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URBAN ENVIRONMENT ASSESSMENT: SPECIAL REFERENCE TO TERRESTRIAL AND AERIAL PHOTOGRAPHIC APPROACHES

by
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ABSTRACT

The following discussion particularly stresses the techniques or research methodologies concerned with urban environment assessment. Given the fact that monitoring the quality of the urban environment is prime, some practical approaches to that problem are seriously needed. Due to the complex nature of the urban environment in terms of the elements, interrelationships of elements, and dynamic nature of their interactions, the author devises a model in the form of a combination approach to assess the urban environmental condition.

The variety of urban environments reflects the social, economic, cultural, political, technological and demographic background of the nation and accordingly there should be a wise selection of the applied techniques and the environmental criteria used for assessing the urban environmental condition.

The combination approach is an integration of terrestrial and aerial photographic approaches. Since each of the aforementioned approaches has its own weaknesses, the combination approach is expected to cover those weaknesses and can give more effective, accurate and reliable data on the urban environmental assessments.

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In order to give more insight about the topic, a simple procedure of the technique is presented with the hope that it can help those involved in such activities.

INTRODUCTION

The urban environment contains a very complex problem. It includes physico-natural, physico-artificial, social, cultural, economic and political subsystems. The contemporary interest in the urban environment in general and its quality in particular can be broadly categorized into two different perspectives. The first is concerned with the quality of the natural environment of urban areas and in this case the quality of air, water, land and other resources found in the urban areas is the main concern. The second perspective is concerned with the development of urban communities, especially human beings in a city.

The quality of life of all people who flock together into so-called urban communities is clearly influenced by the existing natural environment, man-made environment and the inter-relationships between the two (Perloff, 1977). In dealing with problems of urban environment, which are very numerous and complex, one sould have a clear concept and methodology to approach.

Given that the present urban environment is the product of a long and ongoing process, varying from one place to another and ever changing conditions through times, it is suggested that monitoring activities are needed to cope with the problems of environmental deterioration. Since the overall investigations in all parts of the urban areas will consume a lot of time, budget and personnel, one of the existing research methodologies discussed hereafter below is recommended.

ELEMENTS WITHIN THE ENVIRONMENTAL SYSTEM

The urban environment is a system whithin which there is an interrelationship between the existing natural elements and socio-cultural ones. None of the environmental elements functions in an isolated situation, all of them are intricately or intertwining in acting, interacting, dependent, and interdependent relationships. Accordingly, the disturbance in one part of the system will significantly influence the others or the improvement of one of the elements will positively affect the others. Given the facts, the system approach will be apt for any urban environment assessment.

Due to the complex nature of the environmental elements, the assessment

of the environment can be done at various levels and using frameworks. In the system approach, the interactions and interrelationships of the environmental elements should be modelled in such a way in order to know the key elements for remedying the perceived imbalances, such as the environmental deterioration phenomena, hazard or unplanned growth of settlements such as the emergence of the squatter settlements in the peripheries.

In the framework of urban environment analysis, there are at least six major elements forming the system (Perloff, 1971). Those elements are as follows: (1) natural elements, i.e.: the airshed, the watershed, the open space-recreation shed, quiet and noisy zones, old factory zones, micro-climate zones, sunlight exposure; (2) the spatial environment, i.e.: underground space, uncovered land, covered land, radiospectrum space, airways space; (3) transportation-utilities environment, i.e.: (i) transportation: commuting time, alternative modes including mass transit, congestion, safety, stress, aesthetics, e.g. billboards, landscaping. (ii) water supply facilities, (iii). sewerage facilities, (iv). solid waste disposal (v). electricity facilities, (vi). gas facilities, (vii). telephone facilities, (viii). other communication facilities; (4) community-neighbourhood environments, i.e.: (i) community characteristics: mix, e.g. degree of segregation, types of land uses and structures, condition of land uses and structures, community stresses, design environment, e.g.: densities, street lighting, billboards, interest points, landscaping, zoning etc., (ii) services environment (measures of quality and nearness): educational-cultural environment, personal safety and protection, health facilities and services, commercial facilities and services, recreation facilities and services, "caretaker" functions; (5). household shelter, i.e.: housing condition, crowding rats, roaches, and other pests, plumbing, household equipment; (6). workplaces: safety, amenities e.g., eating facilities and sanitation, work challenge indicators, e.g. assembly line, freedom of movement, etc. (Perloff, 1971). Through quantitative techniques these items can be scored and each area under investigation in the city can be evaluated respectively in terms of its environmental conditions.

Since each country has its own peculiarities in its urban environment, the application of techniques and selected items for evaluating the urban environment condition will vary. It is also firmly related to the goal of development the aim of development and the target pursued. The following example shows the Indonesian techniques for evaluating the urban environment conditions executed during the third five year development period. The selection of environmental elements is based on the general problems being faced by Indonesian urban settlements. There are 15 environmental elements used for environmental quality assessment and the result is used for ranking the priority of urban environment development. The first priority is given to the area with the worst condition in terms of environment, and accordingly needs immediate remedy (Table 1).

This table shows the 15 elements used for assessing the urban environment in Indonesia.

TABLE 1. THE MAIN ELEMENTS USED FOR ASSESSING THE URBAN ENVIRONMENTAL CONDITION IN INDONESIA IN THE THIRD FIVE YEAR DEVELOPMENT PERIOD.

No.	Weighted criteria	Weighted factor	Scores		
			3	2	1
1.	flood	3	more than 50% of the area undergo regular flood	less than 50% of the area undergo regular flood	none and only very few areas undergo flooding
2.	drinking water	3	most of the residents buy the drinking water. very poor quality of ground water & salted	some of the residents buy their drinking water. the ground water is good and shallow	most of the residents use piped water from the goverment enter prise and the area has good & shallow ground water
3.	sanitation	3	the area has no septic tanks. very few lavatories and most of the people use water canals	very few septic tanks. many people have lavatories & few of them use canals	most of the people have septic tanks. lavatories & very few use water canal
4.	mortality rate	3	very high	moderate	low
5.	planned land use for future need	1	housing areas	housing areas. light industrial areas	industrial and or commercial areas
6.	accessibility	2	none or very poor	some streets exist but unpaved	good streets & most of them are paved
7.	the age of the kampung	2	long before 1945 (very old)	between 1945—1960 (medium)	new (after 1960)

(continued)

TABLE 1. (continued)

