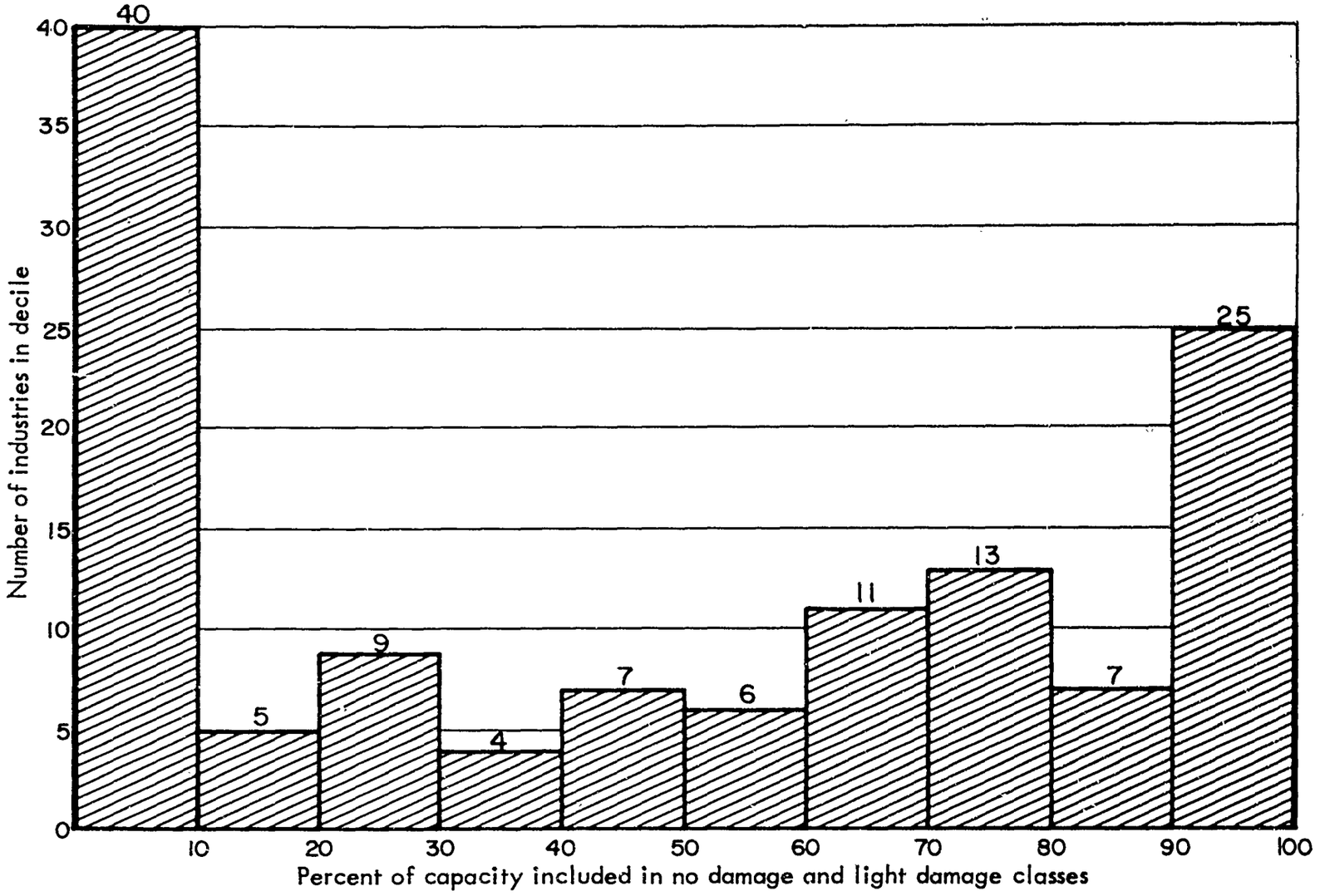


FIGURE 6 Effects of a 10-Mt Attack on 127 Manufacturing Industries

4

CHARACTERISTICS OF THE SURVIVING POPULATION

This section summarizes the effects of a nuclear attack on Houston, Texas in terms of general population characteristics and the characteristics of its labor force; i.e., in terms of their contribution to the functioning of a post-attack community.

4.1 DATA CHARACTERISTICS AND SHELTER ASSUMPTIONS

Weapon effects on economic resources, including production facilities, have been analyzed previously. The data provided in the tables to follow reflect impact on the labor force in terms of occupational skills and industry of employment.

Two protection postures were used to develop input data. They provide a crude measure of the differential effects on the labor force as a function of survival level. The two postures used were: (1) a configuration in which the population of Houston was assumed to be the at-home (the no-special-shelter case) and (2) a configuration in which the residents of Houston were permitted to seek and occupy only fallout shelters located in the census tract in which they live (the National Fallout Shelter Survey-Extended--NFSS-X).

The population characteristics[1] which were examined include the following: General Population Characteristics (Age, Sex, Employment Status); Total Employed by Industry; Total Employed by Occupation; and Total Experienced Civilian Labor Force. The latter group is composed of 12 subgroups and includes such categories as "Professional, Technical and Kindred Workers," "Sales Workers," etc. For each of the major groupings the percent distribution of the component classes was calculated by dividing the total number of people in each component

[1]From the 1960 Census of Population.

class by the total number of people in each major group. These percent distributions were calculated for the pre-attack or base case and for each of the two post-attack configurations.

4.2 DESCRIPTION OF THE ATTACK

The attack chosen consisted of one 10-Mt nuclear weapon detonated at the surface near the center of census tract no. 32 in the downtown area of Houston. The detonation point has the following geographic coordinates: Latitude - 29° 45' 17" N, Longitude - 95° 21' 21" W. The postulated attack occurred at night; the 1960 at-home population was used as the basis for calculating fatalities. Both blast and local fallout were considered in the derivation of the percentages of survival calculated for each census tract for both the sheltered and the unsheltered populations.

4.3 METHOD USED TO COMPUTE FATALITIES AND SURVIVORS

The data to be examined were available on tape and listed by census tract. Since these data could not be conveniently allocated to TVE's (See Sections 2 and 3), this section is based on the application of weapons effects to the population in the census tracts. To do this, it was assumed that the population was distributed evenly throughout each of the census tracts. A percentage of survivors was derived from the blast and fallout fatality functions which have been described in greater detail in R-113.[1]

The percentages of survival were obtained by superimposing the blast and fallout effects overlays onto the census tract map of Houston, shown in Figure 7. Blast effects were considered first; the fallout effects were then applied to the remaining population. For example, in the unsheltered case, census tract no. 74 falls within mortality band 7 (see Table 12); thus, according to the weapons

1. S. E. Eastman, The Effects of Nuclear Weapons on a Single City, IDA Report R-113, Institute for Defense Analyses, Economic and Political Studies Division (Arlington, Va., September 1965).

effects data, 10 percent of the population in the tract would be killed by blast effects. The remaining 90 percent of the population would then be subject to fallout. In this case, the fallout pattern would produce fatalities of 50 percent of the remaining 90 percent of the population in this census tract. Therefore, the cumulative percentage of fatalities for this particular tract is 55 percent. This procedure was used for each of the affected census tracts for which no shelter was available.

For the situation offering some fallout protection, the method of computation of the survival percentage was identical except that in some instances there were two populations to be considered. After identifying all shelter spaces by census tract, the population of each tract was divided into appropriate proportions of sheltered and unsheltered population. For example, census tract no. 74 has a total population of 7523 and 1000 fallout shelter spaces; so that 6523 persons in this tract would not have shelter. Thus, for this census tract there were two populations to be considered: one sheltered and one unsheltered. One thousand persons were assumed to be in the fallout shelters, although still within the blast-mortality band 7 in which 2 percent are calculated to die from blast. The remaining 98 percent of the persons in this group will survive the fallout. The 6523 unsheltered persons will receive greater blast effects and fallout. Ten percent of them will die from blast and half of the remaining 90 percent will die of fallout. The cumulative survival percentage for the tract as a whole is thus 52 percent. In the sheltered case it was assumed that the distribution of the population characteristics of the sheltered group would be identical to the distribution of the population characteristics within the census tract. The percentages of survival were then used to calculate from the census-tract listing, the survivors for each of the various population characteristics.

4.4 RESULTS

The results of the attack on the various population groupings are shown in Tables 13 through 26 and Figures 8 through 20 at the end

of this section (beg. on p. 76). These give the actual number of people in each category for both post-attack cases, i.e., for the no-shelter case and for the NFSS-X case. In addition, the percent distributions are given for the component classes of the major groups in the experienced civilian labor force such as "Total Employed by Industry" and "Professional, Technical and Kindred Workers."

Tables 13 through 26 present data in terms of the pre-attack and post-attack population characteristics of Houston. The first two data columns show the pre-attack total number of persons by category and the number and percent distribution of these totals by component classes. The third and fourth show the same data for persons surviving an attack with a 10-Mt weapon without shelter. The fifth and sixth show the same data for persons surviving the same attack with an NFSS-X shelter configuration.

Changes in the general population characteristics as a result of the attacks were relatively minor. Ten percent of the population survived the attack in the no-shelter case, and 30 percent in the National Fallout Shelter Survey-Extended (NFSS-X) case. The distribution of the population among the various age groups remained relatively unchanged for both post-attack situations in comparison with the pre-attack distribution of ages. The largest distributional changes occurred in the two groups titled, Males over 65, and Females over 65, for both the no-shelter case and for the NFSS-X case, although in the latter case the percentage of change was significantly less.

For the categories dealing with the general employment status of the population, few significant changes occurred. One large increase was observed in the sub-category "Armed Forces" under the main heading "Total, Employment Status." Similarly, this increase also occurred under "Males, Employment Status" for the sub-group Armed Forces. The grouping for unemployed workers also showed a disproportionate loss, although the magnitude of the loss was relatively small for both the unsheltered and the sheltered cases.

Figures 8 through 20 summarize data for certain of the more interesting occupation groups and provide a graphic presentation

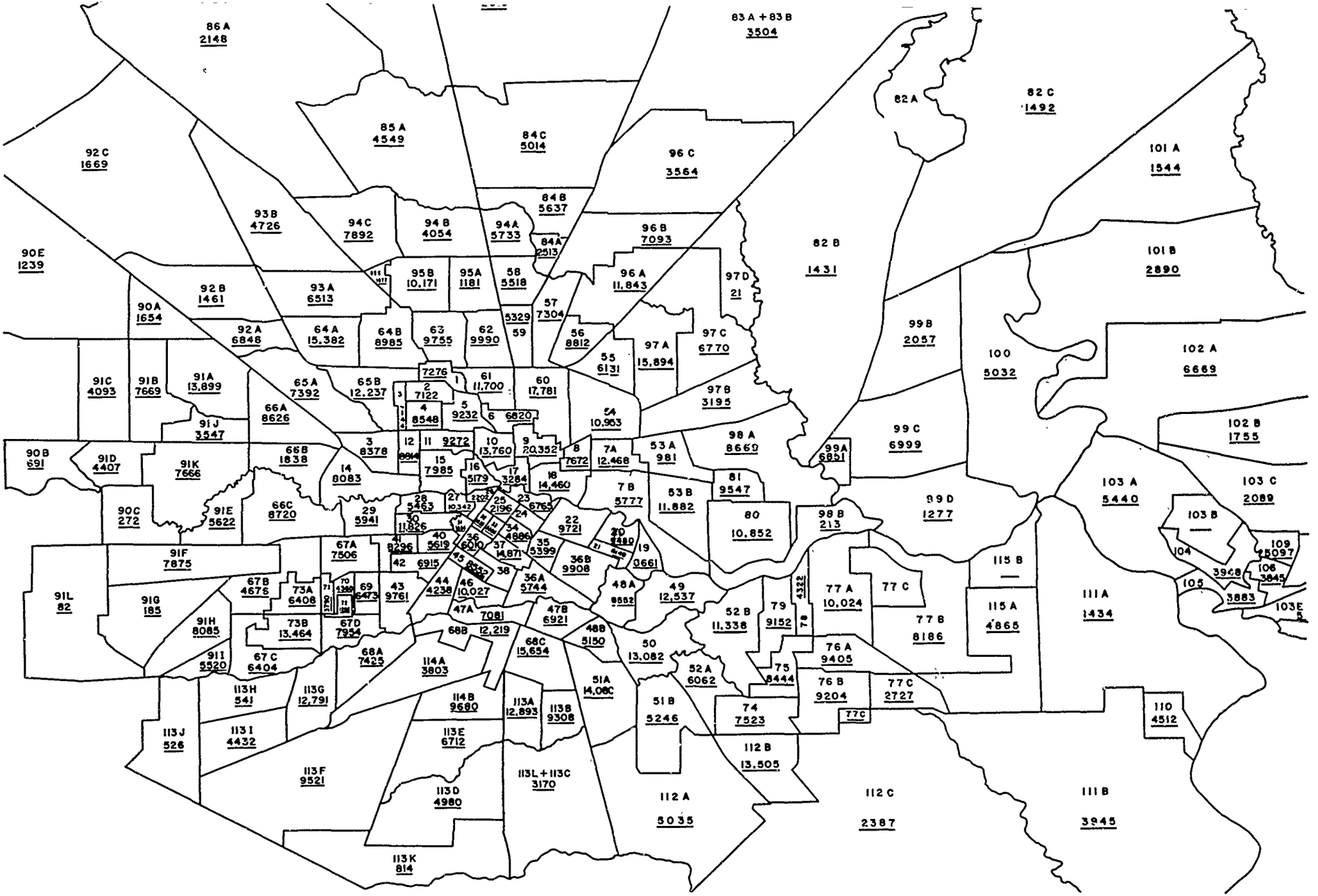


FIGURE 7 Census Tract Map of Houston, Texas
(At-Home Population)

