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UTILIZATION OF MULTIBAND AERIAL PHOTOGRAPHS IN URBAN HOUSING QUALITY STUDIES*

by

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ABSTRACT

The collection and utilization of urban data pose problems for many scientists. Present data collection procedures are frequently expensive, slow, and subject to considerable error. The data generally do not meet the basic requirements of timeliness, flexibility, compatibility and reliability. This paper represents an initial thrust towards generating housing quality data from multiband aerial photographs which meet the above requirements. The study compares the extracted data with those used in the American Public Health Association survey appraisal form. This form is currently being examined by the U.S. Bureau of the Census as a potential basis for the 1970 Census of Housing.

* * *

1. INTRODUCTION

In recent years, increasing interest has been shown in remote sensors as a means for investigating a variety of phenomena. One area of research in which the utility of remote sensors will play a critical role in the near future is in the analysis of urban phenomena, where scientists face an ever-widening gap between data requirements and data availability.[1,2]

The following comments are suggested as basic to the urban data problem. First, a variety of much-needed data are not collected. Of the data which are collected,

the requirements of timeliness, flexibility, compatibility and reliability are frequently not met[3]. This situation exists in part as a result of the inability of of data users to specify their data needs. Secondly, existing data handling systems possess several major limitations.[4] Invariably, these systems give inadequate consideration to the spatial and temporal properties of data, severely detracting from their usefulness in urban and transportation studies. The translation process has not yet been automated, and contents of existing urban data systems are highly inflexible; consequently, only specific classes of questions can be addressed to specific sets of data. Further, the practice of aggregating data to minimize amounts of data stored restricts analysis. In fact, analysis of data pertaining to individuals is precluded, since the minimum level of aggregation at which urban data is presently available from most sources is at the block level.

The preceding observations are illustrative of the complaints which scientists make regarding urban data systems and their contents. This paper attempts to demonstrate that certain types of urban data are available from remote sensor imagery, and to suggest how this technique may contribute towards narrowing the gap between needs and availability of specific urban data. The next step is the integration of the data collection operation and the data handling system.[5,6]

A variety of sources are available which provide a representative history of the utilization of conventional aerial photography, multispectral photography, and other imagery in urban area analysis and synthesis.[7,8,9] This paper is primarily concerned with an evaluation of housing quality from multiband photographs. A literature search of previous symposia and relevant journals indicates a paucity of such empirical studies of urban areas.

2. SEVERAL BASIC CONSIDERATIONS

There are several factors which must be considered when preparing the flight plans for such evaluative studies if the capabilities of the remote sensors are to

be rigorously tested. This testing should be designed so as to appraise both the relative advantages and limitations of the sensors. With respect to camera systems, one factor to be considered is the performance characteristics of the sensor. That is, over what range is the sensor operable, what are its resolution capabilities, and how are its returns affected by varying weather and climatic conditions. Further, the type of data which the imagery is purposed to generate must be specified. Finally, rigorous testing of remote sensors in data collection is very much dependent upon whether or not a precedent exists. When a precedent for data acquisition does exist it may be possible to perform a critical evaluation of the capabilities of different sensors, and thereby determine the relative utility of each sensor for different data acquisition tasks.

3. IMAGERY CHARACTERISTICS AND FLIGHT PLAN FACTORS

Details of the multiband camera system, and the nature of returns from the system have been discussed in detail elsewhere.[10,11] The following statements pertain to this study. The imagery used to generate data was obtained from the Itek nine-lens multiband camera operated 3000 feet above datum on November 19, 1965, at 1300 hours CST. There was a minimum of cloud cover, and the ground was bare. The flight line ran east to west, from Lake Michigan to the western suburb of Oak Park, using the Eisenhower Expressway as guide. The scale of the imagery is approximately 1:6000 on the negatives, and 1:1500 on the 9-inch prints. Ground resolution levels are such that residential chimneys (1 foot by 1 foot) are clearly discernible where contrasts in tone and texture are adequate to differentiate between chimneys and roof-tops.

There are several flight plan factors which relate to the previous section, and are explicated here for the benefit of any group contemplating using this system in a future exercise. In the central city of Chicago, tree foliage does not pose a problem, but many of the suburbs have a high density of tall, high-foliage

trees such as maple, elm, etc. Since the multiband system does not have any penetrating capability, it was necessary to schedule the flight at a time when the trees would be void of foliage, if the suburbs were to be usefully imaged.

In addition to the foliage problem, weather and daylight factors also had to be considered. Summer and winter flights were eliminated (foliage and snow cover) leaving only the Fall or Spring seasons. There are fewer days of inclement weather in the Fall, and daylight is sufficient that seven to nine hours of flight time is available during this season in the Chicago area.

These conditions will vary from region to region, but for purposes of optimizing the use of the aircraft, and protecting against poor quality imagery, they should receive very careful consideration.

