DELINEATING THE SPATIAL DISTRIBUTION OF SEAPORT RELATED LAND USE IN THE BALTIMORE METROPOLITAN AREA USING A REMOTE SENSING BASED GEOGRAPHIC INFORMATION SYSTEM

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by

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This thesis was prepared under the direction of the candidate's thesis advisor, Dr. James P. Latham, Department of Geography and has been approved by the members of his supervisory committee. It was submitted to the faculty of the College of Social Sciences and was accepted in partial fulfillment of the requirements for the degree of Master of Arts.

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ABSTRACT

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A land use classification system was designed for use with aerial photography in order to map four functional categories of land use in a study area divided into four quadrants. The data were analyzed for their spatial and functional relatedness to the operations of the Port of Baltimore.

Where waterfront transshipment land use was dedicated to steel manufacturing and petroleum storage, nearly all test-category land use was located within two kilometers of the harbor in those quadrants. In quadrants where it was engaged in the throughshipment of bulk, containerized, and general cargo, test-category land use still occurred primarily within two kilometers of the harbor, but was also distributed in large numbers six kilometers inland of the harbor. The results support the theory that the test-category land use is related to port activity, and that changes in land use patterns are associated with changes in port activity.

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CHAPTER I

Introduction

Spatial Organization of Port Associated Urban Areas

Urban areas are composed of land use that is diversified within relatively small distances. Their land use often represents contrasting activities, and is influenced by social and economic processes. For example, many urban areas are located along bodies of water that enable ship transportation to gain access to them as well as to commercial shipping lanes. Many major metropolitan regions of the United States center around a port, or are closely linked by inland transportation with a port (Little 1979).

A port is a transportation intensive system that functions as an interface node which connects land markets separated by water (Weigend 1955). Ports accomplish this linkage by engaging various types of land use for the transshipment of cargo and people. This transfer mechanism of ports involves land use that functions, for example, as waterfront transshipment, processing and fabrication, storage, and inland transportation.

Ports may be the impetus for the development of an urban area, or the result of urban area growth. A port generates a flow of income into an urban area by exchanging commodities with markets that may otherwise be located beyond the range of the urban area economy. Port operations make significant contributions toward the stimulation of employment, taxes, and revenue for an urban economy, in addition to the growth of new businesses. Ports in the United States now handle approximately two billion tons of cargo annually (Little 1979). A port's ability to compete for a share of that market depends largely on how effectively its port related land use is spatially arranged to facilitate functional interrelationships (Robinson 1976). Some of the port related factors influencing commerce in an urban area are the characteristics of the port traffic, the number of transshipment sites along its waterfront, and the variety of vessel types accommodated by the port. Transportation of commodities to and from inland locations is an essential factor and may be provided through a network of highways, canals, railroads, and pipelines.

The rapid growth of urban areas and the expanding and intensifying demands being placed on land resources have brought increased pressure on the land that is available for use. Allocating enough land for industry, inland transportation routes, and commodity storage is essential for the economic development of a port and the urban areas that are influenced by it. Of paramount importance is the intelligent use of land that abuts the harbor or waterway. Ports may be able to operate without industry, storage, or even sophisticated inland transportation networks, but the waterfront land used for ship berthing space is directly related to a port's capacity to transship cargo (Bird 1971). All other land use categories involved in the port operation are limited by the capacity and efficiency of waterfront transshipment facilities (Weigend 1958).

Surface space is organized and utilized by the people residing and working in urban areas. These people have a variety of needs that require the land to be used in diverse ways, and in varying degrees of intensity. Of particular interest to geographers is the examination of the regularities in the patterns and spatial organization of urban land use (Northam 1979). This makes it possible to classify geographic phenomena at various scales, and to generalize its character according to selected criteria.

Most urban land is devoted to fulfilling several types of demand for utilization and function. The use can be intensive, for example, as in the case of a residential building with a high rate of occupancy per acre. Or, land use can be extensive, as with recreational land having few users per acre.

The function of an urban area influences its population and economic structure. An awareness of function makes possible the critical analysis of urban patterns.

Identification of function is basic to the classification of land use, determination of its diversity of use, and how that land may be involved with the economic process influencing the urban environment (Bowden 1974, pp. 1823).

The arrangement of spatial patterns in a region can be determined by testing its contents against a specific set of criteria that may be designed to discriminate a functionally cohesive group of features from other phenomena in a region (James 1971, pp. 43). It may be possible to generalize land use categories according to function, in order to differentiate port related land use from that which is unrelated to the operations of the port system.

The establishment of Baltimore's port as an operational system in 1706, predates the incorporation of the city (Klein 1983). Its location is closer to Midwest markets than other east coast ports (Figure 1). The port is 150 nautical miles north of the Virginia Capes, the entrance to Chesapeake Bay from the Atlantic Ocean, where it is sheltered from open waters. Figure 2 shows the location of the Port of Norfolk, 150 nautical miles to the south, which is the nearest major competitor for the Port of Baltimore in total volume handled (Muscatine 1985). The Port of Baltimore lost $20 million during the first half of 1985. That was the poorest performance of any port on the east coast of the United States. Increases in total tonnage handled by the ports of New York, Philadelphia, and Norfolk,

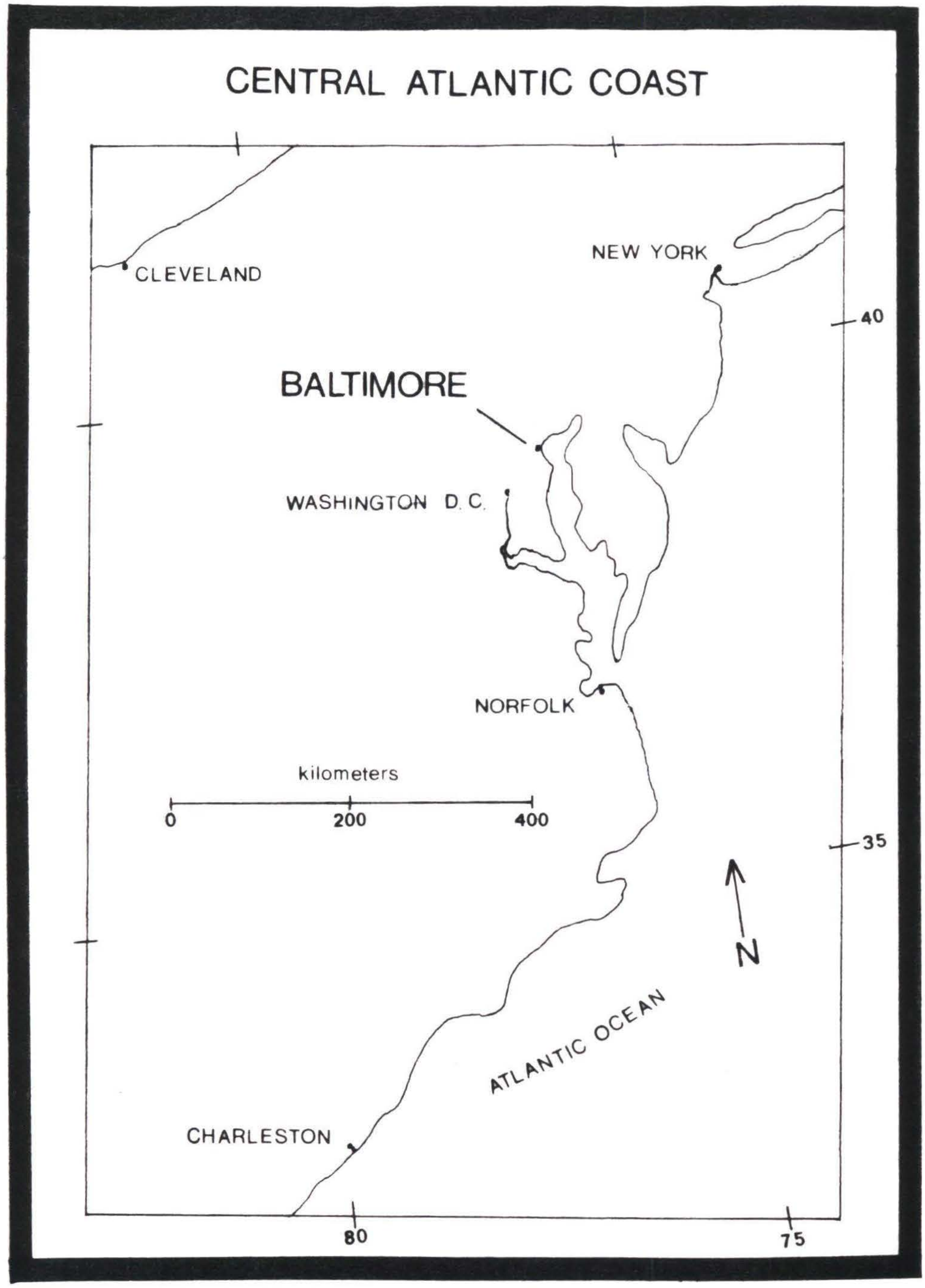


Figure 1. Regional map of the United States central Atlantic coast.