No.	Weighted criteria	Weighted factor	Scores		
			3	2	1
8.	the attitude of the people	2	good participation in the development program	fair participation	vary little or no participation at all
9.	population density	2	high to very high (more than 550 inhabitants/hectare)	moderate (350—less than 550 inh. /hectare)	low to very low (less than 350 inh./hectare)
10.	income/capita	2	very low (less than Rp 30.000/ month)	moderate (Rp 30.000— Rp 60.000/ month)	high (more than Rp 60.000/ month)
11.	location/sites	1	in the city centre	in the outer zones (urban areas)	in the urban fringe areas & outside the city
12.	general condition	1	bad-very bad	moderate	good
13.	general layout of the building	1	hazard setting	fairly ordered setting	very good and ordered setting
14.	schools	2	no schools	very few	many
15.	development impacts	1	very high-high	moderate-low	low-very low

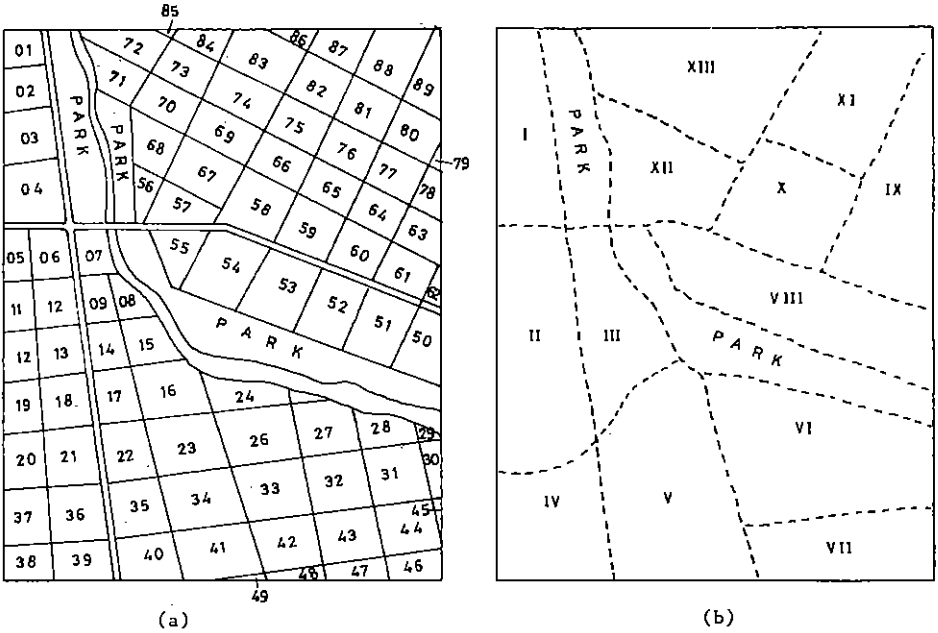
Source: Dir. Jen. Cipta Karya (P4LPK) III. *Pedoman Pelaksanaan Perintisan Perbaikan Lingkungan Perumahan Kota.* quoted by Hadi Sabari Yunus (1980).

TERRESTRIAL APPROACH TO URBAN ENVIRONMENT ASSESSMENT

Urban landscape shows various conditions of environment. In order to know the urban environment throughly, an accurate investigation covering all urban morphological features must be conducted. It is expected that the result will

be reliable and represents the real situation of the study area.

Terrestrial investigation in the urban environment assessment adopts two techniques. The first technique is to investigate the whole areas under study and evaluating the six environment elements set forth. It is usually done through physical or administrative approach. The physical approach stresses the physical subdivisions of the area under study as a base for evaluation. The subdivisions can be based on physico-natural or physico-artificial phenomena. Rivers, ridges, coastlines, refer to physico-natural features whereas channels, streets, airport, settlements refer to physico-artificial features. The administrative approach uses administrative boundaries as its subdivisions. Figure 1 illustrates the application of this technique.



Legenda:

_____ physical boundary

---------- administrative boundary

Figure 1. Physical Approach (a) and Administration Approach (b) to Urban Environment (Perloff, 1971).

The overall investigation needs detailed planning and implementation because it involves considerable time, personnel and budget. Since the effort to assess the urban environment condition is anticipated to be carried out periodically, this technique is rarely adopted.

The second technique is to investigate not the whole area, but only parts of the area under study. It refers to sampling techniques. Since the investigation is concerned with data distributed on space, this technique is also called the areal sampling technique (Gregory, 1975).

There are four main area sampling techniques usually applied in geographical studies: (i) random sampling, (ii) systematic sampling, (iii) stratified sampling, and (iv) combination of the existing sampling techniques.

Random Sampling

The application of this technique requires that first of all the study area should be devided into subdivisions as sampling areas. Three approaches can be applied here: (i) grid system approach; (ii) physical subdivisions approach, and (iii) administrative subdivisions approach.

Grid System Approach. The available map should be gridded in such a way and should be numbered as is the National Grid on the Ordnance Survey Maps of Great Britain, i.e. from west to east and from south to north, so that numbers in both directions are at zero in the south west corner of the area and increase steadily eastwards and northwards.

The sample areas can be selected through point sampling, area sampling and linear sampling. Random sampling numbers or simple random technique can be applied to select sample areas. Figure 2 (a, b, c) presents examples of these three kinds of sampling.

Physical Subdivisions Approach. The available map showing spatial distribution of land use is needed. The subdivision of the study area is usually based on the street patterns. A certain block of land use bounded by streets usually has the same environmental characteristics. By numbering each physical subdivisions, the sample areas can be determined either through random sampling numbers or simple random technique. The example of this technique is depicted at Figure 2d.