4. STUDY CONTEXT

In order to place the study within the broader context of data collection research, it is necessary to indicate how the use of remote sensors may be integrated with prevailing data collection procedures. A fundamental question which must be asked in structuring research on improved methods of data collection is: can the remote sensor provide for the acquisition of data which satisfy the criteria of timeliness, flexibility, compatibility and reliability, more rapidly, accurately, or at lower cost, then other available collection methods. Incorporation of remote sensors into the urban data collection machinery is justified only if some combination of these demands upon the system evokes a positive response. The following observations are intended to illustrate that housing quality data can be extracted from multiband aerial photographs. Research currently in progress will attempt to determine if these data can meet the above specifications.

5. STUDY FRAMEWORK

Determination of housing quality from remote sensor imagery is of interest for both practical and theoretical reasons. First, ascertaining the spatial distribution of different grades of housing quality, and particularly the

identification of areas where standards are low, is of considerable importance to urban planning and public health agencies. This is especially true where health and welfare are concerned. Current methods of housing quality evaluation and data presentation are time-consuming and expensive, and are subject to considerable error.[12,13,14] If remote sensing devices can provide a basis for generating these data, meeting certain specifications, and in so doing, reduce time and cost expenditures, an important service will have been performed.

The theoretical implications of research of this type is illustrative of a problem frequently encountered in the use of remote sensing imagery: that is, the necessity of establishing suitable surrogates for phenomena which cannot be directly observed from the air. Operations of this nature include estimates of shoppers in stores on the basis of the number of cars located in parking lots, analysis of industrial activity on the basis of size of plants and associated railroad sidings, stock piles, yard space, etc., estimates of population based on housing observations, and in this paper, of inferring from an interpretation of exterior conditions, the interior conditions of housing units. (These operations differ in content and objectives, and are presented only as a means of illustrating how surrogates may vary.)

This study recognized that housing quality cannot be directly measured from the air, since quality of housing was defined to include consideration of not only the external features of the dwelling and immediate environment, but also of the internal condition of the dwelling.[15] A necessary hypothesis was that these internal characteristics are consistently associated with other external criteria that may be imaged from a remote sensor. Verification of this hypothesis would facilitate the development of a rapid and efficient survey method, by which areas having the highest propability of possessing low quality housing could be readily identified on a first-generation basis, and more definitive statements could follow.

Communications with officials in Chicago revealed that no part of the metropolitan area had been subjected to a structure-environment appraisal. This factor precludes direct evaluation of multiband imagery relative to other collection methods. However, it has been possible to perform an indirect evaluation of this method by comparing the content of the American Public Health Association environmental survey appraisal form with data extracted from the multiband photographs. It may be possible in future work, should data from other sources become available, to perform cost-efficiency studies and rigorously evaluate the relative utility of the various data collection methods, including those now practised, and those which are proposed.

6. EMPIRICAL OBSERVATIONS

Fifteen small areas in the Chicago region, each covered by one multiband sequence, were selected for detailed study. The areal extent of the images ranged between 3 and 8 blocks containing between 5 and 35 multiple-family dwellings per block in Chicago. In suburbs such as Oak Park, images cover 5 blocks, containing an average of 30 single-family dwellings. Inferences were made about the housing quality in each area on the basis of criteria such as land-crowding, non-residential land uses, private open space, hazards and nuisances associated with the transport network, and basic community facilities. Although most of the above features can be identified on conventional aerial photography, it was often found that a given phenomenon could be distinguished much more readily on one specific band than on any other. In particular, some factors, which were found to be consistent indicators of housing quality, were not readily identifiable on any plate within the visible spectrum, but stood out clearly in the bands of the photographic infrared. The more important of these are listed below.

1) Private landscaping. In the better quality housing areas, landscaping in the form of shrubs, rock gardens, flower beds, etc., is common to almost every lot. The opposite tends to be true in the poor quality areas. Occasionally a

lot supporting a single-family structure in an area of predominantly poorer quality multiple-unit structures will exhibit some landscaping such as patio, shrubs, flower garden, etc. This information is more readily obtained from the photographic infrared. The infrared also helps to differentiate between grass and dirt. Grass-covered front and back yards are found in good housing quality areas, while in poorer areas, dirt rather than grass is evident in the yards. Where grass does exist in poorer districts, it is not as healthy or well-conditioned as in the better quality housing areas, and is patchy in appearance. Occasionally these data can be obtained from a yard-by-yard inspection, but they are more readily acquired when the neighborhood, or at least several lots, can be considered simultaneously. The photographic infrared also clearly reveals footpaths crossing both occupied and vacant lots in the low housing quality areas.

2. Public landscaping. Parkways (strips between streets and sidewalks) are the property of the city. However, the property-owner is obligated to care for that segment of the parkway which fronts on his property. In the better housing quality areas, this strip is invariably grass-covered and well-kept, comparable to the condition of the lawn on which it fronts. In the poorer quality housing areas the parkway is usually a strip of dirt. In the areas studied to date, using the infrared, the white appearance of vegetation in good neighborhoods, and dark appearance of dirt in low housing quality sections have provided a very good first approximation of conditions in the respective areas when compared with the conclusions derived using a battery of variables. A few small, widely-spaced trees are found on the better-kept of these poorer housing quality blocks. Structures in these areas are frequently multiple-unit, so there may be some question as to whether the landlord or tenants are remiss in maintaining the parkways.

