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SCHOOL OF ENGINEERING AND APPLIED SCIENCE

EVALUATION OF FLEETING OPERATIONS IN PORTS

for

MARAD Contract [illegible]

Maritime Administration

U.S. Department of Commerce

by

[illegible], Principal Investigator

Department of Civil Engineering

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by

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October 31, 1980

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16. Abstract (Limit: 200 words)

This research develops a fleeting management evaluation model and tests it on the St. Louis Bi-State Metropolitan Port. A technique employing Markovian Decision Theory is utilized to examine site and operational alternatives to optimally provide through tow and dock delivery fleeting while minimizing harbor congestion over a 20 year planning horizon. Commodity flow forecasts are utilized, various harbor development scenarios are formulated and operational and environmental impacts are analyzed. The evaluation is undertaken from several viewpoints: development sensitive, environmentally sensitive, capital cost and regulatory sensitive, and compromise. Forms of fleeter co-operation and introduction of LASH barge technology is investigated. Conclusions and need for further research is presented. The software is available, and the model and evaluation technique can be generalized to any inland river or deep water port in the nation.

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CHAPTER I

INTRODUCTION

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INTRODUCTION

Introduction

A major aspect of efficient use of waterways and their harbors is the degree of efficiency of fleeting operations in and adjacent to harbor bounds. Determinants of fleeting include the frequency and nature of tows to be made up, and harbor movement of barges to loading and unloading docks influenced by port facilities and private industrial land use cargo handling areas. Major impacts of poor fleeting arrangement include harbor and through-line tow congestion, increased tug travel time, negative environmental impacts, incidence of hazardous cargo potential (i.e., barge breakaway, fires and spills) and poor shoreline land use of industrial potential.

An evaluation system is necessary to respond to all of the above. Fleeting operations should be studied to respond to the inter-related aspects of shoreline industrial and commodity flow growth, and the character of river operation, in meaningful time-frames.

This research makes use of previous Kearney MARAD Studies on the St. Louis Bi-State Port Region, which noted fleeting as a major problem, and proposes an evaluation model to optimize harbor fleeting activities, with respect to work rules, industrial sites, harbor origin-destination and through flow movement operation. It does so by employing an evaluation technique termed Markovian Decision Analysis, which allows the long run operational growth of the harbor to be broken into incremental stages, analyzing optimum fleeting locations and operations for each stage in a manner which maximizes long run benefits. St. Louis is used as a case study, due to the presence of data, the Principal Investigator's thorough knowledge with respect to it, and the critical need for answers to the fleeting problem in the Bi-State Region. The study's findings are currently being used by the St. Louis Metropolitan Port Advisory Council to develop a long range fleeting policy and management plan for the Metropolitan Port. However, the technique developed and tested has complete applicability to any major deep water or inland port or harbor. Thus, the research addresses significant problems and creatively advances the state of the art.

TECHNICAL DESCRIPTION OF PROPOSED RESEARCH

Objectives of the Research

As stated in the introduction, the planning and operational character of fleeting in a port has significant consequences with respect to the land use and river operations of the port system. Therefore, the objectives of the research are:

1) To understand the relationship between fleeting and through-tow makeup.
2) To understand the relationship between fleeting and efficient usage of land and industrial sites and their cargo handling locations in the port area.
3) Based on (1) and (2) above, develop a fleeting evaluation technique which may be used for long and short range planning of investment and operations, and which is responsive to the following aspects of fleeting:

   Congestion and harbor travel time.

   Environmental impacts (dredging, fish and wildlife, water pollution, noise, air quality).

Construction and river maintenance costs.

Commodity flow and intra-harbor origin-destination of barges.

Industrial land use planning.

Size and power characteristics of tugs in the harbor fleet.

4) Test and demonstrate the technique on the St. Louis area using actual site data and operation; subsequently generalize the technique for use on any harbor.

Research Work Plan

The research was processed in seven phases, as illustrated in figure 1. Each phase often had several tasks within it. Phase 1, composed of four tasks, was designed to provide familiarity with respect to St. Louis port, harbor and fleeting operations. Task 1.1 reviewed the conventional professional literature of AAPA, ASCE, TRB and MARAD and the World Bank with respect to port and harbor design and operation. Task 1.2 focused on the St. Louis Bi-State harbor literature, making use of previous Kearney Reports, sources from the District Office of the US Army Corps of Engineers, the Mid-America Ports study and the St. Louis City and Jefferson County Port Studies undertaken in the past, and still underway. Task 1.3 discussed fleeting operations with the major fleeters in St. Louis and major towing companies and industries dependent on fleeting service. This task ascertained general methods and strategies of operation, current and projected problems, and the economics of the fleeting operation in its current status. General patterns of operation with respect to through-tow make-up versus dock delivery fleeting and pricing were established in Task 1.4.

Phase 2 reviewed the complementary land side operation having long term impacts on fleeting. Projected land use shifts in the Port shoreline area with respect to water-related industrial land use were documented in Task 2.1 for the North riverfront area, the Central Harbor, the South riverfront and South of Jefferson Barracks Bridge. In a related manner Task 2.2 reviewed long term commodity projections with an eye to accurately developing their short and long term origin and destination patterns within the harbor. A catalogue of intra-harbor origin-destination patterns was developed as the output of this task. Using such a catalogue, a documentation of the different states or sets of conditions the harbor may be in was developed for 5, 10, 15, 20 year planning horizons in the future. For each of these time periods, a set of mutually exclusive states was defined by:

location set of land side uses.

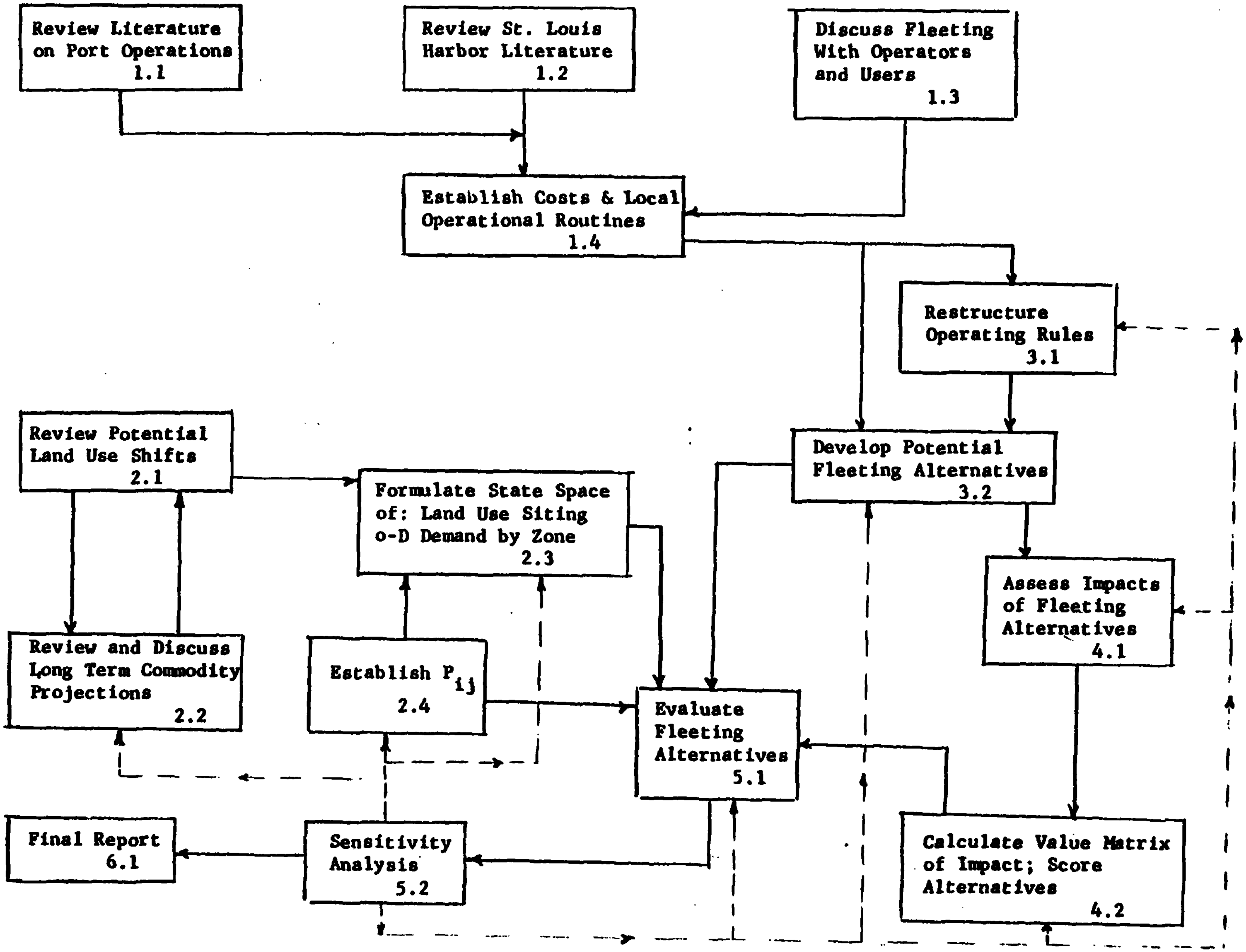
demand level of each commodity.

likely zone or origin-destination pattern of commodity transfer in harbor, by commodity type.

The above states, so developed by the analyst, are a quantitative and descriptively exhaustive list of all of the ways the harbor and its operations could foreseeably develop. A probability matrix, P_{ij} can be attached to the likelihood of transition of the harbor from one of these states to another over a ten year period. These P_{ij} were established in Task 2.4 from review of past harbor trends, national economic and technological trends, and legal, economic, industrial and real estate incentives offered for needed industrial sites along the riverfront. These P_{ij} serve to weight the chances of particular states occurring, and are dealt with further in the evaluation phase.

Figure 1

Research Work Plan



Phase 3 returned to the fleeting operation, and in Task 3.1 investigated the possibility of restructuring general operating strategies for the fleeter, particularly in his priority for through-tow makeup vs dockside delivery. Pricing mechanisms and "segmented fleeting" for various types of operation and the zonal location along the river were investigated, in conjunction with various priority schemes. Using this as input, Task 3.2 generated a comprehensive set of fleeting alternatives to be examined, including:

- Newly constructed anchor or shoreline fleeting sites.
- Converted or reconstructed sites.
- Changed pricing structures.
- Restriction on shoreline dock installation.
- Segmented fleeting, either in the storage or operation of tow make-up by:
  - commodity
  - harbor origin or destination zone
- Priority operations of through-tow make-up vs. dockside service on demand.
- Number, size and horsepower of tugs available for fleeting in the harbor and its adjacent reaches of river.

The above alternatives were each reviewed for their impacts on the following:

- fish and wildlife damage and associated dredging impacts.
- water quality.
- noise.
- construction and maintenance costs.

tug travel time.

harbor congestion.

hazardous cargo incidence (barge breakaway, fire, spill).

For the above impacts where measurements techniques are available, such as relative tug travel time alterations known to fleeters, these were employed. In the environmental areas, use of expert opinion from the Army Corps of Engineers, the Missouri Department of Natural Resources and other appropriate environmental agencies was used to help the analyst develop rankings of the alternatives for each impact. A comprehensive scoring of the above impacts was made in Task 4.2, using a Value Matrix, which attempted to assess the importance of each impact to the decision makers according to several criteria. Table 1 details the effort succinctly. Note that first all costable, or monetary impacts of the alternative are accounted for in both the private and public sectors. The monetary analysis component is then included with the non-monetary components in Section B, and treated as discussed in Table 1. This technique allows each alternative to be scored for each state, and the value of a particular alternative as states transition from one to another can be captured by noting the relative difference in scores. Probably of most importance, it allows the decision maker(s) to articulate their preferences with respect to the importance of the variety of economic and environmental consequences by using the weighting schemes. One may alter the weighting scheme in the sensitivity analyses of the modelling runs, thus yielding the ability to clearly articulate trade-offs between economic and environmental aspects of the problem for particular alternatives. This attribute yields a management framework for rigorous, consistent and systematic alternative and policy justification,

TABLE 1

A NOTE ON VALUE MATRIX FORMULATION

A.) Monetary Component:

- Average Annualized Cost
- B/C Ratios
- Rate of Return
- Net Benefits

B.) Non-Monetary Components-Developing the Value Matrix:

Example

	Relative Weight on 100 Scale
Monetary Component from above	25
Water Quality	5
Dredging	5
Fish and Wildlife	10
Economic Value Added	35
Energy Consumption	15
Land Use-Flora and Fauna	5
	100

The impact level of each non-monetary component is recorded for each alternative used in each state. The alternative with best impact level is given highest weight from above line item. Each other alternative is given proportionally less weight, based on its impact level in proportion to that of alternative having best impact level. This is done on all line item impacts of above, then summed for each alternative for each state. This allows each alternative to be scored for each state. It allows sensitivity analysis to be performed on weighting and impacts included.