Table 12

WEAPONS EFFECTS DATA

(10-Mt Weapon, Surface Burst)

BLAST EFFECTS DATA

Mortality Band	Distance from Ground Zero in Hundreds of Feet	MORTALITY, %	
		Normal Shielding	In Fallout Shelters
1	13	100	100
2	13-149	97	88
3	150-199	90	70
4	200-249	70	44
5	250-299	50	23
6	300-374	30	9
7	375-499	10	2
8	500-579	3	0
9	580-710	0	0

FALLOUT EFFECTS DATA

ERD Band[a]	ERD[b], roentgens	Fatality Estimate[c], %
1	6000	100
2	3000	100
3	1200	100
4	600	50
5	300	0

a. ERD (equivalent residual dose) is the accumulated dose corrected for such recovery (body repair) as has occurred at a specific time. The peak ERD was used in these calculations.

b. George E. Pugh and Robert J. Galiano, An Analytic Model of Close-in Deposition of Fallout for Use in Operational-Type Studies, WSEG Research Memorandum No. 10, Weapons Systems Evaluation Group, JCS, The Pentagon (Washington, D. C., October 15, 1959).

c. The fatality estimates are for normal shielding. For fallout shelters with a protection factor of 40 or more, there are no fatalities from fallout. The shelters in the system used here are all assumed to have a PF of 40 or more.

Table 13

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION: AGE

Population Elements	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Males under 5	80,977	6.51	8,168	6.64	24,545	6.62
Males 5-14	132,604	10.67	14,655	11.91	41,902	11.31
Males 15-19	39,818	3.20	4,263	3.46	12,284	3.32
Males 20-64	326,182	26.24	31,986	25.99	97,100	26.21
Males 65 +	29,055	2.34	2,188	1.78	7,275	1.96
Females under 5	78,846	6.34	7,808	6.34	23,750	6.41
Females 5-14	130,068	10.46	14,345	11.66	40,598	10.96
Females 15-19	43,469	3.50	4,476	3.64	13,151	3.55
Females 20-64	344,462	27.71	32,648	26.53	100,799	27.21
Females 65+	37,677	3.03	2,544	2.07	9,112	2.46
Total Male Population	608,636	100.00	61,261	100.00	183,105	100.00
Total Female Population	634,522	100.00	61,822	100.00	187,409	100.00
Total Population	1,243,158	100.00	123,082	100.00	370,515	100.00

Table 14

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION: EMPLOYMENT STATUS

Population Elements	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Male:						
Employed	318,708	78.87	30,944	78.55	95,492	79.94
Unemployed	13,951	3.45	1,207	3.06	3,828	3.20
Armed Forces	1,159	0.29	353	0.89	529	0.44
Not in Labor Force	70,297	17.40	6,892	17.49	19,604	16.41
Female:						
Employed	151,744	34.88	11,399	27.97	40,531	32.16
Unemployed	6,615	1.52	496	1.22	1,607	1.27
Armed Forces	4	0.00	2	0.00	3	0.00
Not in Labor Force	276,731	63.60	28,851	70.80	83,875	66.56
Total:	839,209	100.0	80,143	100.0	245,468	100.00
Employed	470,452	56.06	42,343	52.83	136,023	55.41
Unemployed	20,566	2.45	1,703	2.13	5,435	2.21
Armed Forces	1,163	0.14	355	0.44	532	0.22
Not in Labor Force	347,028	41.35	35,743	44.60	103,478	42.16

Table 15

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION. TOTAL EMPLOYED, BY INDUSTRY

Population Elements	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Mining	12,226	2.60	677	1.60	3,273	2.41
Construction	34,901	7.42	3,537	8.35	10,714	7.88
Furniture Lumber and Wood	3,063	0.65	110	0.26	687	0.50
Metal Industries	16,651	3.54	1,196	2.82	5,145	3.78
Machinery	21,056	4.48	916	2.16	5,768	4.24
Transportation Equipment	2,118	0.45	293	0.69	756	0.56
Other Durable Goods	6,627	1.41	353	0.83	1,827	1.34
Food and Kindred Products	9,957	2.12	427	1.01	2,428	1.78
Textile and Apparel	2,466	0.52	76	0.18	539	0.40
Printing, Publishing and Allied Industries	6,383	1.36	327	0.77	1,643	1.21
Other Nondurable Products	33,534	7.13	11,858	28.01	17,617	12.95
RR and Railway Express	8,238	1.75	307	0.73	1,844	1.36
Other Transportation	20,191	4.29	1,699	4.01	5,954	4.38
Communications, Utilities Sanitary	14,657	3.12	1,165	2.75	4,408	3.24
Wholesale Trade	28,022	5.96	1,306	3.09	7,336	5.39
Eating and Drinking Places	12,425	2.64	887	2.09	3,014	2.22
Other Retail	61,655	13.11	5,121	12.10	17,515	12.88
Business and Repair Service	14,505	3.08	851	2.01	3,800	2.79
Private Household	19,426	4.13	875	2.07	4,050	2.98
Other Personal Service	16,458	3.50	977	2.31	3,878	2.85
Hospitals	11,751	2.50	816	1.93	2,955	2.17
Education Service	21,692	4.61	2,468	5.83	6,572	4.83
Other Professional Service	19,451	4.13	1,315	3.11	5,293	3.89
Public Administration	13,456	2.86	1,229	2.90	3,995	2.94
Other, Including Not Reported	59,543	12.66	3,555	8.40	15,013	11.04
Total	470,452	100.00	42,343	100.00	136,023	100.00

Table 16

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION: MALES EMPLOYED, BY OCCUPATION

Population Elements	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Professional, Technical and Kindred Workers	39,156	12.29	3,753	12.13	12,105	12.68
Managers, Officials and Proprietors	39,330	12.34	2,748	8.88	11,274	11.81
Clerical and Kindred Workers	23,664	7.42	1,778	5.75	6,748	7.07
Sales Workers	25,230	7.92	1,479	4.78	7,131	7.47
Craftsmen, Foremen and Kindred Workers	63,545	19.94	8,345	26.97	21,257	22.26
Operatives and Kindred Workers	58,168	18.25	7,621	24.63	18,856	19.75
Private Household Workers	593	0.19	14	0.05	112	0.12
Service Workers (Nonprivate Household)	20,433	6.41	1,438	4.65	5,061	5.30
Farmers and Farm Managers	1,366	0.43	139	0.45	323	0.34
Farm Laborers and Foremen	1,390	0.44	134	0.43	361	0.38
Laborers except Farm and Mine	25,218	7.91	2,124	6.87	6,984	7.31
Not Reported	20,615	6.47	1,370	4.43	5,281	5.53
Total	318,708	100.00	30,944	100.00	95,492	100.00

Table 17

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION: FEMALES EMPLOYED, BY OCCUPATION

Population Elements	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Professional, Technical and Kindred Workers	19,828	13.07	1,852	16.25	5,730	14.14
Managers, Officials and Proprietors	6,147	4.05	575	5.04	1,787	4.41
Clerical and Kindred Workers	51,508	33.94	4,029	35.35	14,732	36.35
Sales Workers	11,618	7.66	958	8.41	3,406	8.40
Craftsmen, Foreman and Kindred Workers	1,593	1.05	78	0.69	411	1.01
Operatives and Kindred Workers	9,701	6.39	532	4.66	2,339	5.77
Private Household Workers	17,103	11.27	738	6.48	3,510	8.66
Service Workers Except Household	21,809	14.37	1,845	16.18	5,683	14.02
Farmers and Farm Managers	143	0.09	37	0.33	58	0.14
Farm Laborers and Foremen	177	0.12	21	0.18	43	0.11
Laborers Except Farm and Mine	745	0.49	35	0.31	162	0.40
Not Reported	11,372	7.49	697	6.12	2,669	6.59
Total	151,744	100.00	11,399	100.00	40,531	100.00

Table 18

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION: TOTAL EMPLOYED, BY OCCUPATION

Population Element	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Professional, Technical and Kindred Workers	58,984	12.54	5,606	13.24	17,835	13.11
Managers, Officials, and Proprietors	45,477	9.67	3,323	7.85	13,061	9.60
Clerical and Kindred Workers	75,172	15.98	5,807	13.72	21,481	15.79
Sales Workers	36,848	7.83	2,438	5.76	10,537	7.75
Craftsmen, Foremen and Kindred Workers	65,138	13.85	8,423	19.89	21,668	15.93
Operatives and Kindred Workers	67,869	14.43	8,152	19.25	21,195	15.58
Private Household Workers	17,696	3.76	753	1.78	3,621	2.66
Service Workers, Except Pvt Household	42,242	8.98	3,283	7.75	10,743	7.90
Farmers and Farm Managers	1,509	0.32	176	0.42	381	0.28
Farm Laborers and Foremen	1,567	0.33	155	0.37	405	0.30
Laborers, Except Farm and Mine	25,963	5.52	2,160	5.10	7,146	5.25
Not reported	31,987	6.80	2,068	4.88	7,950	5.84
Total	470,452	100.0	42,343	100.00	136,023	100.00