3. Vacant lots. In the areas of better quality housing, vacant lots are well-tended. The converse is true in poor housing quality areas.[16] This may be due to the much stronger influence of factors such as neighborhood pride,

pressure from neighbors, or strict enforcement of city by-laws in the maintenance of property in higher quality residential areas. The photographic infrared clearly differentiates between grass, and weeds and bushes in terms of both tone (variation in "color") and texture (evenness of well-maintained yards, versus roughness in appearance of vegetation in yards or lots "gone to seed"). In addition the infrared may reveal litter more reliably than returns from the visible portion of the spectrum; this in part varies from lot to lot, as some litter is more highly contrasted with a light background, and some with a dark background.

4. Curbing. In areas of better quality housing the curb line is unbroken on all blocks. In the poorer quality areas, the curb line is frequently broken, as a result of cars being parked on parkways or front yards, or has not kept pace with building. The photographic infrared imagery usually reveals this feature more readily and reliably than the visible imagery, but again, given certain conditions, the visible may be more useful.

The above four factors, which are a function of the nature of multispectral imagery, and others noted in the original report,[17] have led to some tentative statements as to those features which are most commonly associated with the occurrence of poor quality housing in the study area. These were found to be:

i) the presence of litter, garbage, wrecked or derelict cars, and piles of lumber and rubbish throughout a neighborhood or block, on both occupied and vacant lots.

ii) the lack of landscaping and grass in occupied lots,

iii) the lack of grass on parkways,

iv) the number of vacant lots,

v) the existence of non-residential hazards and nuisances, primarily industrial plants and warehouses which frequently have outdoor storage areas covered with debris, and

vi) the extent of lot-crowding, i.e., the lack of open or play area that

exists on residential lots.

7. CONCLUSIONS

The criteria for identification of poor quality housing outlined above have not yet been established statistically. However, on the basis of frequency of appearance and level of association for each criterion, it has been possible to select and qualitatively evaluate low quality housing indicators.[18] In exploring the validity of this technique it is instructive to compare the evaluation procedure with that used by the American Public Health Association (APHA).[19] Of the 24 items contained in the APHA environmental survey appraisal form, 20 can be estimated for small areas using multiband photographs. In addition, 10 items not included in the APHA survey form were found to be consistent indicators of low quality housing in the Chicago multiband study. (See Table 1)

It is possible that the Bureau of the Census will rely heavily on the APHA appraisal form for providing environmental data in the 1970 or 1975 Census of Population and Housing.[20] If the form is adopted the multiband technique will gain added significance since it could provide data on rapidly changing housing patterns that would be compatible with much of the data obtained on a regular basis by the Census. A point to be made here which makes this research more generally applicable is that although the investigation to date has been confined to identifying areas of low quality housing, it can be readily expanded to include a variety of housing considerations. The Census data would also provide ground truth which could be used to check for systematic errors in interpretation of the imagery.

The extent to which acquisition of housing data from multi-spectral photographs can replace the collection of such data by field enumerators has yet to be established by controlled experiment. One factor which should be emphasized is that the socio-economic background and experience of the enumerator are

TABLE 1: ENVIRONMENTAL CRITERIA USED IN THE EVALUATION OF HOUSING QUALITY

ITEM	Criteria Used by APHA	Criteria Extractable from Imagery	Extractable Criteria Used in Housing Quality Study
A. LAND CROWDING			
1. Coverage by Structures	X	X	X
2. Residential Building Density	X	X	X
3. Population Density	X		
4. Residential Yard Areas	X	X	X
5. Building Frontages		X	X
6. Multiple versus Single Unit Structures		X	X
B. CONDITION OF PRIVATE FREE SPACE			
7. Landscaping		X	X
8. Condition of Grassed Areas		X	X
9. Presence of Litter or Garbage		X	X
C. NONRESIDENTIAL LAND USES			
10. Areal Incidence of Nonresidential Uses	X	X	X
11. Linear Incidence of Nonresidential Uses	X	X	X
12. Specific nonresidential Hazards and Nuisances	X	X	X
13. Smoke Incidence	X	X	X
14. Hazards to Morals and Public Peace	X		
15. Non Structure-supporting Land (Utilized)		X	X
16. Non Structure-supporting Land (Unutilized)		X	X
17. On-street Parking		X	X
D. HAZARDS AND NUISANCES FROM TRANSPORTATION SYSTEM			
18. Street Traffic	X	X	X
19. Railroads and Switchyards	X	X	X
20. Airports	X	X	
21. Alleyways		X	X
E. HAZARDS AND NUISANCES FROM NATURAL PHENOMENA			
22. Surface Flooding	X	X	
23. Swamps and Marshes	X	X	
24. Uneven Ground	X	X	
F. INADEQUATE UTILITIES AND SANITATION			
25. Sanitary Sewage System	X		
26. Public Water Supply	X		
27. Streets and Sidewalks	X	X	X
28. Condition of Parkways		X	X
G. INADEQUATE BASIC COMMUNITY FACILITIES			
29. Elementary Public Schools	X	X	X
30. Public Playgrounds	X	X	X
31. Public Playfields	X	X	X
32. Other Public Parks	X	X	X
33. Public Transportation	X		
34. Food Stores	X		

important sources of variation in evaluating housing conditions; the employment of experienced photointerpreters would help to greatly reduce this variation, not only because of potentially superior training, but also because fewer persons would need to be involved in data acquisition.