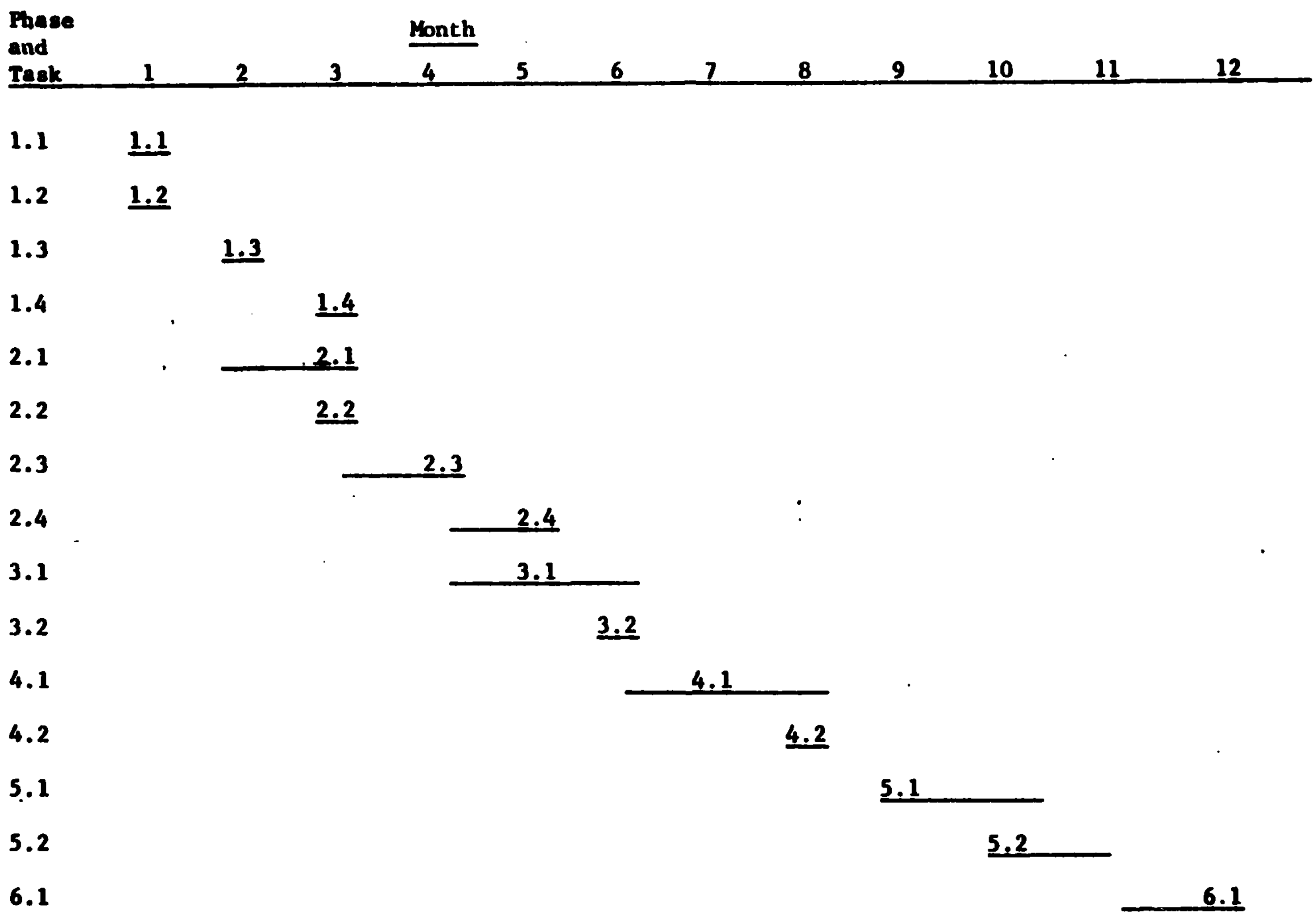
and adequate inclusion of the viewpoints of the pragmatic power structure surrounding the problem.

The combination of the likely states of harbor development and the associated probabilities from phase 2 and the delineation of impacts of the alternatives from phase 4 were combined and evaluated in phase 5, having two tasks. Task 5.1 used the above in a process termed Markovian Decision Theory, which investigates, through simultaneous equation techniques, the relative value of the harbor being in a particular state and employing a particular alternative with its impacts scored as recorded in the output. The value matrices of 4.2 develop an optimal set of fleeting alternatives for each specific possible harbor state at each time period in the future, resulting in a growth, planning and operational policy for harbor fleeting. Task 5.2 was a sensitivity analysis, altering appropriate probability parameters, alternatives specification, and impact weights, and yielding an exhaustive set of solutions for any set of parameters the regional port is likely to be found in. Finally, the statements relating to the above were synthesized in Task 6.1 and documented in this final report with appropriate text, graphics and appendices.

Phasing and Scheduling

The phasing and scheduling of the project is illustrated in figure 2. The first month effort reviewed the literature on port operations and the St. Louis Harbor, Tasks 1.1 and 1.2, respectively. Task 1.3, discussions with fleeting operators was completed during the second month. The establishment of conclusions as to local costs and operating patterns, Task 1.4, overlapping with Task 1.3, was completed at the end of the third month.

Figure 2, Phasing and Scheduling



Task 2.1, review of potential land use shifts, was made during the second and third month, while related review of commodity flow and intra-harbor origin-destinations was completed during the third month. The formulation of the harbor states, Task 2.3 were completed during the third and fourth month, and the related P_{ij} transition probabilities were formulated during the fourth and fifth month. The restructuring of operating rules, Task 3.1, was reviewed during the period of the third through the sixth month, with a final set of fleeting alternatives generated in Task 3.2 during the fifth and sixth months. Their impacts in Task 4.1 were assessed during the sixth, seventh and eighth month, with value-matrix scoring of them in Task 4.2 during the eighth month. Formal evaluation modelling of the fleeting alternatives occurred during the ninth and tenth months, with sensitivity analysis of them in Task 5.2 extending through the eleventh month. The final report writing of Task 6.1 occurred during the eleventh and twelfth month of the contract period.

Availability of Computer Software

The evaluation model computer software developed and tested in this research is available at the following locations, through contact of the individuals listed below:

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Overview of Forthcoming Chapters

The following chapters detail the research operations described above. Chapter II is a literature search related to port planning and studies relevant to the St. Louis Bi-State Region, and a description and justification of the St. Louis Bi-State Metropolitan Port as the case study area. Chapter III is a detailed description of fleeting operations and relevant fleeting data for the region, followed by a rigorous research mathematics treatment of the evaluation modelling approach in Chapter IV. Chapter V is the computational modelling results of the St. Louis case study data, and appropriate sensitivity analysis, followed by Chapter VI, which draws appropriate research and operational conclusions, and comments on potential further research which could enhance the state of the art.

CHAPTER II

LITERATURE SEARCH - SELECTION OF CASE STUDY AREA

CHAPTER II

LITERATURE REVIEW - SELECTION OF CASE STUDY AREA

Introduction

The objective of this chapter is to briefly review literature which aided in background knowledge and problem formulation. The chapter includes general aspects of U.S. port planning, regional port planning studies of relevance to the St. Louis Bi-State Metropolitan Port, and the rationale for selection the St. Louis regional port as the case study area.

General Aspects of U.S. Port Planning

Four articles are worthy of discussion to aid in overviewing U.S. port planning. In preparing Port Development in the United States[1], the panel of authors had specific objectives: a) assessing implications of technology and public policy upon port planning, development, and operations, as well as upon the port locations and service areas and b) determining the structure of relationships between local and Federal governments with respect to ports. Major areas of concern including containerization, maintenance and dredging, and land use and environmental impact have been leading to conflict between private port organizations and governmental authorities. The increasing importance of port development to the economy in terms of foreign trade gave further impetus to the study.

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[1] Port Development in the United States - prepared by the Panel on Future Port Requirements of the United States Maritime Transportation Research Board, Commission on Socioeconomic Systems, National Research Council, National Academy of Sciences, Washington, DC, 1976.

In successive chapters, technological change, institutional perspectives, data requirements, and current issues are examined to determine the impacts of port development upon land use, metropolitan and regional economics, the labor force, physical and social attributes of cities and regions, and the coastal environment. Recommendations are set forth for port financing, planning and development, rates and regulation, environmental priorities and labor issues. The report concludes with appendices on Federal port studies, commodity forecasts, Federal agencies dealing with port operations, planning, and regulation, and a flowchart of the process required to obtain Congressional authorization for water resources projects.

In a somewhat similar study, Federal Port Policy in the United States[2], examines the impact of changes in shipping technology and increasing environmental concern on port policy. While focusing primarily upon deepwater ports and Federal policies, this text also addresses inland port and waterway concerns, and state, regional, and local needs in the planning, construction, operations, and policy arenas.

The authors first discuss port planning from local and national perspectives. Port operational structure and the effects of the "container revolution" are reviewed, along with a historical perspective of the Federal role in policymaking (regulatory power, user charges, evaluation of projects, legislation), and an overview of activities (organizational, policy research, planning and development)

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[2] Federal Port Policy in the United States - Henry S. Marcus, James E. Short, John C. Kuypers, Paul O. Roberts, MIT Press, Cambridge, Mass., 1976.

involving Federal, state, and local agencies. Regulatory and operations activities are illustrated with several Federal Maritime Commission cases.

The second part of the text covers the Federal organizations which are key actors in policy development and implementation: the Environmental Protection Agency and the Council on Environmental Quality, the Army Corps of Engineers, the Maritime Administration, the Coast Guard, and the Department of Transportation. Policy summaries, duties and responsibilities, and relevant literature by the agencies are cited along with organizational charts, funding, and procedural outlines, where applicable.

Key elements of port development and conclusions and recommendations are summarized in the final two chapters. The Federal influences of funding, implementation of existing regulations, and policy formulation are contrasted with the lack of a comprehensive Federal port policy, particularly in the areas of container-handling capacity and environmental protection. A series of Appendices covering statutes, organizational lists and procedures, legislation, port project areas, and Federal water resources expenditures is included.

The Inland Navigation Simulation Model developed by the Army Corps of Engineers to study the most efficient methods possible for operating the inland waterways and to aid in the selection of efficient size, location, and timing of waterways improvements is discussed in <u>Transportation Research Record 704</u>[3]. The model also evaluates system

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[3] Lengyel, B.W., et al. "Inland Navigation Simulation Model," <u>Transportation Research Record 704</u>, January 1978, Transportation Research Board, National Academy of Sciences, Washington, D.C.

performance for waterways planning, project studies, and operations. Waterways are modeled as nodes (ports, locks, junction points) and links (sections of river between nodes). Within each lock, processing time is shown in approach, entry, chamber, and exit segments. Commodities are modeled as individual shipments with discrete origins and destinations.

Data for the model was obtained from navigation charts and the Corps Performance Monitoring System, the Waterborne Commerce Statistics Center, vessel data, and Coast Guard regulations, as well as from field studies. Probability distributions in various systems were tested for randomness. Sensitivity analyses were run on the effects of towing equipment, timing and size of shipments, lock characteristics, port handling, and waterway characteristics. The final model tests involved the reproduction of system conditions for a given time period.

Three versions of the model were developed and tested. The original nationwide scale of the model was reduced to cover a portion of the Ohio River system only. The majority of modifications in the model from version to version involved logic alterations to accomodate the study of various lock types and lockage policies. Final results from the third version showed fair agreement with the historical data. Limitations of computer time, money, and resources prevented further modifications to improve the models' flexibility.

A recent document, The Mid America Ports Study, is a comprehensive multi-state study of port capacity, commodity forecasts and future port investment needs to the year 2000 in the study area of all states encompassing the inland water flows in the Mississippi River

Basin and the Gulf Intra Coastal Waterway.[4] Seventeen states participated in the study. The final report consists of nineteen volumes, with a detailed study volume for each of the participating states. The main report in volume one is divided into four phases, which can be summarized as follows:

1) The Definition Phase - which develops the study regions and sub-regions, and inventories economics, demographics, present commodity flow and the current port facilities over the 17 states, followed by a detailed overview of U.S. rail, water and cargo handling facilities and their locations within the study area.

2) The Analysis and Forecast Phase - utilizes information on current port institutional structures, together with forecasts of future shipper and cargo handling technology, in conjunction with an econometric oriented modal split model to yield commodity forecasts and an analysis of port capacity to the year 2000 over all reaches of the river in the study area.

3) The Requirements Phase - translates the above findings into investment needs and their related terminal development costs against a variety of scenarios, including the impacts of user charges, presence or lack of congestion at specific lockage facilities on the upper Mississippi, and various potentials for future local and federal participation in port planning.

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[4] Mid-America Ports Study - Volumes I-XIX, June 1979, by Tippets - Abbett - McCarthy - Stratton, for the Maritime Administration, U.S. Department of Commerce.

4) The Conclusions Phase - specifically states:

1) Cargo in the Mid-American Port region will exceed existing capacity by 700 million tons by the year 2000.

2) Coal will account for about 35% of the above capacity deficiency.

3) A Capital Investment of 9.5 billion will be required to service these deficiencies, resulting in the construction of 1000 new terminals and development of 11,000 acres of land.

4) Major revision of our port planning structures is necessary, with vigorous participation at the state level, and insistence on port master planning at the local level.

This report offers an excellent format from which to study very recent transportation legislative changes likely to influence port planning, specifically truck and rail deregulation, and their effects on a region in conjunction with various types of user charges.

Regional Port Planning Studies

The St. Louis metropolitan Bi-State Port consists of seven port districts (St. Charles, Tri-City, St. Louis, St. Louis County, Southwest, Jefferson, and Kaskaskia) organized as the St. Louis Bi-State Regional Port, administered by the St. Louis Bi-State Development Agency, which has charter powers similar to the Port of New York Authority with respect to implementation of multi-jurisdictional public works programs. Two regional studies are relevent as a brief, yet comprehensive overview of issues facing the St. Louis Bi-State Regional Port.

The Port of Metropolitan St. Louis Study, by A.T. Kearney, Inc., April, 1977, analyzes the present operational and land-use profiles of the Port of Metropolitan St. Louis, and develops alternatives to upgrade them in order to transform the Port into a vital industrial center and intermodal transportation hub.

Over the last decade, tonnage on the inland waterway system has been increasing by about five percent annually, but the St. Louis area tonnage was increasing at a significantly lower rate; in 1972, a Port Development Task Force was formed to study this problem and to recommend a course of action tc alleviate it. A.T. Kearney, Inc. and East-West Gateway Coordinating Council coordinated the research effort, with the former preparing an Executive Summary, a Study of the Port, and Appendices covering the port profile, commodity market analysis, port operations analysis, an analysis of new development sites, and market research findings. East-West Gateway prepared inventories of land use and roads and bridges, and a port atlas. The selection of a set of sites for regional development emphasis was a joint effort.

The study develops a profile of the port from historical, environmental, and transportation access viewpoints. Dock structures and facilities are inventoried in detail, particularly with respect to cargo-handling capabilities and service by utilities. Relationships between dock facilities and intermodal transfers are examined, as well as the effects of river stage on cargo handling efficiency.