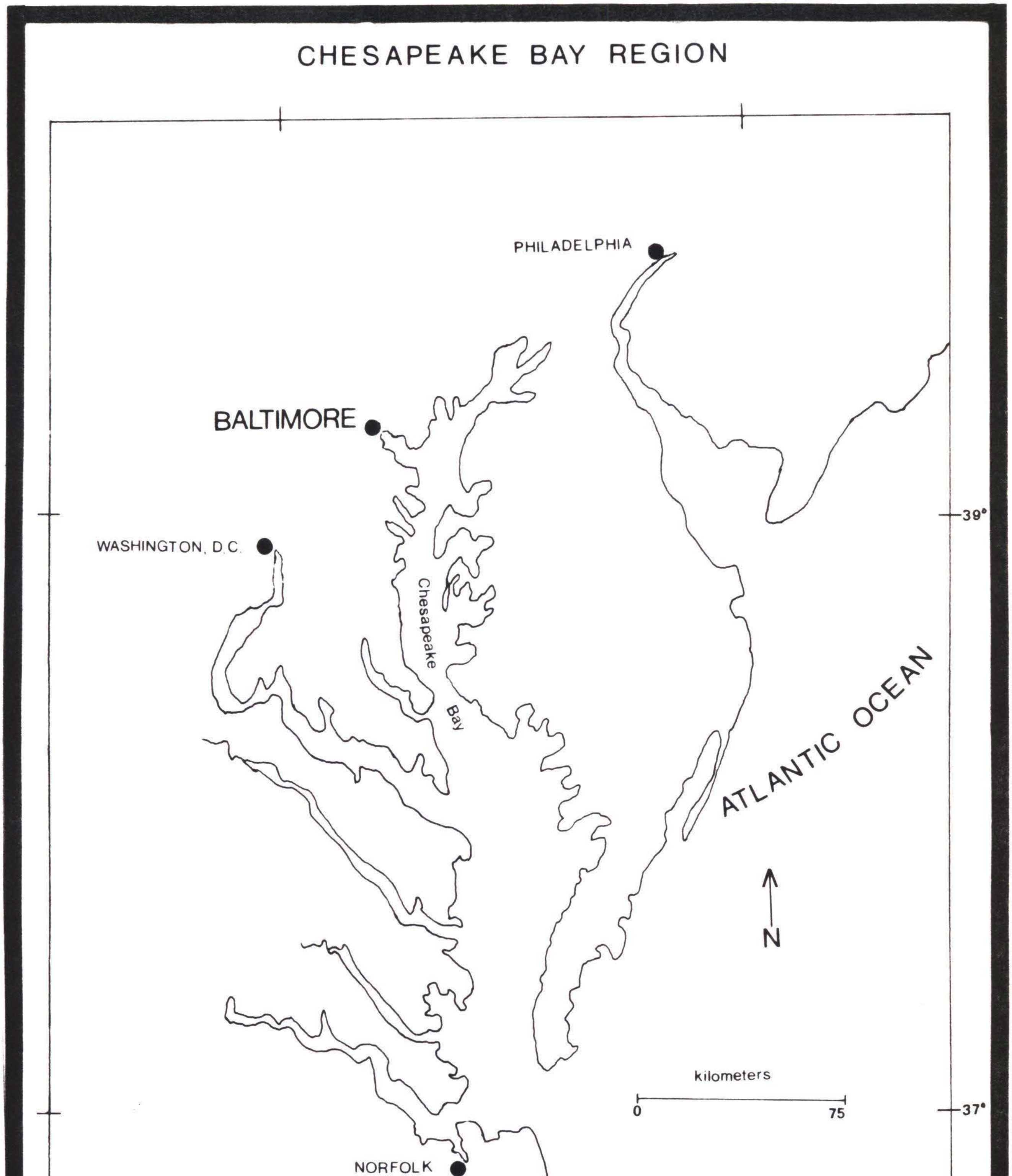


Figure 2. Chesapeake Bay region.

were achieved at the expense of the Port of Baltimore (Washington Post 1985).

Statement of the Problem

This study intends to develop a remote sensing based methodology for systematically inventorying, delineating, and analyzing the spatial distribution of four groups of land use categories within the Baltimore metropolitan area to determine their functional relatedness to the port. The methodology will be used specificly to determine if there is a spatial relationship between the locations of test-category land use functions and the land-harbor interface that would suggest a relationship to port operations. Also, the results will be evaluated in order to explain if changes in land use patterns are associated with changes in port activity. And finally, the methodology will be considered for its suitability for application to a variety of port types with the expectation of producing objective results.

Literature Survey

Much of the published research on port geography examines the situation of ports, that is, they focus on the transportation relationship of the port land use to its hinterland, or to other ports (Marti 1985). Many studies consider the economic impact of port operations on its hinterland or surrounding urban area (Schut 1977).

Some studies did examine the functional relationship that waterfront transshipment land use has with storage facilities, processing and fabrication industries, and inland transportation networks. Their primary focus, however, was on the efficiency of site operations (Wickham 1980). Many studies that characterized ports according to their operations did so without mapping the locations of significant land uses within the port system, except in a very general way. There are studies that regarded the waterfront area as the port and the surrounding urban area as the beginning of the hinterland, without discriminating the spatial distribution of functions compiled through a systematic land use analysis (Schut 1977). There was a consensus that a port is a system, made up of a collection of land use categories that share a functional interrelationship (Robinson 1976).

Undiscovered during this literature search were studies that used aerial photography as a sole source to compile a systematic record of detailed changes in port related land use occuring over small distances.

Contribution to Research

This study should prove to be an addition to the knowledge of techniques used to analyze ports and urban areas with aerial photography. It develops a geographic information system based on objective criteria for delineating the spatial extent of selected land use categories and features, and for recording their changes over small distances.

The methodology enables distances between the harbor and installations to be measured from discrete points along the land-harbor interface. Following that, it will be possible to quantify the spatial distributions of small changes in land use patterns in order to evaluate their relationship to the land-harbor interface. This methodology should prove flexible enough to accommodate any land use categories that might be selected for testing. In this way, different land use patterns could be mapped and quantified to determine their spatial and functional relationships.

CHAPTER II

Methodology

Four groups of land use categories were selected that are commonly located near ports. They are waterfront transshipment, processing and fabrication, storage, and inland transportation. The land use categories that perform these functions may be involved with the port operation to varying degrees of intensity.

There is a finite amount of land available along the land-harbor interface for use by these categories. It is assumed that the costs of competing for this space, versus the functional advantages of occupying it, will largely influence where some land use categories are located. It is also assumed that the land use categories which are most dependent on proximity to the land-harbor interface for their efficient operations will be located closest to it (Robinson 1976).

It is understood that installations located at various distances inland from the waterfront may have been sited on the basis of a requirement to be located amongst the infrastructure of similar land use categories.

It is further assumed that patterns of intra-port transportation networks suggest the functional relationships that may exist amongst the facilities in a port (Robinson 1976, pp. 78). Therefore, to delineate and quantify the spatial relationships of certain land use categories may provide information about what type of products are principally handled by a port and where those activities occur. Only the kind of information that can be discerned from photointerpretation will be used in this study to analyze these spatial arrangements.

Land Use Classification

Urban areas can be enormously complex when viewed from either aerial or ground perspectives. To successfully understand urban patterns it is therefore necessary to employ an orderly procedure for analyzing them (Higgs 1978, pp. 290). Raw data on urban phenomena does not provide useful information for problem solving unless it is organized in a meaningful and systematic manner that facilitates the perception of urban character (Anderson 1977).

Classification systems attempt to group land use patterns according to the similarity of their functional characteristics. This can best be done using a system of classes arranged in hierarchial order. Such a system permits inductive generalization of land use categories (Avery 1977, pp. 159).

A system based on these principles was developed by the United States Geological Survey for generalized classification of basic land use and land cover types (Level I) and their first subdivision of categories (Level II). This system (Table 1) is intended to provide a foundation for users to expand upon by adding more detailed classification levels.

TABLE 1

GEOLOGICAL SURVEY LAND USE CLASSIFICATION SYSTEM FOR LEVELS I AND II

---

1 Urban or Built-up Land

- 11 Residential
- 12 Commercial and services
- 13 Industrial
- 14 Transportation, Communications and Utilities
- 15 Industrial and Commercial Complexes
- 16 Mixed Urban or Built-up Land
- 17 Other Urban or Built-up Land

2 Agricultural Land

- 21 Cropland and Pasture
- 22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
- 23 Confined Feeding Operations
- 24 Other Agricultural Land

3 Rangeland

- 31 Herbaceous Rangeland
- 32 Shrub and Brush Rangeland
- 33 Mixed Rangeland

TABLE 1-Continued

4	Forest Land
41	Deciduous Forest Land
42	Evergreen Forest Land
43	Mixed Forest Land
5	Water
51	Streams and Canals
52	Lakes
53	Reservoirs
54	Bays and Estuaries
6	Wetland
61	Forested Wetland
62	Nonforested Wetland
7	Barren Land
71	Dry Salt Flats
72	Beaches
73	Sandy Areas Other than Beaches
74	Bare Exposed Rock
75	Strip Mines, Quarries, and Gravel Pits
76	Transitional Areas
77	Mixed Barren Land
8	Tundra
81	Shrub and Brush Tundra
82	Herbaceous Tundra
83	Bare Ground Tundra
84	Wet Tundra
85	Mixed Tundra
9	Perennial Snow or Ice
91	Perennial Snowfields
92	Glaciers

Source: (Anderson, et al. 1976, pp. 8)

The classification system used in this study attempts to classify categories of transportation, industrial, and commercial and industrial complexes of urban or built-up land use at greater levels of detail than is provided for by the Geological Survey system. A Level III and IV expansion of that system was developed to accomplish this (Table 2).

TABLE 2

LAND USE CLASSIFICATION SYSTEM, LEVELS I-IV

1 Urban or Built-up Land

13 Industrial

131 Mechanical Processing
- 1311 concrete products
- 1312 agricultural products
- 1313 non-ferrous metals
- 1314 ore concentration
- 1315 wood products

132 Chemical Processing
- 1321 non-ferrous metals
- 1322 petroleum products refining
- 1323 mineral processing
- 1324 halogens production
- 1325 acids production
- 1326 plastics products
- 1327 alcohols production

133 Heat processing
- 1331 non-ferrous metal smelting
- 1332 ferrous metal smelting
- 1333 steel rolling mill
- 1334 steel foundry
- 1335 ceramic products

134 Light Fabrication
- 1341 aircraft engines
- 1342 motor vehicle assembly
- 1343 fertilizer mixing
- 1344 meat packing

TABLE 2-Continued

		1345	cannery
		1346	seafood packing
		1347	boat building
		1348	electronics products
		1349	explosives products
	135	Heavy Fabrication	
		1351	structural steel
		1352	machinery manufacturing
		1353	ship building and repair
		1354	railroad car assembly
		1355	locomotive manufacturing
14	Transportation		
	141	Waterfront Transshipment	
		1411	quay
		1412	pier
		1413	wharf
		1414	transit terminal
	142	Inland Transportation	
		1421	railroad
		1422	railroad yard
		1423	divided highway with median
		1424	divided highway
		1425	inland waterway
		1426	pipeline
15	Industrial and Commercial Complexes		
	151	Open Storage	
		1511	containerized cargo
		1512	bulk fuel products
		1513	bulk agricultural products
		1514	industrial waste
		1515	raw materials
		1516	manufactured products
	152	Covered Storage	
		1521	commercial warehouses
		1522	petroleum product tanks
		1523	natural gas tanks
		1524	industrially associated

It was discovered early during the photointerpretation that Level IV classification of processing and fabrication categories could not be accurately identified. Therefore, it was decided that the entire study would be conducted at Level III in order to produce comparable data.

The system is intended to facilitate classification of selected land use categories. Land use categories other than those listed at Levels III and IV (Table 2), such as residential, commercial, or cropland are generalized as other land use, and are shown as such in the land use functions map (Map 1). Harbor water is also depicted in Map 1 in order to delineate the land-harbor interface.