One eventual development in housing quality studies may be that several criteria will suffice to identify low quality housing, eg., the litter and lot-crowding factors. This possibility will have to be thoroughly investigated by data users and collectors, in terms of meaning of the data, what is to be done with the data, and what the data is to do for users.

An evaluation of the utility of the multiband sequence relative to other unclassified sensors is made somewhat difficult by the absence of these sensors on the same flight. In fact, it is sometimes difficult to determine if differences in tones between frames are due to actual variations in spectral returns, or to differences in processing. A significant contribution is believed to have been made to the study by the photographic infrared bands. For the most part only bands 4 (measures reflected light in the visible part of the spectrum) and 7 (measures reflected light in the near-infrared part of the spectrum) were necessary, as the analysis of other bands provided only marginal data. If this observation holds in studies of a variety of areas, the quantity of imagery would be greatly reduced, as would film and processing costs, should this technique be adopted for future use.

The research reported on here depends on associational material for the analysis of the imagery. The automation of this data collection method will require thorough examination of the structure of the recognition process, for example: will spectral signatures provide a sufficient basis for interpretation, or will we have to be concerned as well with the more difficult problem of utilizing concepts of spatial association, spatial structure, and context.

In terms of future research, the following considerations should receive

priority:

i) extension of the type of work reported above to imagery from a number of cities; this would provide a basis for the application of statistical techniques to attempt to determine appropriate weights to be attached to specific indicators of poor quality housing. This will be dependent upon

ii) development of clear statements from potential data users and collection as to definitions and content of the desired data set. The development of reproducible measures of housing quality is essential if the requirements of compatibility and reliability of data are to be met.