Commodity flows for waterborne coal, fuels, cash grains, durable manufactured goods, mining products, and chemicals are based on 1972 patterns and are factored down from Bureau of Economic Analysis Region 114 data covering 87 counties in the region. Origin-destination tables are given for each commodity. Port operations are presented for loading, unloading, and storage operations for thirteen major dry bulk, liquid bulk, and general cargoes. Handling characteristics and facility requirements are given, along with detailed flowcharts and costs for typical loading and unloading operations.

Market research findings gathered from interviews with major waterway users are employed as a basis for industrial site selection and development, as well as for the development of fleeting areas, recreational entities, and harbor improvement plans. The plans are devised to maximize economic benefit to the St. Louis region as a whole, occasionally to the disadvantage of local interests. Criteria for selection fell into either "critical", "important", or "minor" categories, while development was staged I: 0-5 yrs.; II: 5-15 yrs.; III: 15-25+ yrs. to reflect available funds for preparation and the accompanying required planning horizon.

The selection of industrial development sites proceeded in four stages. A preliminary screening identified fifty-five sites (19 on the Missouri River, 30 on the Mississippi, and six on the Kaskaskia River), with water-side access and topography, environmental sensitivity, land-side access, and susceptibility to flooding used as screening criteria. Market research showed opportunities for twelve major manufacturing activities (domestic grain milling, grain storage and transfer, fertilizer storage and distribution, specialty chemical manufacturing, basic chemical production, petroleum storage and distribution, small-scale petroleum refining, aluminum reduction, general cargo and Foreign Trade Zone, large metal fabrication, shop construction and repair, and coal transfer) on twenty-two of the sites from the preliminary screening.

In further refinement, a separate volume gives detailed site analyses of these areas, including color-coded maps, utility availability, land- and water-side access, and recommended improvements. Final site screening for industrial development is accomplished on the basis of a systematic screening of all sites which met the express criteria, and the role of those sites in the context of a regional development plan. It was found that one or more site alternatives were feasible for each manufacturing opportunity with the exception of ship construction and repair, and that some sites were possibly suited for more than one opportunity. Here, along with individual site analyses, the regional-emphasis priority prevailed. The final analysis allocated development to 22 sites, allowing an overlap of opportunities on some sites, and the possibility of short-run interregional competition in certain areas. Many of the sites selected require upgrading of existing facilities in lieu of new construction. All sites selected for development to the year 2000 requirements of the Port were capable of being developed in Stage I or Stage II formats. Barge fleeting is presented in the report as a critical regional port concern in order to sustain the commodity flow and offer efficient port-terminal delivery systems to support the above proposed development sites.

Corps of Engineers Study

The St. Louis District, U.S. Army Corps of Engineers St. Louis Harbor Evaluation Study, April, 1978, was authorized through a resolution by the Committee on Public Works, U.S. House of Representatives, which called for a review of reports on the Mississippi River to determine causes, and reduction or elimination, of the problem of sedimentation in the St. Louis Harbor. It represents a first-phase study for, "determining the advisability of making a detailed study of improvements for the St. Louis Harbor area on and/or adjacent to the Mississippi River in the vicinity of St. Louis, Missouri". The harbor limits are taken from River Mile 191.2 at the mouth of Watkins Creek to

River Mile 169.0, Jefferson Barracks Bridge. A nine-foot channel depth and a minimum 300' width at low water (-3.5 feet at the Market Street, St. Louis guage) are maintained therein under the River and Harbor Act of 1927.

Physical aspects of the harbor concerns include hazards to navigation in the form of bridge piers, reduced visibility and manueverability in poor weather (fog, wind, currents), and ice; river stages of abnormally high and low water, and the extreme range in river stages throughout the harbor. Local concern prompted a long succession of studies, beginning in 1964 after a winter of extremely low flows and heavy sediment deposition.

The study substance includes a set of Tables of tonnage inbound, outbound, and within the harbor for 1972 through 1976 for limits of miles 171.0-190.0 ("old limits") and miles 138.8-208.8 ("new limits"). Investigation of the sedimentation problem was initiated by analyzing sediment records for the Missouri River and Upper Mississippi, and a model was constructed at the Waterways Experiment Station, Vicksburg, Mississippi.

In the context of navigational issues, a summary of projected land needs is presented. Existing use areas within the harbor, land use trends, land requirements, land available for development, and the impacts of river fluctuations are discussed. The Federal posture of limiting Corps of Engineers responsibility to the provision of access channels and general navigational aids, and giving local agencies enforcement power for harbor development and land-use control is discussed as a preface to the formulation of the Corps' Plan of Study. Two objectives, National Economic Development and Environmental Quality, control the formulation of an appraisal process and a set of evaluation criteria which lead to a contribution to National Objectives (here, related Soley to the sedimentation issue), and the choice of alternatives for further analysis. These objectives yield a number of alternatives presented for consideration: the construction of a lock and dam downstream of Jefferson Barracks, dredging throughout the harbor, dredging at selected locations, constructing regulating works; and selected construction of fleeting areas.

An economic analysis of problems arising from siltation was prepared by the Corps on the basis of extensive interviews. The Corps stresses caution with respect to economic rationale of terminal use, and possible future interference by anchor fleeting with safety and navigational-channel maintenance procedures. The critical issue by 2000 seems to be that of land availability; their projected demand for 565 acres of land and 5000' of waterfront footage not requiring extensive flood protection may cause developmental constraints by 1985.

The study includes detailed Appendices elaborating on the main findings. Appendix A gives cost estimates for nine alternative regulating works, a fleeting area, and four off-channel harbors, based on a 6 5/8% interest rate and 50-yr amortization period. Appendix B is a benefit evaluation based on the Kearney study and interviews with local fleeters and operators. Appendix C presents the results of the hydraulic model investigation of shoaling conducted at the Waterways Experiment Station. Appendix D gives the Summary and Analysis of St. Louis Sedimentation Records in relation to the harbor sedimentation problem.

Choice of the St. Louis Bi-State Regional Port as a Case Study Site

The research techniques developed herein will be demonstrated on the St. Louis Bi-state Regional Port as the case study site. As stated in the literature review, the regional port is composed of seven local port districts over a 70 mile reach of river encompassing all St. Louis river commercial activities. It is an appropriate case study locale due to the following:

1) It is the largest inland port on the national river system, in terms of commodity flow, carrying 22 million tons in 1977, with forecast ranges of 71-100 million tons by year 2000.

2) It is the port immediately below lock and dam 26, yielding the major tow break up point on the inland river system, resulting in a 1977 fleeting volume of 42,800 barges per nine month navigation season.

3) As such, fleeting is considered one of the port region's most critical problems, and this locale is the epitome of fleeting problems nationwide.

4) Noticeable impact of fleeting on other modal operations and industrial park and terminal development occurs, as will be discussed in forthcoming chapters.

5) The port is truly multimodal in nature, interacting with rail, truck, TOFC, COFC and terminal capabilities to process the commodity flow. Thus, fleeting operations affect all aspects of the port and terminal activities.

6) A rich data base exists, due to active on going port planning, active public terminal operators, several local port studies and a recently accepted commodity flow forecast which is discussed in chapter 3.

7) Proximity of the principal investigator to the site and familiarity with port operations and data bases.

The forthcoming chapter details the inventory of fleeting, operational and commodity flow data necessary to develop the case study evaluation.

CHAPTER III

INVENTORY OF FLEETING OPERATIONS AND DATA

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Introduction

The port of metropolitan St. Louis is the most active inland port in the United States. Significant levels of barge traffic are handled through the port for through tows, transshipments, and local loading or discharge. To accommodate this traffic, it is essential that adequate and conveniently-located fleeting areas be provided. This chapter discusses the permit procedures, commodity flows, and operational issues that relate to fleeting in the St. Louis Bi-State Port Region.

Permit Procedures

Before any work in or affecting navigable waters may commence, a permit must be issued by the Department of the Army, Corps of Engineers, according to Section 10 of the Rivers and Harbors Act (1899) and Section 404 of the Federal Water Pollution Control Act (PL-92-500). The St. Louis area falls within the jurisdiction of the St. Louis Corps District.

Rules for Permits

Applicants must file form ENG 1721, issue of 1 April 1974 which provides a number of general conditions under which proposed activities are governed. In general, permits are issued for a given length of shoreline and for a maximum width (measured from the shore outwards to the channel). Maximum allowable capacity is also computed by length, assuming that each barge is 200' long. Fleeting permit requirements for anchor barges must take into consideration the related aspects of the preservation of shoreline habitats and channel navigation parameters, particularly when considering the proposed disposal methods for dredge spoil, and the anchoring methods to be utilized. For a detailed discussion of these requirements as applied to proposed anchor barge sites, refer to the Appendix D.

'Grandfather' Permits

Fleeters in operation as of December, 1968, but not authorized by Corps of Engineers permit, are considered to fall under the category of "grandfather clause" operators. In 1968, those fleeters were given the opportunity to obtain a permit under a nationwide all inclusive permitting process applied to all operators in business before this date.

Presently-Utilized Fleeting Areas

The "permanent capacity" of a fleeting site is a function of its length. In most cases, the ceiling on the number of barges which may be fleeted is based on the applicant's request, although the Corps occasionally sets a lower limit for reasons of safety. The data on fleeting operations has been collected from the Corps' files of current permit holders. Out of a total of 38 fleeting areas examined in the Port of St. Louis, 18 have permits in force, seven have permits pending in various stages, and thirteen are operating under grandfather clauses which are still under investigation. Using the aerial fly-over of June, 1980, and scale drawings of the related locations, the following capacities, based on a typical width abreast of 200' and non-impedance of navigational channels and docks, have been developed:

Permitted Capacity	554	Barges
Grandfather Capacity	489	Barges
Total Capacity	1043	Barges

Detailed site information is presented on these facilities in Appendix C.

Regional Scenarios

To facilitate the understanding of origin-destination and commodity flow levels in the St. Louis Bi-State region, a set of regional scenarios was constructed. Waterborne commodity flows are greatly tied to the demand for raw material inputs to basic industry. Thus, an initial examination of regional economic parameters often tied to basic industry allows a knowledgeable starting point from which to refine macro-scale commodity flow forecast model output.

As can be seen from attached Table 2, the ideal, or "economic boom" state shows relatively great increases in regional population, total employment, manufacturing employment and personal income over a two decade future period. The high growth state shows significant, but more realistically attainable levels of these parameters, while the norm state represents status quo without meaningful growth in economic indicators, and the low state depicts the region in decline relative to other national and mid-west economic centers.

Regional Commodity Flow Forecasts

A set of refined St. Louis Bi-State Regional commodity flows based on the above regional economic scenarios was developed as follows:

1) Bureau of Economic Analysis Region (BEAR) regression forecasts of previous St. Louis port studies were reviewed for levels of original data aggregation, commodity classification and statistical quality of variance.

2) Detailed reviews of industrial and port related market studies and surveys were made to accurately assess target industries of the St. Louis region having an impact on waterborne commodity movement on the river, and responding in a predictable manner to national economic and trade behavior.

Table 2

ECONOMIC GROWTH STATES
ST. LOUIS METROPOLITAN AREA

		Percent Increase	
A.	Population	1980-1990	1990-2000
	State 1 Ideal	17.0	13.0
	State 2 High	14.0	10.0
	State 3 Norm	11.3	7.3
	State 4 Low	8.0	6.0
B.	Total Employment		
	State 1 Ideal	28.0	24.0
	State 2 High	21.9	17.9
	State 3 Norm	15.6	14.1
	State 4 Low	11.5	10.5
C.	Manufacturing Employment		
	State 1 Ideal	34.1	26.7
	State 2 High	25.1	15.2
	State 3 Norm	13.3	11.0
	State 4 Low	12.6	9.4
D.	Personal Income		
	State 1 Ideal	143.3	124.0
	State 2 High	119.9	110.0
	State 3 Norm	98.6	89.5
	State 4 Low	62.9	55.3

Source: REAL ESTATE ANALYSTS LIMITED, July, 1979.

3) Detailed interviews were performed with barge operators, railroads, trucking and basic industries and agricultural interests making use of the river and unique intermodal linkages and unit train-unit tow combinations along the St. Louis riverfront.

4) The baseline commodity flows from step 1 were then adjusted to reflect the regional wealth and marketing impacts. Adjustments were made to yield output for three of the four economic states, as illustrated in Table 3.

5) At the request of community industrial interests, the high growth state was studied in detail, as a basis for design of particular port facilities and development of an industrial incentives strategy.

A review of Table 3 in light of the above exhibits several results worthy of note. They are:

1) No forecast was made for the ideal or "economic boom" state. It was felt that the number of simultaneous economic-inflation, energy and international political and trade factors required to be in harmony to achieve such a status was unrealistic to assume, yielding no real meaning to such forecast outcome.

2) Forecasts for the other three states poignantly exhibit the difference between high and declining regional economic activity and its relation to port development and waterborne commodity flow. The gross total of flows for the high state (71,768,956 short tons) is 23% higher than the norm-status quo state (58,135,580 short tons), which is 36% higher than the tonnage of the low-regional decline state (42,828,903 short tons).