Table 19

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION: PROFESSIONAL, TECHNICAL AND KINDRED WORKERS

Population Element	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Accountants and Auditors	6,259	10.48	337	5.98	1,769	9.84
Actors, Dancers, and Entertainers	326	0.55	12	0.21	75	0.42
Airplane Pilots and Navigators	426	0.71	51	0.91	155	0.86
Architects	470	0.79	8	0.14	134	0.75
Artists and Art Teachers	458	0.77	21	0.36	115	0.64
Authors	68	0.11	7	0.12	20	0.11
Chemists	934	1.57	193	3.42	390	2.17
Chiropractors	129	0.22	17	0.29	44	0.25
Clergymen	1,335	2.24	131	2.33	362	2.01
Professors and Instructors						
Agricultural Sciences	0	0.00	0	0.00	0	0.00
Biological Sciences	78	0.13	0	0.00	19	0.10
Chemistry	48	0.08	0	0.00	13	0.07
Economics	16	0.03	0	0.00	2	0.01
Engineering	44	0.07	2	0.03	11	0.06
Geology and Geophysics	22	0.04	0	0.00	5	0.03
Mathematics	49	0.08	0	0.00	11	0.06
Medical Sciences	97	0.16	0	0.00	15	0.09
Physics	38	0.06	0	0.00	9	0.05
Psychology	31	0.05	0	0.00	8	0.04
Statistics	0	0.00	0	0.00	0	0.00
Natural Sciences	8	0.01	0	0.00	1	0.00
Social Sciences	154	0.26	10	0.18	33	0.19
Other Subjects and Unspecified	415	0.70	11	0.19	87	0.49
Dentists	526	0.88	44	0.78	145	0.80
Designers	359	0.60	23	0.41	95	0.53
Dieticians and Nutritionists	196	0.33	8	0.13	43	0.24
Draftsmen	3,062	5.13	240	4.25	805	5.03
Editors and Reporters	488	0.82	25	0.44	124	0.69
Aeronautical Engineers	40	0.07	2	0.03	12	0.07
Chemical Engineers	1,176	1.97	380	6.75	606	3.37
Civil Engineers	1,633	2.74	159	2.83	537	2.98
Electrical Engineers	967	1.62	56	0.99	297	1.65
Industrial Engineers	562	0.94	63	1.12	211	1.18
Mechanical Engineers	1,551	2.60	194	3.44	571	3.18
Metallurgical Engineers and Metallurgists	100	0.17	14	0.24	38	0.21
Mining Engineers	845	1.42	35	0.62	230	1.28
Sales Engineers	1,058	1.77	34	0.61	288	1.60
Engineers Not Classified	780	1.31	62	1.10	243	1.35
Farm and Home Management Advisors	20	0.03	2	0.03	5	0.03
Foresters and Conservationists	19	0.03	2	0.03	3	0.02
Funeral Directors and Embalmers	130	0.22	10	0.17	32	0.18
Lawyers and Judges	2,330	3.91	89	1.58	600	3.34
Librarians	476	0.80	28	0.50	118	0.65
Musicians and Music Teachers	1,416	2.37	176	3.11	405	2.25
Agricultural Scientists	4	0.01	2	0.03	2	0.01
Biological Scientists	66	0.01	3	0.05	13	0.07
Geologists and Geophysicists	1,429	2.40	15	0.26	347	1.93
Mathematicians	41	0.07	0	0.00	13	0.07
Physicists	49	0.08	0	0.00	6	0.04
Miscellaneous Natural Scientists	33	0.05	4	0.06	12	0.07
Nurses--Professional	4,403	7.38	323	5.73	1,165	6.48
Nurses--Student Professional	381	0.64	21	0.38	74	0.41
Optometrists	57	0.10	2	0.03	13	0.07
Osteopaths	16	0.03	0	0.00	7	0.04
Personnel and Labor-Relations Workers	945	1.58	94	1.67	319	1.77
Pharmacists	700	1.17	40	0.72	178	0.99
Photographers	315	0.53	19	0.34	80	0.44
Physicians and Surgeons	1,850	3.10	95	1.68	459	2.55
Radio Operators	209	0.35	50	0.88	96	0.53
Recreation and Group Workers	150	0.25	14	0.25	45	0.25
Religious Workers	391	0.66	6	0.10	145	0.81
Social and Welfare Workers (Except Group)	412	0.69	17	0.30	110	0.61
Economists	93	0.16	8	0.14	31	0.17
Psychologists	85	0.14	0	0.00	20	0.11
Statisticians and Actuaries	122	0.20	15	0.27	38	0.21
Miscellaneous Social Scientists	8	0.01	0	0.00	2	0.01
Surveyors	366	0.61	19	0.33	93	0.51
Teachers, Elementary	6,989	11.72	804	14.27	2,198	12.22
Teachers, Secondary Schools	3,334	5.59	468	8.31	1,077	5.99
Teachers (Not elsewhere classified)	820	1.37	98	1.75	250	1.39
Technicians, Medical and Dental	1,144	1.92	87	1.55	299	1.66
Technicians, Electrical and Electronic	408	0.68	27	0.48	114	0.63
Technicians, Other Engineering and Physical	2,040	3.42	596	10.58	925	5.14
Technicians (Not elsewhere classified)	411	0.69	35	0.62	96	0.53
Therapists and Healers	192	0.32	10	0.18	50	0.28
Veterinarians	80	0 13	10	0.17	28	0.15
Others	2,989	.01	310	5.50	889	4.94
Total	59,654	100.00	5,637	100.00	17,984	100.00

Table 20

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION:
MANAGERS, OFFICIALS AND PROPRIETORS (NON-FARM)

Population Elements	Distribution					
	Pre-Attack		Post Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Buyers and Department Heads	824	1.79	264	7.81	424	3.20
Conductors	148	0.32	16	0.46	35	0.26
Officers, Pilots, Pursers, Engineers (Ship)	2,489	5.41	155	4.58	424	5.47
Officials and Inspectors (State and Local)	609	1.32	52	1.54	193	1.46
Purchasing Agents and Buyers	1,072	2.33	67	1.98	319	2.41
Managers, Salaried (Eating and Drinking Places)	646	1.40	43	1.28	178	1.35
Managers, Salaried (Other Industries)	22,380	48.64	1,590	46.97	6,490	49.05
Managers, Self-employed (Eating and Drinking Places)	1.520	3.30	100	2.94	399	3.02
Managers, Self-employed (Other Industries)	14,620	31.78	979	29.93	3,997	30.21
Others	1,702	3.70	119	3.51	473	3.57
Total	46,010	100.00	3,385	100.00	13,232	100.00

Table 21

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION: CLERICAL AND KINDRED WORKERS

Population Elements	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Attendants, Physicians and Dental Office	570	0.74	50	0.84	163	0.74
Bookkeepers	7,149	9.26	602	10.11	2,120	9.63
Cashiers	5,397	6.99	493	8.28	1,585	7.20
Dispatchers and Starters	571	0.74	39	0.65	161	0.73
Mail Carriers	1,678	2.17	139	2.34	480	2.18
Office Machine Operators	2,555	3.31	179	3.01	719	3.27
Payroll and Timekeeping Clerks	748	0.97	81	1.35	250	1.14
Secretaries	15,013	19.44	1,037	17.43	4,192	19.05
Shipping and Receiving Clerks	2,052	2.66	80	1.35	465	2.11
Stenographers	2,721	3.52	292	4.90	854	3.88
Stock Clerks and Storekeepers	1,843	2.39	169	2.84	528	2.40
Telegraph Operators	112	0.15	12	0.20	33	0.15
Telephone Operators	2,956	3.83	202	3.40	799	3.63
Typists	3,332	4.32	315	5.30	965	4.39
Others	30,511	39.52	2,261	38.00	8,696	39.51
Total	77,208	100.00	5,950	100.0	22,012	100.00

Table 22

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION: SALES WORKERS

Population Elements	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Insurance Agents, Brokers and Underwriters	3,324	8.77	197	7.80	910	8.41
Real Estate Agents and Brokers	1,822	4.81	99	3.94	478	4.42
Sales--Retail Trade	18,354	48.44	1,482	58.69	5,377	49.69
Sales Other Than Retail	14,393	37.98	747	29.58	4,057	37.49
Total	37,893	100.00	2,524	100.00	10,822	100.00

Table 23

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION: CRAFTSMEN, FOREMEN AND KINDRED WORKERS

Population Elements	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		MPSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Bakers	630	0.93	21	0.23	138	0.61
Blacksmiths	70	0.10	2	0.02	12	0.05
Boiler Makers	777	1.14	241	2.75	407	1.80
Bricklayers, Stone Masons and Tile Setters	1,310	1.92	117	1.34	364	1.61
Cabinet Makers	442	0.65	33	0.38	119	0.53
Carpenters	6,477	9.51	902	10.31	2,214	9.79
Cement and Concrete Finishers	586	0.86	45	0.52	155	0.69
Compositors and Typesetters	1,045	1.53	41	0.47	238	1.05
Cranemen, Derrickmen and Hoistmen	997	1.46	159	1.82	373	1.65
Electricians	2,740	4.02	463	5.29	1,055	4.66
Electrotypers and Stereotypers	68	0.10	6	0.07	18	0.08
Engravers except Photo	65	0.10	0	0.00	20	0.09
Excavating, Grading, and Road Machine Operators	1,379	2.02	224	2.56	523	2.31
Foremen (Not elsewhere classified)	9,139	13.42	1,302	14.88	3,347	14.79
Forgemen and Hammermen	75	0.11	4	0.05	20	0.09
Furriers	0	0.00	0	0.00	0	0.00
Glaziers	181	0.27	17	0.20	48	0.21
Heat Treaters, Annealers and Temperers	168	0.25	6	0.07	39	0.17
Jewelers, Watchmakers, Gold/ Silversmiths	206	0.30	29	0.34	73	0.32
Job Setters (Metal)	37	0.05	2	0.02	8	0.03
Linemen and Service Men, Telephone, Telegraph	1,998	2.93	194	2.22	647	2.86
Locomotive Engineer	411	0.60	18	0.21	103	0.45
Locomotive Firemen	314	0.46	20	0.22	83	0.37
Loom Fixers	3	0.00	0	0.00	0	0.00
Machinists	5,721	8.40	553	6.33	1,723	7.62
Air Conditioning, Heating and Refrigeration, Repairmen	813	1.19	95	1.09	274	1.21
Airplane Mechanics	428	0.63	105	1.20	194	0.86
Automobile Mechanics	5,006	7.35	490	5.60	1,489	6.58
Office-Machine Mechanics	249	0.37	24	0.27	56	0.25
Radio and Television Mechanics	696	1.02	86	0.98	235	1.04
RR and Car-Shop Mechanics	311	0.46	18	0.21	65	0.29
Mechanics (Not elsewhere classified)	8,218	12.07	1,139	13.02	2,804	12.39
Millers (Grain, Flour, etc.)	35	0.05	4	0.05	13	0.06
Millwrights	385	0.57	94	1.08	175	0.77
Molders (Metal)	175	0.26	0	0.00	31	0.13
Opticians, Lens Grinders and Polishers	178	0.26	2	0.02	27	0.12
Painters (Construction and Maintenance)	3,559	5.23	341	3.97	1,015	4.49
Paperhangers	83	0.12	10	0.11	21	0.09
Pattern and Model Makers (Except paper)	79	0.12	10	0.12	28	0.12
Photoengravers and Lithographers	168	0.25	10	0.11	48	0.21
Plasterers	203	0.30	37	0.42	69	0.30
Plumbers and Pipe Fitters	2,976	4.37	808	9.24	1,345	5.95
Pressmen, Plate-Printers	497	0.73	14	0.16	109	0.48
Rollers and Roll Hands Metal	143	0.21	2	0.02	33	0.15
Roofers and Slaters	514	0.75	37	0.42	152	0.67
Shoemakers and Repairers (except factory)	212	0.31	19	0.21	55	0.24
Stationary Engineers	2,732	4.01	402	4.59	969	4.28
Stone Cutters and Carvers	35	0.05	4	0.05	13	0.06
Structural Metal Workers	628	0.92	90	1.02	227	1.00
Tailors	211	0.31	3	0.03	44	0.19
Tinsmiths, Coppersmiths, and Sheet Metal Workers	839	1.23	72	0.82	230	1.02
Tool and Die Makers and Setters	478	0.70	38	0.43	146	0.65
Upholsterers	479	0.70	15	0.17	119	0.53
Craftsmen and Kindred Workers (Not elsewhere classified)	944	1.39	245	2.80	412	1.82
Others	1,993	2.93	131	1.50	503	2.22
Total	68,106	100.00	8,748	100.0	22,623	100.00

Table 24

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION: OPERATIVES AND KINDRED WORKERS