FIGURE 1

Low Quality Housing Area

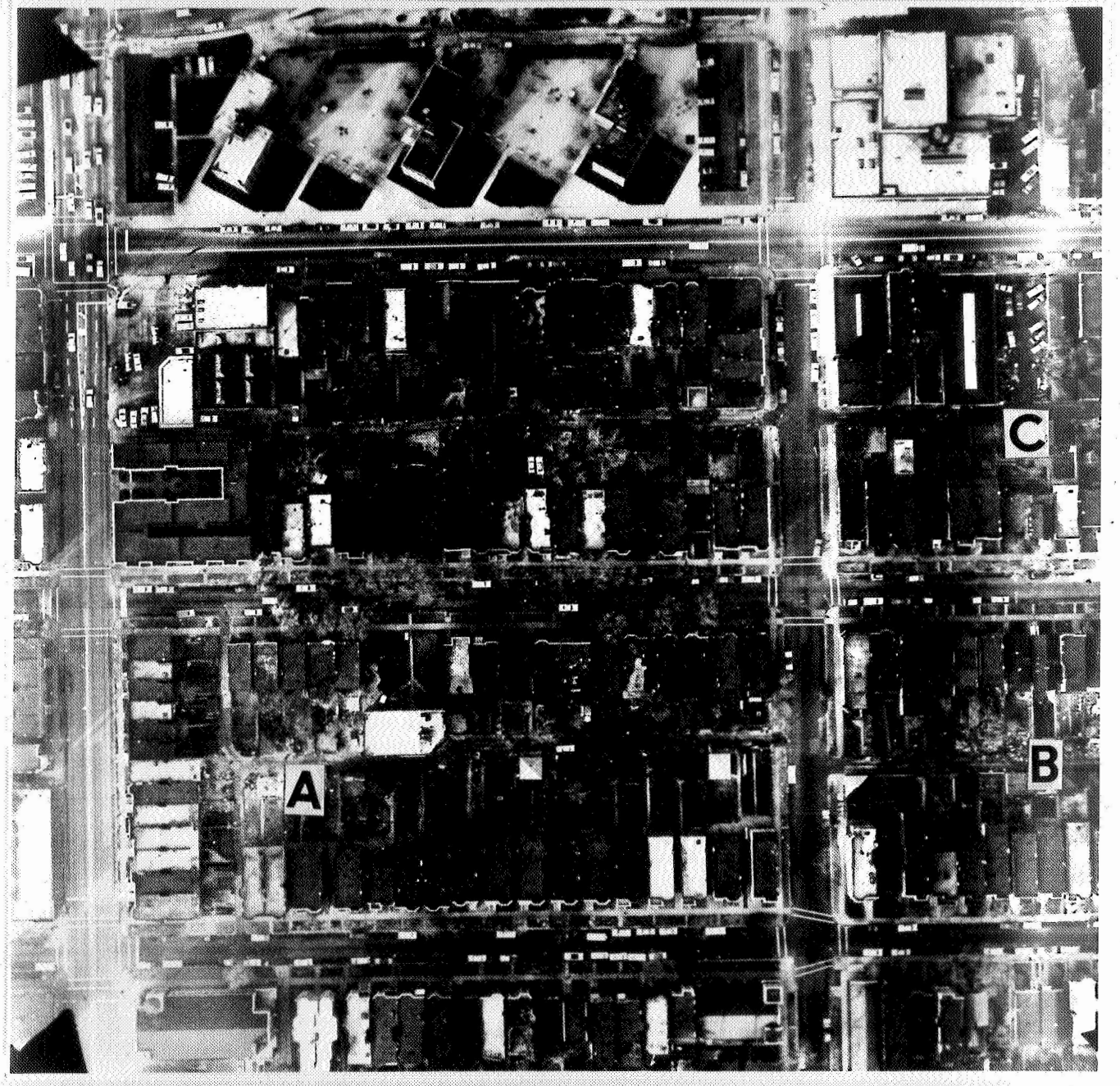

Figure 1. Multiband Imagery: .55-.60 microns. Lexington St. W., Chicago. Compare the low areal coverage of housing in the upper center block with the high coverage in the remaining blocks. Note the extensive amount of garbage and litter at A and B in the residential area, and outside a small plant a C. Further, note the small play area per lot, and the small number of garages necessitating heavy on-street parking, especially overnight. Finally, observe the alleys strewn with litter and garbage. Forage food and harborages for rats are spread almost throughout the imaged area.

FIGURE 2

Low Quality Housing Area

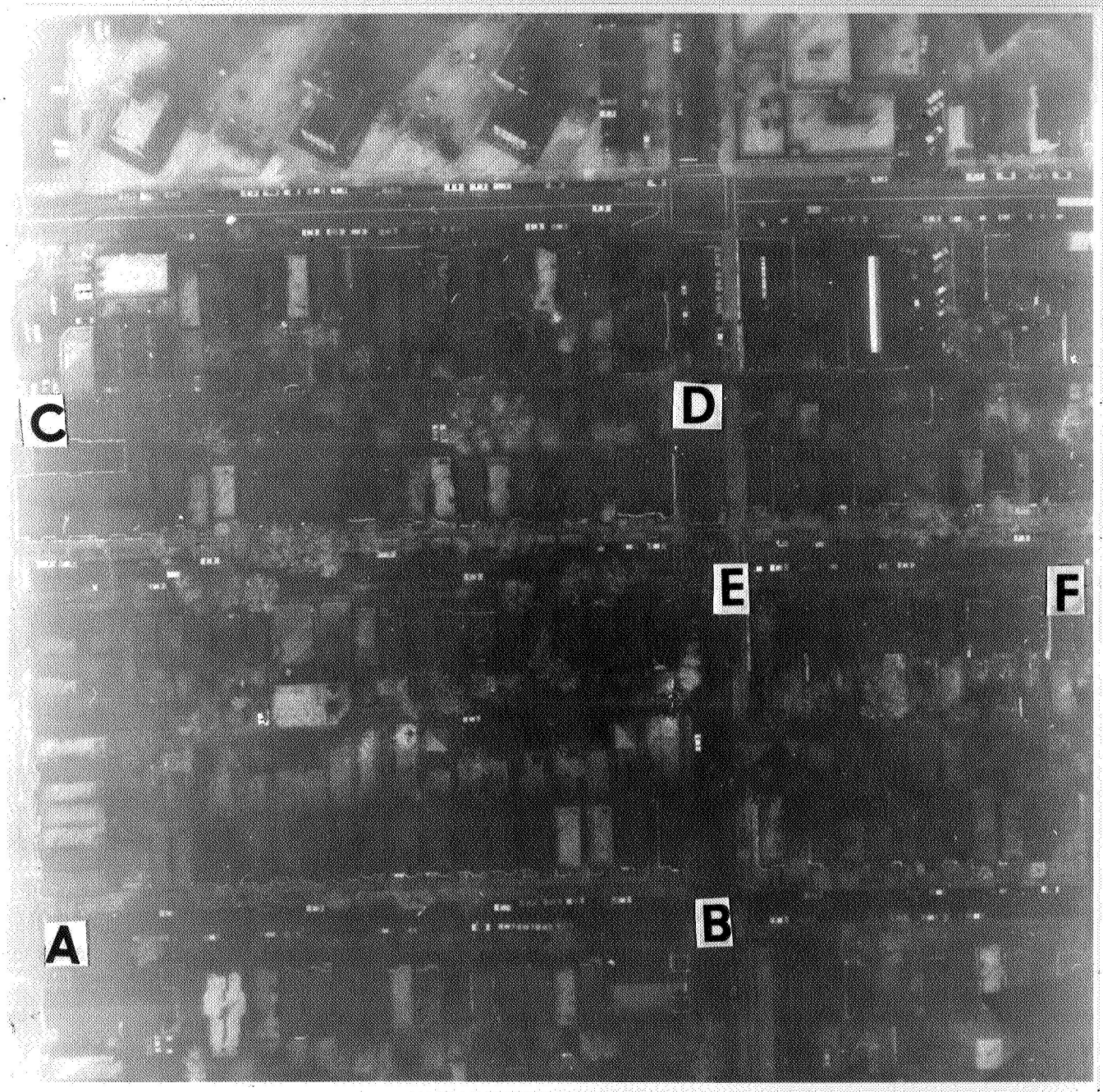

Figure 2. Multiband Imagery: .70-.81 microns. Lexington St. W., Chicago. Note the poor condition or total lack of grass at A- B, C- D, E- F.