Administrative Subdivisions Approach. The areal subdivision is based on the legal administrative boundaries existing in the study area. The lowest rank of administrative subdivisions is usually chosen as sample areas because they usually consists of homogeneous neighborhoods. Like the previous technique, administrative subdivisions approach can also adopt random sampling numbers

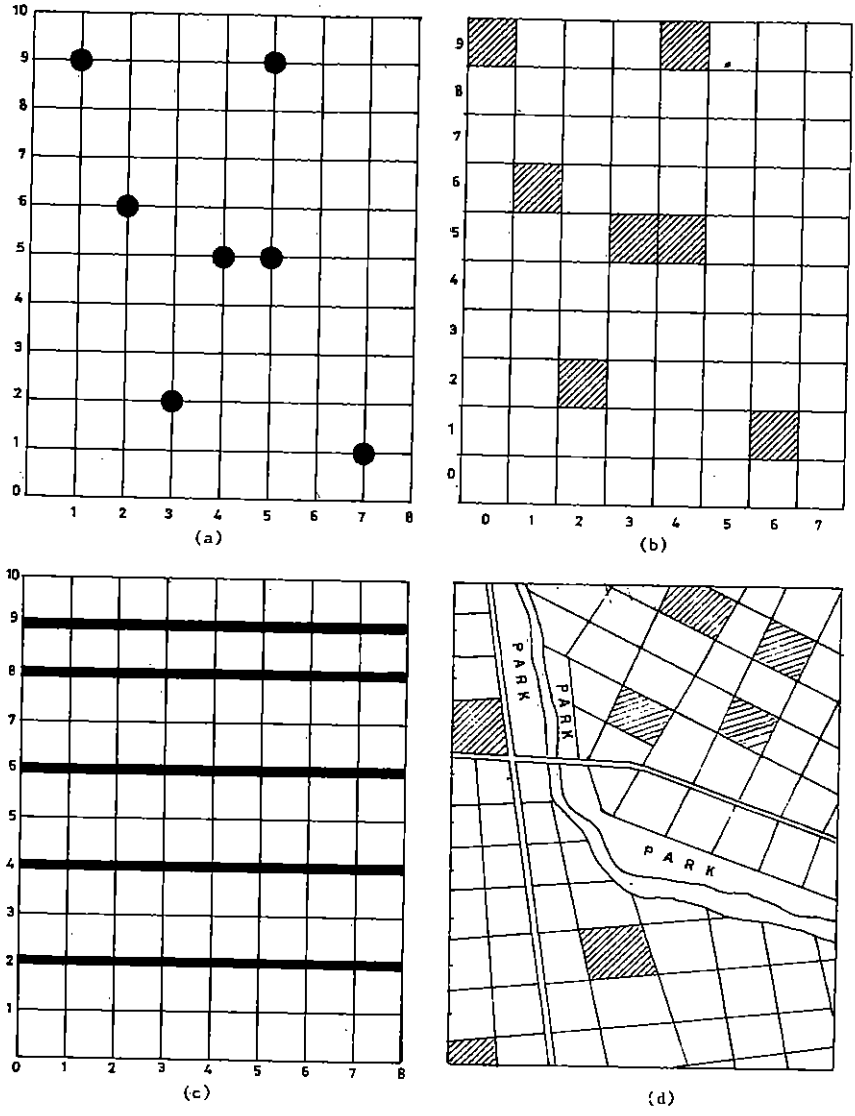


Figure 2. Random Sampling (Gregory, 1975)

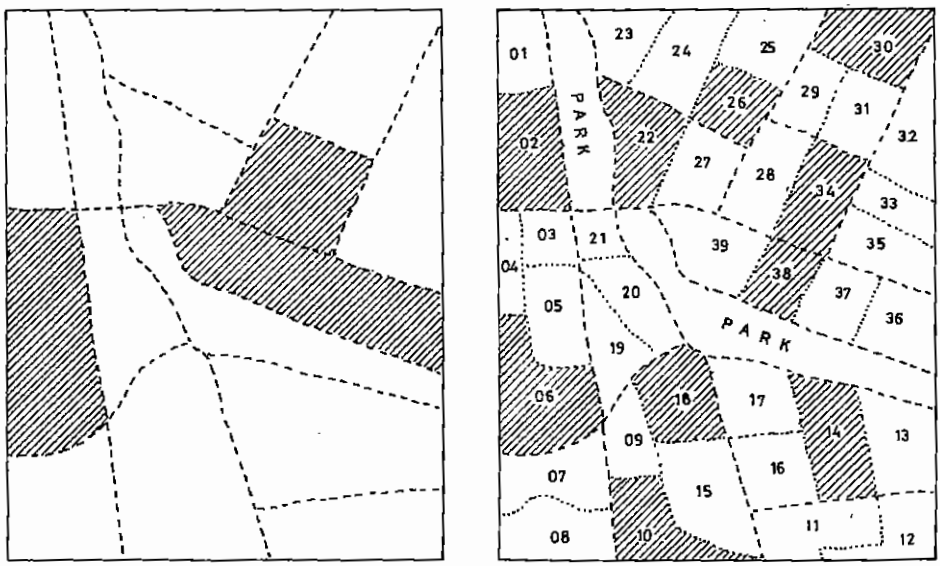
or simple random technique to determine tha sampling areas (Figure 3a).

Systematic Sampling

The application of systematic sampling is nearly the same as that of random sampling. The principal difference is in the ways of selecting the sampling areas. In the systematic sampling, only the first sample area is randomly selected. The other sample areas are chosen based on a given interval number. Like the previous techniques, the systematic sampling is also characterized by three main categories of areal subdivisions.

In this technique, the distribution of the sample areas are controlled by the chosen interval and the magnitude of desired sample areas. Figure 3b depicts systematic sampling over administrative subdivisions and Figure 4a represents systematic sampling over physical subdivisions.

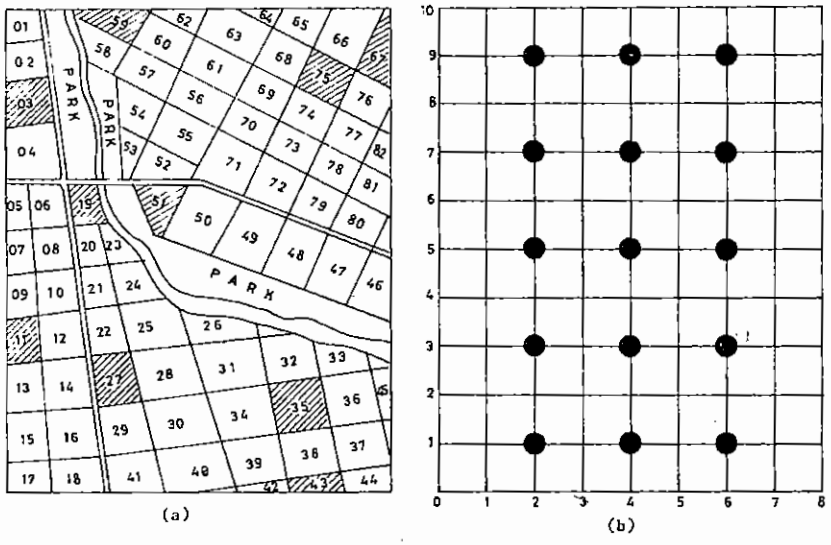
The third areal subdivisions follow the geometrical pattern made on the map of the study area. The area is gridded that and the sample areas will be distributed in a regular pattern over the study area. Figures 4b, c and d are examples of point systematic, area systematic and linear systematic samplings.