3) Key commodities can be identified from the table which represent response to the unique intermodal-agricultural hinterland location of St. Louis, and/or its strategic position below Lock and Dam 26, or in response to regional market study indicators. These are:

   Cash Grains and Grain Products
   Coal
   Petroleum and Petroleum Products
   Chemicals
   Fabricated Metals

For the purposes of port district facility design, and future interaction with potential growth industries likely to be attracted to the region, achievement of the high growth state economic target and port development was stated as the planning goal by the analysts over

Table 3

ST. LOUIS BI-STATE REGION WATERBORNE COMMODITY FLOW PROJECTIONS - 1976-2000
(TONNAGE IN SHORT TONS)

COMMODITY	YEAR 2000 HIGH GROWTH STATE % INCREASE	YEAR 2000 HIGH GROWTH STATE TONNAGE	YEAR 2000 NORM GROWTH STATE % INCREASE	YEAR 2000 NORM GROWTH STATE TONNAGE	YEAR 2000 LOW GROWTH STATE % INCREASE	YEAR 2000 LOW GROWTH STATE TONNAGE
CASH GRAINS	100	6,918,000	68	4,704,000	55	3,770,000
IRON ORE	50	15,000	42	12,600	38	11,400
METAL ORES	54	78,945	44	64,326	40	58,478
COAL	372	30,000,000	319	25,725,804	218	17,580,645
PETROLEUM & PROD.	66	14,613,663	54	11,956,633	41	9,078,184
SUGAR	35	220,000	29	182,285	23	144,571
GRAIN MILL PROD.	45	2,637,000	39	2,285,400	34	1,992,400
LUMBER PRODUCTS	90	5,250	80	4,667	68	3,967
PAPER PRODUCTS	90	72,000	85	68,000	79	63,200
CHEMICALS	160	3,427,460	109	2,334,957	90	1,927,946
FUELS (SEE PETROLEUM PROD.)	-	-	-	-	-	-
IRON & STEEL PROD.	102	1,489,000	85	1,240,833	76	1,109,451
NON FERROUS PROD.	84	78,000	78	72,429	68	63,142
FABRICATED METAL	114	74,000	91	59,070	60	38,947
MINING PRODUCTS	108	5,894,000	90	4,911,666	66	3,601,889
NON DURABLE MFG.	60	191,638	48	153,310	36	114,983
DURABLE MFG.	100	6,055,000	72	4,359,600	54	3,269,700
		71,768,956		58,135,580		42,828,903

High is 23% higher than norm - Norm is 36% higher than low.

the 20 year development horizon. The following comments are relevant to the above key commodities as forecast for the high growth state:

1) Grain - A Commodity in Crisis of Demand and Carrier Supply

A crisis in the movement of grain from the farmer to the export port has been building to an overwhelming proportion since 1973. With national attention on the negative balance of payments, little attention has been directed toward the dramatic growth of grain exports within the same time period as the escalation of the O.P.E.C. prices for oil. Grain marketers generally agree that the 1979 exports of mid-west grains will double the 1973 quantities. Some indicate that the total may be as much as three times the 1973 total. The national transportation capability, whether it be truck, rail, or water, has been overwhelmed by the dynamic growth in the requirement for grain transportation.

As such, the transportation industry has overloaded the builders of covered hopper cars and the shipyards with orders for new equipment in an effort to meet this demand. Each mode has made a commendable effort to accomodate the extremely rapid increase in the demand for transportation equipment to carry grain from the farmer to the port. Since very little of the grain from the upper mid-west moves to the Gulf Coast by truck, the preponderence of this burden has fallen upon the railroads and the water carriers. Concurrently, decrease in the availability of fuel for power for the transfer has occurred as a result of the energy crisis. This factor has further aggravated the crisis in movement of the grain.

For some time leaders in the grain and transportation industries have been speaking out in public in an effort to attract attention to the crisis in the movement of grain. One of their strongest points is the pre-eminence of grain in countering the pattern of negative balance of payments. These leaders are consistently urging that the grain marketers, the transportation industry, and governments join and make a united effort to implement the movement of grain to the ports for export. Provincial differences, fleeting capacity problems in the St. Louis region below Lock & Dam 26, many regulations, and proprietary interests will have to yield to the common objective if the crisis is to be conquered.

2) Coal - Unit Intermodal Co-ordination

In a like manner, the most phenomenal increase in tonnage is western coal through one to three 100 car unit trains interchanging with a daily 10 barge unit tow bound for power plants in Louisiana. This break-bulk occurs at the Burlington-Northern-ACBL Coal Terminal in the North St. Louis river front area. Two more such terminals are in the planning pre-construction stages in the Bi-State Region, and will be capable of efficiently servicing Illinois soft coal if the demand and environmental restrictions allow it.

3) Petroleum - The Energy Center Concept

Increases in petroleum and petroleum products represent some inter-regional short distance movements which complement the pipeline confluence in and north of the St. Louis Region. The potential of grain-related fuels is currently under investigation in the region, and "energy centers" of port industrial land use are envisioned at key riverside locations. Land options are currently being considered for gasahol plants surrounded by grain product-related land uses. Thus, the increase in petroleum product tonnage is largely seen to service such "energy center" concepts, and yield a variety of petroleum haulages (raw gasoline, alcohols, glycols, etc.).

4) <u>Chemicals - Positive Inertia of Facilities and Skills in Place</u>

Somewhat related to the above, continued regional increase in chemical flows correlates with detailed regional market analyses exhibiting St. Louis' continued growth as a center of chemical manufacturing, research and education. The sunk cost of facilities and highly trained personnel for the chemicals industry available in St. Louis cause its growth inertia to increase, as well as the presence of good surface transportation for shipment of small packaged finished products.

5) <u>Fabricated Metals - A Need for Labor Intensive Industry</u>

The growth in fabricated metals represents a regional economic demand for more labor intensive basic industry identified in marketing studies. It is felt the St. Louis region could absorb two or three new major fabricated metal plants, with at least one being located near the Central Harbor area. The presence of available and redevelopable land north of the Central Harbor and pressure to reduce unemployment drive the need to establish this industry set in the port zone, thus yielding the increased forecast of tonnage.

<u>River Operations Impacts of the Above</u>

The above increases in regional commodity flow into and out of the St. Louis Metropolitan Port, in addition to through traffic will have several impacts on port operations worthy of careful monitoring: They are:

1) An Increase in Number of Tows and Related Harbor Congestion. Achieving the high growth state from above will cause some 86,400 barges to be handled in a towing season in the year 2000 in the St. Louis area. This, in conjunction with through traffic, will yield potentials for congestion, and fleeting must respond in an orderly and managed format.

2) The Need for Maximum Intermodal and Rail-Water Co-operation. Given the forecast commodity flow potential for growth in coal, grain and increased use of the St. Louis public terminals, it will be imperative to achieve maximum efficiencies in unit train-unit tow and joint rail water-through rates. Sluggishness of modes to opt for co-operation will impede a geographic and "facilities in place" locational advantage of the region for the key cargoes discussed above. Managed fleeting to properly insure timely placement of barges at locations of intermodal operation is critical to the region's economic success.

Fleeting Operational Routines and Concerns

Based on interviews with the fleeters in the region, several stable operating patterns and concerns become apparent. Since the region is immediately below Lock and Dam 26, the St. Louis Bi-State Metropolitan Port is a major junction for tow make up and local dock delivery to St. Louis waterside industry. Some 70% of all fleeting operations in the harbor are for through tow make-up, while the remaining 30% serves the dock delivery of St. Louis Industrial Port operations. The average time a barge sits in a fleeting site is 5 days. Fleeters typically charge an average of $100 per hour, or $100 per barge to fleet. They indicate a strong preference for tow make-up work versus dock delivery. Since tow make-up-break-up includes handling a range of 15-40 barges, it represents a large, fixed price revenue and time commitment for the fleeters' service.

As a result, the localized one to six barge dock delivery to industrial sites takes second priority, often causing industrial docks delay in unloading after the through tow carrying their commodity has entered the St. Louis regional harbor. This may further exacerbate land-side rail, truck and industrial processing transportation they have scheduled at their plant site.

Local government officials are concerned about the capability of providing adequate fleeting capacity for future commodity flows, but not using riverfront shoreline which could more profitably earn revenue as an industrial land use tract.

All fleeters, government officials, barge line companies, and industry personnel interviewed expressed common concerns for generation of siting and operational improvements. A synthesis is as follows:

1.) Future fleeting capacity requirements must be met.

2.) Environmental problems must be dealt with.

3.) A balance between fleeters' shoreline operations and industrial shoreline use must be appropriately developed.

4.) Harbor congestion, particularly central harbor congestion, must be minimized in the future.

5.) Local dock delivery must receive better scheduling performance.

6.) Barge breakaway and hazardous cargo movement is a critical problem.

7.) Fuel rates and fleeting costs are a potential critical problem in length of haul for delivery.

8.) Potential Coast Guard regulation of fleet manning and potential monitoring of fleeting sites by boat are not looked upon with favor.

9.) Insurance regulations prohibiting one fleeter from entering another's fleet to move a single barge inhibit operations, but protect the private enterprise, competitive aspect of the business.

10.) Hydrological and diking improvements to the channel, while improving over-all harbor operations, could further limit future fleeting location sites.

Environmental Data

The environmentally sensitive groups have historically opposed fleeting as damaging to natural resources. Port development interests desire accurate fleeting-related environmental research output to allow them to adequately establish planning and design guidelines which provide meaningful direction for fleet siting to allow orderly commercial development. As a result of the vocal impact of environmental concerns, it is appropriate to include known information on the impact of the following environmental attributes on fleeting decision making in this research:

fish and wildlife
dredging
water quality
air quality
noise

A review of the literature shows a paucity of documented research on fleeting and the above impacts. To improve the knowledge base, selected agencies, including the Environmental Protection Agency, Missouri Department of Natural Resources, the Illinois Department of Conservation, and Department of Interior, were questioned as to specific impacts of fleeting on the above environmental attributes. Their responses are contained in Appendix D. Again, no specific fleeting related research output appears to exist, with the exception of a loose relationship of lessened fish growth in areas where sunlight is prohibited due to long standing moorage of barges.

To correct this lack of research, the St. Louis District Corps of Engineers has recently entered into contract with a consulting firm to jointly document specific fleeting related environmental effects. Recent conversation with their project engineer confirms the present lack of such documentation.[5]

As such, the letter output of Appendix D from environmental agencies and port-development groups, in conjunction with general EIS, EIA data on recent permit decisions by the corps of engineers was used to form the environmental components of the case study model evaluation structure in Chapter V.

The forthcoming chapter will present an overview of the evaluation modelling format to be tested, followed by the formulation of case study evaluation of fleeting alternatives in Chapter V.

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[5]Discussion with Paul Jenson, Project Engineer, Espey, Huston, Inc. on the St. Louis Harbor Study, now underway, on October 14, 1980, and October 23, 1980.

CHAPTER IV

OVERVIEW OF EVALUATION MODELLING APPROACH

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Brief Review of Relevant Markovian Decision Theory Structure

This chapter reviews the significant elements of the evaluation modelling structure. The approach involves the formulation of a state space, delineation of fleeting alternatives, state transition probabilities, and reward matrices for the system under study.

In an analysis of an existing or proposed system from a Markovian framework, the basic concern lies with the trajectory of the process, i.e. the sequence of system states, rather than in the time interval between successive states (although this sequence of time intervals can be considered a random variable). More directly, a system can be described in terms of its state transitions given discrete time intervals. The state variable descriptors capture the dynamics of the system.

The basic assumption of a Markov process lies in its relationship between the successive states of the system. The composition of the states used in this research project are further developed and elaborated on in Chapter V. The notation for the formulation of the state space is:

$s(n)$ state at time interval n, $n = 1, 2, \ldots$

$i, j, k, \ldots m$ any sequence of states $1, 2, \ldots N$.

The actual Markovian assumption has the following formulation:

$$P\{s(n+1) = j \mid s(n) = i, s(n-1) = k, \ldots s(0) = m\} = P\{s(n+1) = j \mid s(n) = i\}$$

where P is a probability measure.

The Markovian property is equivalent to the conditional probability of any future "event", given any past "event". In addition, the future state of the system is independent of the past events and depends upon only present state of the process.[6] In essence, the system's being in state j at time n+1 has only to do with the previous state i, and not all previous states of the system from time zero. For the postulated Markov Process previously defined, a significant assumption concerns the ergodic property. This property asserts that the final long run steady state probabilities are independent of the initial starting state.

The next step in the modelling formulation is the development of k alternatives for fleeting. These k alternatives are formulated in conjunction with different assumptions affecting the region under study, which are also discussed in Chapter V.

The state transition probabilities, also developed in Chapter V, are the probabilities P_{ij} of a system in state i going to state j in the next time interval. Several assumptions are made with respect to the transition probabilities, in order to maintain accuracy, and remove some of the modelling complexity. These are: 1) There is a finite set of states 1, 2, ... N of the system which may be occupied at any time. 2) The time interval spacing is assumed to be constant. 3) The p_{ij} measures are independent of time and therefore do not change with time.

There are two constraints on the probability measures:

First, for all i, j,

$$0 \leq p_{ij} \leq 1 .$$

Second, the probabilities are normalized,

$$\sum_{n=1}^{N} p_{ij} = 1 \qquad i = 1,2,\ldots N .$$

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[6] Operations Research by Frederick S. Hillier and Gerald J. Lieberman, Holden-Day, Inc. 1974.

As a result, the matrix of the transition probabilities, $N \times N$, is referred to as a stationary matrix.

The stochastic inputs for this evaluation methodology consist of the single step transition probabilities for the Markov process. The determination of these probabilities are critical to the analysis, and reflect professional evaluation of the port development and fleeting issues in the St. Louis region.

In studying the dynamics of a transportation system, our concern is with the future state of the system given its present state. The matrix of the transition probabilities, P_{ij}, is composed of the probabilities of the system currently in state i, moving to state j in the next transition. The transition time period will be a time span which allows the port development and commodity flows to develop recognizable shifts representing regional growth implications. In addition, for each fleeting alternative there is a P_{ij} matrix which is a stochastic matrix. This results in:

$$P^k = P^k_{ij}$$

where k equals the number of fleeting alternatives under study, and i and j correspond to the different growth states. This property reflects the inherent degree of association of changes of port development in conjunction with various fleeting alternatives.

The remaining component of the evaluation structure is the reward matrix, R^k_{ij} reflecting gains to the system of a state transtion from i to j when alternative k is employed. The formulation of the reward matrices is developed in detail in Chapter V. The matrix of rewards generated by the markov process is a random variable with the same probabilistic relations of the Markov process. Thus, there are k matrices of transition probabilities, each referred to as P^k, and k reward matrices, R^k, each associated with the k^{th} alternative.