Population Elements	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Apprentices	537	0.75	60	0.71	170	0.77
Asbestos and Insulation Workers	412	0.58	162	1.91	229	1.03
Assemblers	1,127	1.58	68	0.80	328	1.48
Attendants (Auto Service and Parking)	2,947	4.12	399	4.70	924	4.16
Blasters and Powdermen	28	0.04	12	0.14	12	0.05
Brakemen (RR)	178	0.25	9	0.11	33	0.15
Bus Drivers	1,091	1.53	55	0.66	265	1.19
Chainmen, Rodmen, Axmen (Surveying)	85	0.12	2	0.02	31	0.14
Checkers, Examiners, Inspectors (Mfg)	1,274	1.78	144	1.70	426	1.92
Deliverymen and Routemen	3,462	4.84	203	2.39	876	3.95
Dressmakers and Seamstresses (except factory)	998	1.40	44	0.52	221	0.99
Dyers	29	0.04	0	0.00	4	0.02
Fillers, Grinders, and Polishers (Metal)	653	0.91	15	0.18	181	0.82
Furnacemen, Smeltermen and Pourers	240	0.34	20	0.23	89	0.40
Heaters (Metal)	20	0.03	6	0.07	9	0.04
Knitters, Loopers and Toppers (Textile)	7	0.01	0	0.00	0	0.00
Laundry and Dry Cleaning Workers	3,919	5.48	176	2.08	836	3.77
Meat Cutters (except Slaughterhouse and Pkg.)	1,195	1.67	107	1.26	342	1.54
Mine Operatives and Laborers (Not elsewhere classified)	1,477	2.07	299	3.53	526	2.37
Motormen (Mine, Factory, Logging, etc.)	17	0.02	2	0.02	5	0.02
Motormen (Street, Subway and Elevated)	0	0.00	0	0.00	0	0.00
Oilers, Greasers (Except Auto)	372	0.52	68	0.80	154	0.69
Packers and Wrappers	2,282	3.19	143	1.68	598	2.69
Painters (except Const and Maint)	1,050	1.47	176	2.07	346	1.56
Photographic Process Workers	313	0.44	12	0.14	67	0.30
Power-Station Operators	189	0.26	48	0.57	89	0.40
Sailors and Deck Hands	922	1.29	253	2.98	451	2.03
Sawyers	142	0.20	5	0.06	41	0.18
Sewers and Stichers (Mfg)	767	1.07	19	0.23	179	0.81
Spinners (Textile)	32	0.04	0	0.00	8	0.04
Stationary Firemen	296	0.41	74	0.87	145	0.65
Switchmen (RR)	1,138	1.59	70	0.83	279	1.26
Taxicab Drivers and Chauffeurs	1,030	1.44	33	0.40	216	0.97
Truck and Tractor Drivers	13,240	18.52	819	9.66	3,271	14.74
Weavers (Textile)	50	0.07	0	0.00	11	0.05
Welders and Flame Cutters	4,818	6.74	597	7.04	1,685	7.59
Other Spec Operations and Kindred Workers	287	0.40	75	0.89	127	0.57
Manufacturing--Durable Goods	8,471	11.85	438	5.17	2,268	10.22
Manufacturing--Nondurable Goods	10,600	14.83	4,357	40.78	5,178	23.33
Nonmanufacturing Indust (Incl not reported)	5,801	8.11	405	4.78	1,577	7.10
Total	71,496	100.00	8,478	100.00	22,198	100.00

Table 25

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION: SERVICE WORKERS (NON-PRIVATE HOUSEHOLD)

Population Elements	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Attendants (Hospitals and other Institutions)	1,965	4.38	131	3.78	484	4.26
Barbers	1,603	3.57	105	3.04	398	3.51
Charwomen, Janitors and Porters	10,223	22.79	587	16.91	2,289	20.17
Cooks	4,091	9.12	308	8.89	1,004	8.85
Elevator Operators	643	1.43	28	0.80	132	1.17
Hairdressers and Cosmetologists	3,376	7.53	278	8.00	931	8.20
Housekeepers and Stewards	818	1.82	97	2.79	238	2.09
Midwives	4	0.01	0	0.00	0	0.00
Practical Nurses	1,377	3.07	162	4.67	404	3.56
Firemen, Fire Protectors	1,018	2.27	52	1.50	287	2.53
Guards, Watchmen, Doorkeepers	1,774	3.95	293	8.45	654	5.76
Policemen and Detectives	1,524	3.40	143	4.11	465	4.10
Sheriffs, Constables and and Marshalls	168	0.37	26	0.76	59	0.52
Waiters, Bartenders and Counter Workers	7,942	17.71	757	21.83	2,119	18.67
Watchmen (Crossing and Bridge) Tenders	118	0.26	1	0.04	35	0.31
Other Service Workers	8,213	18.31	501	14.43	1,851	16.31
Total	44,857	100.00	3,469	100.00	11,350	100.00

Table 26

EFFECTS OF A 10-MT ATTACK ON HOUSTON POPULATION: LABORERS (EXCEPT MINE)

Population Elements	Distribution					
	Pre-Attack		Post-Attack			
			No Shelters		NFSS-X	
	Number	% of Total	Survivors	% of Surviving Total	Survivors	% of Surviving Total
Farm Laborers, Unpaid Family Workers	192	11.46	19	10.77	57	12.81
Farm Laborers, Excluding Unpaid Workers	1,484	88.54	157	89.23	389	87.19
Total Farm Laborers	1,676	100.00	176	100.00	446	100.00
Carpenters and Helpers Exc Log and Mine	556	1.79	68	2.66	159	1.90
Fishermen and Oystermen	48	0.15	11	0.42	19	0.23
Longshoremen and Stevedores	2,485	8.00	82	3.24	744	8.86
Lumbermen, Raftsmen, Woodcutters	57	0.18	14	0.55	26	0.31
Warehousemen (not elsewhere classified)	1,213	3.90	70	2.76	307	3.65
Other Specified Laborers	2,709	8.72	170	6.69	665	7.92
Durable Goods	3,407	10.97	153	6.01	846	10.08
Nondurable Goods	3,053	9.83	734	28.87	1,300	15.50
Nonmanufacturing Industry (Incl Not Reported)	17,537	56.45	1,241	48.79	4,324	51.54
Total Laborers (except Farm & Mine)	31,065	100.00	2,544	100.00	8,390	100.00

of the changes in the composition of the Houston population. The percentage changes by component classes have been grouped by quintiles and shown on the horizontal scale. The frequency with which changes in the number of component classes occurred within the quintile limits are shown on the vertical scale.

These figures show the pre-attack number of persons by groups and the number and percent distribution for major component classes. The far left and far right columns of the tables accompanying Figures 8 through 20 show the percent change from pre-attack proportions for each component class in the no-shelter case and for NFSS-X respectively. This relationship can be expressed as

$$\frac{\frac{C_1}{G_1} - \frac{C}{G}}{\frac{C}{G}}$$

where G and G_1 are the pre-attack and post-attack group totals, respectively, and C and C_1 similar measures for the component classes. This calculation was made for the no-shelter case and repeated for NFSS-X. In most cases, in order to avoid the large and meaningless deviations that would occur in the component classes containing relatively small numbers of persons, they were grouped into a single "Other" class normally aggregating about one-third of the pre-attack group total. To illustrate, in Table 13, in the group, Professional, Technical and Kindred Workers, the component class of Physicians and Surgeons accounted for 3.1 percent of all professional workers in the pre-attack case, 1.7 percent in the no-shelter case and 2.6 percent in the NFSS-X case. As shown in Figure 13, this is equal to a change for the component class of -46 percent between the no-shelter case and the pre-attack case and a change of -18 percent between the NFSS-X case and the pre-attack case.

In the category labeled "Total, Employed by Industry," the subgroup "Other Non-Durable Manufacturing" experienced a 300 percent

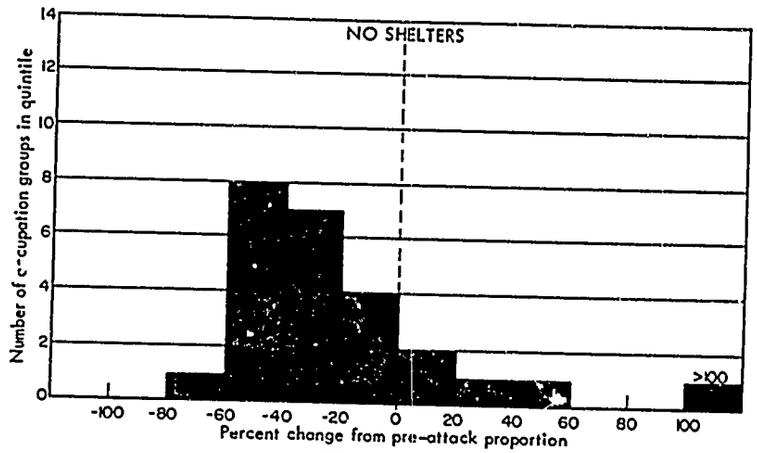
increase (percent change in the post-attack distribution over the pre-attack distribution) for the no-shelter case and an 80 percent increase for NFSS-X. The reason for this very large, disproportionate change in the distribution of workers in this particular industrial group can be explained by the fact that a majority of these workers live in census tracts that were not affected by either the blast or the fallout. Whereas some of the other industrial groups, e.g., Communications, Utilities, etc., were spread out over the city, it seemed that the workers in the non-durable manufacturing group were clustered in the southeastern part of Houston and were away from the direct blast area. Because of the wind pattern assumed for this attack, they were also generally remote from the areas of heavy fallout.

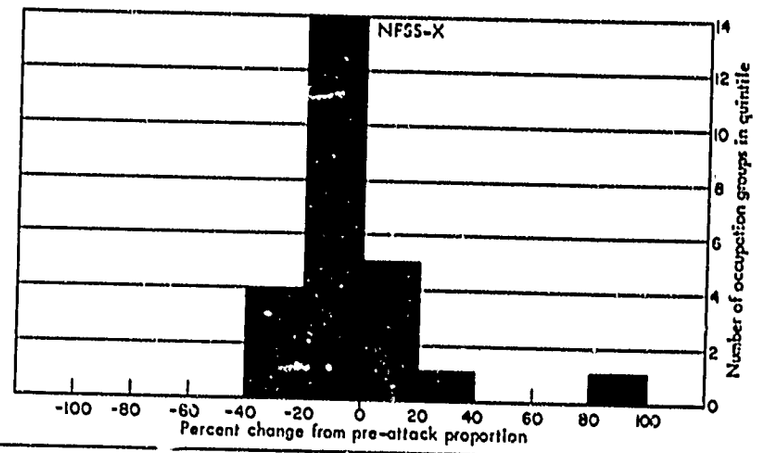
Figure 8 graphically illustrates the changes in the distribution of the component groups for the category "Total Employed, By Industry" and demonstrates the fact that the NFSS-X program, while generally reducing the total number of fatalities also tends to minimize disproportionate changes in the distribution of the groups of workers in the twenty-five stated industrial classifications. This seems to hold true for each of the remaining categories of workers examined in this Study.

For the next three main categories - Males, Females, and Total Employed by Occupation, there were twelve sub-categories which were examined. Significant increases occurred in the proportion of Craftsmen, Foremen and Kindred Workers for both males and for the total group, in both the sheltered and unsheltered cases. A one-third increase occurred in the proportion of the sub-category "Operatives and Kindred Workers," for the no-shelter case, although a decline was registered in the shelter case. The largest proportionate declines in both cases occurred for Private Household Workers. The changes in the distributions of the component occupations for the category "Total, Employed by Occupation" are shown in Figures 9, 10, and 11.

The bulk of the data in the most detailed form are presented in Tables 12 through 20, which show the total civilian labor force and its subgroups. The experienced civilian labor force is made up of the employed and the experienced unemployed (i.e., persons who have worked at any time in the past). The subgroups include such headings as sales workers, clerical workers, and operatives. Eight of the twelve subgroups are graphically presented.

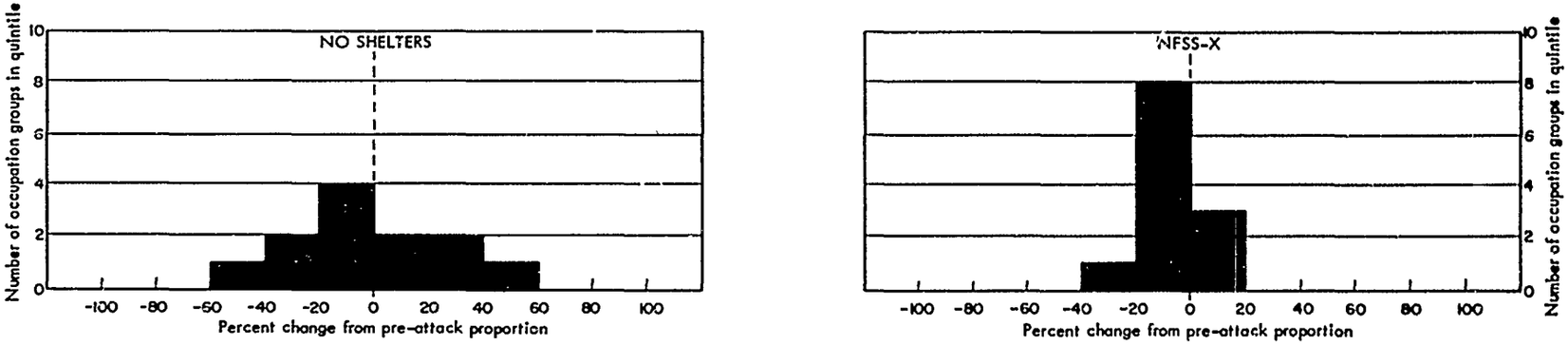
In summary, the differences between the post-attack and pre-attack distribution were smaller for the sheltered than for the unsheltered population. To the extent that the viability of a post-attack society depends on retaining some reasonable relationship between the post-attack and pre-attack distribution of skills among the experienced labor force, this result reinforces the argument for a shelter program: the more shelters are provided, the more equipped the community is to survive in the long run.