(a) (b)

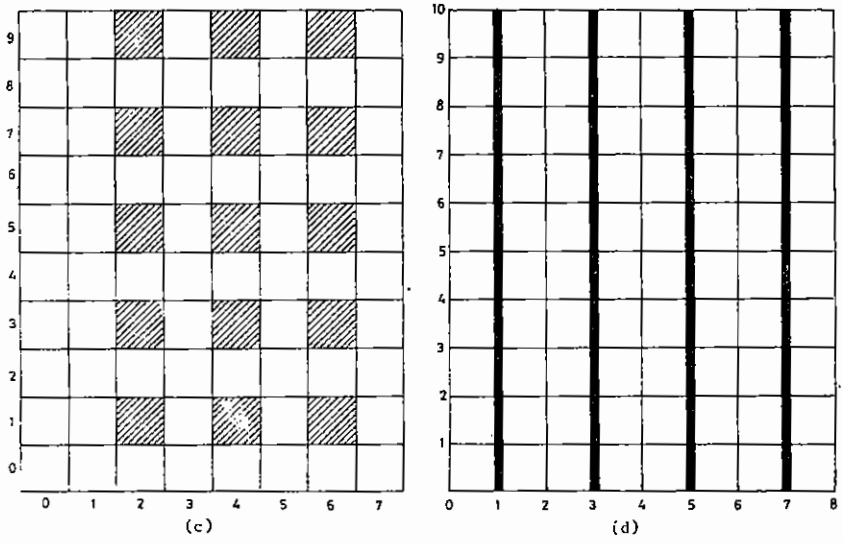
(a) Simple random technique in Administrative Approach. (b) Systematic Sampling in Administrative Approach.

Figure 3. Systematic Sampling



(a) Systematic Sampling in Physical Subdivisions Approach.

(b) Point Systematic Sampling in Grid System Approach.



(c) Area Systematic Sampling in Grid System Approach.

(d) Lineair Systematic Sampling in Grid System Approach.

Figure 4. Systematic Sampling

Stratified Sampling

In urban studies, stratification is usually based on secondary data of population variables, such as occupational structures, income level, population density etc. Since environmental condition involves both physical and non-physical phenomena, it cannot be easily assessed from these variables. Anyway, the idea of stratified sampling can be outlined as follows.

Non-geometrical subdivisions of the areas generate scattered pattern of the same strata of certain phenomena, because the spatial distribution of environmental phenomena tends to be scattered in urban areas. The selection of sample areas needs a special treatment; therefore, it usually creates several difficulties in the stratum classification.

Geometrical areal subdivisions have more regular pattern of sampling areas than non-geometrical subdivisions. This technique is appropriate in urban areas where street patterns follow a geometrical system. Point sampling, area sampling and linear sampling can be adopted here. The main weakness of stratified sampling through terrestrial approach is the areal differentiation of strata. As soon as the terrestrial investigation finishes over the study area, the result of the survey will be out of data. It is due to the fact that the terrestrial approach to strata differentiation takes a very long time. This weakness can be overcome by remote sensing approach, which will be discussed later in this article. Figure 5 presents examples of non-geometrical and geometrical subdivisions in the stratified sampling.

Combination of Sampling Techniques

There are many combinations which can be generated from these three main sampling techniques. The following discussion merely presents two simple examples of combination i.e.: (i) hierarchical sampling and (ii) unaligned sampling matrix.

Hierarchical Sampling. In hierarchical sampling, data are taken from a variety of levels to gain an understanding of an entire process of hierarchical phenomena. For example, sampling might range from microsite local levels through regional samples, interregional samples and perhaps on a state or national basis. In this case, the actual selection of the exact points or areas involved is only guided by the hierarchy (Lounsbury and Aldrich, 1979: 116).

Based on the proposed major subdivisions of the study area, sampling areas are selected through simple random, systematic or stratified sampling. The next phase is to select the minor subdivisions within the selected major samples. The hierarchical order is subject to the variation of the phenomena existing in the

study area (Figure 6a).

Unaligned Sampling Matrix. A geometrical pattern is needed for the purpose to this technique. As previously mentioned, the map of the study area is gridded. Each cell has a sample area(s) which is determined by first drawing a random number and taking that number of paces eastwards from the origin and then drawing a second random number to give the numbers of paces to be taken northwards. Figure 6b illustrates the procedure of this technique. Sampling techniques vary from a very simple form to a very complex design (Silk, 1979).