The relative total expected reward or relative value, $v_i(n)$ is the expected total earnings or gain of the next n transitions, given the system is initially in state i. The mathematical relation is as follows, where the terms have been previously explained,

$$v_i(n) = \sum_{j=1}^{N} p_{ij} \left(r_{ij} + v_j(n-1)\right) \qquad i = 1,2,\ldots N$$

$$= q_i + \sum_{j=1}^{N} p_{ij}\, v_j\,(n-1)$$

where

$$q_i = \sum_{j=1}^{N} p_{ij}\, r_{ij}$$

is the expected immediate reward for state i.

The above equation on q_i is manipulated through a simultaneous equation solution approach, termed the Policy Iteration Technique, which uses a Markovian solution to find:

$$K^* = \max_k \{q_i^k + \sum_{j=1}^{n} P_{ij}^k\, V_j\}$$

where

q_i^k = the expected reward from the next stage transition, given the starting growth state i, for transportation alternative k,

p_{ij}^{k} = single step transition probabilities, growth state i to growth state j, for transportation alternative k,

V_j = relative total expected reward or relative value accruing to the system under the previous policy,

N = the maximum number of states

For each state i, the alternative, k*, is found which maximizes the test quantity and is the optimal alternative for that particular state. A composite of these k* for each state of the system is termed the optimal decision or policy vector

$$d^* = \begin{bmatrix} k_1^* \\ k_2^* \\ \cdot \\ \cdot \\ \cdot \\ \cdot \\ k_n^* \end{bmatrix}$$

which delineates a complete strategy for all possible states of the system.

The text quantity k^* represents the selection criteria by which one alternative is considered optimal in relation to the other fleeting alternatives for each system state. Symbolically, this maximized test quantity for each transition represents the alternative to be selected for each state, based on a set of rewards and values relative to all alternatives. As such, this test quantity is not an absolute measure of benefits for the selected fleeting alternatives, but rather a means of relative ordering of their worth, given the stochastic properties of the entire system. For complete coverage of the mathematics, see Howard[7] and/or Appendix A.

Markovian Decision Theory is a highly relevant tool in emerging port development systems evaluation research. It allows an optimum seeking approach to be pursued in light of the inherent uncertainty of the real world process, and in the environments, termed states, under which the decisions may be obtained.

Past historical studies, or experimentation, may allow the probability distributions of the states and their transitions to be built, along with cataloging the rewards with respect to the impacts of a fleeting alternative on a particular state. If one reads the above closely, it is apparent this method closely simulates the real-world process of placing fleeting alternatives in an uncertain set of environments, and probilistically accruing several environmental and user impacts each with associated costs, gains, and the propensities for altering the state structure. Chapter V will illustrate the above technique on the St. Louis Metropolitan Bi-State Port fleeting data.

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[7] Howard, Ronald A., Dynamic Programming and Markov Processes, M.I.T. Press, Cambridge, Mass., 1960.

CHAPTER V

CASE STUDY EVALUATION

CHAPTER V

CASE STUDY EVALUATION

Introduction

The objective of this chapter is to demonstrate the Markovian decision theory approach to fleeting management on the St. Louis Metropolitan Bi-State Port as a case study site. The forthcoming pages will format an appropriate state space for the port region, generate a set of reasonable alternatives to be tested, develop transition and reward matrices, and analyze and interpret the model output. Subsequently, selected sensitivity analyses on critical parameters will be performed, yielding insight into the variety of solutions, or likely dominance of a solution present in the decision process over a wide array of parametric changes.

Formation of State Spaces

Five states of harbor development have been developed for a 20 year planning period to the year 2000. The specific development locations referred to below are illustrated in Figure 3. The following input data was employed to formulate the states:

Future port district land use plans

Regional economic growth

Regional commodity flow forecasts

Present fleeting volumes

Projected fleeting volumes

Likely zone or origin-destination pattern of commodity transfer in harbor, by commodity type

The states resulting from meaningful combinations of the above input data are as follows:

1) Continuation of status quo growth rates and unplanned patterns of the St. Louis Bi-State Harbor Region.
2) Maximum development in the North Riverfront and Tri-Cities sites with full development of port-related coal facilities throughout the region, including the Kaskaskia River junction.
3) Maximum development in North Riverfront and Tri-Cities districts, without full development of port-related coal facilities throughout the region.
4) Development of North Riverfront, Tri-Cities, Chesley and Arsenal Island - Cahokia Chute sites, with full development of port related coal facilities throughout the region, including the Kaskaskia River junction.
5) Development of North Riverfront, Tri-Cities, Chesley and Arsenal Island - Cahokia Chute sites, without full development of port related coal facilities throughout the region.

Capacity Analysis

The current 1980 fleeting activity is 42,812 barges per year, with 70% consisting of through tow makeup and 30% being dock delivery.[8] An extrapolation of the commodity flow information of Table 3 in Chapter III indicates some 86,500 barges will require fleeting in the year 2000. As such, the above harbor states are formatted in terms of local dock delivery barge origin-destination by port district development zone, as illustrated in Table 4.

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[8]City of St. Louis Port Administrator, Working Paper to Port Commission on St. Louis Regional Fleeting, June 1979.

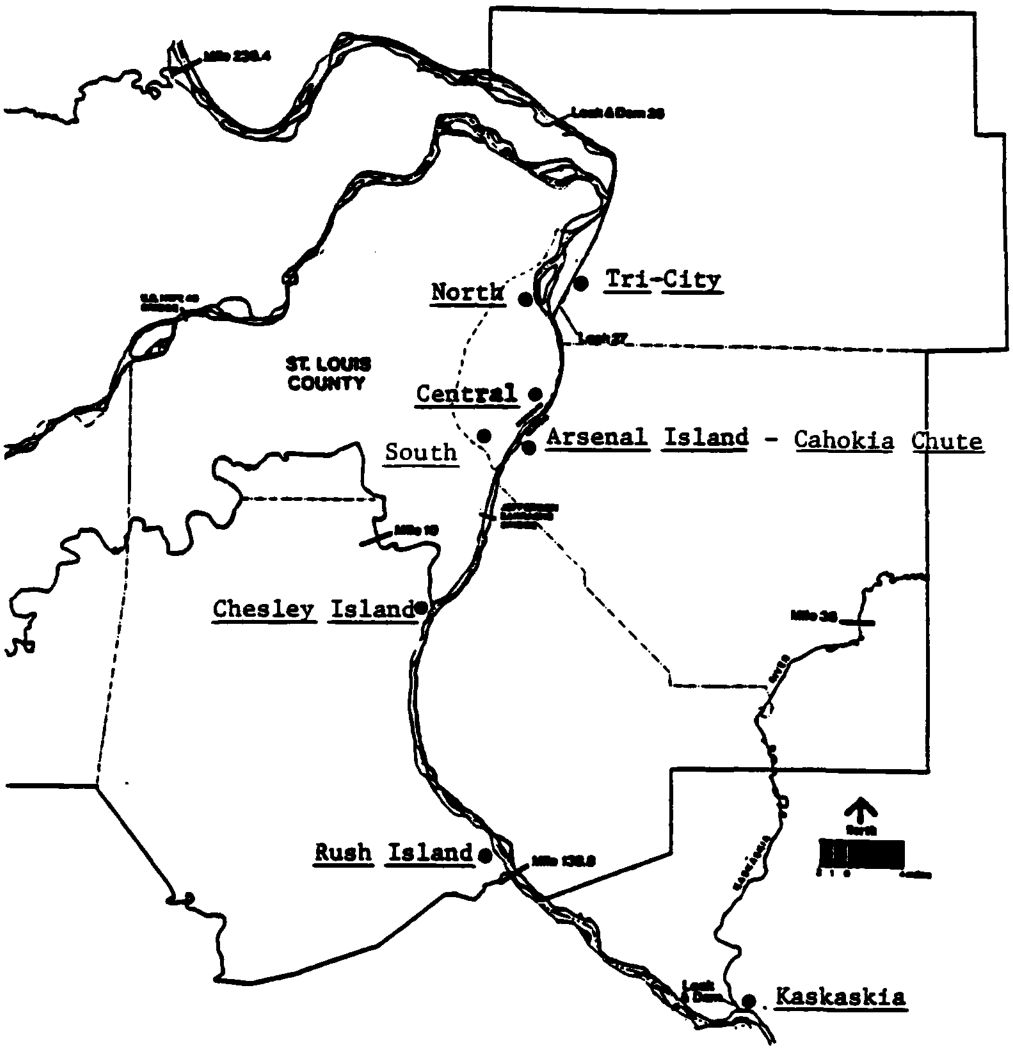

Figure 3

Potential Port Development Locations

Table 4

Local Dock Delivery Barge Origin-Destinations by Port District Development Zone

Commodity	St. Louis North	St. Louis Central	St. Louis South	Arsenal Island - Cahokia Chute	Chesley Island	Rush Island	Tri-City	Kaskaskia
Cash Grains	412						618	
Iron Ore	1		1				1	
Metal Ores	6						3	
Coal	3,600							
Petroleum Prod.	519		173				1,037	
Sugar	5		3				9	
Grain Mill Prod.	158						85	
Lumber Prod.	1		1				1	
Paper	4		4				2	
Chemicals	251		126				251	
Iron & Steel	67						157	
Non-Ferrous Prod.	6						4	
Fabricated Metal	8		2				1	
Mining Prod.	91		364				455	
Non-Durable Mfg.	5		5				11	
Durable Mfg.	901							
Total Barges	6,035		679				2,635	

State 1. Region in Status Quo 1980–2000

Table 4 (cont.)

Commodity	St. Louis North	St. Louis Central	St. Louis South	Arsenal Island - Cahokia Chute	Chesley Island	Rush Island	Tri-City	Kaskaskia
Cash Grains	412						618	
Iron Ore	1		1				1	
Metal Ores	6						3	
Coal	3,517						2,322	1,196
Petroleum Prod.	519		173				1,037	
Sugar	5		3				9	
Grain Mill Prod.	158						85	
Lumber Prod.	1		1				1	
Paper	4		4				2	
Chemicals	251		126				251	
Iron & Steel	67						157	
Non-Ferrous Prod.	6						4	
Fabricated Metal	8		2				1	
Mining Prod.	91		364				455	
Non-Durable Mfg.	5		5				11	
Durable Mfg.	901							
Total Barges	5,952		679				4,957	1,196

State 2. High Growth; Full Coal Development and Prominent North Riverfront and Tri-City Development 1980-2000

Table 4 (cont.)

Commodity	St. Louis North	St. Louis Central	St. Louis South	Arsenal Island - Cahokia Chute	Chesley Island	Rush Island	Tri-City	Kaskaskia
Cash Grains	412						618	
Iron Ore	1		1				1	
Metal Ores	6						3	
Coal	3,571						2,322	
Petroleum Prod.	519		173				1,037	
Sugar	5		3				9	
Grain Mill Prod.	158						85	
Lumber Prod.	1		1				1	
Paper	4		4				2	
Chemicals	251		126				231	
Iron & Steel	67						157	
Non-Ferrous Prod.	6						4	
Fabricated Metal	8		2				1	
Mining Prod.	91		364				455	
Non-Durable Mfg.	5		5				11	
Durable Mfg.	901							
Total Barges	6,006		679				4,957	

State 3. High Growth; Prominent North Riverfront and Tri-City Development, Without Full Coal Development 1980-2000

Table 4 (cont.)

Commodity	St. Louis North	St. Louis Central	St. Louis South	Arsenal Island - Cahokia Chute	Chesley Island	Rush Island	Tri-City	Kaskaskia
Cash Grains	412						618	
Iron Ore	1		1				1	
Metal Ores	6						3	
Coal	3,517						2,322	1,196
Petroleum Prod.	778			172	86		692	
Sugar	4		3	2	1		8	
Grain Mill Prod.	122			25	12		85	
Lumber Prod.	1			2	1		1	
Paper	4		3	2	1		2	
Chemicals	188		143	95	47		188	
Iron & Steel	59			8	4		156	
Non-Ferrous Prod.	6			2	1		4	
Fabricated Metal	5		2	2	1		2	
Mining Prod.	92		364				455	
Non-Durable Mfg.	4		4		1		10	
Durable Mfg.	901			2				
Total Barges	6,100		520	313	155		4,547	

State 4. High Growth; Prominent North Riverfront, Tri-City, Chesley and Arsenal Island - Cahokia Chute Development with Full Coal Development 1980-2000

Table 4 (cont.)

Commodity	St. Louis North	St. Louis Central	St. Louis South	Arsenal Island - Cahokia Chute	Chesley Island	Rush Island	Tri-City	Kaskaskia
Cash Grains	412						618	
Iron Ore	1		1				1	
Metal Ores	6						3	
Coal	3,570						2,322	
Petroleum Prod.	778			173	86		692	
Sugar	4		3	2	1		8	
Grain Mill Prod.	122			25	12		85	
Lumber Prod.	1			2	1		1	
Paper	4		3	2	1		1	
Chemicals	188		143	95	47		188	
Iron & Steel	59			8	4		156	
Non-Ferrous Prod.	6			2	1			
Fabricated Metal	5		2	2	1		2	
Mining Prod.	92		364				455	
Non-Durable Mfg.	4		4		1		10	
Durable Mfg.	901			2				
Total Barges	6,153		520	313	155		4,543	

State 5. High Growth; Prominent North Riverfront, Tri-City, Chesley and Arsenal Island - Cahokia Chute Development Without Full Coal Development 1980–2000

Appropriate analysis of long run saturation and capacity deficiency, assuming a nine month navigation season is as follows:

A) <u>Current Capacity; Related Saturation Dates</u>

$$\frac{\text{1044 current spaces} \times 365 \times .75}{\text{5 days/barge/space}} = C = \text{current capacity}$$

$$C = \frac{285{,}795}{5} = 57{,}159 \text{ current seasonal capacity of harbor}$$

57,159	current seasonal capacity
-42,800	current seasonal fleeting volume
14,359	

$$\frac{14{,}359}{2{,}200} = 6.5 \longrightarrow \text{saturation in 7 years, i.e. 1987.}$$

(2,200 = annual increment in barge fleeting volume extrapolated from commodity flow forecast)

B) <u>Future Space Needs</u>

86,500 - 42,800 = 43,600 future seasonal capacity required

$$\frac{\Delta C \times 365 \times .75}{5} = 43{,}700$$

$$\Delta C \times 365 \times .75 = 218{,}500$$

$$\Delta C = \frac{218{,}500}{274} = 797.45 \longrightarrow \text{800 new spaces needed by year 2000.}$$

Given the design, application and permit review time, seven years is not an inordinate length of time prior to saturation. The above 800 spaces must be related to dock delivery and through fleeting demands in the context of available sites, as will be examined further in this chapter in conjunction with the evaluation model output.