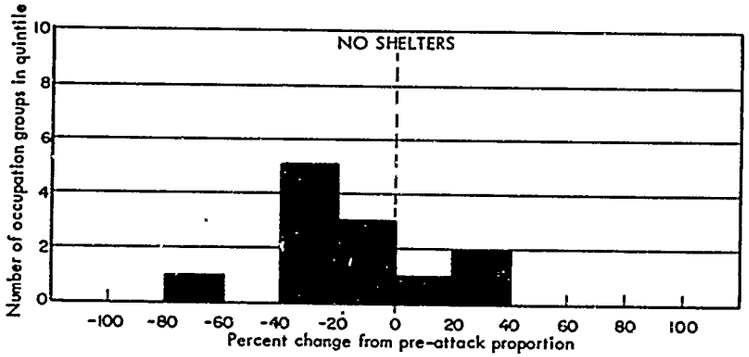
Post Attack: No Shelter, % Change	Occupation Group	Pre-Attack Distribution: Total Number	Pre-Attack Distribution: % of Total	Post Attack: NFSS-X, % Change
---	Total Employed, by Industry	470,452	100	---
-38	Mining	12,226	2.6	-7
+13	Construction	34,901	7.42	+6
-60	Furniture, lumber and wood	3,063	0.65	-23
-20	Metal industries	16,651	3.54	+7
-52	Machinery	21,056	4.48	-5
+53	Transportation equipment	2,118	0.45	+24
-41	Other durable goods	6,627	1.41	-5
-52	Food and kindred products	9,957	2.12	-16
-65	Textile and apparel	2,466	0.52	-23
-43	Printing, publishing and allied	6,383	1.36	-11
+293	Other non-durable goods	33,534	7.13	+82
-58	Railroad and railway express	8,238	1.75	-22
-6	Other transportation	20,191	4.29	+2
-12	Communications, utilities, sanitary	14,657	3.12	-4
-48	Wholesale trade	28,022	5.96	-10
-21	Eating and drinking places	12,425	2.64	-16
-8	Other retail	61,655	13.11	-2
-35	Business and repair service	14,505	3.08	-9
-50	Private household	19,426	4.13	-28
-34	Other personal service	16,458	3.50	-19
-23	Hospitals	11,751	2.50	-13
+26	Education service	21,692	4.61	+5
-25	Other professional service	19,451	4.13	-6
+1	Public administration	13,456	2.86	+3
-34	Other, including not reported	59,543	12.66	-13

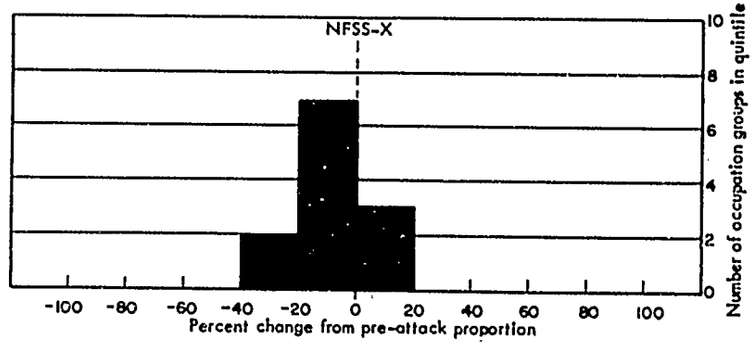
FIGURE 8 Effects of a 10-Mt Attack on the Labor Force: Total Employed, by Industries



Post Attack: No Shelter, % Change	Pre-Attack Distribution: Occupation Group	Total Number	% of Total	Post Attack: NFSS-X, % Change
---	Total Employed, by Occupation	470,452	100	---
+6	Professional, technical and kindred workers	58,984	12.54	+5
+31	Farmers and farm managers	1,509	0.32	-12
-19	Managers, officials and proprietors	45,477	9.67	-1
-14	Clerical and kindred workers	75,172	15.98	-1
-26	Sales workers	36,848	7.83	-1
+44	Craftsmen, foremen and kindred workers	65,138	13.85	+15
+33	Operatives and kindred workers	67,869	14.43	-8
-53	Private household workers	17,696	3.76	-29
-14	Service workers, non-private household	42,242	8.98	-12
+12	Farm laborers and foremen	1,567	0.33	-9
-8	Laborers, except farm and mine	25,963	5.52	-5
-28	Occupation not reported	31,987	6.80	-14

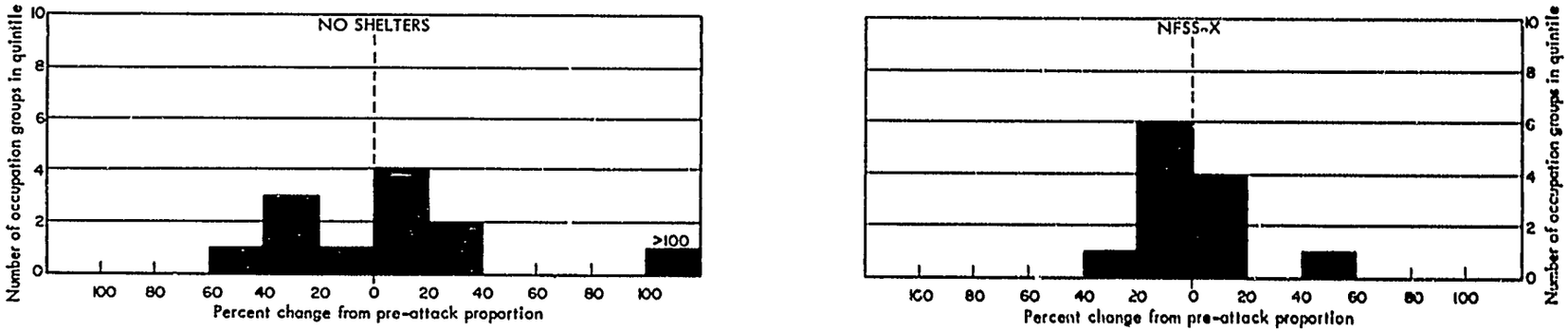
FIGURE 9 Effects of a 10-Mt Attack on the Labor Force: Total Employed, by Occupation





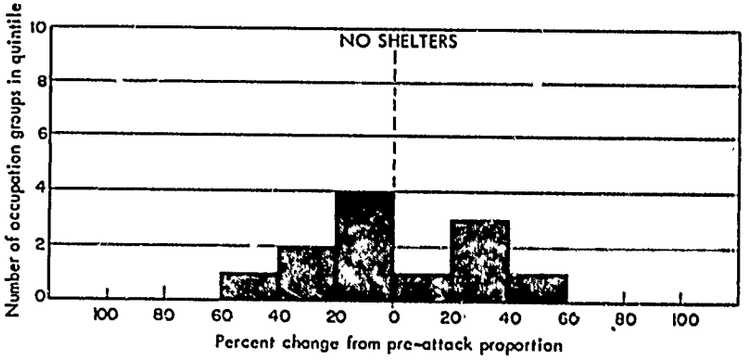
Post Attack: No Shelter, % Change	Pre-Attack Distribution: Occupation Group	Total Number	% of Total	Post Attack: NFSS-X, % Change
---	Males Employed, by Occupation	318,708	100	---
-2	Professional, technical and kindred workers	39,156	12.29	+3
+5	Farmers and farm managers	1,366	0.43	-21
-28	Managers, official and proprietors	39,330	12.34	-4
-23	Clerical and kindred workers	23,664	7.42	-5
-40	Sales workers	25,230	7.92	-6
+35	Craftsmen, foremen and kindred workers	65,545	19.94	+12
+35	Operatives and kindred workers	58,168	18.25	+8
-74	Private household workers	593	0.19	-37
-27	Service workers	20,433	6.41	-17
-2	Farm laborers	1,390	0.44	-13
-13	Laborers, except farm and mine	25,218	7.91	-8
-32	Occupation not reported	20,615	6.47	-15

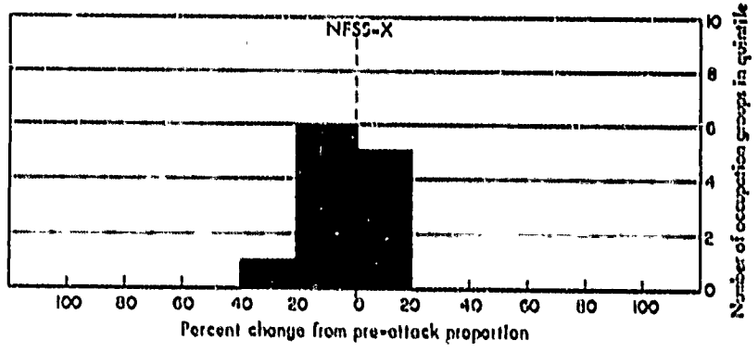
FIGURE 10 Effects of a 10-Mt Attack on the Labor Force: Males Employed, by Occupation



Post Attack: No Shelter, % Change	Pre-Attack Distribution: Occupation Group	Total Number	% of Total	Post Attack: NFSS-X, % Change
---	Females Employed, by Occupation	151,744	100	---
+24	Professional, technical and kindred workers	19,828	13.07	+8
+266	Farmers and farm managers	143	0.09	+56
+24	Managers, officials and proprietors	6,147	4.05	+9
+4	Clerical and kindred workers	51,508	33.94	+7
+10	Sales workers	11,618	7.66	+9
-34	Craftsmen, foremen and kindred workers	1,593	1.05	-4
-27	Operatives and kindred workers	9,701	6.39	-10
-43	Private household workers	17,103	11.27	-23
+13	Service workers	21,809	14.37	-2
+12	Farm laborers	177	0.12	-9
-8	Laborers, except farm and mine	745	0.49	-5
-29	Occupation not reported	11,372	7.49	-14

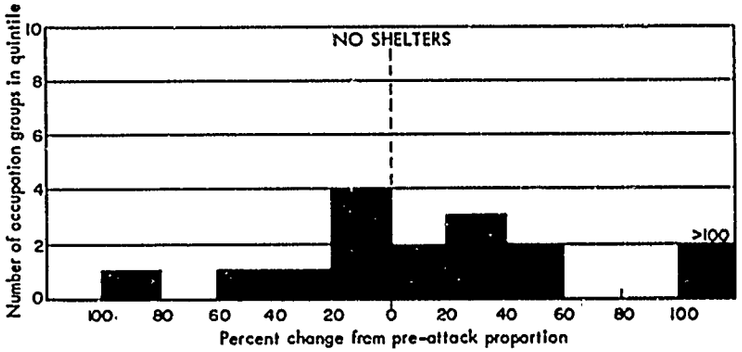
FIGURE 11 Effects of a 10-Mt Attack on the Labor Force: Females Employed, by Occupation