Selection of a Sampling Design

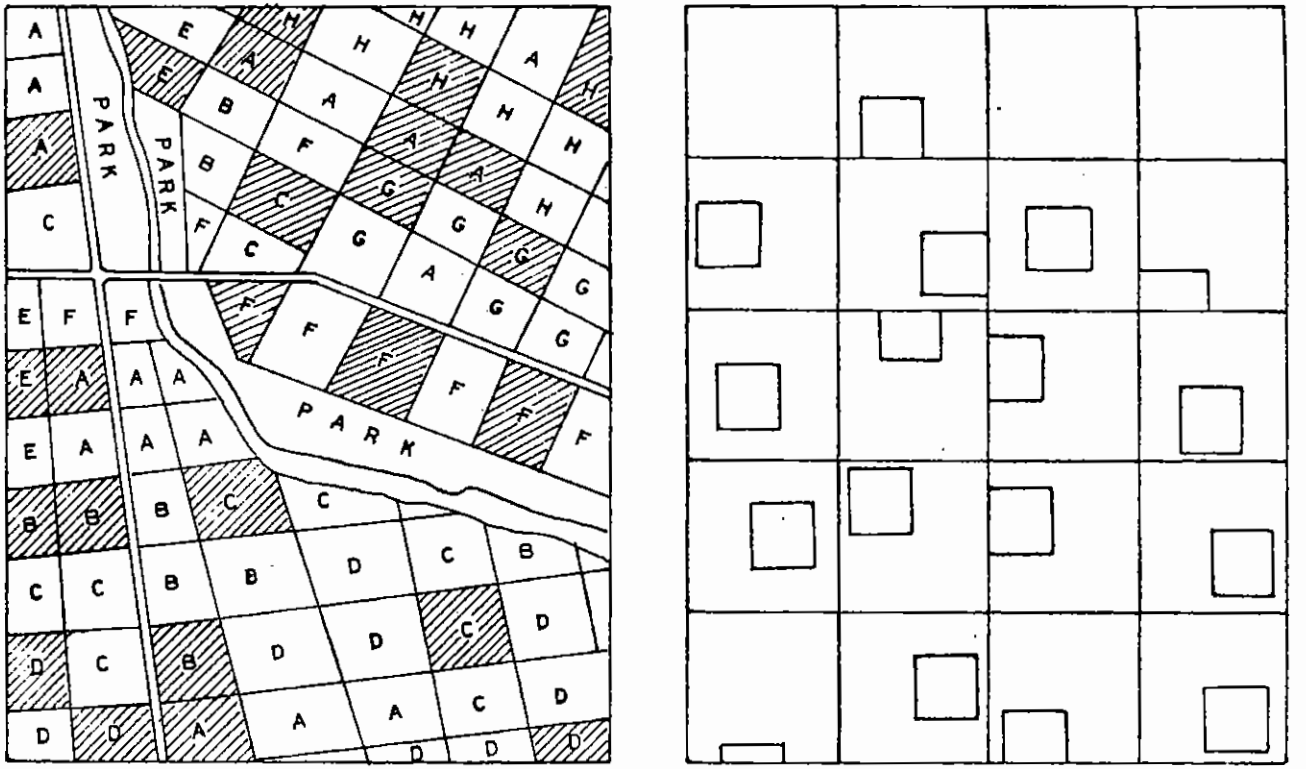
Several types of sampling procedure in the terrestrial approach and their basic principles have been discussed. It is intended to give a general outline of the ideas of various sampling techniques before the application of remote sensing approach. A researcher should keep in mind that the sampling procedure is not the goal of the investigation but merely a means to collect data essential for solving the problem, accurately and in the most efficient manner. As a medium to achieve the goal it has some weaknesses.

If the researcher does not consider the variations of the urban features, this technique will always miss phenomena that should be represented in the investigation. The reliability of the result of environmental assessment in urban area would therefore be deficient.

The advances of technology related to geographical research may in some degree play a part in achieving accuracy and reliability in the survey. In relation to the environmental assessment of urban areas, this paper will only deal with remote sensing image as one of the geographical research devices. Its role in achieving greater accuracy and reliability for the survey is undeniable, because it is complementary in nature to areal sampling techniques.

REMOTE SENSING APPROACH TO URBAN ENVIRONMENT ASSESSMENT

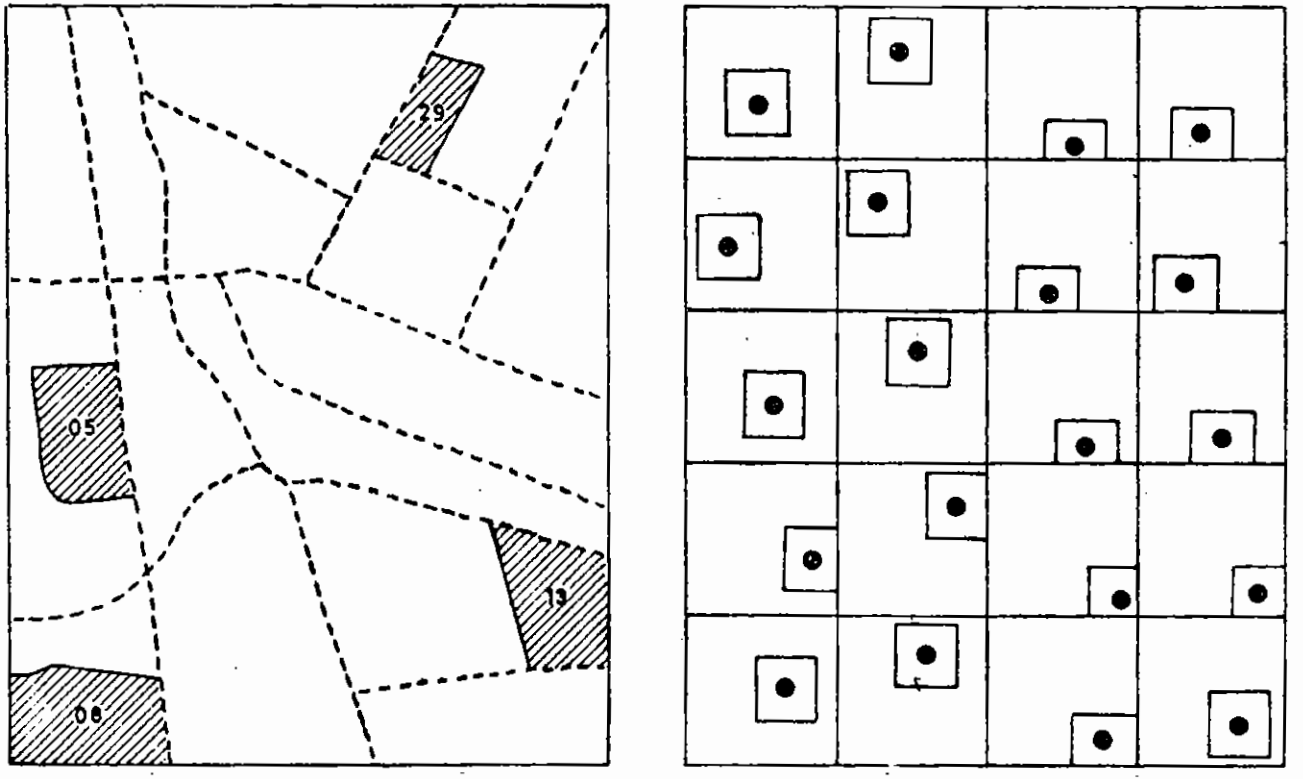
The role of remote sensing in areal differentiation in some respects is unquestionable. It is due to the fact that aerial photographs in particular depict every feature on the earth surface. In this case the variation of landscape features can be very easily detected on the aerial photographs as compared to the previous approach (terrestrial techniques). The following aerial photograph gives a very simple example of urban landscapes in Indonesia. In this respect one can easily delineate some different environmental conditions which cannot be



(a) Non-Geometrical Subdivisions in Stratified

(b) Geometrical Subdivisions in Stratified Sampling

Figure 5. Stratified Sampling



(a) Hierarchical Sampling in Administrative Approach.