Evaluation Criteria

As stated previously, fleeting activity must respond to a variety of commercial and transportation stimuli, and in so doing yields meaningful impacts on the environment, energy and economic resources of a region. Through the interview and correspondence discussed in Chapters II and III, it was concluded that the following entities appear to be the most germane criteria for evaluation of fleeting alternatives in the St. Louis Bi-State Port:

- Acquisition and Capital Cost
- Maintenance Expense
- Fish and Wildlife Impacts
- Impacts on Flora and Fauna
- Noise
- Water Quality
- Energy Consumption
- Breakaway Safety
- Local Dock Delivery
- Through Tow Makeup Congestion

A variety of viewpoints exist in the region with respect to the amount of emphasis to be put on each of the above impacts, ranging from environmentally sensitive concerns to growth oriented perspectives. The evaluation process will illustrate the capability of responding to the above viewpoints further in this chapter.

Generation of Alternatives

A plausible set of siting and operational alternatives were developed to be evaluated for the above fleeting activities. Locations worthy of consideration are as follows, illustrated in accompanying figure 4.

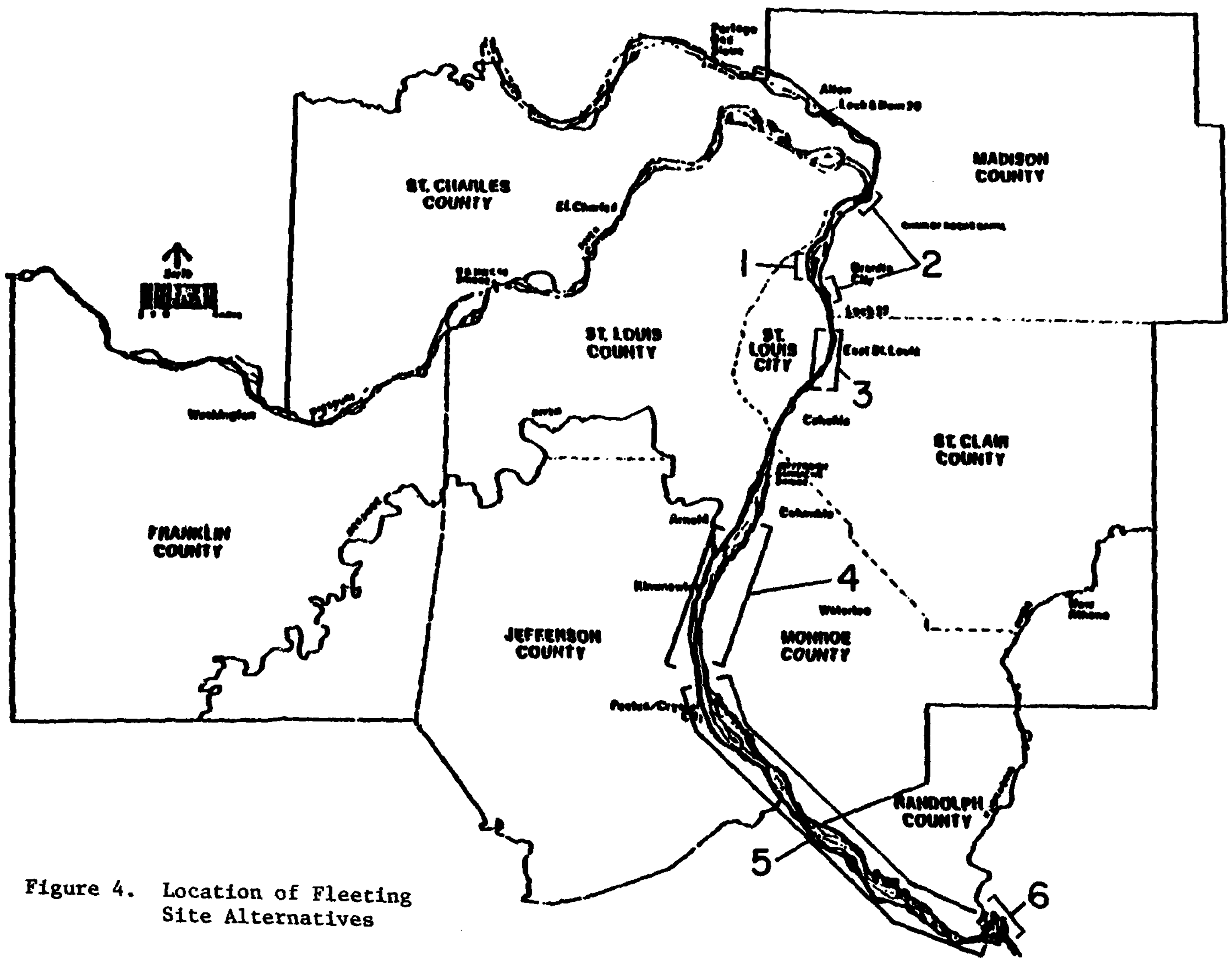

Figure 4. Location of Fleeting Site Alternatives

Site	Description
1	Mosenthien Island Slack Water Location; Gabaret Chute
2	Tri-Cities Shoreline Location North and South of Lock and Dam 27
3	Central Harbor, Missouri and Illinois Shorelines
4	Immediately South of Jefferson Barracks Bridge (termed Near South), Missouri and Illinois Shorelines
5	Distantly South of Jefferson Barracks Bridge (termed Far South, in the Festus, Crystal City Locale, Southern Monroe County) on Missouri and Illinois Shorelines
6	Kaskaskia River, in the Oxbows Locale, going upstream from the confluence with the Mississippi River

Based on the above evaluation criteria, and the necessity to promote comprehensive harbor planning, reasonable combinations of the individual sites were reformatted into a final set of alternatives for evaluation, illustrated in Table 5.

Table 5 - Fleeting Alternatives for Analysis

Alternative Number	Site Composition
1	1,2,5
2	1,2,5,6
3	3,4,5
4	5,6
5	4,6
6	1,2,4,5,6
7	3
8	1,2,3
9	1,2,4

Formulation of $[p_{ij}]^k$

Each fleeting alternative will have relative potential for influencing the various states of harbor development alluded to earlier. Likewise, each state will require slightly different fleeting resources, as the harbor development transitions over a 20 year period. To capture these facts, a series of transition matrices, $[p_{ij}]^k$ are developed to illustrate the likelyhood of harbor state development transition, given the fleeting alternatives (k=1,...,9). These are compiled by virtue of the interviews with port planning officials in the region, regional planning trends, and historical knowledge of port and fleeting operations. The p_{ij}^k are presented in following Table 6. Due to the threshold time required for facilities development, and time typically required to show accrued impact of public works decisions, the p_{ij} are for 10 year periods, assuming each p_{ij} stable over two ten year periods to encompass the 20 year planning horizon.

Formation of $[R_{ij}]^k$

In a like manner, the rewards, or gain or loss of being in a particular state by virtue of employing the kth fleeting alternative are presented in Table 7. Due to lack of specific data on environmental impact as discussed in Chapter III, and order of magnitude information on capital costs and energy consumption, the impacts were ranked on a 10 scale, synthesizing information from the fleeters, port agencies and environmental groups. The raw information is contained in Appendix D.

Table 6

Transition Matrices

10 year period

p_{ij} stable over two ten year periods

Alt k=1=(1,2,5)

State j → / State i ↓	1	2	3	4	5
1	.20	.10	.60	.05	.05
2	.05	.60	0.0	.35	0.0
3	.05	.10	.60	.05	.20
4	.05	0.0	0.0	.95	0.0
5	.05	0.0	0.0	.35	.60

p_{ij}

Alt k=2=(1,2,5,6)

State j → / State i ↓	1	2	3	4	5
1	.05	.65	.05	.20	.05
2	.05	.70	0.0	.25	0.0
3	.05	.60	.05	.25	0.5
4	0.5	0.0	0.0	.95	0.0
5	.05	0.0	0.0	.90	.05

Table 6 (cont.)

Alt k=3=(3,4,5)

State i ↓ / State j →		1	2	3	4	5
State i	1	.5	.05	.1	.15	.20
	2	.05	.05	0.0	.35	.55
	3	.05	.1	.3	.1	.4
	4	.05	0.0	0.0	.95	0.0
	5	.05	.1	0.0	.1	.8

Alt k=4=(5,6)

State i ↓ / State j →		1	2	3	4	5
State i	1	.6	.15	.1	.1	.05
	2	.05	.60	0.0	.35	0.0
	3	.05	.70	0.0	.25	0.0
	4	.0	0.0	0.0	.95	0.0
	5	.05	0.0	0.0	.95	0.0

Alt k=5=(4,6)

State i ↓ / State j →		1	2	3	4	5
State i	1	.30	.1	.05	.50	.05
	2	.05	.25	0.0	.7	0.0
	3	.05	.15	0.0	.8	0.0
	4	.05	0.0	0.0	.95	0.0
	5	.05	0.0	0.0	.95	0.0

Table 6 (cont.)

Alt k=6=(1,2,4,5,6)

State j →		1	2	3	4	5
State i ↓	1	.1	.45	0.0	.45	0.0
	2	.05	.30	0.0	.65	0.0
	3	.05	.30	0.0	.65	0.0
	4	.05	0.0	0.0	.95	0.0
	5	.05	0.0	0.0	.95	0.0

Alt k=7=(3)

State j →		1	2	3	4	5
State i ↓	1	.85	.05	.05	.026	.025
	2	.70	.3	0.0	0.0	0.0
	3	.70	0.0	.3	0.0	0.0
	4	.70	0.0	0.0	.3	0.0
	5	.70	0.0	0.0	0.0	.3

Alt k=8=(1,2,3)

State j →		1	2	3	4	5
State i ↓	1	.25	0.0	.75	0.0	0.0
	2	.1	.6	0.0	.1	.2
	3	.1	0.0	.6	.1	.2
	4	.3	0.0	0.0	.5	0.2
	5	.5	0.0	0.0	0.0	.5

Table 6 (cont.)

Alt k=9=(1,2,4)

State j →		1	2	3	4	5
State i ↓	1	.05	0.0	.70	0.0	.25
	2	.05	.4	0.0	.55	0.0
	3	.05	0.0	.4	0.0	.55
	4	.3	0.0	0.0	.2	.5
	5	.4	0.0	0.0	0.0	.6

Table 7

Value Matrix Scores

STATE 1

Status Quo

Alternative	1	2	3	4	5	6	7	8	9
	(1,2,5)	(1,2,5,6)	(3,4,5)	(5,6)	(4,6)	(1,2,4,5,6)	(3)	(1,2,3)	(1,2,4)
Impact	1	2	3	4	5	6	7	8	9
Cost	1	1	8	4	4	1	9	1	1
Mnt. Expense	1	1	7	4	4	1	9	1	1
Fish & Wildlife	1	1	7	1	1	1	9	1	1
Flora & Fauna	3	1	7	1	1	1	9	3	3
Noise	8	8	2	9	8	8	1	1	8
Water Quality	6	2	6	2	2	2	8	6	6
Energy Consumption	8	8	4	1	5	10	2	6	8
Breakaway Safety	3	3	7	10	8	3	1	1	1
Local Dock Delivery	9	8	2	1	2	10	1	4	10
Through Tow Makeup Congestion	8	10	5	10	9	10	1	1	8

Scale: 10 = Best

1 = Worst

Table 7 (cont.)

STATE 2

Maximum Development of North Riverfront, Tri Cities and Full Coal Development

Alternative	1	2	3	4	5	6	7	8	9
	(1,2,5)	(1,2,5,6)	(3,4,5)	(5,6)	(4,6)	(1,2,4,5,6)	(3)	(1,2,3)	(1,2,4)
Impact	1	2	3	4	5	6	7	8	9
Cost	1	1	8	4	4	1	9	1	1
Mnt. Expense	1	1	7	4	4	1	9	1	1
Fish & Wildlife	1	1	7	1	1	1	9	1	1
Flora & Fauna	3	1	7	1	1	1	9	3	1
Noise	8	8	2	9	8	8	1	1	8
Water Quality	6	2	6	2	2	2	8	6	6
Energy Consumption	9	10	5	6	7	10	1	4	6
Breakaway Safety	3	3	7	10	8	3	1	1	1
Local Dock Delivery	8	10	1	2	4	10	1	4	5
Through Tow Makeup Congestion	10	10	4	10	6	10	1	1	3

Scale: 10 = Best

1 = Worst

Table 7 (cont.)

STATE 3

Maximum Development of North Riverfront, Tri Cities, without Full Coal Development

Alternative	1	2	3	4	5	6	7	8	9
	(1,2,5)	(1,2,5,6)	(3,4,5)	(5,6)	(4,6)	(1,2,4,5,6)	(3)	(1,2,3)	(1,2,4)
Impact	1	2	3	4	5	6	7	8	9
Cost	1	1	4	4	4	1	9	1	1
Mnt. Expense	1	1	7	4	4	1	9	1	1
Fish & Wildlife	1	1	7	1	1	1	9	1	1
Flora & Fauna	3	1	7	1	1	1	9	3	1
Noise	8	8	2	8	8	8	1	1	8
Water Quality	6	2	6	2	2	2	8	6	6
Energy Consumption	10	9	6	1	7	8	2	3	5
Breakaway Safety	3	3	7	10	8	3	1	1	1
Local Dock Delivery	10	10	1	1	3	10	1	10	10
Through Tow Makeup Congestion	9	10	5	10	7	10	1	1	2

Scale: 10 = Best

1 = Worst

Table 7 (cont.)