FIGURE 3

Better Quality Housing Area

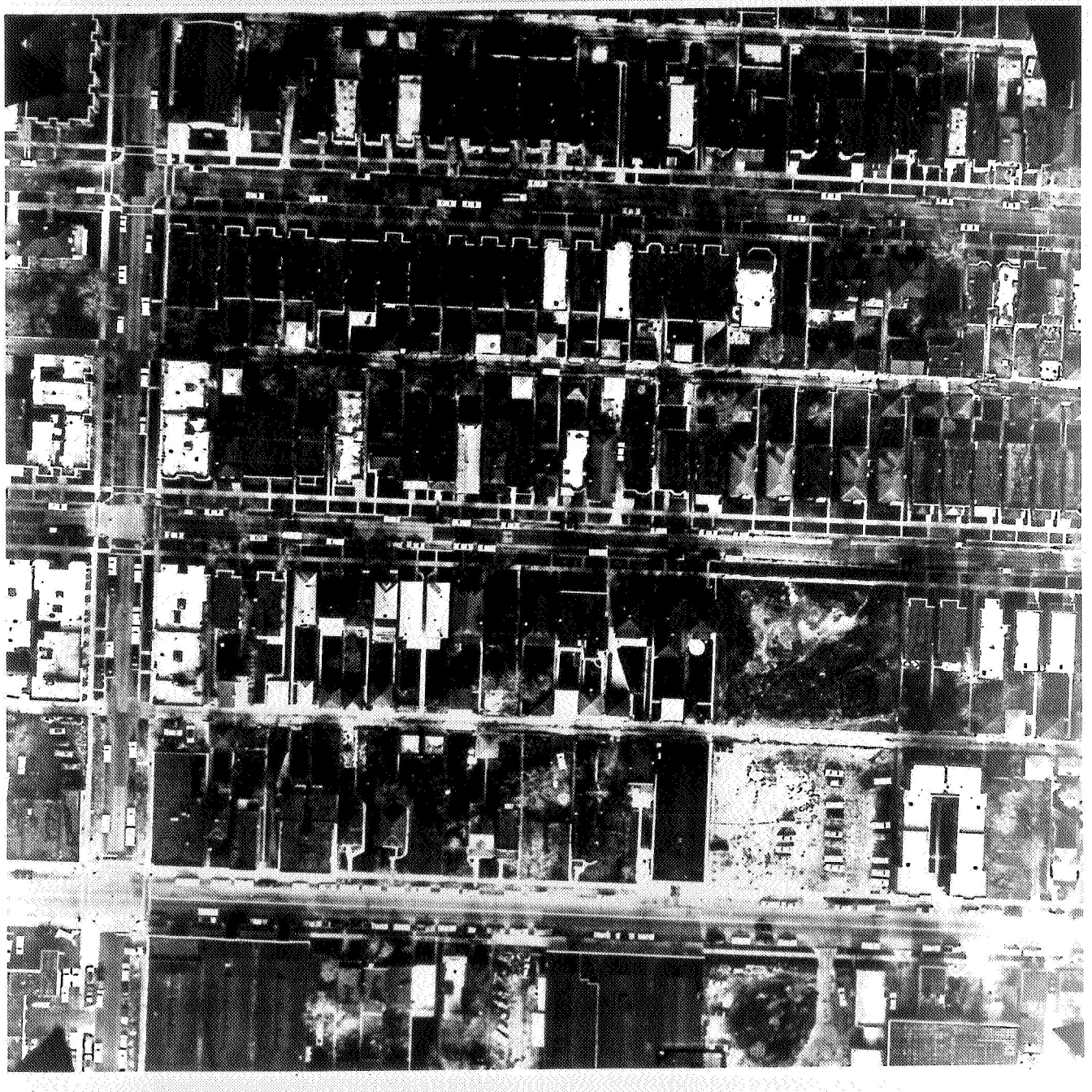

Figure 3. Multiband Imagery: .55-.60 microns. W. Jackson Blvd., Chicago. This area contains a high density of dwellings which appear to be well-maintained. Note also such positive features as the number of single-family houses, and the fact that the parkways, streets, yards, vacant lots and alleys are almost totally free of litter.