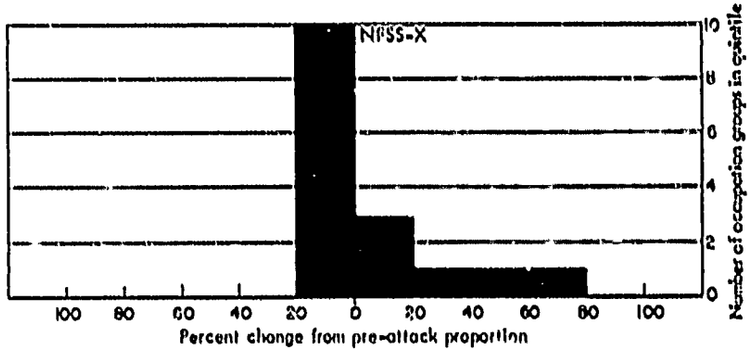




Post Attack: No Shelter, % Change	Pre-Attack Distribution: Experienced Civilian Labor Force	Total Number	% of Total	Post Attack: NFSS-X, % Change
---	Total, Experienced Civilian Labor Force	(490,147)	100	---
+5	Professional, technical and kindred workers	59,654	12.2	+5
+33	Farmers and farm managers	1,240	0.3	0
-18	Managers, officials and proprietors	46,010	9.4	0
-15	Clerical and kindred workers	77,208	15.8	-1
-26	Sales workers	37,893	7.7	0
+43	Craftsmen, foremen and kindred workers	68,106	13.9	+15
+32	Operatives and kindred workers	71,496	14.6	+8
-50	Private household workers	18,655	3.8	-29
-14	Service workers (non-private household)	44,857	9.2	-13
+33	Farm laborers and foremen	1,676	0.3	0
-8	Laborers, except farm and mine	31,065	6.3	-6
-28	Not reported	31,987	6.5	-14

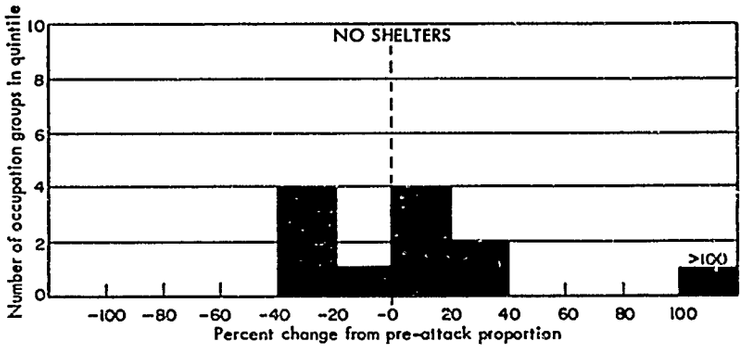
FIGURE 12 Effects of a 10-Mt Attack on the Labor Force: Total Experienced Labor Force

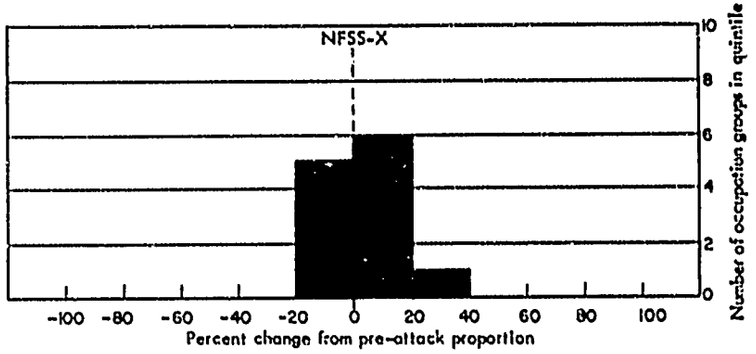




Post Attack: No Shelter, % Change	Pre-Attack Distribution: Occupation Group	Total Number	% of Total	Post Attack: NFSS-X, % Change
---	Professional, Technical and Kindred Workers	59,654	100	---
+22	Teachers, elementary schools	6,989	11.72	+4
-43	Accountants and auditors	6,250	10.48	-6
-22	Nurses, professional	4,403	7.38	-12
+49	Teachers, secondary schools	3,334	5.59	+7
-17	Draftsmen	3,062	5.13	-2
-2	Lawyers and judges	2,130	3.91	-15
+209	Technicians, engineering and physical	2,040	3.42	+50
+46	Physicians and surgeons	1,850	3.10	-18
+3	Civil engineers	1,633	2.74	+8
+32	Mechanical engineers	1,551	2.60	+22
-89	Geologists and geophysicists	1,429	2.40	-20
+31	Musicians and music teachers	1,416	2.37	-5
+4	Clergymen	1,335	2.24	-10
+243	Chemical engineers	1,176	1.97	+71
-19	Technicians, medical and dental	1,144	1.92	-14
-17	Others	39,742	33.03	-13

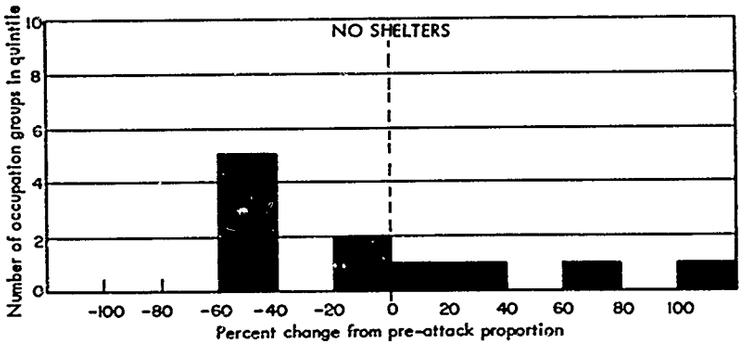
FIGURE 13 Effects of a 10-Mt Attack on the Labor Force: Professional, Technical, & Kindred Workers

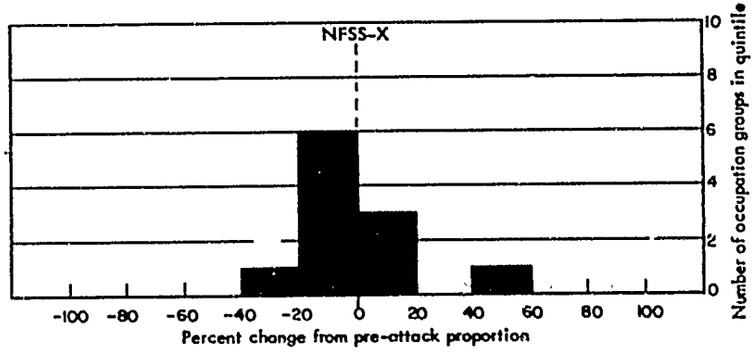




Post Attack: No Shelter, % Change	Pre-Attack Distribution			Post Attack: NFSS-X, % Change
	Occupation Group	Total Number	% of Total	
---	Craftsmen, Foremen and Kindred Workers	68,106	100	---
+11	Foremen, not elsewhere classified	9,139	13.42	+11
+8	Mechanics, not elsewhere classified	8,212	12.07	+3
+8	Carpenters	6,477	9.51	+3
-25	Machinists	5,721	8.40	-9
-24	Automobile mechanics	5,006	7.35	-10
-24	Painters, construction and maintenance	3,559	5.23	-14
+111	Plumbers and pipe fitters	2,976	4.37	+36
+32	Electricians	2,740	4.02	+16
+14	Stationary engineers	2,732	4.01	+7
-24	Linemen, servicemen (telephone & telegraph)	1,998	2.93	-2
+27	Excavating, grading & road machine operators	1,379	2.02	+14
-18	Others	18,167	26.67	-9

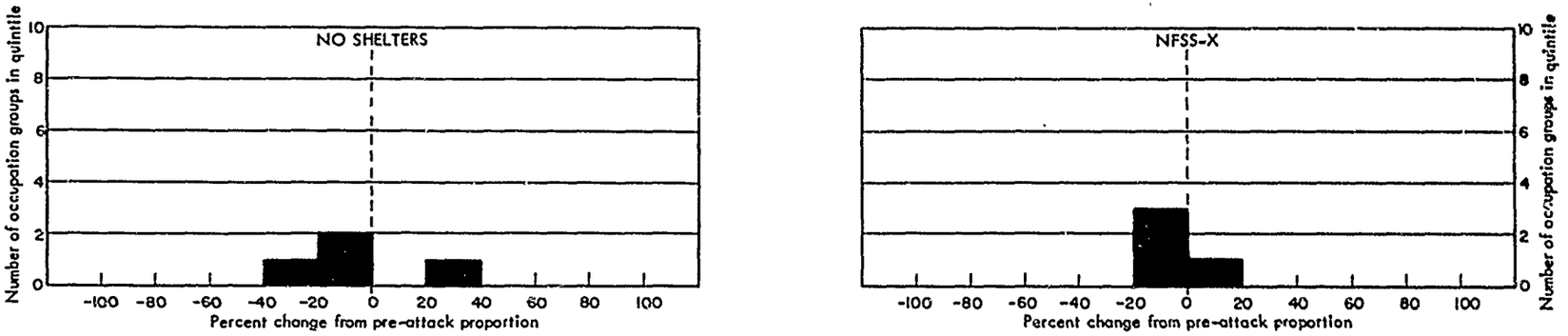
FIGURE 14 Effects of a 10-Mt Attack on the Labor Force: Craftsmen, Foremen, & Kindred Workers





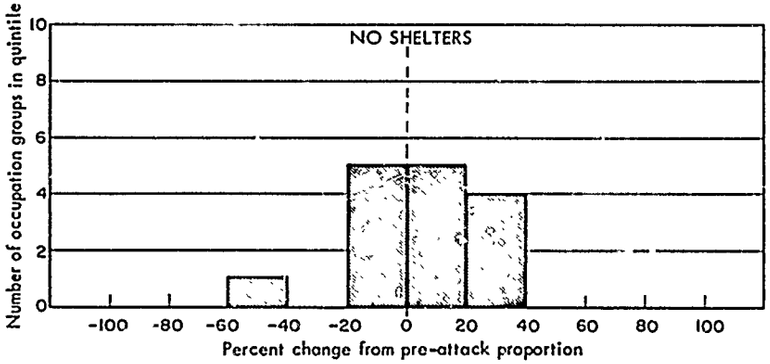
Post Attack: No Shelter, % Change	Pre-Attack Distribution: Occupation Group	Total Number	% of Total	Post Attack: NFSS-X, % Change
---	Operatives and kindred workers	71,496	100	---
-66	Truck and tractor drivers	13,240	18.52	-20
+175	Manufacturing: non-durable goods	10,600	14.83	+57
-56	Manufacturing: durable goods	8,471	11.85	-14
-41	Non-manufacturing industries	5,801	8.11	-12
-18	Laundry and dry cleaning	3,919	5.48	-31
+4	Welders and flame cutters	4,818	6.74	+13
-51	Deliverymen and routemen	3,462	4.84	-18
+14	Attendants: auto service & parking	2,947	4.12	+1
-47	Packers and wrappers	2,282	3.19	-16
+71	Mine operatives and laborers	1,477	2.07	+15
-10	Others	14,479	20.25	-1

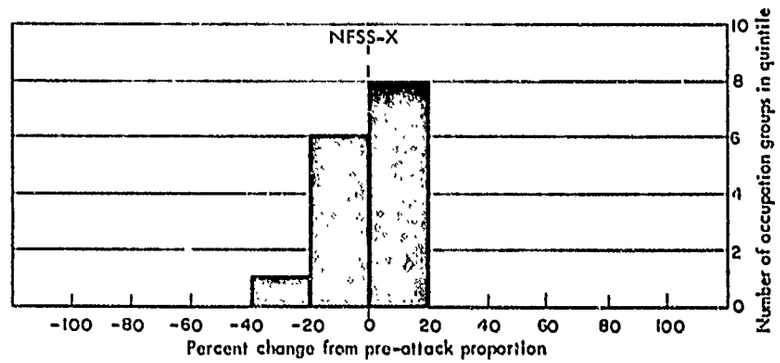
FIGURE 15 Effects of a 10-Mt Attack on the Labor Force: Operatives & Kindred Workers



Post Attack: No Shelter, % Change	Pre-Attack Distribution: Occupation Group	Total Number	% of Total	Post Attack: NFSS-X, % Change
---	Sales Workers	37,893	100	---
-11	Insurance agents, brokers & underwriters	3,324	8.77	-4
-18	Real estate agents and brokers	1,822	4.81	-8
+21	Sales, retail trade	18,354	48.44	+3
-?2	Sales other than retail	14,693	37.98	-1