STATE 4

Maximum Development of North Riverfront, Tri-Cities,

Chesley and Arsenal Island - Cahokia Chute and Full Coal Development

Alternative	1	2	3	4	5	6	7	8	9
	(1,2,5)	(1,2,5,6)	(3,4,5)	(5,6)	(4,6)	(1,2,4,5,6)	(3)	(1,2,3)	(1,2,4)
Impact	1	2	3	4	5	6	7	8	9
Cost	1	1	9	4	4	1	9	1	1
Mnt. Expense	1	1	7	4	4	1	9	1	1
Fish & Wildlife	1	1	7	1	1	1	9	1	1
Flora & Fauna	3	1	7	1	1	1	9	3	1
Noise	8	8	2	9	8	8	1	1	8
Water Quality	6	2	6	2	2	2	8	6	6
Energy Consumption	8	9	5	4	6	10	1	4	6
Breakaway Safety	3	3	7	10	8	3	1	1	1
Local Dock Delivery	6	8	4	1	2	10	1	3	4
Through Tow Makeup Congestion	10	10	6	10	8	10	1	1	6

Scale: 10 = Best

1 = Worst

Table 7 (cont.)

STATE 5

Maximum Development of North Riverfront, Tri-Cities,

Chesley and Arsenal Island - Cahokia Chute without Full Coal Development

Alternative

	1	2	3	4	5	6	7	8	9
	(1,2,5)	(1,2,5,6)	(3,4,5)	(5,6)	(4,6)	(1,2,4,5,6)	(3)	(1,2,3)	(1,2,4)
Impact	1	2	3	4	5	6	7	8	9
Cost	1	1	9	4	4	1	9	1	1
Mnt. Expense	1	1	7	4	4	1	9	1	6
Fish & Wildlife	1	1	7	1	1	1	9	1	1
Flora & Fauna	3	1	7	1	1	1	9	3	1
Noise	8	8	2	9	8	8	1	1	8
Water Quality	6	2	6	2	2	2	8	6	6
Energy Consumption	8	9	5	4	6	10	1	5	6
Breakaway Safety	3	3	7	10	8	3	1	1	1
Local Dock Delivery	8	5	4	1	4	9	1	4	10
Through Tow Makeup Congestion	9	10	9	10	7	10	1	1	3

Scale: 10 = Best

1 = Worst

Importance Weighting of Criteria

As stated earlier, the criteria may be weighted in order to investigate results relative to a variety of viewpoints. For this analysis, four viewpoints were used in the evaluation:

1) Economic Development and Energy Sensitive - This set of weightings emphasized commercial development and industrial value added by virtue of maximizing the weighting of dock delivery criteria. In addition, fuel consumption due to fleeting patterns was given significant weight.

2) Environmentally Sensitive - This set of weightings emphasized environmental attributes, with large weightings given to the total of environmental impacts, with particularly large weighting to fish and wildlife and water quality, since these appear most frequently in the literature and correspondence alluded to in Chapter III and Appendix D.

3) Cost and Regulatory Sensitive - This set of weightings could be considered the "federal sector regulatory position", where emphasis is given to safety regulation (breakaway safety) and capital and maintenance costs, since the federal agencies are likely to be charged with these responsibilities in the harbor.

4) Compromise - This set of weightings is essentially an "equal interest" approach with an attempt to equally weight the above three perspectives.

The weightings are illustrated in Table 8.

Table 8

Importance Weightings

Impact	Criteria Type: Economic Development and Energy Sensitive	Environmentally Sensitive	Cost and Regulatory Sensitive	Compromise
Cost	.05	.025	.20	.11
Local Dock Delivery	.55	.025	.15	.22
Through Tow Makeup Congestion	.018	.025	.05	.05
Mnt. Expense	.05	.025	.20	.11
Fish & Wildlife	.016	.30	.025	.09
Flora & Fauna	.016	.15	.025	.08
Noise	.016	.05	.025	.08
Water Quality	.016	.30	.025	.08
Energy Consumption	.25	.05	.1	.07
Breakaway Safety	.018	.05	.2	.11
	1.000	1.000	1.000	1.000

As stated in Chapter IV and Appendix A, the process works by developing:

$$\text{score}_i\ k = \sum_{x=1}^{M} r_x^k\, w_x$$

where

i = system state, $i=1,2,\ldots 5$.

k = fleeting alternative $1,\ldots,9$.

r_x^k = rank value of that alternative k, for impact criteria x from Table 7, impacts $x=1,\ldots,M$.

w_x = weighting of that impact.

x = number of impact critera.

Reward matrices are then calculated by computing the change in score likely as the harbor transitions from one state to another as follows:

$$r_{ij}^k = (\text{score}_j^k) - (\text{score}_i^k) \quad i \neq j,$$

and $$r_{ij}^k = \text{score}_i^k \quad i = j$$

The $[R_{ij}]^k$ for the above $k = 9$ alternatives are illustrated in Table 9.

Table 9

Reward Matrices

A) Economic Development and Energy Sensitive Perspective

REWARD MATRIX FOR ALTERNATIVE 1

0.	-247.	106.	-162.	-54.
247.	0.	353.	85.	193.
106.	-353.	0.	-268.	-160.
162.	-85.	268.	0.	108.
54.	-193.	160.	-108.	0.

REWARD MATRIX FOR ALTERNATIVE 2

0.	160.	135.	25.	-140.
160.	0.	-25.	-135.	-300.
135.	25.	0.	-110.	-275.
-25.	135.	110.	0.	-165.
140.	300.	275.	165.	0.

REWARD MATRIX FOR ALTERNATIVE 3

0.	-113.	-106.	59.	66.
113.	0.	7.	172.	179.
106.	7.	0.	165.	172.
-59.	-172.	-165.	0.	7.
-66.	-179.	-172.	-7.	0.

REWARD MATRIX FOR ALTERNATIVE 4

0.	180.	-2.	75.	75.
180.	0.	-182.	-105.	-105.
2.	182.	0.	77.	77.
-75.	105.	-77.	0.	0.
-75.	105.	-77.	0.	0.

REWARD MATRIX FOR ALTERNATIVE 5

0.	154.	101.	23.	131.
154.	0.	-53.	-131.	-23.
101.	53.	0.	-78.	30.
-23.	131.	78.	0.	108.
131.	23.	-30.	-108.	0.

REWARD MATRIX FOR ALTERNATIVE 6

0.	0.	-50.	0.	-55.
0.	0.	-50.	0.	-55.
50.	50.	0.	50.	-5.
0.	0.	-50.	0.	-55.
55.	55.	5.	55.	0.

REWARD MATRIX FOR ALTERNATIVE 7

0.	-25.	0.	-25.	-25.
25.	0.	25.	0.	0.
0.	-25.	0.	-25.	-25.
25.	0.	25.	0.	0.
25.	0.	25.	0.	0.

Table 9 (cont.)

REWARD MATRIX FOR ALTERNATIVE 8

0.	-50.	35.	-105.	-125.
50.	0.	85.	-55.	25.
-35.	-85.	0.	-140.	-60.
105.	55.	140.	0.	80.
125.	-25.	60.	-80.	0.

REWARD MATRIX FOR ALTERNATIVE 9

0.	-337.	-89.	-387.	-37.
337.	0.	248.	-50.	300.
89.	-248.	0.	-298.	52.
387.	50.	298.	0.	350.
37.	-300.	-52.	-350.	0.

B) Environmentally Sensitive Perspective

REWARD MATRIX FOR ALTERNATIVE 1

0.	7.	15.	-3.	0.
-7.	0.	8.	-10.	-7.
-15.	-8.	0.	-18.	-15.
3.	10.	18.	0.	3.
0.	7.	15.	-3.	0.

REWARD MATRIX FOR ALTERNATIVE 2

0.	15.	10.	5.	-2.
-10.	5.	0.	-5.	-12.
-10.	5.	0.	-5.	0.
-5.	10.	5.	0.	-7.
2.	17.	12.	7.	0.

REWARD MATRIX FOR ALTERNATIVE 3

0.	0.	-97.	15.	-72.
0.	0.	-97.	15.	-72.
97.	97.	0.	112.	25.
-15.	-15.	-112.	0.	-87.
72.	72.	-25.	87.	0.

REWARD MATRIX FOR ALTERNATIVE 4

0.	27.	-5.	15.	15.
-27.	0.	-32.	-12.	-12.
5.	32.	0.	20.	20.
-15.	12.	-20.	0.	0.
-15.	12.	-20.	0.	0.

Table 9 (cont.)

REWARD MATRIX FOR ALTERNATIVE 5

0.	7.	7.	2.	5.
-7.	0.	0.	-5.	-2.
101.	53.	0.	-78.	30.
-2.	5.	5.	0.	3.
-5.	2.	2.	-3.	0.

REWARD MATRIX FOR ALTERNATIVE 6

0.	0.	-10.	0.	-2.
0.	0.	-10.	0.	-2.
10.	10.	0.	10.	8.
0.	0.	-10.	0.	-2.
2.	2.	-8.	2.	0.

REWARD MATRIX FOR ALTERNATIVE 7

0.	-5.	0.	-5.	-5.
5.	0.	5.	0.	0.
0.	-5.	0.	-5.	-5.
5.	0.	5.	0.	0.
5.	0.	5.	0.	0.

REWARD MATRIX FOR ALTERNATIVE 8

0.	-10.	-10.	-13.	-5.
10.	0.	0.	-3.	5.
10.	0.	0.	-3.	5.
13.	3.	3.	0.	8.
5.	-5.	-5.	-8.	0.

REWARD MATRIX FOR ALTERNATIVE 9

0.	-65.	-15.	-60.	-40.
65.	0.	50.	5.	25.
15.	-50.	0.	-45.	-25.
60.	-5.	45.	0.	20.
40.	-25.	25.	-20.	0.

C) <u>Cost and Regulatory Perspective</u>

REWARD MATRIX FOR ALTERNATIVE 1

0.	-310.	-275.	-350.	-325.
310.	0.	35.	-40.	-15.
275.	-35.	0.	-75.	-50.
350.	40.	75.	0.	25.
325.	15.	50.	-25.	0.

REWARD MATRIX FOR ALTERNATIVE 2

0.	-130.	-140.	-170.	-215.
130.	0.	-10.	-40.	-85.
140.	10.	0.	-30.	-75.
170.	40.	30.	0.	-45.
215.	85.	75.	45.	0.

Table 9 (cont.)

REWARD MATRIX FOR ALTERNATIVE 3

0.	-10.	-75.	65.	80.
10.	0.	-65.	75.	90.
75.	65.	0.	140.	155.
-65.	-75.	-140.	0.	15.
-80.	-90.	-155.	-15.	0.

REWARD MATRIX FOR ALTERNATIVE 4

0.	-137.	-205.	-172.	-172.
137.	0.	-68.	-35.	-35.
205.	68.	0.	33.	33.
172.	35.	-33.	0.	0.
172.	35.	-33.	0.	0.

REWARD MATRIX FOR ALTERNATIVE 5

0.	35.	25.	5.	30.
-35.	0.	-10.	-30.	-5.
-25.	10.	0.	-20.	5.
-5.	30.	20.	0.	25.
-30.	5.	-5.	-25.	0.

REWARD MATRIX FOR ALTERNATIVE 6

0.	0.	-20.	0.	-15.
0.	0.	-20.	0.	-15.
20.	20.	0.	20.	5.
0.	0.	-20.	0.	-15.
15.	15.	-5.	15.	0.

REWARD MATRIX FOR ALTERNATIVE 7

0.	-415.	-405.	-415.	-415.
415.	0.	10.	0.	0.
405.	-10.	0.	-10.	-10.
415.	0.	10.	0.	0.
415.	0.	10.	0.	0.

REWARD MATRIX FOR ALTERNATIVE 8

0.	-20.	0.	-35.	-10.
20.	0.	20.	-15.	10.
0.	-20.	0.	-35.	-10.
35.	15.	35.	0.	25.
10.	-10.	10.	-25.	0.

REWARD MATRIX FOR ALTERNATIVE 9

0.	-125.	-65.	-125.	50.
125.	0.	60.	0.	175.
65.	-60.	0.	-60.	115.
125.	0.	60.	0.	175.
-5.	-175.	-115.	-175.	0.

Table 9 (cont.)

D) <u>Compromise Perspective</u>

REWARD MATRIX FOR ALTERNATIVE 1

0.	-5.	41.	-56.	-17.
5.	0.	46.	-51.	12.
-41.	-46.	0.	-97.	-58.
56.	51.	97.	0.	39.
17.	-12.	58.	-38.	0.

REWARD MATRIX FOR ALTERNATIVE 2

0.	58.	51.	7.	-59.
-58.	0.	-7.	-51.	-117.
-51.	7.	0.	-44.	-110.
-7.	51.	44.	0.	-66.
59.	117.	110.	66.	0.

REWARD MATRIX FOR ALTERNATIVE 3

0.	-20.	-52.	67.	82.
20.	0.	-32.	87.	102.
52.	32.	0.	119.	134.
-67.	-87.	-11[illegible].	0.	15.
-82.	-102.	-134.	-15.	0.

REWARD MATRIX FOR ALTERNATIVE 4

0.	57.	-8.	21.	21.
-57.	0.	-65.	-36.	-36.
8.	65.	0.	29.	29.
-21.	36.	-29.	0.	0.
-21.	36.	-29.	0.	0.

REWARD MATRIX FOR ALTERNATIVE 5

0.	43.	26.	2.	41.
-43.	0.	-17.	-41.	-2.
-26.	17.	0.	-24.	15.
-2.	41.	24.	0.	39.
-41.	2.	-15.	-39.	0.

REWARD MATRIX FOR ALTERNATIVE 6

0.	-88.	-102.	-88.	-110.
88.	0.	-14.	0.	-22.
102.	14.	0.	14.	-8.
88.	0.	-14.	0.	-22.
110.	22.	8.	22.	0.

Table 9 (cont.)

REWARD MATRIX FOR ALTERNATIVE 7

0.	-7.	0.	-7.	-7.
7.	0.	7.	0.	0.
0.	-7.	0.	-7.	-7.
7.	0.	7.	0.	0.
7.	0.	7.	0.	0.