FIGURE 4

High Quality Housing Area

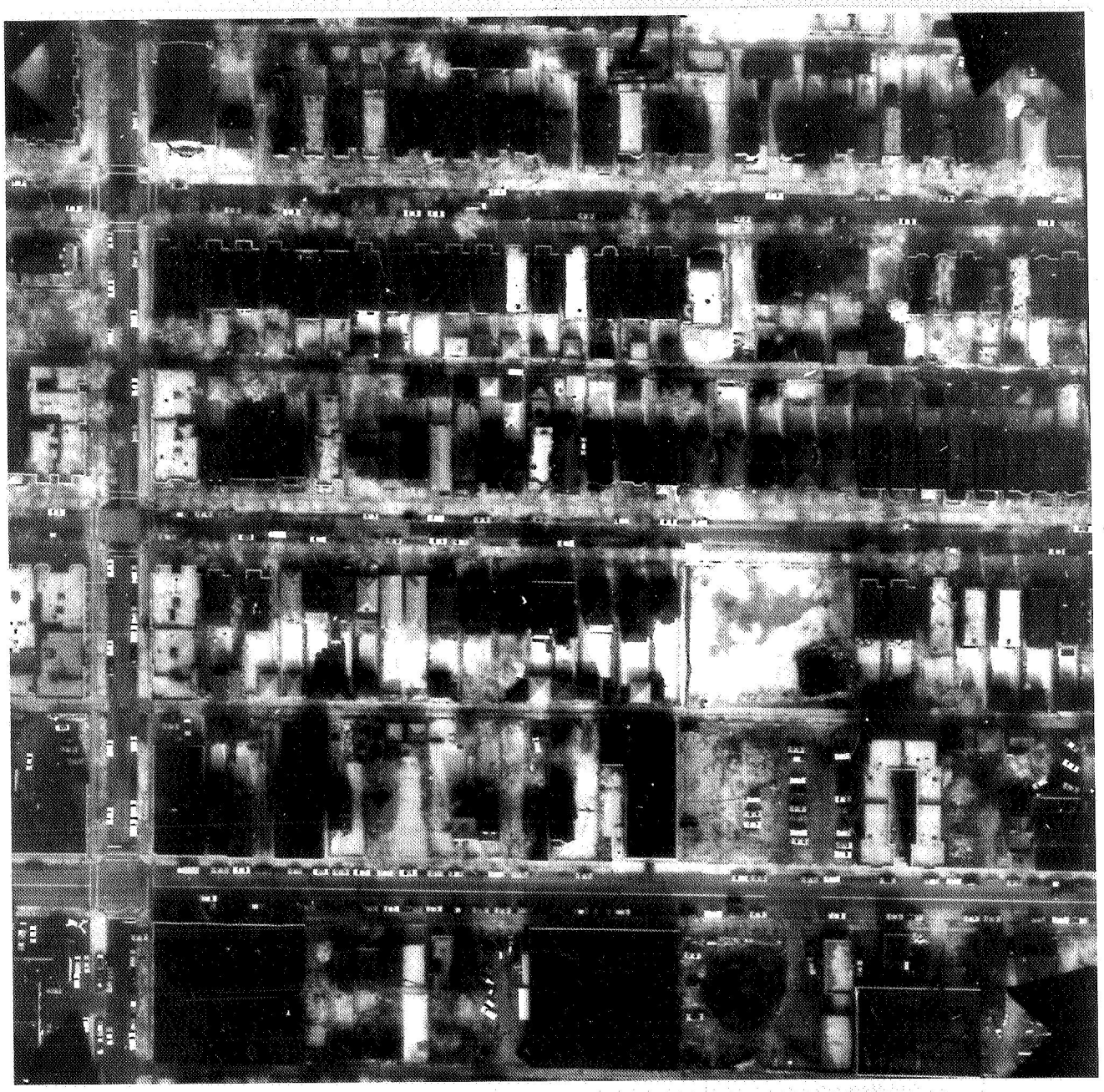

Figure 4. Multiband Imagery: .70-.81 microns. W. Jackson Blvd., Chicago
Note the larger proportion of parkways and yards covered with grass, and the improved condition of the grass relative to the area of the previous Figure.

FIGURE 5

High Quality Housing Area

Figure 5. Multiband Imagery: .55-.60 microns. Van Buren Ave. Oak Park, Illinois. Note the variety of modern housing styles, ample private yard space, clean yards, streets, alleys, parkways, provision of off-street parking, minimum of non-structure-supporting land, and absence of noxious commercial or industrial activity.