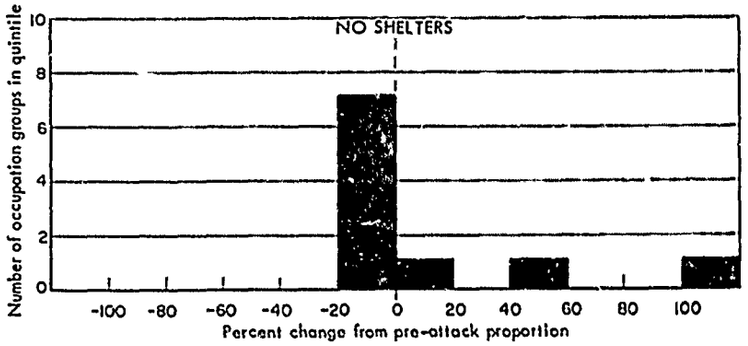
FIGURE 16 Effects of a 10-Mt Attack on the Labor Force: Sales Workers

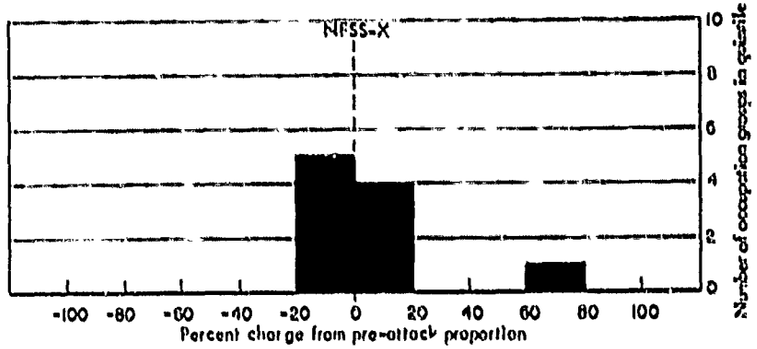




Post Attack: No Shelter, % Change	Pre-Attack Distribution			Post Attack: NFSS-X, % Change
	Occupation Group	Total Number	% of Total	
---	Clerical and kindred workers	77,208	100	---
+14	Attendants: physicians and dental office	570	0.74	0
+9	Bookkeepers	7,149	9.26	+4
+18	Cashiers	5,397	6.99	+3
-12	Dispatchers and starters	571	0.74	-1
+8	Mail carriers	1,678	2.17	+1
-9	Office machine operators	2,555	3.31	-1
+39	Payroll and timekeeping clerks	748	0.97	+18
-10	Secretaries	15,013	19.44	-2
-49	Shipping and receiving clerks	2,052	2.66	-21
+39	Stenographers	2,721	3.52	+10
+19	Stock clerks and storekeepers	1,843	2.39	+1
+33	Telegraph operators	112	0.15	0
-11	Telephone operators	2,956	3.83	-5
+23	Typists	3,332	4.32	+2
-4	Others	30,511	39.52	-1

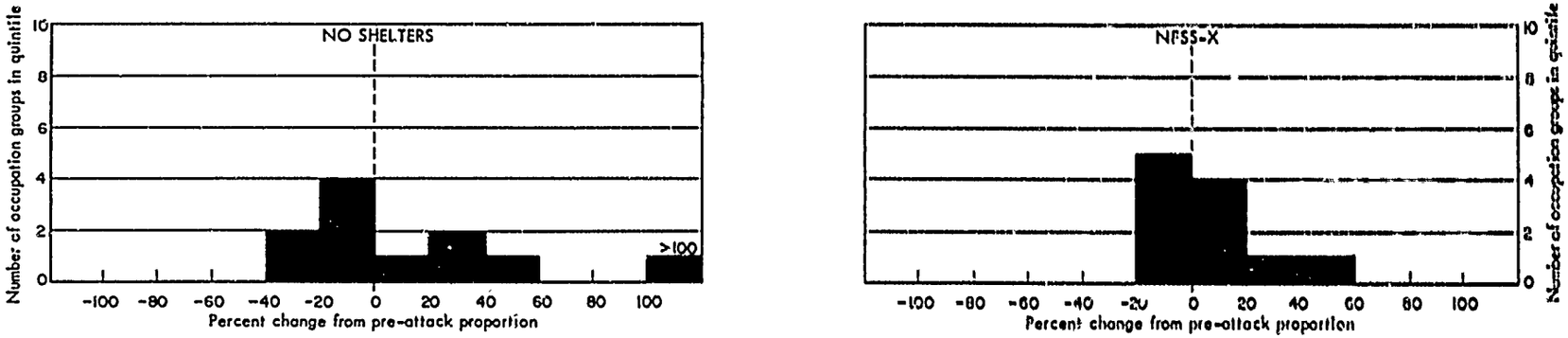
FIGURE 17 Effects of a 10-Mt Attack on the Labor Force: Clerical & Kindred Workers





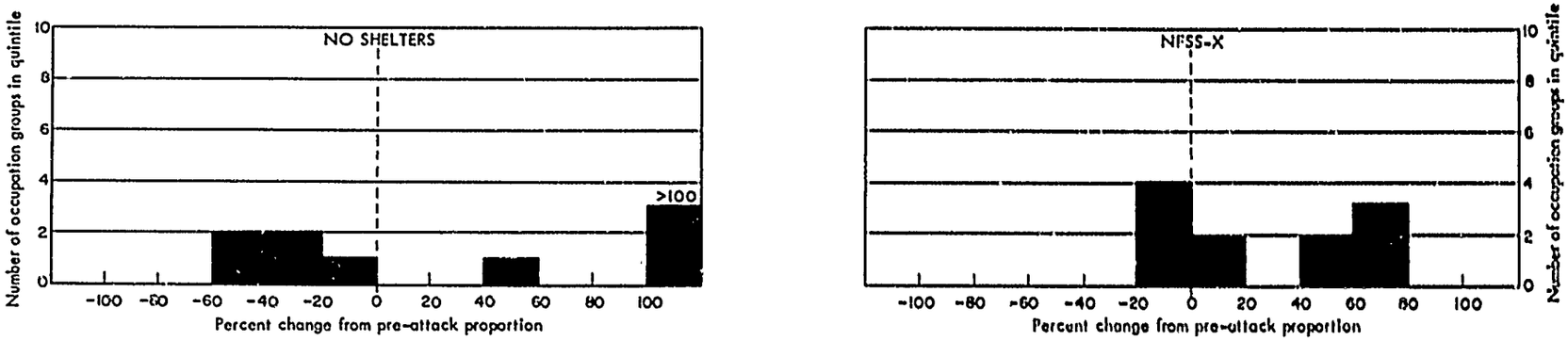
Post Attack: No Shelter, % Change	Pre-Attack Distribution: Occupation Group	Total Number	% of Total	Post Attack NFSS-X, % Change
---	Managers, Officials and Proprietors (Non-Farm)	46,010	100	---
+336	Buyers and department heads	824	1.79	+79
+43	Conductors (railroad)	148	0.32	-18
-15	Officers, pilots, pursers, engineers (ship)	2,489	5.41	+1
+17	Officials and inspectors (state and local)	609	1.32	+11
-15	Purchasing agents and buyers	1,072	2.33	+4
-8	Managers, salaried (eating & drinking places)	646	1.40	-4
-3	Managers, salaried (other industries)	22,380	48.64	+1
-11	Managers, self-employed (eating and drinking places)	1,520	3.30	-8
-9	Managers, self-employed (other industries)	14,620	31.78	-5
-5	Other managers, officials and proprietors	1,702	3.70	-4

FIGURE 18 Effects of a 10-Mt Attack on the Labor Force: Managers, Officials, & Proprietors (Non-Farm)



Post Attack: No Shelter, % Change	Pre-Attack Distribution: Occupation Group	Total Number	% of Total	Post Attack: NFSS-X, % Change
---	Service Workers, Non-Private Household	44,857	100	---
-26	Charwomen, janitors & Porters	10,223	22.79	-11
+23	Waiters, bartenders & counter workers	7,942	17.71	+5
-3	Cooks, non-private household	4,091	9.12	-3
+6	Hairdressers and cosmetologists	4,476	7.53	+9
-14	Attendants, hospitals, etc.	1,965	4.38	-3
+113	Guards, watchmen, doorkeepers	1,774	3.95	+46
-15	Barbers	1,603	3.57	-2
+21	Policemen and detectives	1,524	3.40	+21
+52	Practical nurses	1,377	3.07	+16
-34	Firemen, fire protectors	1,018	2.27	+11
-15	Others	9,964	22.21	-8

FIGURE 19 Effects of a 10-Mt Attack on the Labor Force: Service Workers (Non-Private Household)



Post Attack: No Shelter, % Change	Pre-Attack Distribution: Occupation Group	Total Number	% of Total	Post Attack: NFSS-X, % Change
---	Laborers, Except Farm and Mine	31,065	100	---
+49	Carpenters and helpers	556	1.79	+6
+180	Fishermen and oystermen	48	0.15	+53
-60	Longshoremen and stevedores	2,485	8.0	+11
+205	Lumbermen, raftsmen & woodcutters	57	0.18	+72
-29	Warehousemen, not elsewhere classified	1,213	3.90	-6
-23	Other specified laborers	2,709	8.72	-9
-45	Durable goods industries	3,407	10.97	-8
+194	Non-durable goods industries	3,053	9.83	+58
-14	Non-manufacturing industry, including not reported	17,537	56.45	-9

FIGURE 20 Effects of a 10-Mt Attack on the Labor Force: Laborers (Non-Farm and Non-Mine)

5

ECONOMIC RELATIONSHIPS

5.1 PER CAPITA PROPERTY VALUES

Civil defense planning must be concerned not only with protecting people during and after an attack, but also with the conditions which would greet survivors in the post-attack world. The effects of nuclear weapons on the population of Houston considered in R-113[1] were expressed in terms of human fatalities and survivors. Sections 2 and 3 of this study presented data on weapons effects expressed in terms of loss in property values and economic output. Section 4 presented an analysis of the occupational characteristics of the Houston population after a 10-Mt attack. This section assembles a few of these major findings and considers their interrelationships.

Post-attack physical property values, subjected to the sixteen hypothetical attacks (eight weapons, two targets each), varied from 94 percent of the pre-attack value for a 0.1-Mt weapon to 10 percent for a 100-Mt weapon. The same attacks on the unsheltered population of Houston result in 86 percent and 2 percent rate of survival, respectively. The survivors of larger attacks, in a limited sense, become richer. Table 27 depicts the per capita wealth for unsheltered survivors of the sixteen hypothetical attacks. The higher the yield of a weapon, the greater the per capita "wealth" of the survivors, with the greatest increase being found in real estate improvements.

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1. See S. E. Eastman, The Effects of Nuclear Weapons on a Single City, IDA Report R-113, Institute for Defense Analyses, Economic and Political Studies Division (Arlington, Va., September 1965).

Table 27

PRE- AND POST-ATTACK HOUSTON 1963 PROPERTY VALUES

TOTAL AND PER-CAPITA

Weapon Yield Mt (1)	Population Thous. (2)	Real Estate Improvements millions of $ (3)	(3)/Pop., $ (4)	Machine Equipment Inventories millions of $ (5)	(5)/Pop., ($) (6)	Non-Taxable Property millions of $ (7)	(7)/Pop., ($) (8)	Home Furnishings et al millions of $ (9)	(9)/Pop., ($) (10)	Total millions of $ (11)	(11)/Pop., $ (12)
Pre-Attack	1,226	6.274	5,117	2,373	1,936	1,229	1,002	1,402	1,144	11.277	9,198
Ground Zero: At-home Population Centroid											
0.1	1,059	5.972	5,639	2.198	2,076	1.155	1,091	1.317	1,244	10.641	10,048
0.5	745	5.314	7,133	1.693	2,272	0.977	1,338	1.226	1,646	9.230	12,389
1.0	584	5.006	8,572	1.457	2,495	0.817	1,399	1.125	1,926	8.405	14,392
3.0	395	4.198	10,628	1.213	3,071	0.716	1,813	0.901	2,281	7.028	17,792
5.0	299	3.816	12,763	1.081	3,615	0.651	2,177	0.768	2,569	6.317	21,127
7.0	269	3.551	13,201	0.979	3,639	0.606	2,253	0.693	2,576	5.829	21,669
10.0	222	3.141	14,149	0.876	3,946	0.549	2,473	0.568	2,559	5.134	23,126
100.0	36	0.764	21,222	0.241	6,694	0.143	3,972	0.060	1,667	1.208	33,556
Ground Zero: At-work Population Centroid											
0.1	872	5.619	6,444	1.883	2,159	1.116	1,280	1.351	1,549	9.969	11,432
0.5	583	5.302	9,094	1.639	2,811	1.025	1,758	1.232	2,113	9.197	15,775
1.0	459	5.016	10,928	1.439	3,135	0.923	2,011	1.120	2,440	8.498	18,514
3.0	289	4.308	14,907	1.206	4,173	0.691	2,391	0.920	3,183	7.125	24,654
5.0	234	3.916	16,735	1.078	4,607	0.640	2,735	0.807	3,449	6.441	27,526
7.0	200	3.621	18,105	0.967	4,835	0.606	3,030	0.719	3,595	5.913	29,565
10.0	159	3.229	20,308	0.879	5,528	0.556	3,497	0.610	3,836	5.274	33,170
100.0	21	0.745	35,476	0.229	10,905	0.126	6,000	0.057	2,714	1.156	55,048

a. Detail may not total to 100% due to independent rounding.