Classification decision making

Multiple uses of land may occur on a single parcel of land. They can occur simultaneously in both horizontal and vertical dimensions, as may occur in urban areas. Uses may occur alternately in time, such as with agricultural land, or undeveloped land in proximity to industrial installations which may periodically be used for open storage of raw materials or products.

All of these activities would not necessarily be recorded on aerial photographs taken at a single point in time. It may be necessary to base classification on the areal predominance of the apparent land use within a survey plot at the time the scene was recorded (Anderson 1974).

Therefore, only the features observable within the dimensions of each survey plot are used to measure which land use category occupies the most area. This provides an objective system for generalizing land use patterns, and is the basis of this study's land use classification system. A broader view of surrounding survey plots was also used to facilitate classification of land use in individual survey plots.

The survey plots that segment the study area are 80 meters square. The size of the cells in the grid overlay is one millimeter square. The use of 1:80,000 scale aerial photography provides correspondence between the size of survey plots in the photography and the actual distances on the ground. A calibrated reticle located in an eye piece of the stereoscope made it possible to measure the area occupied by various land use categories in each of the survey plots.

Compilation of data record

As each survey plot was analyzed and assigned a land use classification code, a record of this decision was made. Each survey plot is considered to be a file of information. The data was organized according to quadrant and survey plot locations from the grid overlay as it was compiled during the photointerpretation phase. Information about a particular survey plot is recorded, for example, as NE-023119-155. The northeast quadrant is identified by NE, with 023 representing the X location on the grid, and the Y value is indicated by 119. The Level III land use category of heavy fabrication is represented by the classification code 155. More numbers or letters could be added to such a file in order to include additional descriptive information. It is apparent that data compiled in this way are compatible with automated storage and retrieval systems.

The study data base contains land use information on more than 10,000 survey plots. To provide a textual listing of all survey plot records would require a minimum of 200 pages. It was decided that the only data representation provided would be in coded format (one digit) and displayed in the matrix map of land use functions (Map 1).

Test-Categories of Land Use

Waterfront transshipment

Waterfront transshipment operations are conducted where inland transportation systems interface with waterborne modes. Waterfront transshipment facilities are the functional core of port operations. They may be involved in the movement of goods through the port or associated with industrial facilities. The waterfront transshipment function is commonly conducted with facilities such as wharves, piers, quays, and transit terminals (Figures 3-6).

Storage

Storage facilities may be very important to port

Figure 3. Waterfront transshipment (bulk cargo pier).

Figure 4. Waterfront transshipment (bulk cargo pier).

Figure 5. Waterfront transshipment (quays and transit terminals).

Figure 6. Waterfront transshipment (transit terminal pier).

operations. They provide a means for staging goods for various periods of time that may be intended for transshipment. The storage function is conducted with facilities such as warehouses, open storage yards, and liquid storage tanks. Various categories of storage land use are used widely throughout urban areas (Figures 7-10).

Processing and fabrication

Processing and fabrication plants may benefit from the operations of a port without necessarily being essential to its basic operations. Some installations require access to waterfront transshipment facilities in order to receive or ship its raw materials or products. Raw materials may arrive from inland sources or by ship. Product markets may be accessible by ship or various inland transportation modes. However, an installation may be located near the harbor but not require the use of waterfront transshipment facilities, since it may have been sited on the basis of land cost, zoning, or proximity to inland transportation networks.

Examples of processing plants are petroleum refining, ore concentration, sugar refining, and metals smelting. Fabrication plants include motor vehicle assembly, and ship building. Figures 11-20 show examples of processing and fabrication plants.

Figure 7. Covered storage
(commercial warehouse).

Figure 8. Covered storage
(industrially associated).

Figure 9. Open storage (containerized cargo).

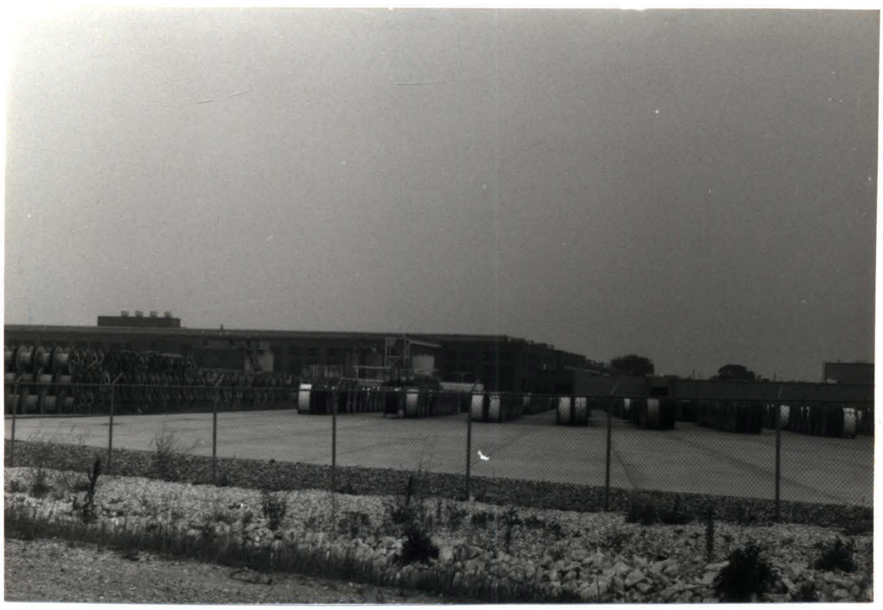


Figure 10. Open storage (manufactured products).

Figure 11. Mechanical processing (agricultural products); soybean products.

Figure 12. Mechanical processing (industrial raw materials).

Figure 13. Chemical processing (petroleum products refining).

Figure 14. Chemical processing (petroleum products refining).

Figure 15. Heat processing (steel rolling mill).

Figure 16. Heat processing (agricultural products); sugar products.

Figure 17. Heavy fabrication (shipbuilding and repair).

Figure 18. Heavy fabrication (structural steel).

Figure 19. Light fabrication (electronics products).

Figure 20. Light fabrication (motor vehicle assembly).

<u>Inland transportation</u>

This function is customarily performed by railroad, roadway, pipeline, and inland waterway. These inland transportation modes facilitate the movement of cargo to and from transshipment sites at the land-harbor interface, processing and fabrication plants, and storage facilities. They also link the other land use categories with inland markets. Figures 21 and 22 show examples of railroad. Roadway is a common transportation land use feature, and examples are not shown.

Study Area Delineation

This section of the chapter explains the procedures that were used to delineate the study area. This involved segmenting the study area into a matrix of survey plots. Aerial photographs of the study area were aligned to a grid overlay which corresponds to the scale of the survey plots. The aerial photographs were interpreted, using the Level III and IV land use classification system, to develop a record of the land use within each survey plot. These data were used to compile a matrix map of the survey plots.

<u>Center of the study area</u>

It was decided that the study area would be divided into four quadrants (northeast, southeast, southwest, and northwest), and that the harbor would be the general center

Figure 21. Inland transportation (railroad yard).

Figure 22. Inland transportation (railroad). Note its functional relationship to the industrial plant.

of it. To locate it objectively involved the use of an overlay of concentric circles (Figure 23). This was moved about over a frame of aerial photography that contained the largest portion of what appeared to be the harbor. A point was established at the center of the circle (Figure 23), from which all survey plots would emmanate in an X Y coordinate system. Figure 24 shows the relationship of the circle to landmarks along the harbor.

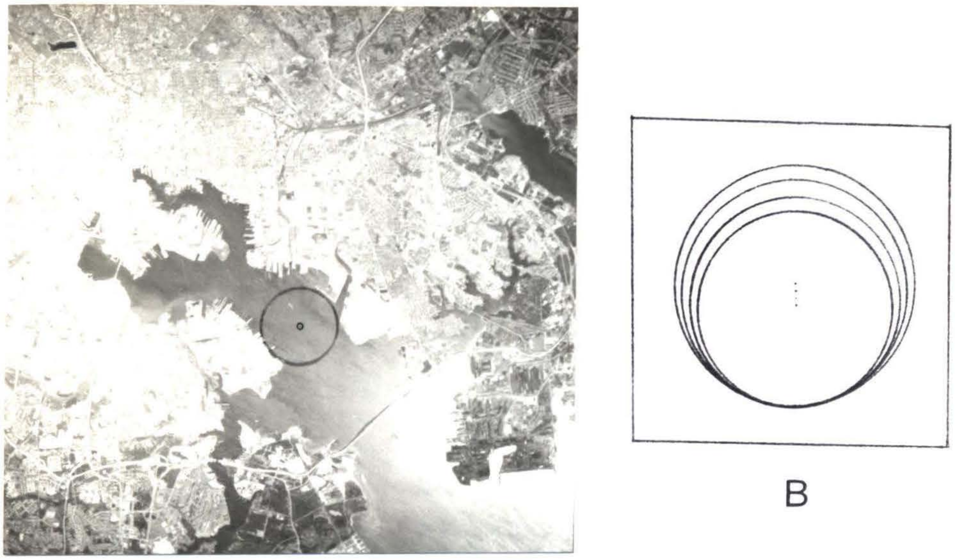
Using large scale 7.5 minute quadrangle maps, prominant features were selected from the study area that also could be found on the aerial photographs. These served as landmarks for aligning the grid overlay to each frame of aerial photography used in this study.

Photointerpretation

Several stereo pairs of 1:80,000 scale black and white transparent positive aerial photographs were selected to cover the study area. The frames were recorded on a mission flown in April 1981, and were purchased from the United States Geological Survey (USGS 1982). A Bausch and Lomb Zoom 240 stereoscope was used to facilitate the photointerpretation (Figure 25). This machine has a calibrated reticle in one eye piece, and a mechanical drive that permits very precise movement of the reticle for mensuration.

The scale of the aerial photography used in this study was selected for several reasons. The coverage

A



B

Figure 23. Center of the study area (A) established with a graduated circles overlay (B).

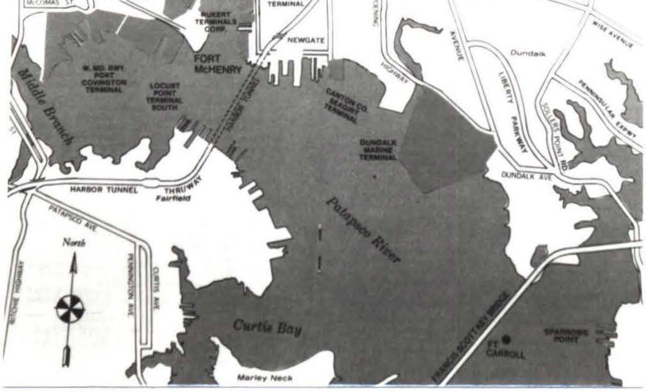


Figure 24. A map of the same area of the harbor shown above.