FIGURE 6

High Quality Housing Area

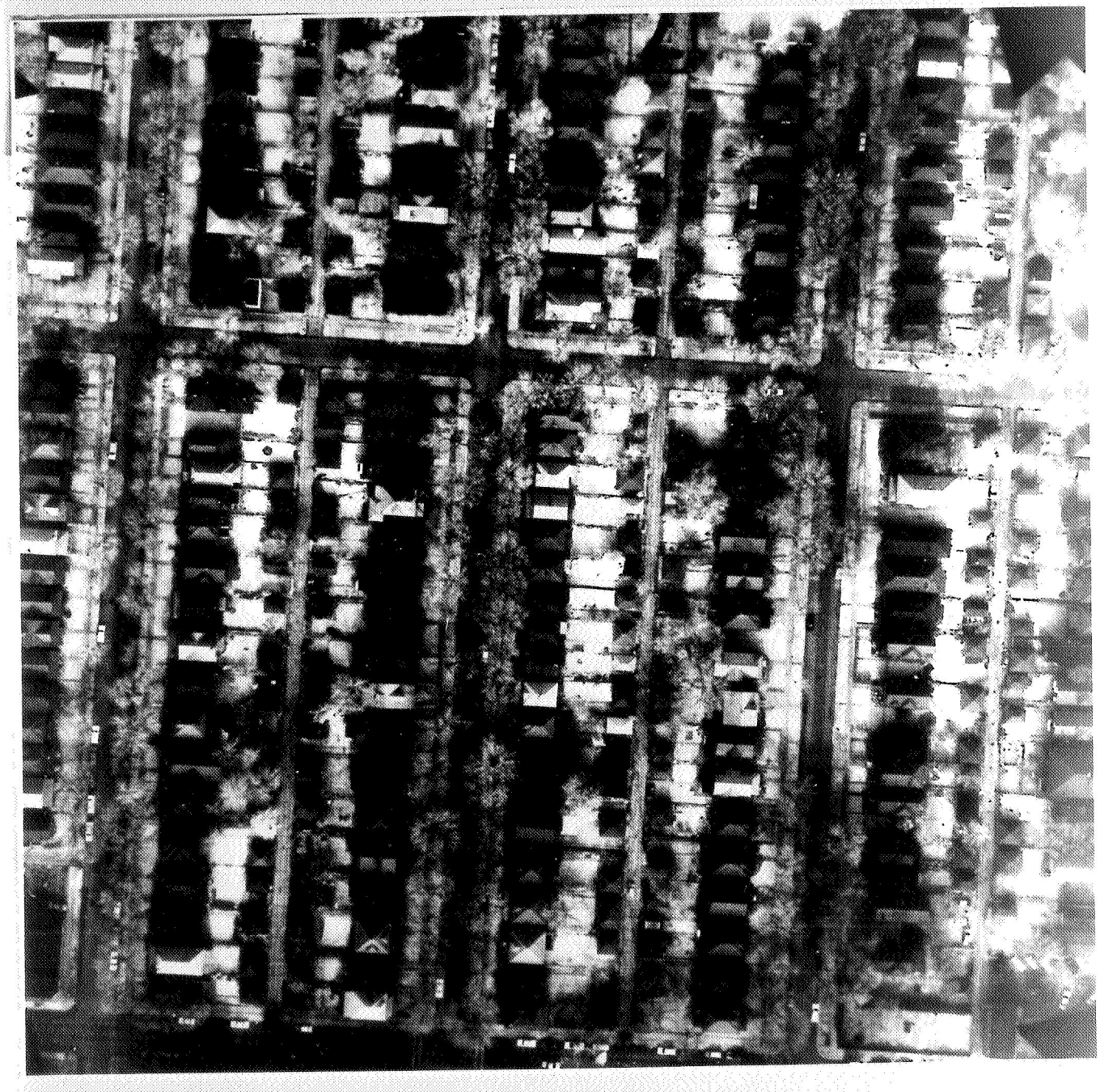

Figure 6. Multiband Imagery: .70-.81 microns. Van Buren Ave., Oak Park, Illinois. Note that all areas which could support grass, including yards and parkways, do so, and that the grass is in very good condition even though it is November.

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13. City of Chicago, Department of Buildings, "Comparative Study Census Tract 670, Block 10," May, 1962.

14. U.S. Bureau of the Census. "Measuring the Quality of Housing, An Appraisal of Census Statistics and Methods," Working Paper No. 25. Page 17 of the report notes that "the undercounting of occupied dilapidated units by the 1960 Census is placed at 1.1 million units; in 1950, occupied dilapidated units were overcounted by 3.5 million units. The 1.1 million figure represents 35% of the true total of occupied dilapidated units." Errors of this type and magnitude have serious repercussions for urban renewal people, for instance, who are concerned with the growth and decline of slum housing.

    The gravity of the situation becomes even more apparent when one realizes that a number of communities (including the city of Chicago) do not consider census data helpful in determining housing conditions by block (page 18 of the report), and they are not used in housing studies.

    The total cost of field work for the 1960 Census of Population and Housing was about $60 million, paid to 160,000 enumerators, 10,000 crew leaders, and 2,000 office workers. These figures serve to illustrate the scope of the program and the cost of operations. For more details see:

    U.S. Bureau of the Census, U.S. Census of Population and Housing, 1960: Enumeration Time and Cost Study. Washington, D.C., 1963.

15. A technical point to be made concerns the meaning of housing quality. The requirement of uniform classification is frequently absent from housing data not only because of an inability to agree on a standard, national definition, but due to the subjective decisions which enumerators must make when in the field. Housing quality in the past has been defined purely in structural terms (the Census defines housing quality in terms of sound, deteriorating, and dilapidated structures, plus condition of plumbing facilities), as well as in terms of structural and environmental conditions in combination. (The American Public Health Association [APHA] uses the latter approach.) The appraisal form developed by the APHA has been adopted by a number of communities, large and small, carrying out their own housing quality studies. This factor was taken as an indication of acceptance of the APHA method, and served as a precedent for the appraisal form developed to measure housing quality on the basis of data extractable from multiband aerial photographs.

16. In addition to the condition of the vacant lots, the numbers of vacant lots in the two types of areas differ considerably. The large number of vacant lots in areas of poor quality housing may be due to factors such as angularity or irregularity of the lots, objectionable adjacent land use precluding building or utilization, or undesirable neighborhood characteristics.

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