The relative proportions of two of the four types of physical property to all property shift with increasing weapon yields as was shown in Figure 1. Nontaxable property and household furnishings, automobiles, and miscellaneous nontaxable property, which tend to be distributed more evenly over the area of weapon effects, retain fairly constant relationships to total physical property value. The proportion of real-estate improvements increases with weapons of greater yield, while the proportion of machinery, equipment and inventories decreases. Although no assumptions can be made about the distribution of these values to inventories which might be useful during the immediate post-attack period or to machinery and equipment, it does imply that measures to protect or preserve materiel necessary for economic output should be included in civil defense planning. Also, the surviving real-estate improvements which would be on the outskirts of the metropolitan area are largely residential, rather than those which previously contributed to the industrial and trade activities of the community.

These results could provide guidance in planning the protection of property. If it is desired to maintain the pre-attack proportions of the components of property values within some reasonable limits, consideration should be given first to the property in the center of the city. The goal of this policy would be to raise all lines in Figure 1 to the level of real-estate improvements through a protection program. All would then coincide and the pre-attack proportions would be maintained within bounds.

The post-attack increase in per capita physical property values also is significant when considering population protection systems. These results were merged with the results of the shelter postures designed for Houston using an algorithm presented elsewhere.[1]

---

1. Grace J. Kelleher, A Damage-Limiting Shelter-Allocation Strategy, IDA Study S-186, Institute for Defense Analyses, Economic and Political Studies Division, (Arlington, Va., April 1965).

Briefly, the shelter postures are developed to hold fatalities below a specified "alpha" level, regardless of the actual ground zero, while assigning shelters of varying strengths to those population elements with the lowest cost per space. Table 28 lists 12 of the 23 postures analyzed in S-186 cited above. The postures are described by the shelter strengths allocated from a choice of 300-, 100-, and 35-psi shelters, the alpha level accepted, and the resulting total posture cost.

These data suggest that if the entire population is given any kind of shelters, even fallout shelters, and the attack is upon the at-home population for whom the shelter posture was designed, they will emerge "poorer" on the average. If the population were at work and therefore unable to reach the shelters allocated for the resident population, there are postures which would have the effect of maintaining or increasing post-attack per capita wealth. But the stronger the shelters available, the poorer the survivors will be.

It seems, then, that unsheltered people are more destructible than unsheltered property, but sheltered people are less destructible than unsheltered property. If one purpose of a shelter program is to maintain per capita property values within bounds, protection must be given to property as well as to people; and if the pre-attack proportions are to be reasonably maintained, protection should be assigned to machinery, equipment and inventories in the middle of the city.

5.2 POST-ATTACK OUTPUT AND POPULATION

Economic output measures provide an interesting snapshot of a metropolitan economy. Unfortunately, they do not reveal the dynamic interactions among sectors or the interactions of the Houston economy with the rest of the national economy. It is impossible to know whether the required raw materials or labor would be available for any industry. Therefore, the post-attack economic output was considered by damage category and interpreted as a capacity within a sector which may or may not be usable after a given attack.

Table 28

PER CAPITA HOUSTON PHYSICAL PROPERTY VALUES BY SHELTER POSTURE FOR THREE SINGLE WEAPON ATTACKS[a]

Posture				3 Mt				10 Mt				100 Mt			
				At-Home		At-Work		At-Home		At-Work		At-Home		At-Work	
No.	Type Shelter[b] psi	10 Mt α Level[c]	Cost Millions of $	Surv. Pop. 1000's	Per Capita Value $	Surv. Pop. 1000's	Per Capita Value $	Surv. Pop. 1000's	Per Capita Value $	Surv. Pop. 1000's	Per Capita Value $	Surv. Pop. 1000's	Per Capita Value $	Surv. Pop. 1000's	Per Capita Value $
	Unprotected Population			394.6	17,810	228.9	24,661	221.8	23,147	159.3	33,099	35.7	33,822	21.4	53,988
12	100	11	287	1139.5	6,168	808.9	8,808	1095.0	4,688	716.8	7,358	573.7	2,105	312.5	3,700
13	35	11	290	1134.7	6,193	786.1	9,064	1094.9	4,689	685.4	7,695	462.9	2,609	202.9	5,699
14	300	20	299	1122.2	6,263	770.2	9,251	980.9	5,234	633.8	8,321	388.7	3,107	217.1	5,325
15	100	20	201	1085.7	6,473	760.2	9,372	992.8	5,171	627.1	8,377	357.3	3,381	195.0	5,929
16	35	20	201	1074.4	6,542	746.2	9,549	984.1	5,217	600.2	8,787	268.1	4,506	104.6	11,055
17	300	30	181	1057.4	6,646	702.2	10,147	859.1	5,976	531.9	9,917	250.8	4,816	117.3	9,860
18	100	30	144	1019.2	6,896	673.1	10,585	858.3	5,982	522.5	10,095	279.3	4,324	108.6	10,642
19	35	30	142	1031.3	6,815	679.9	10,788	876.7	5,855	510.5	10,331	216.1	5,589	78.5	14,744
20	300	35	104	1017.1	6,910	660.0	10,796	798.8	6,427	483.8	10,902	208.2	5,801	80.4	14,389
21	100	35	104	1006.3	6,984	646.3	11,024	805.0	6,377	476.2	11,098	231.5	5,218	79.4	14,563
22	35	35	104	1007.0	6,979	639.9	11,133	808.1	6,353	470.6	11,207	201.5	5,995	71.2	16,246
23	Fallout[d]	37	104	991.7	7,087	621.7	11,461	776.4	6,613	443.9	11,883	195.6	6,174	69.2	16,698

a. Effects shown for at-home and at-work population centroids. The pre-attack per capita value is $9,198.
b. PF ≥ 40 fallout protection is provided all population elements that do not receive blast shelter protection in these postures.
c. The level at which fatalities were upper-bounded.
d. Posture 23 provides PF ≥ 40 fallout protection for all population elements.

Although the economic output measures for Houston give only an indication of post-attack capacity remaining in the various sectors, it is possible to compare these capacity measures with the post-attack labor force distribution. Section 4 presents data pertinent to this question. The basic input data, obtained from the 1960 Census of Population, were by census tract. Selected pre-attack population characteristics were compared with the post-attack distribution when (1) no shelters are provided and (2) if fallout shelters are provided for the entire population, i.e., the NFSS-X case.

Survivors employed by economic sector are compared in Table 29 with those portions of the economic output, or capacity, which would be available after a 10-Mt attack targeted at the at-home population centroid. If no shelters are provided, approximately the same proportion of the labor force survives (9 percent) as the capacity of all sectors allocated to the no-damage category (7 percent). In spite of this, there would be large discrepancies between immediately available capacity and available labor force within individual sectors. Only 6 percent of mining employees survive while 28 percent of mining industry capacity is in the no-damage category. In all the other sectors the proportion of the former labor force surviving exceeds the proportion of the capacity not damaged.

If one considers capacity which was allocated to the no-damage and light-damage categories as being available for use, the relative post-attack capacity always exceeds the relative surviving unsheltered labor force. If the population were sheltered, the proportion of the post-attack labor force would exceed the proportion of capacity in the no-damage and light-damage categories in five of the sectors: construction; food and kindred products; transportation, etc.; wholesale trade; and retail trade. When the moderately damaged capacity is also included proportionate post-attack capacity in two of these sectors--construction and transportation--would exceed the proportionate surviving labor force.

Table 29

PRE-ATTACK AND POST-ATTACK HOUSTON ECONOMIC OUTPUT AND EMPLOYMENT[a]

Sector & Industry	Economic Output					Population Classified by Industry of Employment				
							Post-attack Survivors			
							No Shelter Case		NFSS-X	
	Pre-attack Value, Millions of $	Percent of Pre-Attack Value[b]				Pre-attack Total	Number	Percent of Pre-attack	Number	Percent of Pre-attack
		No Damage	Light Damage	Moderate Damage	Heavy Damage					
Mining	129,715	27.7	40.8	.7	30.9	12,226	677	5.54	3,273	26.77
Construction	240,000	4.1	10.2	23.5	62.2	34,901	3,537	10.14	10,714	30.70
Manufacturing										
Furniture, Lumber & Wood	17,068	.6	38.8	1.6	58.9	3,063	110	3.57	687	22.42
Metal Industries	160,983	0	70.6	4.7	24.7	16,651	1,196	7.18	5,145	30.90
Machinery	183,055	0	74.5	8.8	16.7	21,056	916	4.35	5,768	27.39
Transportation Equipment	10,091	3.5	82.0	2.2	12.3	2,118	293	13.82	756	35.68
Other Durable Goods	53,404	1.1	57.5	9.8	31.6	6,627	353	5.33	1,827	27.57
Food & Kindred Products	139,976	.6	12.6	6.2	80.7	9,957	427	4.29	2,428	24.38
Textile & Apparel	10,774	0	42.8	1.2	56.0	2,466	76	3.09	539	21.84
Printing, Publishing, Allied	68,511	1.1	49.8	.04	49.1	6,383	327	5.12	1,643	25.75
Other Non-Durables	474,995	32.4	59.0	2.8	5.8	33,534	11,858	35.36	17,617	52.53
Total Manufacturing	1,118,857	13.9	56.5	4.6	24.9	101,855	15,556	15.27	36,410	37.74
Transportation, etc.	409,744	3.5	13.8	12.5	70.2	43,086	3,171	7.35	12,206	28.32
Wholesale Trade	347,000	3.9	10.1	6.9	78.9	28,022	1,306	4.66	7,336	26.18
Retail Trade	356,000	3.8	10.7	10.7	74.8	74,080	6,008	8.11	20,529	27.71
Other Sectors	993,748	1.4	9.3	4.7	84.5	176,282	12,098	6.86	45,555	25.84
TOTAL	3,595,064	7.2	25.9	7.5	59.4	470,452	42,543	9.00	136,023	28.91

a. 10.0-Mt single-weapon attack; ground zero: at-home population centroid.
b. Detail may not total to 100% due to independent rounding.

To the extent that the economic output data are reliable, these comparisons have stark implications for a post-attack world. Employees in the three sectors in which the survivors exceed available or repairable capacity--food and kindred products, wholesale trade, and retail trade--do not characteristically have transferable skills. Furthermore, these are three sectors which would receive immediate pressure in a post-attack environment.

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13. ABSTRACT

This Study summarizes the work done to develop a method for measuring the nuclear blast effects on the economic resources of a single city. The method developed was applied to data describing the Houston, Texas, Standard Metropolitan Statistical Area. The results were expressed in terms of weapon effects on economic output, property values, and population characteristics, including the experienced labor force.

The Study indicates the methods used to obtain the input data required to analyze weapon effects on the economy of a large metropolitan area. In addition, the Study includes a description of the problems encountered in developing the data and the steps taken to overcome such difficulties. These data were distributed to single cells of a 65 x 65 one-kilometer square matrix which was used to measure overpressure effects on economic resources for eight weapons of yields ranging from 0.1 megaton to 100 megatons. Weapon effects on economic resources were related to effects on the population of Houston for the same simulated attack conditions.

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