Figure 25. Bausch and Lomb Zoom 240 stereoscope, used to facilitate the photointerpretation phase of the study.

selected was the most recent black and white photography of the study area available at 1:80,000 scale. This scale facilitated the use of the desired survey plot size of 80 meters square. Also, it was cost effective since it was possible to cover the study area with only nine frames of photography. In addition, an intended objective of this study is to determine if the desired results can be obtained using aerial photography of this scale and resolution quality. Figures 26-29 show three frames of photography from which most of the study area was mapped.

The photointerpretation process began at the center of the study area, which in each quadrant is survey plot X1Y1. The stereoscope was then moved along the

Figure 26. Northwest portion of the study area.

Figure 27. Most of the central portion of the study area.

Figure 28. Most of the southeast portion of the study area.

Y axis, so that the land use in each survey plot could be interpreted and the data recorded. Survey plots occupied by harbor were recorded for mapping purposes in order to facilitate the delineation of the land-harbor interface (an essential element in quantifying the location of the data). At a stopping point, discussed in the next section, the stereoscope was returned to the Y1 position but advanced to the X2 column where the process was repeated. This continued until the quadrant was completely interpreted.

There were two modifications to this process. The criteria that were used to determine where the photointerpretation in each quadrant would stop, and the two modifications to that process are covered in the next section. This section addresses those issues in a complete discussion of how the the outer boundaries of the study area were delineated.

Outer boundary delineation

An essential element in this methodology is the delineation of the spatial extent (outward from the land-harbor interface) of the test categories of land use. It is based on an objective, systematic set of criteria that provide a rational basis for terminating the photointerpretation and data compilation process, while making it possible to display patterns of land use transition.

As the photointerpretation was conducted along

X-tracks of survey plots, zones of distance from the land-harbor interface were determined from the tabulated record and later mapped. The distance zones are composed of two-kilometer tracks (each containing 25 survey plots) that radiate out from the land-harbor interface. Figure 29 shows part of the northwest quadrant as an example of this. The template in Figure 29 is 25 survey plots square. It was used to measure survey plot tracks and to determine zone boundaries for subsequent mapping. The zone which begins at the land-harbor interface was designated as zone 1, the next one inland as zone 2, and so on for each quadrant.

Zone boundaries were preliminarily mapped in each quadrant, then modified according to the shape of the harbor in adjacent quadrants, after their data was compiled and mapped. It was necessary first to photointerpret zones 1 through 3 in each quadrant, then map the data, and finally to evaluate the distance zones. This was done to determine which tracks of survey plots still needed to be analyzed before two successive tracks of 25 survey plots were reached that contained less than 20% of test-category land use. This percentage criterion was the basis for determining when photointerpretation along each track would be terminated, and the resulting shape of the zones and outer boundary in each quadrant. A 20% minimum was decided upon as a reasonable degree of generalization while still provide a meaningful level of data.

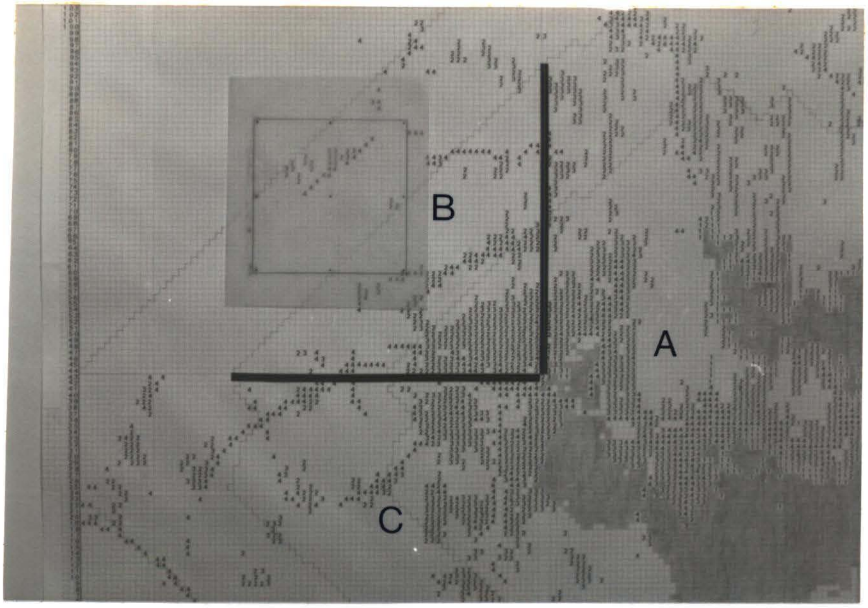


Figure 29. A portion of the northwest quadrant. The outer-most function-harbor survey plot (X98Y44) is inside the vertex of of the triangle formed by the bold lines. The mensuration template is shown in the upper left. (A) indicates the area where the standard procedure was applied, (B) modification 1, and (C) modification 2.

This process was repeated until the photointerpretation phase reached the survey plot in each quadrant which represented a function-harbor interface farthest away from the center of the study area. In Figure 29 this survey plot plot is shown inside the vertex of the bold lines. The location of the survey plot bearing this distinction was determined for each quadrant, and was calculated by adding the X and Y values of those survey plots that were candidates (i.e., must be part of the test group of functions). These survey plots are at X018Y026 in the northeast quadrant, X115Y052 in the southeast quadrant, X029Y087 in the southwest quadrant, and X098Y044 in the northwest quadrant.

The survey plot in each quadrant having the highest combined numerical value was considered to be farthest away from the center of the study area.

Because this study attempts to measure the influence of the land-harbor interface, it is important to determine the most outward extremities that are occupied by test-categories of land use. This is also important in order to continue to establish distance zones based on an objective point of origin.

Modification 1

At this loction in each quadrant, it became necessary to modify the way these 90 degree sections of the distance zones were measured. Since it was no longer possible to measure tracks of survey plots from right angles to the land-harbor interface, the outermost survey plot representing a function-harbor interface became the starting point. This required that each track of survey plots be measured in an L-shaped pattern, which still consisted of 25 survey plots.

The L-shaped track begins as one survey plot along an X axis (reference Figure 29), then turns north or south (determined by the first direction in the respective quadrant's name) along the Y axis and extends for 24 survey plots. The adjacent track in the same distance zone begins at the same starting point, but extends instead for two survey plots along the X axis, and then for 23 along the Y axis. This procedure was repeated until the last track consisted of 25 survey plots entirely along the X axis.

Modification 2

A second modification to the system for compiling distance zones was necessary. It was applied to the area of a quadrant that is located between the X axis border of the quadrant, and the X and Y axes that border the outermost function-harbor interface survey plot (Figure 29). In this case the tracks are started at right angles to the land-harbor interface and measured in straight lines again.

Statistical Processing

This section of the study discusses the procedures that were used to quantify the compiled and mapped data.

Use of preliminary maps

At this stage in the study, photointerpreted data have been tabulated, mapped, and organized according to the distance zone they are located in. Map 1 was made from four large preliminary sheets. After Map 1 was produced they were used to compile the statistical data on the spatial distribution of the land use functions.

Distance zone demarcation lines were drawn on the preliminary maps after Map 1 was produced, and a procedure was developed for collecting the statistical data. This procedure required manually counting the data on the preliminary maps for each function in each zone. This provided a data base of the spatial distribution of each function.

Also collected during this procedure were the data on the spatial relationships for each of the four groups of functions. It was decided that a spatial relationship existed when at least one side of a survey plot adjoined with another survey plot. Corner to corner contact was not considered to be adjacent. A clear plastic straight edge, mechanical counter, and tabular record facilitated this procedure.

Percentages, ratios, and chi square computations on the spatial relationships of the functions were used to supplement the analysis. Chi square was computed according to standard formulas and procedures (Weinberg 1974). In the tables the names of the functions (and quadrants) are reduced to two letter abbreviations: WF (waterfront transshipment), H (harbor), PF (processing and fabrication), ST (storage), IT (inland transportation), O (other land use). Level III land use categories are abbreviated as follows: LF (light fabrication), HF (heavy fabrication), MP (mechanical processing), CP (chemical processing), HP (heat processing), OS (open storage), CS (closed storage), RR (railroad), HW (highway).

CHAPTER III

Analysis

In this section the information that was developed from the the photointerpretation, statistical processing, and map compilation will be used to examine the spatial and functional characteristics of the study area. The analysis will focus on significant land use patterns, highlighting their spatial and functional relationships. This will be conducted by emphasising key locations in the study area, such as the land-harbor interface, which may illustrate the degree of port-relatedness that test-categories have to them.

Discussion

Land-harbor interface

An examination of this one survey plot-wide linear place will provide an understanding of its functional characteristics. It will also begin to explain the spatial relationship between zone 1 test-categories and the land-harbor interface. Table 3 will be used to show which test-categories occupy what percentage of the land-harbor interface in each quadrant. The percentages of zone 1 test-categories having a spatial relationship to the land-harbor interface, are displayed in Table 4. Table 5 will be used to illustrate the relationship between the amount of test-category land use adjoining the interface in a quadrant, and the zone 1 test-category land use remaining in the quadrant.

Northeast quadrant

In the northeast quadrant, the short length of land-harbor interface is intensively occupied by test-categories. Only 8% of it is occupied by other land use categories (Table 3). The segment of the interface from the northwest border to NE-X015Y015, is occupied by a mixture of test-categories comprised of processing, fabrication, waterfront transshipment, and inland transportation (Map 1). This segment of the interface is spatially related to a contiguous pattern of test-category land use which extends to the northwest.

South of NE-X015Y015, the interface is occupied almost entirely by waterfront transshipment, which is spatially and functionally related to a large containerized cargo terminal (Map 1, Figures 30 and 31).