(b) Unaligned Sampling Matrix in Geometrical Subdivisions Approach.

Figure 6. Hierarchical Sampling

executed from terrestrial approaches. Here at least six subdivisions of environmental conditions or environmental units can be distinguished. (Figures 7, 8). Those are:

Environmental Unit 1: areas occupied by non-housing features. Institutional buildings are dominant in these areas. Vegetation coverage is very low.

Environmental Unit 2: areas occupied by regular pattern of houses. Medium to small houses are the common features. Vegetation coverage is low to medium.

Environmental Unit 3: areas occupied by regular pattern of houses. Medium to large houses are dominating the areas. Vegetation coverage is low to medium.

Environmental Unit 4: areas occupied by irregular pattern of houses. Small to medium size of houses are the common features. These areas are mostly covered by vegetation.

Environmental Unit 5: areas occupied by irregular pattern of houses. Small to medium size of houses are dominant in these areas. Vegetation coverage is not as high as the Environmental Unit 4. It is due to the fact that these areas have higher accessibility as compared to the Environmental Unit 4.

Environmental Unit 6: agricultural areas in the city. Most of the Indonesian cities are characterized by the existence of agricultural areas within their administrative boundaries. These areas are mostly designed to catch the future expanding functions.

The delimitation of the study area into some environmental units cannot be easily executed through the terrestrial approach. On the contrary, this approach cannot reveal some data concerning economic, cultural, social, and the other human behavioural phenomena that are really playing an important role in creating specific environmental units within the urban areas.

The successful application of remote sensing is premised on the integration of multiple, interrelated data sources and procedures. No single approach combination is appropriate to be applied for all resource inventory and environmental monitoring. In fact, many inventory and monitory problems are not amendable at all to solution by means of remote sensing.

Remote sensing as a tool of analysis is best applied in concert with others; it is not an end itself. The application of remote sensing can give a better view of the environment than that of any other method of observation, because the real picture of the land surface can be seen as it is from above. Accordingly, one would be able to delineate urban environmental categories from the distri-

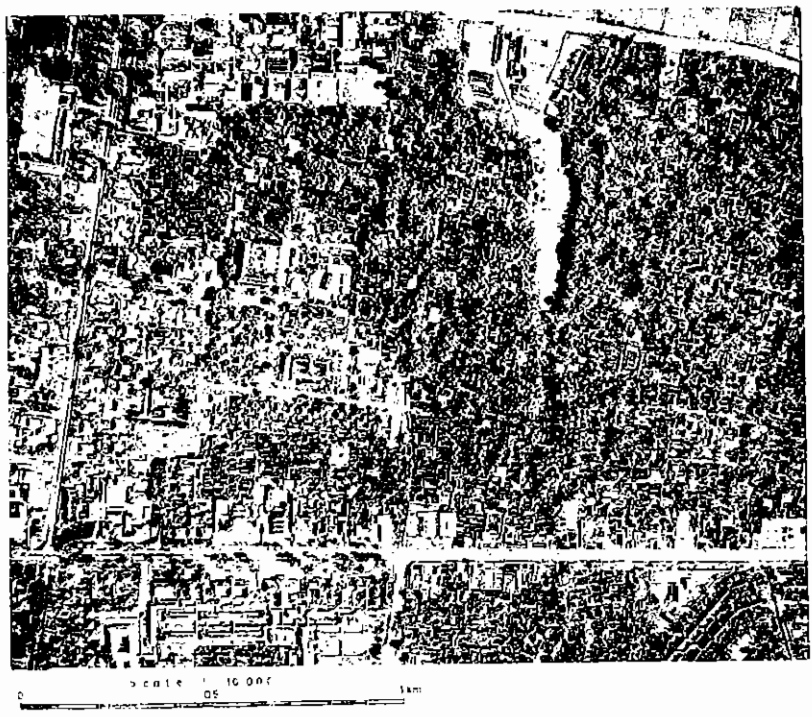


Figure 7. Aerial Photograph of Northern Part of Yogyakarta.

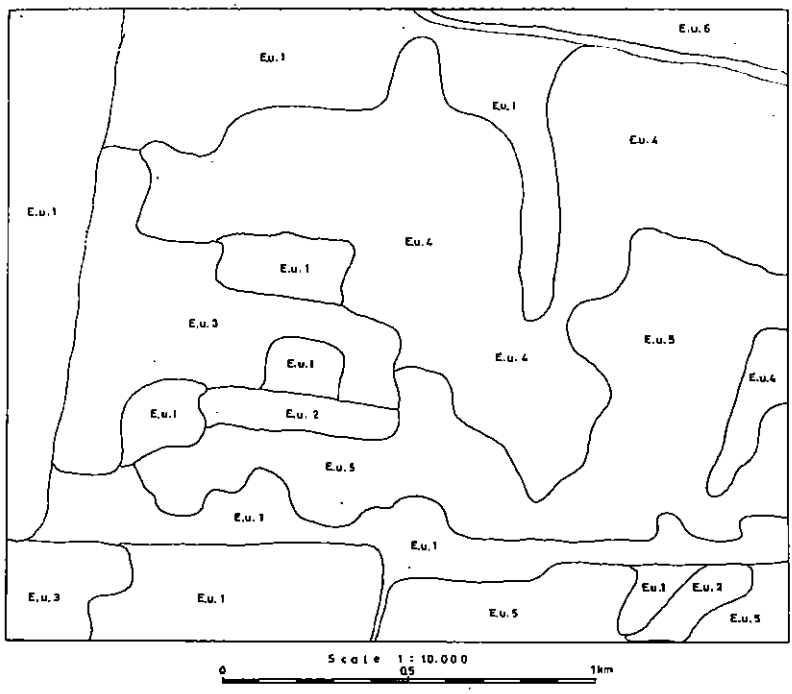


Figure 8. Categorization of Urban Environmental Unit through Aerial Photographic Approach.

bution of spatial arrangements of the land use patterns. The terrestrial approach needs a lot of time, manpower, and budget to carry out such works. The readily available images allow delineation of land use types and also the urban environment categories very easily.

In order to give more insight about the use of remote sensing techniques for urban environment assessment Table 2 can give a practical guidance concerning the selection of aerial photographs.

Remote sensing approach is merely based on visual features on the images. Since an urban environment system does not merely consist of physical features, relying upon remote sensing approach to reveal urban environment condition will be frustrated. The terrestrial approach still plays a great role in these endeavors and will be complementary in nature to the remote sensing approach.