Waterfront transshipment occupies 67% of the land-harbor interface in this quadrant, with processing and fabrication land use in adjoining proximity to 17% of it (Table 3). Table 4 shows that despite the extensive occupancy of the land-harbor interface by waterfront transshipment in this quadrant, only 53% of its survey plots have

TABLE 3

PERCENTAGE OF LAND HARBOR INTERFACE WITH SPATIAL RELATIONSHIP TO TEST-CATEGORY LAND USE

	WF	PF	ST	IT	O	Harbor-rim survey plots
NE	67	17	3	5	8	75
SE	9	5	10	8	69	660
SW	15	13	19	5	48	318
NW	40	17	15	6	21	572

TABLE 4

PERCENTAGES OF ZONE-1 FUNCTIONS WITH SPATIAL RELATIONSHIP TO LAND-HARBOR INTERFACE

	WF	PF	ST	IT
NE	53	6	1	4
SE	84	4	9	13
SW	70	7	7	5
NW	70	5	9	5

Figure 30. Containerized cargo terminal (A). The portion of the terminal (B) shown in Figure 31.

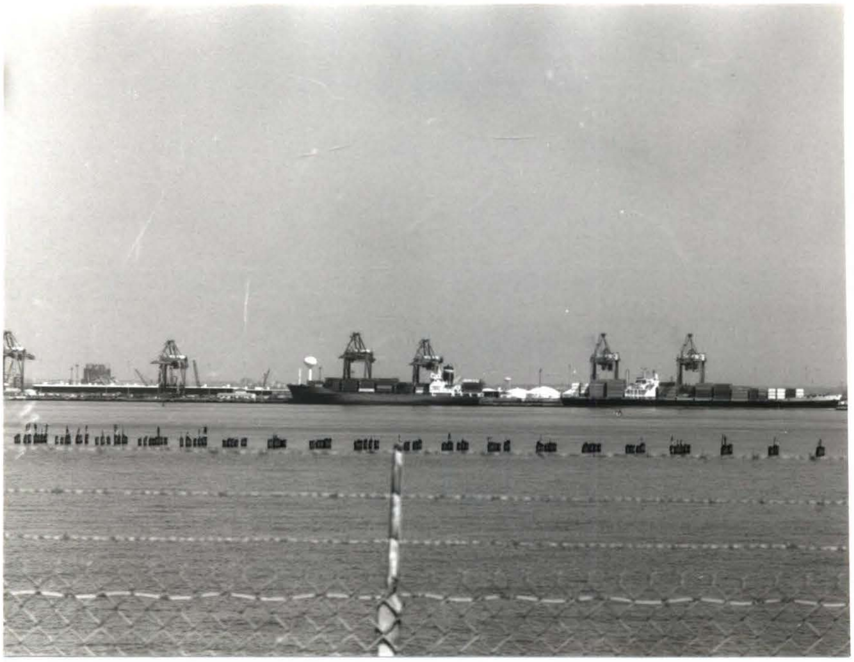


Figure 31. View of the containerized cargo terminal at (B) shown in Figure 30.

adjoining proximity to the harbor. This results from the broad pattern of quayage located there.

Southeast quadrant

The length of the interface segment in the southeast quadrant is the longest is the study area. It is also the most extensively occupied by other land use types, 69% (Table 3). The southern portion of a containerized cargo terminal extends south from the northeast quadrant (Map 1). It comprises much of the 9% of interface in this quadrant that is occupied by waterfront transshipment land use (Table 3). At SE-X070Y015 begins a contiguous pattern of test-category land use which extends south along the interface to SE-X070Y060. This segment adjoins patterns of railroad, open storage, waterfront transshipment, shipbuilding, and open storage yards (Figures 32 and 33). Other land use abuts a very large segment of the interface to approximately SE-X040Y110. From there, north to the end of the quadrant interface, a very diffused pattern of test-categories adjoins the harbor, comprised largely of waterfront transshipment facilities (Map 1).

Southwest quadrant

The east segment of the interface (SW-X001Y040 to SW-X025Y090) is occupied by three patterns of test-categories which are not spatially related, or linked by by inland transportation. Processing, fabrication, and

Figure 32. Shipbuilding (A) steel processing and fabrication (B), railroad (C), open storage (D). The shipbuilding yard (A) is also shown in Figure 33.

storage comprise the easternmost pattern which extends into the southeast quadrant (Map 1). The center pattern along this segment is an amalgam of storage, processing, fabrication, and inland transportation. To the south of it, a naval base lies just inland of a crescent shaped pattern of waterfront transshipment, which adjoins almost no test-category land use. Across that branch of the harbor a contiguous pattern of waterfront transshipment adjoins a field of storage buildings that are too widely spaced to meet the

Figure 33. The shipbuilding yard shown as (A) in Figure 32.

classification criterion (Map 1, Figure 27).

Farther to the northwest, spatial relatedness to the interface increases in a nearly contiguous pattern of processing, fabrication, storage, and waterfront transshipment land use. Most of this pattern is associated with a large field of petroleum storage tanks which begins at SW-X040Y020 and extends into the northwest quadrant to NW-X035Y005 (Map 1, Figure 34). This extensive pattern of petroleum storage tanks contributes significantly to the 19% of the interface occupied by storage land use in this quadrant (Table 3). It intermittently adjoins waterfront transshipment land use along its northern segment. Many piers were interpreted in the aerial photography but were not recorded because they were too narrow to meet the land use classification criteria (Figure 34).

Figure 34. Petroleum storage tank field (A), narrow piers (B), railroad yard (C), shipbuilding yard (D).

Except for a section that crosses the lower extent of the harbor, inland transportation is nearly nonexistant along this section of the interface (Map 1). Other land use categories occupy 48% of the interface (Table 3). Percentages of southwest quadrant zone 1 test-category land use adjoining the interface, are similar to most categories in most other quadrants (Table 4).

Northwest quadrant

The land-harbor interface pattern in this quadrant is long and intricate. It begins at NW-X020Y001, where the northern extent of the storage land use pattern adjoins a shipbuilding complex consisting of processing and fabrication, and storage land use (Map 1, Figure 27).

To the west, a long segment of the land-harbor interface is almost exclusively occupied by other land use categories, except for an inland transportation route, which which crosses the harbor at NW-X080Y020 and dissipates. Spatial relatedness of test-categories to the interface increases dramatically at NW-X090Y020 and continues in a nearly uninterrupted pattern to the northeast quadrant border (Map 1).

Along that segment between NW-X095Y020 and NW-X070Y025, the land-harbor interface is primarily comprised of alternating patterns of heterogeneous test-categories (Map 1). Except for some open land it forms a nearly contiguous pattern along its extent. Only a few waterfront transshipment survey plots are located along this segment of the interface. Processing and fabrication, and storage are spatially related to 17% and 15% of the interface, respectively (Table 3), and much of that occurs along this segment.

Waterfront transshipment land use abuts 40% of the interface in this quadrant (Table 3). Much of this spatial relatedness occurs along the remaining segment of the interface from NW-X070Y025 to the northeast quadrant border (Map 1).

This pattern has an extensive functional relationship to the the test-categories located inland of it. Major marine terminals are located along the interface between NW-X070Y030 and NW-X050Y050, and are spatially related to a pattern of processing and fabrication, storage, and inland transportation categories which extends inland various distances from the land-harbor interface (Map 1, Figure 26).

The figures in Table 3 show that inland transportation adjoins a similar percentage of the land-harbor interface in each quadrant, despite the wide variation in its length. This indicates that inland transportation land use occurs along the interface to a degree that is nearly proportional to the length of the interface in the southwest, northwest, and northeast quadrants. In the southeast quadrant, it suggests the lack of development that has occured there.

Table 4 shows that most quadrants have similar percentages of zone 1 processing and fabrication, storage, and inland transportation adjoining the interface. This indicates that the infrastructure of zone 1 test-categories adjoining the interface occurs in similar proportions in each quadrant.

In Table 5 it can be observed that as the amount of test-category land use adjoining the harbor in each quadrant increases, so does the amount of test-category land use found in the remainder of zone 1. The northeast quadrant

TABLE 5

RATIO OF TEST CATEGORIES AT LAND-HARBOR INTERFACE, TO REMAINDER OF TEST-CATEGORIES IN ZONE 1, AND TO ZONE 2

	no. at Harbor-rim	no. left in zone 1	ratio	no. in zone 2	ratio
NE	69	680	9.9:1	621	9.0:1
SE	205	1725	8.4:1	144	0.7:1
SW	165	1559	9.4:1	109	0.7:1
NW	452	2908	6.4:1	1672	3.7:1
Total	891	6872	7.7:1	2546	2.9:1

has the largest proportion of zone 1 test-category land use in relation to that which adjoins the harbor (9.9:1). The northwest quadrant has the least with a ratio of 6.4 : 1. The ratio for each quadrant deviates by 28.5% from the study area mean of 7.7 : 1. It is therefore a crude measure of a trend but better serves as a means of determining how intensively zone 1 is utilized relative to how extensively the land-harbor interface is occupied. It can be derived that in the northwest quadrant, for example, less zone 1 test-categories inland of the interface are present to interact functionally with those test-categories adjoining the land-harbor interface than does occur in the northeast quadrant. Similar comparative statements can be made pertaining to the other quadrants.

TABLE 6

PERCENTAGES OF ZONE-1 FUNCTIONS WITH SPATIAL RELATIONSHIP TO WATERFRONT LAND USE

	WF	PF	ST	IT
NE	94	10	5	11
SE	78	3	5	1
SW	83	3	2	1
NW	90	5	7	4

TABLE 7

PERCENTAGE OF ZONE 1 CATEGORIES WITH SPATIAL RELATIONSHIP TO INLAND TRANSPORTATION

	WF	PF	ST
NE	12	17	13
SE	5	11	11
SW	3	11	14
NW	8	16	28

Proximity to
waterfront transshipment

This section will examine the spatial relationships that test-categories have to waterfront transshipment sites in the study area. Also, a description of the resulting functional relationships will be discussed. The figures in Table 6 show the percentages of zone 1 test-categories adjoining waterfront transshipment land use. The percentages of test-categories which are spatially related to the inland transportation category are shown in Table 7. The number of survey plots for each Level III category located in each zone, is displayed according to quadrants in Tables 8, 9, 10, and 11.

Northeast quadrant

Waterfront transshipment land use in this quadrant consists of 95 survey plots (Table 8), most of which are spatially related to two large patterns of test-category land use in the northeast quadrant (Map 1). Beginning at NE-X010Y015, a processing and fabrication complex adjoins waterfront transshipment and extends northwest beyond zone 1 and into the northwest quadrant (Map 1, Figure 35). Movement linkage in this pattern is made possible by a portion of the inland transportation network which adjoins 12% of the waterfront transshipment in the northeast quadrant (Table 7).

The second large pattern consists primarily of

TABLE 8

SPATIAL DISTRIBUTION OF LEVEL-III LAND USE CATEGORIES, NORTHEAST QUADRANT

Zones	WF	LF	HF	MP	HP	CP	OS	CS	RR	HW
1	95	99	72	46	0	0	317	17	69	34
2	--	15	26	55	0	0	13	10	3	80
3	--	26	95	26	0	0	2	0	73	86
4	--	28	6	7	0	0	0	3	3	59
5	--	1	0	0	0	0	0	0	0	4

storage land use located along the southeast segment of the harbor. This is a large containerized cargo terminal (Figures 30 and 31) which forms a homogeneous pattern of open storage land use adjoining a line of quayage and extends inland to NE-X050Y001 (Map 1). Inland transportation adjoins 13% of the storage in the northeast quadrant (Table 7). Much of that spatial relationship occurs at the marine terminal, where minor routes provide movement linkage from waterfront transshipment sites to more prominent routes and to the industrial patterns inland of zone 1 (Map 1).

Southeast quadrant

Test-category land use adjoins the majority of

Figure 35. Piers and cargo terminals comprise this waterfront transshipment area (A), adjoined by a railroad yard (B). In zone 3 an extensive railroad yard converges with spatially prominent highway routes (C).

southeast quadrant waterfront transshipment land use, consisting of 73 survey plots (Table 9), concentrated primarily at five sites. The first is the southern extent of the marine terminal in the northeast quadrant discussed above. Its characteristics are not materially different in this quadrant. The second is a shipbuilding yard located at SE-X070Y035. The third major site is located at SE-X090Y050

TABLE 9

SPATIAL DISTRIBUTION OF LEVEL-III LAND USE CATEGORIES, SOUTHEAST QUADRANT

Zones	WF	LF	HF	MP	CP	HP	OS	CS	RR	HW
1	73	5	437	27	0	330	626	46	310	76
2	--	16	35	0	0	0	13	5	57	18

and is associated with a large steel plant. The fourth site is located at SE-X040Y110 and is associated with two thermal electric power plants. The fifth site is a small petroleum terminal located at SE-X015Y050. Only 5% of this waterfront transshipment land use is adjoined by inland transportation. By comparison, zone 1 inland transportation adjoins more processing and fabrication (11%) and storage (11%) in this quadrant (Table 7).

The waterfront transshipment land use at the shipyard is spatially related to part of the larger processing and fabrication complex of the steel plant which it adjoins in a pattern that includes open storage and railroad (Figure 32, Map 1). However, the portion located between the harbor and SE-X090Y025 to SE-X090Y045, is mostly involved with shipbuilding. The large pattern of railroad adjoining this complex is not spatially related to the waterfront transshipment facilities associated with the shipyard. It is instead spatially related to the heavy fabrication facility there (Figure 36). It is functionally related to other locations within the steel plant and provides movement linkage to locations northeast of zone 1. Beyond that point, the track narrows to less than the width required for classification where the pattern diminishes.

The third waterfront transshipment site to be discussed is associated with the offloading of coal used by heat processing components of the steel plant. The coal is conveyed to open storage yards which adjoin segments of the harbor. It is moved to the steel plant by rail lines that

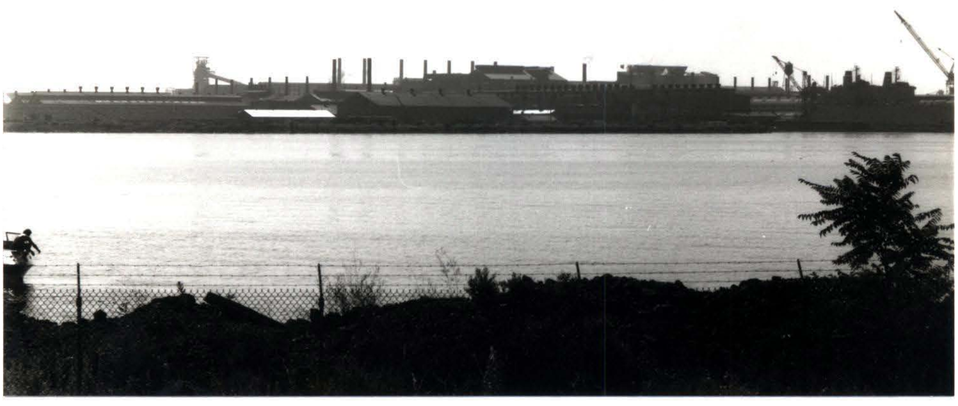


Figure 36. Processing and fabrication complex associated with the shipbuilding yard, also shown in Figure 32.

also adjoin the open storage yards, but principally inland of the waterfront transshipment facilities (Map 1, Figure 32). These spatial and functional relationships account for the small pattern of railroad which adjoins this waterfront transshipment site. The large amount of railroad in zone 1 (Table 9) is primarily involved with providing movement linkage amongst the processing and fabrication installations of the steel plant.

The two thermal electric power plants utilize coal and oil. The waterfront transshipment land use located here is functionally dedicated to offloading the fossil fuels (Figure 28). One pattern of heat processing land use associated with this complex adjoins the waterfront transshipment site. The other is located inland a short distance. Both are linked by rail to each other and to a diffused pattern of petroleum strorage tanks northwest of the waterfront transshipment site (Map 1). A single track spur, although too narrow to meet the classification criterion, links processing and fabrication land use to the north (Map 1).

The small oil terminal at SE-X015Y050 is loosely adjoined by a complex of processing and fabrication, and open storage. It is in close proximity to a major highway which connects this quadrant, otherwise divided by the harbor (Map 1). However, this waterfront transshipment site has limited tank storage capacity. The route of a single track of railroad connecting the pier with industrial complexes nearby and in the southwest quadrant (too narrow to record) indicate some of the functional relationships of this waterfront transshipment site (Figures 27 and 28).

Southwest quadrant

The two patterns of waterfront transshipment land use located along the south portion of the harbor branch are associated with the military facilities there. The majority of the 70 recorded waterfront transshipment survey plots in this quadrant comprise these two sites (Table 10). Other test-categories adjoining these sites are almost non-existent (Map 1).

The remaining several sites are small and dispersed widely along the interface. They are spatially related to a processing and fabriction complex and to the petroleum storage field which adjoins the harbor (Map 1). Several piers located along this section were not recorded, however, because they are too narrow to meet the classification criterion.

Inland transportation is spatially related to very little of the waterfront transshipment land use in this quadrant (Tables 5 and 7). By comparison, much more zone 1 processing and fabrication (11%), and storage (14%) is spatially related to inland transportation (Table 7). Map 1 also shows that prominent movement linkage patterns primarily extend to locations further inland.

Northwest quadrant

The number of survey plots of waterfront transshipment land use found in this quadrant, 327, is the largest in

TABLE 10

SPATIAL DISTRIBUTION OF LEVEL-III LAND USE CATEGORIES, SOUTHWEST QUADRANT

Zone	WF	LF	HF	MP	CP	HP	OS	CS	RR	HW
1	70	259	92	186	5	0	553	268	227	64
2	--	7	0	0	0	0	10	0	0	48
3	--	0	0	0	0	0	16	1	0	24
4	--	0	0	0	0	0	0	0	0	3

the study area (Table 11). Most of the sites are located between NW-X070Y030 and NW-X050Y050. A site located at NW-X035Y005 is associated with a shipbuilding yard that extends to the south in a contiguous pattern of processing and fabrication, and storage land use (Map 1). Inland transportation is not spatially related to this waterfront transshipment site.

The waterfront transshipment site located at NW-X100Y045 is spatially related to a large pattern of test-category land use. Inland transportation adjoins 8% of the waterfront transshipment survey plots in this quadrant (Table 7), but none of it occurs at this site.

Waterfront transshipment facilities located between NW-X070Y030 and NW-X060Y050 function as major marine terminals with a spatial relationship to a large, continuous pattern of test-categories. Prominent patterns of inland transportation land use provide these terminals with significant movement linkage routes to the west (Map 1).

TABLE 11

SPATIAL DISTRIBUTION OF LEVEL-III LAND USE CATEGORIES, NORTHWEST QUADRANT

Zone	WF	LF	HF	MP	CP	HP	OS	CS	RR	HW
1	327	726	417	134	18	65	737	226	484	226
2	--	333	109	81	0	0	161	57	117	138
3	--	162	152	0	0	3	116	15	96	67
4	--	35	2	0	0	0	2	0	7	13
5	--	2	0	0	0	0	0	0	0	4

To the northwest of these marine terminals a narrow pattern of shipbuilding land use adjoins waterfront transshipment categories. The spatial relationship does not extend further inland, however, as a large pattern of other land use encroaches on the harbor from the north (Map 1). The lower extent of this pattern, which adjoins the Baltimore central business district north of the shipyard, is residential in character (Figure 37). None of the shipyard's processing and fabrication, or storage facilities is adjoined by inland transportation land use.

North of the shipyard, across the harbor, a small pattern of test-category land use is spatially related to the waterfront transshipment facilities there. In a very short distance inland its pattern becomes diffused. Inland transportation does adjoin the waterfront transshipment facilities, but not to a significant extent (Map 1).

To the east, a prominent pattern of waterfront transshipment land use extends along the interface between NW-X055Y055 and NW-X030Y055. This section is largely comprised of active municipal facilities. Its limited spatial relationship with test-category land use, however, particularly inland transportation, suggests that a limited amount of activity occurs here, compared with other marine terminals in the study area. An expansive pattern of residential land use encroaches on this waterfront area just north of the narrow band of test-category land use which adjoins it (Map 1).

The waterfront transshipment land use located between NW-X030Y055 and the border with the northeast

Figure 37. Baltimore central business district (A), shipbuilding yard (B).

quadrant is comprised of serveral marine terminals. They are adjoined by a contiguous pattern of test-category land use, the center of which is occupied by a large railroad yard. Spatially, the marine terminals are associated with the most contiguously extensive pattern of test-category land use in the study area.

The degree of generalization used in this study to classify land use precludes display of the extensive spatial relationship that exists between spurs of the rail yard and these waterfront transshipment facilities (Map 1, Figure 35). Inland transportation adjoins 16% of the processing and fabrication and 28% of the storage located in zone 1 of this quadrant, and much of that spatial relationship occurs near this complex of marine terminals (Table 7).