On the one hand the remote sensing approach will supply physical information on environmental unit delimitation and on the other hand the terrestrial approach will confirm the result obtained through remote sensing and providing other non-physical and physical information. In conjuncton with this case, the so-called combination approach (terrestrial—photographic approach), is the best way to assess environmental condition of the urban areas.

TABLE 2. URBAN FEATURES IDENTIFIABLE AT FOUR LEVELS OF INTERPRETATION

ERTS—1 satelite imagery (LANDSAT 1)	High Altitude photography RB—57 1:120,000	High Altitude photography RB—57 1:60,000	Medium Altitude Black & White 1:15,840
Urban vs. Rural areas	Individual structures	Residential areas: (detailed discernable at preceeding scales)	Residential areas: (detailed discernable at preceeding scales)
Core	Residential areas	Single family residential	Housing types
Residential vs. Commercial	Shopping Plaza	Swimming Pools	High rise structures
	Commercial Cluster		
	Strip Commercial		
	Administrative building	Apartment Complex	Garden apartments
	Schools	Mobile homes sale	Pleasure boat sales
	University Complex	Parking Lots with cars	Building under constructions
	Cemetery	Commercial Areas	Institutional buildings
	Golf Course	(more detailed disable at preceeding scales)	Commercial Areas (more detailed discernible at preceeding
	Baseball-diamond		
	Drive in theater		

(continued)

TABLE 2. (continued)

ERTS—1 satelite imagery (LANDSAT 1)	High Altitude photography RB—57 1:120,000	High Altitude photography RT—57 1:60,000	Medium Altitude Black & White 1:15,840
	Marinas	Industrial Areas (more detailed discernible at preceeding scales)	scales)
	Heavy industry		Industrial Areas (more detailed discernible at preceeding scales)
	Tank form		
	Light industry	Boat dock	
Excavations	Excavating industries	Extracting industries	Power plats
Airports	Airports: terminal-building, aircraft-hangars	Fabricating	Coal piles
		Processing	Overhead crane
		Gas Storage	Water pipes
Highways	Highway interchanges	Transportation-facilities (more detailed discernible at preceeding scales)	Open storage areas
	Devided highways		Measure size of buildings
	Bridges		
	Rest areas		Transportation facilities (more detailed discernible at preceeding scales)
Railways	Railroads switching yards		
Utilities	Power line right of way		R.R. Box Cars
	Secondary roads		
	Tertiary roads		
	Port facilities		

Sources: (1) Davis, Jeanne M. (1960).
(2) Gary K. Higgs and M. Sullivan, (1973) *A Comparative Analysis of Remote Sensing Scale/System Attributes for a Multi-Level Land Use Classification System*, quoted by Henderson (1979).

THE COMBINATION APPROACH TO URBAN ENVIRONMENT ASSESSMENT

The application of this approach is based on several considerations:

1. The remote sensing approach can only give physical information that relate to visual features depicted on the image(s). Non-physical informations such as education, health, occupation of the people cannot be collected.
2. Remote sensing is able to classify urban land uses in such a way that will be used as descriptors of urban environment condition.
3. Land use types delineated on the images will be considered as environmental strata used as a basis to determine sampling areas.

4. Point 3 is based on the fact that carrying out an "overall investigation" will consume considerable amounts of manpower, time and money.
5. The terrestrial approach will not probably be able to come up with the representative environmental condition, because sampling techniques applied through random, stratified or systematic methods will always be followed by uncertainty of the degree of representativeness. It is due to the fact that the distribution of sample areas is not matched with the distribution of land use types as environmental descriptors.
6. Combination approach has specific characteristics as compared to the terrestrial or remote sensing approach respectively. This approach eliminates the deficiencies of each approach.

Procedure of Investigation

In general there are two main different activities carried out through the combination approach. The first activities are executed in the laboratory (laboratory activities) and the second activities are done in the field (field activities). Laboratory activities are concerned with image interpretation, sample analysis, data processing and data analysis. Samples such as water sample or soil samples need laboratory analysis.

The second activities are concerned with collecting primary data. Non-physical data such as income, health, cleanliness and so forth can be collected through "direct communication technique" (interview) or "indirect communication technique" (recording data from legal sources). Physical data are collected through direct or contact observation on the objects concerned. This procedure is illustrated in Figure 9.

The procedure of the combination approach can be outlined as follows:

Step 1: Preparing images of the study areas. Meanwhile, informations of the cultural, social, economic and physical backgrounds of the area concerned should also be collected from secondary sources (statistical records, documents etc.).

Step 2: Preparing image mosaics or image at a small scale. It is designed to get general picture concerning the environmental situation of the study area.

Step 3: Field orientation. It is designed to confirm the general knowledge of the study areas found out in the laboratory or secondary data. It is suggested that field orientation should cover all environmental variations as delineated on the images.

Step 4: Image interpretation and analysis. It is entirely executed in the laboratory. There are seven basic characteristics of images that should be considered in this step. Since urban environmental analysis needs detailed features,