Quantifying the spatial relationships that test-categories have to waterfront transshipment (Table 5) provides an objective look at the nature of activities in particular quadrants and the spatial patterns of waterfront transshipment land use. Similarly, Table 7 shows that inland transportation adjoins less waterfront transshipment in the south quadrants than in the north quadrants, which contain large marine terminals. The descriptive information provided previously characterizes the waterfront transshipment land use in the south quadrants as spatially related primarily to a steel manufacturing plant and to a petroleum storage facility. When combined, this information suggests that the functional relationship of waterfront transshipment land use in the south quadrants is confined to the patterns of processing and fabrication and storage land use that it adjoins. Inland transportation land use in the north quadrants has a more extensive spatial relationship to waterfront transshipment facilities involved in less specialized transshipment operations than is the case in the south quadrants (Tables 5 and 7).

In places where prominent routes of inland transportation adjoin waterfront transshipment sites which function as marine terminals, contiguous and integrated patterns of test-category land use extend inland, in some cases beyond zone 1. This relationship occurs most conspicuously in the north quadrants. In the south quadrants, where this spatial relationship does not occur, test-categories are located principally in zone 1. This correspondence is reflected in Tables 8 through 11, where the spatial distribution of test-category land use can be compared, and will be discussed more thoroughly in the next section.

Zonal distributions

The focus of the analysis now moves inland through zone 1 and beyond. Most of the significant land use patterns in the study area have been described in detail in the previous sections. This section will emphasize the changes in land use patterns that occur in the zones by examining their dispersal throughout the study area. Several statistical measures will be used to provide a concise look at the changes in land use patterns which occur as distance from the land-harbor interface increases inland.

Northeast quadrant

Nearly all the storage land use in this quadrant (92%) is located in zone 1. Processing and fabrication is more widely dispersed with 43% located in zone 1. Less inland transportation is located in zone 1 of this quadrant

(25%) than is found in the others (Table 12).

Table 8 shows the Level III composition of each zone in the northeast quadrant. The bulge in the railroad category in zone 3 results from the railroad yard located there, and a similar trend in the highway category draws attention to the convergence of inland transportation routes in zone 3 (Map 1, Figure 35).

TABLE 12

PERCENTAGES OF TEST-CATEGORY LAND USE IN ZONE 1

	WF	PF	ST	IT	All Categories
NE	--	43	92	25	55
SE	--	94	97	84	93
SW	--	99	97	79	94
NW	--	61	73	62	67

These patterns of railroad and highway are spatially related to clusters of processing and fabrication. Zone 1 open storage is principally involved with the marine terminal, and its numbers diminish sharply inland of zone 1. It is notable that in zone 3 the decline in heavy fabrication and heat processing coincides with the decline in railroad, suggesting a functional relationship. In zone 4, however, light fabrication actually increases as the amount of highway gradually declines. This indicates a functional independence from major highways, and this spatial pattern can be observed at NE-X015Y110 in Map 1.

Table 13 shows the percentages of inland transportation that are spatially related to processing and fabrication and storage in each zone. In zone 1, 43% of the inland transportation adjoins storage land use, much of which undoubtedly is associated with the marine terminal located there. Throughout the rest of the quadrant inland transportation is spatially related to almost no storage land use. Beginning in zone 1, processing and fabrication is adjoined by a large amount of inland transportation, continuing as a trend through zone 3, after which spatial relatedness drops sharply.

TABLE 13

PERCENTAGES OF INLAND TRANSPORTATION WITH SPATIAL RELATIONSHIP TO TEST-CATEGORY LAND USE

	NE		SE		SW		NW	
Zone	PF	ST	PF	ST	PF	ST	PF	ST
1	37	43	24	19	21	38	31	38
2	29	1	25	8	2	4	40	20
3	29	0	--	--	0	0	39	25
4	11	2	--	--	0	0	5	0
5	0	0	--	--	--	--	0	0

The spatial distribution of the test-category functions were subjected to chi square testing to derive a comprehensive interpretation of relatedness patterns. A significance level of .01 was used, at 12 degrees of freedom, with an appropriate value of 26.22, for each quadrant. Table 14 figures were computed to arrive at a chi square value of 486, which is 18.5 times larger than the appropriate value, and nearly twice as large as for the other quadrants (Table 15). The test was intended to measure the dependence of the distribution on proximity to zone 1. Therefore, the hypothesis which states that test-category land use in the northeast quadrant is spatially related to zone 1, should be rejected.

TABLE 14

SPATIAL DISTRIBUTION OF TEST-CATEGORY FUNCTIONS, NORTHEAST QUADRANT

Zones	WF	PF	ST	IT	Totals
1	95	217	334	103	749
2	--	96	23	83	202
3	--	147	2	159	308
4	--	41	3	62	106
5	--	1	0	4	5
Totals	95	502	362	411	1370

TABLE 15

CHI SQUARE RESULTS OF TEST-CATEGORY SPATIAL RELATEDNESS TO ZONE 1

	NE	SE	SW	NW
chi square value	486	89	185	263
ratio of chi square value to a.v.	18.5	3.4	7.1	10

The absence of waterfront transshipment as a variable in zones 2 through 5 increased the relatedness of the distribution to zone 1. This effect is countered by the large distribution of processing and fabrication, and inland transportation land use dispersed through zone 4 (Table 14). When these figures are combined with observation of Map 1, it can be determined where test-category land use patterns change to other land use in the northeast quadrant. It is more difficult to conclude that these changes in land use patterns are associated with changes in port activity.

It is clear that the predominant acreage of storage land use is spatially related to zone 1, and most of that is functionally related to port operations (marine terminal). Large amounts of processing and fabrication in zones 2 and 3 are spatially related to inland transportation routes. Movement linkage of these industrial sites to the waterfront area of northeast quadrant is less well defined, and therefore their functional relationship to port operations is less certain.

Southeast quadrant

Table 12 shows that nearly all test-catagory land use in this quadrant is located in zone 1 (93%). Only inland transportation land use is located beyond zone 1 to any significant degree. The Level III composition of this distribution is displayed in Table 13. Heavy fabrication and heat processing acreage, functioning as a steel plant, is predominant in zone 1, followed by open storage. Much of it. Light fabrication is primarily located in zone 2, and it is difficult to determine its functional relationship to railroad or highway routes.

The railroad category in zone 1 is largely involved functionally with the operations of the steel plant. This accounts for much of the 24% of inland transportation land use adjoining processing and fabrication in zone 1. This spatial relationship continues in zone 2 where 25% of the inland transportation in that zone adjoins processing and fabrication (Table 13). This occurs primarily north of the harbor. It is there, where most of the 19% of zone 1 inland transportatation adjoining processing and fabrication is located (Map 1). South of the harbor most inland transportation does not adjoin processing and fabrication land use. The 8% of railraod and highway that is spatially related to to storage in zone 2 is more than occurs in zone 2 of other quadrants.

A chi square value for the southeast quadrant was obtained using the figures in Table 16. The obtained value of 89 and the chi square-to-appropriate value ratio of 3.4 are shown in Table 15. These low figures indicate that the distribution of test-categories in this quadrant is more than twice as spatially related to zone 1 than the next most related (southwest) quadrant.

TABLE 16

SPATIAL DISTRIBUTION OF TEST-CATEGORY FUNCTIONS, SOUTHEAST QUADRANT

Zones	WF	PF	ST	IT	Totals
1	73	799	672	386	1930
2	0	51	18	75	144
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
Totals	73	850	690	461	2074

Test-category land use in this quadrant is obviously spatially related to zone 1. It has a consistent functional relationship to waterfront transshipment sites facilitated by inland transportation linkages.

The limited spatial distribution of test-category land use appears to be associated with the specialized nature of the waterfront transshipment sites. Only the south portion of the marine terminal, and possibly the pier at SE-X015Y050, are engaged in through shipment operations. The other sites are more certainly dedicated to facilitating the operations of processing and fabrication complexes which are located adjacent to them.

Southwest quadrant

Virtually all (99%) processing and fabrication in this quadrant is located in zone 1. Only 3% of storage is located in zones farther inland than zone 1. Inland transportation occurs primarily in zone 1, with only 21% located further inland (Table 12).

The distribution of land use displayed in Table 10 shows that, despite the wide distribution of highway beyond zone 1, very little test-category land use occurs farther inland. All railroad is located in zone 1, and appears to be primarily functionally related to the processing and fabrication facilities, the large petroleum storage field, and the shipbuilding yard (Figure 34). This conclusion is supported by the fact that 38% of zone 1 inland transportation is spatially related to storage, and that 21% adjoins processing and fabrication (Table 13). Also, in zone 2 only 2% of inland transportation adjoins processing and fabrication, and 4% adjoins storage. Farther inland spatial relatedness ceases entirely.

The figures in Table 17 were used to compute the chi square value for this quadrant, which is shown in Table 15. The distribution of storage and inland transportation in zones 2 and 3 apparently contributed to the chi square value being more than twice as large (185) as the more congested southeast quadrant. It is considerably smaller than the widely dispersed northeast quadrant. When combined with all the other evidence, it is apparent that test-category land use is spatially related to zone 1.

TABLE 17

SPATIAL DISTRIBUTION OF TEST-CATEGORY FUNCTIONS, SOUTHWEST QUADRANT

Zones	WF	PF	ST	IT	Totals
1	70	542	821	291	1724
2	0	7	10	48	65
3	0	0	17	24	41
4	0	0	0	3	3
5	0	0	0	0	0
Totals	70	549	848	366	1833

The waterfront transshipment sites in this quadrant that are associated with military facilities are adjoined by almost no test-category land use. A large marine terminal engaged in the transshipment of general cargo does not exist exist in this quadrant. Several piers, too narrow to meet that land use classification criterion, are located at points along the land-harbor interface where contiguous patterns of test-categories adjoin the land-harbor interface. The piers and these adjoining patterns appear to share specialized operational characteristics (Figures 34). Movement linkage routes are predominately located within those contiguous patterns of test-category land use. It follows that the piers are functionally related to them.

Prominant routes of inland transportation connect connect with less waterfront transshipment land use (3%) than occurs in any other quadrant (Table 7). Two rather prominent routes of inland transportation extend into inland zones (Map 1). The abrupt change in land use patterns, from test-categories to other types, seems related to the particular function of waterfront transshipment facilities. In addition, the lack of inland transportation categories adjoining those facilities may be associated with test-category land use being primarily located in zone 1.

Northwest quadrant

It can be observed in Table 12 that the percentage of test-category land use is much less confined to zone 1 than is the case in the south quadrants. Table 11 shows the wide distribution of large amounts of land use in the quadrant. The transition from zone 1 to zone 2 occurs more gradually than in the northeast quadrant. No category occurs within inland zones in amounts larger than is found in zone 1. Chemical and heat processing categories are confined to zone 1, where the principal acreage of open storage and railroad are located. The amount of light fabrication declines inland at about the same rate as does highway. The rate at which heavy fabrication declines inland of zone 1 is similar to that of railroad. More open storage acreage is located in zone 1 than any other category, but declines sharply farther inland.