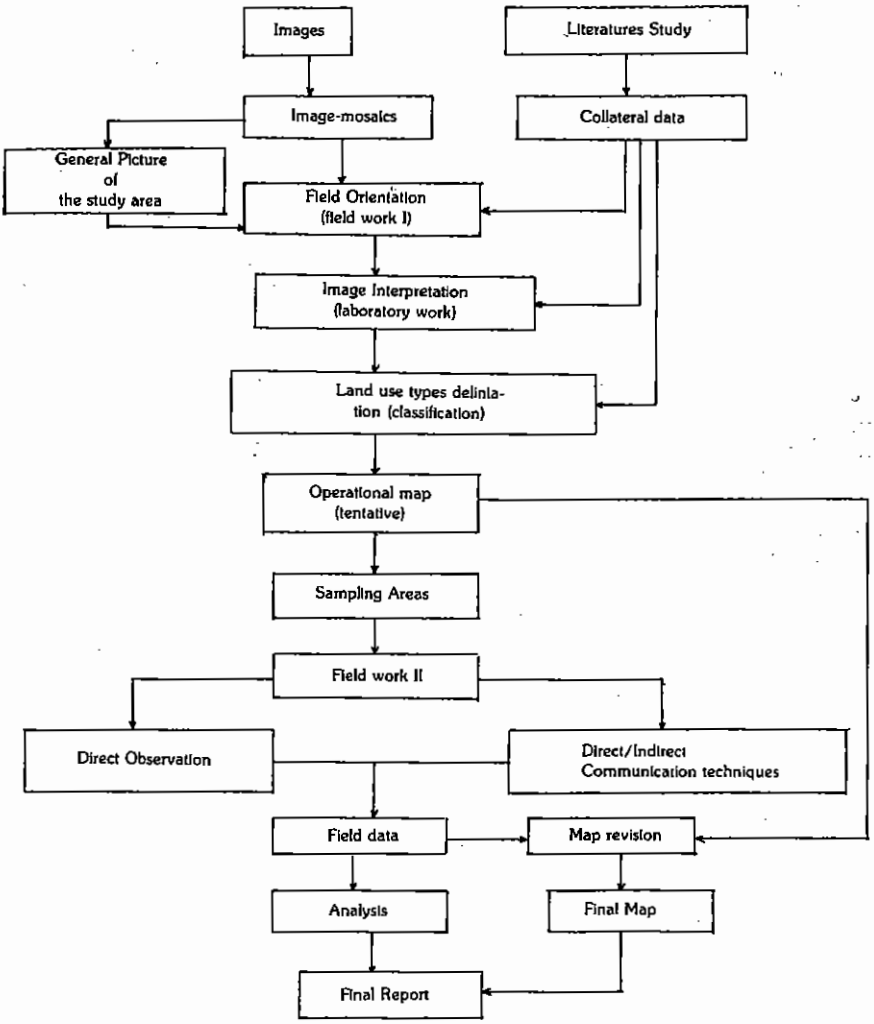


Figure 9. Procedure for the Combination Approach to Urban Environment Assessment

large scale images are more suitable for this purpose than small scale images. Since each feature on the image has different characteristics, the seven items concerned with interpretation should be properly comprehended, i.e.: shape, size, pattern, shadow, tone, texture and site.

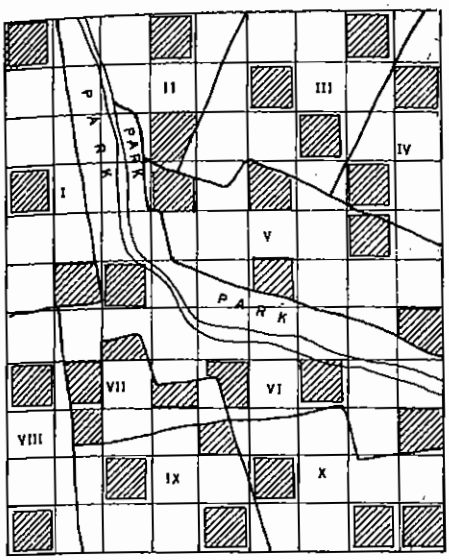
Shape refers to general form, configuration, or outline of individual objects. Size of objects on the images must be considered in the context of the scale of the image. Pattern relates to the spatial arrangement of objects. The repetition of certain general forms of relationship is characteristic of many objects, both natural and constructed, and gives objects pattern that aids the interpreter in recognizing them.

Shadows are important to the interpreter in two opposing respects: (i) the shape or outline of a shadow affords a profile view of objects which aid interpretation and (ii) objects within shadows reflect little light and are difficult to discern on the images which hinders interpretation. Tone refers to the color or relative brightness of objects on the photographs. Without tonal differences, the shapes, patterns and textures of the objects could not be discerned. Texture is the frequency of tonal change on the image. It is produced by an aggregation of unit features that may be too small to be discerned individually on the images, such as tree leaves and leaf shadows. It is a product of their individual shape, size, pattern, shadow and tone. As the scale of the image is reduced the texture of any given objects becomes progressively finer and ultimately disappears. Site or location of objects in relation to other features can be very helpful in identification (Lillesand, Thomas M. and Kiefer, Ralp W., 1979).

By considering these seven basic characteristics of the image, land use types boundaries can be delineated and the result of this step is a tentative land use map. This map will be used as a base map to select appropriate sampling design over the study area. Several physical elements relating to environment assessment will be identified at this stop, such as building density, number of buildings, street pattern, vegetation coverage etc.

Step 5: Sampling design. In fact, there are two techniques which can be adopted in this step, namely sampling and overall observation. Since the overall observation shows several disadvantages, as previously explained, it will not be discussed thoroughly. The main emphasis of this step is on the application of sampling techniques to urban environment assesment.

Any sampling technique as discussed in the terrestrial approach, can be applied here. Land use classification should be done prior to the selection of sampling design. Figure 10 shows the application of one of sampling techniques. Each land use category is represented by proportional amounts of sample areas. By employing such technique, urban land use assessment can be worked out accurately and thoroughly.



Legend:

Environment Category	Cells	Sampling areas
I	10	3
II	6	2
III	10	3
IV	6	2
V	15	5
VI	12	4
VII	8	3
VIII	7	2
IX	9	3
X	10	3

Sample areas 30%

: boundary of environment category

: Sample area

Figure 10. Combination Approach to Urban Environment Assessment

Step 6: Field work. Frequently it is very difficult to find out the sample areas. In order to help field-worker(s), to find out the exact locations of the sample areas, some materials such as operational maps, operational images, pocket stereoscope should be provided for them. In this case field worker(s) should be familiar with remote sensing techniques. The collected data can be used to revise the tentative map of the study area.

Step 7: Analysis. It is entirely done in the laboratory or at the office. Since environmental assessment concerns a lot of variables, it is suggested that a computer be used as a tool for analysis and data processing. Quantitative and qualitative techniques are applied here. In general, qualitative techniques are executed through image interpretation and map analysis, while quantitative techniques are carried out through statistical analysis.

Step 8: Making a final report. The final report should be organized in such a way as to comply with the report standard. Each agency has its own standard for publications.

By following the procedure of combination approach to urban environment assessment, it is expected that the result of the study will be reliable and accurate.

CONCLUSION

Based on the brief discussion of the application of remote sensing to urban environment study, some important points can be drawn. The first point is that in facing environment conditions that consist of physical and non-physical phenomena, remote sensing itself is not able to reveal all variables concerned with environments.

Secondly, terrestrial techniques do not guarantee the representativeness of the result due to their inability to categorize great variations of land uses in urban areas into representative classes that will be used as a base to select an appropriate sampling design.

Thirdly, there should be a technique which is able to eliminate those weaknesses. A combination of the remote sensing approach and the terrestrial approach will give more satisfactory results than either of them either separately applied. In other words, the terrestrial approach should operate side by side with remote sensing for the study of urban environments.

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