A greater percentage of inland transportation land use adjoins processing and fabrication in both zones 2 and 3 than occurs in zone 1 (Table 13). Map 1 shows the wide distribution of inland transportation land use and the contiguous patterns of processing and fabrication and storage that adjoin it. The most prominent of these patterns is a blend of test-categories which extends from the marine terminal at NW-X010Y020. The two large complexes of processing and fabrication in the northeast quadrant (near NE-X010Y080) are functionally related to this pattern through significant railroad and highway routes (Figure 35).

A larger percentage of inland transportation adjoins storage land use in zones 2 and 3 than it does in the other quadrants (Table 11). Storage land use is spatially related to 38% of the inland transportation in zone 1, which is more than occurs in zones 2 or 3. It is the same percentage as occurs in zone 1 of the southwest quadrant, and somewhat less than found in zone 1 of the northeast quadrant. These figures point to an infrastructure of processing and fabrication and storage land use in zones 2 and 3, that is facilitated by an extensive network of railroad and highway routes (Map 1).

Table 18 was used to compute the chi square value for this quadrant, which is shown in Table 15. The ratio of chi square value to appropriate value of 10 indicates that the distribution of test-category land use is more spatially related to zone 1 than is the case in the northeast quadrant, but more widely scattered than the southeast and southwest quadrants.

Observation of Map 1 indicates complex patterns of land use radiating inland in all directions of the quadrant. Changes in land use patterns from test-categories to other categories occur most abruptly in the central portion of the quadrant. There, the central business district of Baltimore and a broad pattern of residential land use encroach upon the harbor. It is divided by a diffuse pattern of test-category land use extending to the northwest. Transition zones generally occur in more gradual and diffuse patterns where significant transportation routes extend inland of zone 1 (Map 1).

Where other land use patterns encroach nearest to

TABLE 18

SPATIAL DISTRIBUTION OF TEST-CATEGORY FUNCTIONS, NORTHWEST QUADRANT

Zones	WF	PF	ST	IT	Totals
1	327	1360	963	710	3360
2	0	523	218	255	996
3	0	317	131	163	611
4	0	37	2	20	59
5	0	2	0	4	6
Totals	327	2239	1314	1152	5032

the harbor, there is a conspicuous absence of prominent inland transportation routes connecting waterfront transshipment facilities. Only narrow roads rim the land-harbor interface in these places (Figure 27). The waterfront transshipment area near NW-X040Y060 is a particularly clear example of this (Map 1).

Spatial relatedness to port activities is extensive in this quadrant. But the wide distribution of large contiguous patterns of test-category land use inland of zone 1, facilitated by inland transportation routes, identifies the presence of a functionally related infrastructure. Where inland transportation does not adjoin waterfront transshipment, large patterns of test-category land use do not extend inland.

Ground Investigation

After the photointerpretation and map compilation phases were completed a ground investigation of the study area was conducted. Ten percent of each Level III category was sampled, based on their numbers displayed in Tables 8 through 11. In order to avoid site identification problems, homogeneous spatial patterns were selected from Map 1, as well as facilities that could be located easily in the aerial photography.

Table 19 shows the Level III accuracy percentages. Also shown are the accuracy percentages for each functional category based on a consolidation of the Level III category accuracy and for the data base as a whole. The land use category percentages are stratified according to how large the Level III amounts are in relation to the combined categories for each function. In this way a Level III category influences the accuracy percentage only to the extent of its numerical presense in the data base. For example, chemical processing land use was correctly identified through photointerpretation in 90% of the survey plots sampled. Only 23 survey plots were classified as chemical processing in the study area. That category has a very small influence on the accuracy percentage for the processing and fabrication group of categories.

The categories which were the most difficult to identify were light fabrication and the warehouse component

TABLE 19

PHOTOINTERPRETATION ACCURACY BASED ON GROUND INVESTIGATION

	WF	LF	HF	MP	CP	HP	CS	OS	RR	HW
Level III	95	61	89	73	90	82	78	89	100	100

	WF	PF	ST	IT
Function	95	75	87	100

	ALL CATEGORIES
Study Area	86

of covered storage. They were involved in the most cases of error. Figure 38 shows an example of a light fabrication plant, and Figure 39 shows a warehouse. A typical error was misidentifying a light fabrication plant or warehouse for a commercial office, or vise versa.

The warehouse shown in Figure 40 was misidentified as a light fabrication plant because of the raised sections of roof from which overhead cranes might be suspended. The light fabrication plant shown in Figure 41 is an example of a building easily misidentified as a warehouse.

Many piers were located along the land-harbor interface that were not wide enough to meet the areal predominance criterion. As a result more waterfront transshipment sites occured in the study area than were recorded by photointerpretation. Figure 42 shows an example of such a pier.

Figure 38. Light fabrication plant (electronics manufacturing) similar in appearance to a commercial office.

Figure 39. Covered storage land use is similar in appearance to a commercial office when trucks are not at the loading docks.

Figure 40. The roof of this warehouse is similar in appearance to a light fabrication building.

Figure 41. This light fabrication building lacks distinctive features which increases the probability of it being misidentified as a warehouse.

Figure 42. A coal transshipment pier, too narrow for classification.

The level of photointerpretation accuracy achieved in this study was largely dependent on the experience of the investigator, which includes seven years of academic research in remote sensing applied mostly to urban area and seaport analysis. Three years of professional work experience as a photointerpreter, dealing with subject matter similar to that included in this study, was particularly instrumental in producing the accuracy results.

CHAPTER IV

Conclusions

Spatial Relatedness

The majority of test-category land use in the study area is demonstrably spatially related to zone 1. Table 20 shows the spatial distribution of test-category functions in the study area and strongly supports this conclusion. Examination of Map 1 shows that distributions of zone 1 functions largely adjoin the land-harbor interface in contiguous patterns. These are in large part functionally specialized relationships that may not be associated with test-category land use patterns located inland of zone 1.

Functional Relatedness

The inland transportation network located throughout zone 1, inland of the land-harbor interface, is extensive and spatially related to industry and storage. Much of that industry and storage is contiguous with the same categories located along the interface. Railroads and highways are not always present at the interface to provide movement linkage to them and to the more extensive inland transportation network located farther inland.

It is therefore concluded that those patterns of

TABLE 20

SPATIAL DISTRIBUTION OF TEST-CATEGORY FUNCTIONS, ALL QUADRANTS OF THE STUDY AREA

Zones	WF	PF	ST	IT	Totals
1	565	2918	2790	1490	7763
2	-	677	269	461	1407
3	-	464	150	346	960
4	-	78	5	85	168
5	-	3	0	8	11
Totals	565	4140	3214	2434	10309

industry and storage spatially related to the interface, but not having transportation linkage to it, are probably not as functionally related to the land-harbor interface as they are to the infrastructure of industry and storage with which they do have movement linkage. It also follows that those patterns of industry and storage spatially related to the interface, and furnished with transportation linkage to it, probably have a significant functional relationship to test-category land use located there, but not neccessarily only to waterfront transshipment land use.

Relatedness to Port Activity

A large number of the industry and storage patterns adjoining the land-harbor interface are integrally involved with piers and quays located there. In the south quadrants where waterfront transshipment sites are principally involved with facilitating petroleum storage, steel manufacturing, and electric power production, test-category land use is confined primarily to zone 1.

In the north quadrants, where waterfront transshipment sites are principally involved with facilitating the through-shipment of containerized and general cargo and bulk coal adjacent to prominant rail and highway routes, test-category land use is spatially distibuted in large amounts inland through zone 3. The more extensive the occurance of this spatial relationship, the more contiguous is the pattern and the farther inland it extends.

Where inland transportation routes extend beyond zone 1 but without having a link to waterfront transshipment sites, large amounts of industry and storage do not occur. It can be concluded, therefore, that the spatial and functional relationships between inland transportation and waterfront transshipment are major factors in the changes in test-category land use patterns beyond zone 1. Along the land-harbor interface and inland to the limit of zone 1, most changes in patterns of test-category land use are to some degree functionally associated with waterfront transshipment sites.

Methodology Effectiveness

The methodology used in this study serves as an effective system for collecting, inventorying and mapping the test-category land use from remote sensing data. The compiled information is compatible with statistical processing that was applied to it. The methodology facilitated the analysis of the data base to determine the spatial and functional relationships of the land use categories in question. By limiting the data collection source to aerial photography it is more difficult to conclude with certainty that changes in land use patterns are associated with changes in port activity.

Further testing of the methodology might usefully be applied to other ports that have different site and situation factors. A comparison of the results would give a clearer perspective on the feasibility of using this methodology to analyze a variety of port types. The methodology should prove to be particularly useful for conducting time series studies to compare the changes in spatial and functional relationships.

By using 80 meters square survey plots, the methodology should prove to be compatible with Landsat imagery, considering its 80 meters square pixel size. This correspondence would facilitate testing of Landsat imagery with a TV scanner to compare the resultant spatial patterns.

The alphanumeric form of the data base used in this methodology could be easily adapted to a micro-computer system for automated storage and retrieval in file format, or as a symbol coded map. Special mapping software is not necessary in this case. It is about 50% more time consuming to enter the data into a computer for mapping than to compile the map manually. However, if a study area were to be examined more than once, the time expenditure would prove worthwile.

The principal disadvantage to the methodology in this study is the small scale of the aerial photography. Even with the use of a 30x magnification stereoscope the resolution of the photography was inadequate for use by this researcher to determine Level IV categories of processing and fabrication land use. Use of large scale, higher resolution aerial photography would make it possible to determine Level IV classification of industrial categories. Doing so would increase the size of the data base and the number of frames of photography. These additional data handling and cost factors would have to be considered in relation to the resulting increase in information.

GLOSSARY

Land use category: Subdivisions of land use types that more specifically define the nature of the use.

Land use function: A group of land use categories which are involved in similar operations such as storage, processing and fabrication, waterfront transshipment or inland transportation.

Land use type: The broadest generalization of major uses of land such as urban or built-up, agricultural, range and forest purposes.

Photointerpretation: The act of examining photographic images for the purpose of identifying objects and judging their significance.

Resolution: The ability of the entire photographic system, including lens, exposure, processing, and other factors, to render a sharply defined image.

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