REWARD MATRIX FOR ALTERNATIVE 8

0.	-14.	23.	-36.	-7.
14.	0.	37.	-22.	7.
-23.	-37.	0.	-59.	-30.
36.	22.	59.	0.	29.
7.	-7.	30.	-29.	0.

REWARD MATRIX FOR ALTERNATIVE 9

0.	-165.	-67.	-172.	0.
165.	0.	98.	-7.	165.
67.	-98.	0.	-105.	67.
172.	7.	105.	0.	172.
0.	-165.	-67.	-172.	0.

Model Output - Interpretation of Results

To aid in interpreting the model results, the site map of Figure 4 has been included herein as Figure 5. Allocation of maximum possible capacity addition to the year 2000 has been made for each site in the model output, as illustrated in Table 10. The allocations are based on preliminary screening of sites for their physical capability to accommodate the assigned number of spaces, and a revised proportion of through-tow and dock delivery to 60% and 40%, respectively, versus the current 70% through tow and 30% local dock delivery. This is justified on the basis of more intensive land use planning for the harbor development states, yielding a relative increase in barges requiring dock delivery fleeting. Thus, a 'typical' allocation of the 800 spaces will be 300 for local dock delivery, and 500 for through tow makeup.

Table 10

Maximum Possible Capacity Allocation by Year 2000 at Each Site

	Site 1	2	3	4	5	6
Barge Spaces	150	150	20	100	600	50
Status*	L	L	L	L	T	L

*Status: L = Local Dock Delivery Fleeting Area

T = Through Tow Makeup Fleeting Area

The results and interpretation of the model runs are as follows:

A) Port Development Sensitive Viewpoints

The policy vector solution is as follows:

State	Policy Vector of Alternatives	Value Vector
1	2	108.7500
2	3	179.4583
3	4	146.7500
4	9	291.8999
5	2	206.8168

The policy vector indicates that for state 1, the current status quo, a fleeting plan should be implemented as per alternative 2 - which is composed of developing capacity at sites (1,2,5,6) to allow maximum port development gains - with sites 1 and 2 emphasizing local dock delivery, site 6 relating to opening up coal service at Kaskaskia, and site 5 the far south river location used to accommodate through fleeting.

If the harbor system existed in state 2 with adequate fleeting and industrial land use relationships developed to that time, further gain could be had by adding additional capacity according to alternative 3 - consisting of sites 3, 4, 5. Sites 3 and 4 should be used for local dock delivery, and 5 for through tow breakup.

If state 3, without full coal development prevailed, the alternative 4 should be employed - composed of further capacity addition sites 5 and 6 to help alleviate through tow congestion, and open up the Kaskaskia coal terminal service.

If state 4 - full port site development and full coal development was in existence, further fleeting improvements could be made by virtue of additional capacity as per alternative 5 - sites 1, 2, and 4, yielding further adequacy of northern and Chesley and Arsenal Island area dock delivery service. Whereas, if state 5 existed without full coal, future development could be emphasized by maximum uses of sites 1, 2, 5 and 6 - to gain coal fleeting capabilities at Kaskaskia in 6 and further use of 5 for through tow storage areas.

B) Environmentally Sensitive Weightings

Using this perspective, the policy vector is as follows:

State	Policy Vector of Alternatives	Value Vector
1	1	23.7007
2	9	8.0476
3	3	42.9313
4	9	31.5646
5	3	19.7170

Given the impacts if in state 1, environmental mitigation appears to best be served by using sites 1 and 2 for dock delivery and site 5 - the far south shoreline, for through tows. Although this has environmental damage to Mosenthien, the conclusion can be interpreted as being less damaging than dealing with a truly pristine area such as Kaskaskia. In a like manner, both states 2 and 4 which have full coal development, emphasize implementation of alternative 9 (sites 1,2,4) and states 3 and 5 emphasize implementation of alternative 3 (sites 3,4,5).

This may be interpreted that for full coal development in either of the states, fleeting is best emphasized in the North Harbor and near Chesley, minimizing further environmental damage in the Kaskaskia region, with some emphasis on through tow fleeting at site 4. While for states 3 and 5, without full coal development, less environmental damage can occur by grouping fleeting for dock delivery in central and near south harbors, with through fleeting at the far south shoreline, again avoiding use of the kaskaskia area.

C) Cost and Regulatory Perspective

Using this viewpoint, the policy vector is as follows:

State	Policy Vector of Alternatives	Value Vector
1	3	17.7500
2	7	290.4998
3	7	283.4998
4	7	290.4998
5	7	290.4998

This solution emphasizes a balance of minimum cost and maximum safety perspectives. For status quo of state 1, it implements alternative 3 (sites 3,4,5) with dock delivery potential in sites 3 and 4 and through tow makeup in 5. The rest of the states call for implementation of alternative 7 (site 3 - central harbor only) - which is essentially the current dominant fleeting pattern. Although alternative 7 is optimal from a cost minimization perspective, it is infeasible by virtue of being unable to accommodate the 800 additional spaces required, and by virtue of City of St. Louis policy prohibiting further significant shoreline fleeting expansion in locations which are specifically capable of being used for industrial income-producing real estate operation requiring water access.

D) Compromise

The compromise or "all perspectives equal" policy vector is as follows:

State	Policy Vector of Aternatives	Value Vector
1	2	45.5322
2	3	98.4293
3	3	71.3000
4	9	137.6000
5	2	93.4503

This output is surprisingly similar to that of the developmental interests, wherein long run future gain is maximized if in state 1 by implementation of fleeting capabilities for dock delivery at 1, 2 and 6, (coal service at Kaskaskia) and through tow makeup on the far south shoreline of site 5. Once North Harbor and Tri-Cities development with full coal (state 2) or without full coal (state 3) has occurred, future fleeting capacity should be built into site 3, the central harbor, site 4, the near south, and site 5, far south to achieve potential future development at Chesley and Arsenal Islands, with adequate through-tow makeup capabilities. Upon development of all port facilities and coal development of state 4, further capacity should be added in North Harbor,

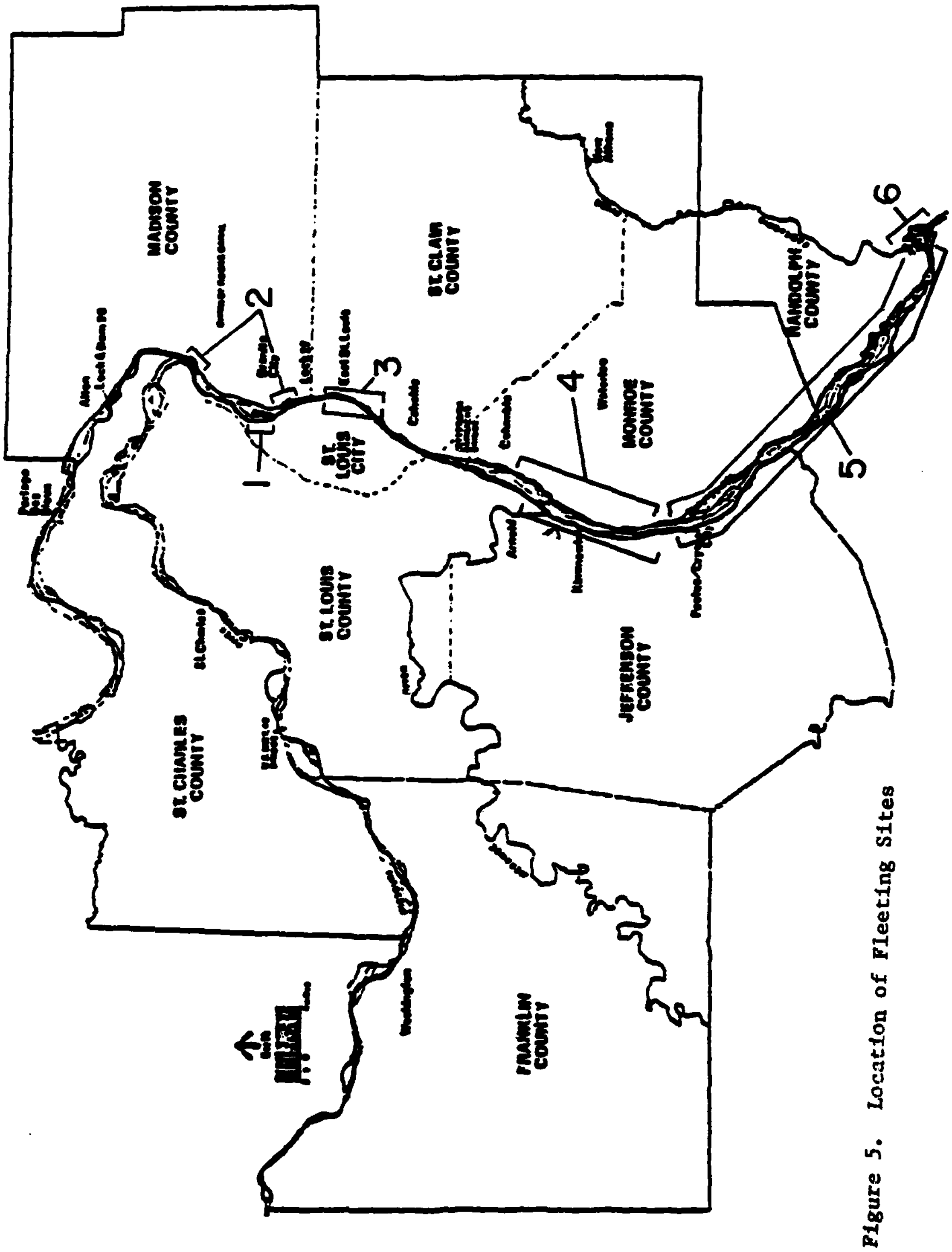

Figure 5. Location of Fleeting Sites

Tri-Cities and Near South, to assure adequate dock delivery, while if in state 5, adequate capacity should be placed in 1, 2, 5 and 6 to encourage future full coal development at Kaskaskia and continued local dock delivery.

Sensitivity Analysis

To illustrate the flexibility of the model to changes in input data in addition to the alterations in importance viewpoints illustrated above, three other sensitivity analyses were run. They are:

A) Capital Cost Reduction

B) Fifty percent reduction in fuel usage, by virtue of a common dock delivery boat, leaving each individual fleeter's boats free to work through tow makeup.

C) Revised dock delivery with a significant LASH barge fleet component.

A) Capital Cost Reduction

To investigate the impact of lowered capital costs, a 20% reduction in capital costs for the slack water and constructed fleeting location was conceptualized, thus improving the rankings in the value matrix scores of all alternatives containing sites 1 and 2. This parametric change was examined for the most cost-conscious viewpoint, that of the cost and regulatory perspective. The results are as follows:

State	Policy Vector of Alternatives	Value Vector
1	1	103.5558
2	3	130.0479
3	3	150.2522
4	9	75.3047
5	2	51.9754

It should be readily noted that this reduction in cost significantly alters the solution. Alternatives 1 (sites 1,2,5) and 4 (sites 1,2,4) and 5 (sites 1,2,5,6) all contain the North Riverfront slack water high cost site 1 and the relatively high cost Tri-Cities site 2 complex, with the above alternatives being recommended for states 1, 4 and 5 respectively. In addition, shoreline fleeting construction costs of alternative 3 are recommended for states 2 and 3. These results are different from the dominance of low cost alternative 7 (site 3), central harbor concentration, recommended in the previous section.

B) Common Dock Delivery Boat

As stated earlier, interviews indicated a minimum desire to co-operate among fleeters, due to the private enterprise, competitive nature of their business. In view of the dominant preference for through tow makeup work versus dock delivery, and the contradictory critical demand for good local service by terminals and industries, one option was highly worthy of testing. This is the concept of a common boat or boats handling all dock delivery for all fleeters, based on a co-operative agreement among them to support such a boat. Their tugs are then left to operate solely in tow makeup work. Based on the amount of local origin-destination redundant tow activity in the harbor, it is likely this could save significant amounts of fuel. As such, this concept was tested by improving all fuel consumption rankings in the value matrix scores indicating a "fuel bonus" for co-operation. The most appropriate test of this concept is in the environmentally sensitive weightings, thus conceiving an environment vs. energy scenario. The results are as follows:

AD-A096 158 WASHINGTON UNIV ST LOUIS MO DEPT OF CIVIL ENGINEERING F/G 13/2
EVALUATION OF FLEETING OPERATIONS IN PORTS.(U)
OCT 80 L E HAEFNER MA79SAC00105
UNCLASSIFIED MA-PORT-520-81039 NL

END
DATE
FILMED
4-81
DTIC

State	Policy Vector of Alternatives	Value Vector
1	1	66.9357
2	3	40.6414
3	4	90.4690
4	9	40.4617
5	7	34.6455

The results are not significantly different from the previous runs, with the exception of results for state 1 and state 5. For state 1, alternative 1 (sites 1,2,5) implies that long run gain can be maximized, including full coal development without implementing site 6, justifying use of relatively less accessible fleeting areas for Kaskaskia service by virtue of lower energy expenditures. Likewise, implementation of future full coal development from state 5 suggests additional capacity at site 3, central harbor only. This again suggests trading off increased travel versus capital implementation of an immediately adjacent fleeting site, by virtue of lowered overall energy cost in harbor activities.

C) Introduction of LASH BARGE Technology into the Local Fleet

It is appropriate to examine the impact on St. Louis harbor fleeting if a significant amount of the future growth in local dock delivery was to be accommodated by LASH barges. These smaller dimension vessels (61'6" x 35') would yield two significant changes in local harbor characteristics.

a) They would increase diversity in cargo, thus allowing altered transition in the harbor development states, emphasizing those states with potential for general cargo.

b) They would require more manuevering of tugs to fleet a like number of barges, thus increasing fuel costs significantly.

The above alterations have been investigated for the future growth in barges to be fleeted for dock delivery, with 30% of their composition being LASH barges. This investigation is conceptualized by altering the transition matrices as shown in Table 11, with more weight being added to the transition probabilities of p_{13}^{k}, p_{23}^{k}, p_{25}^{k}, thus emphasizing general harbor development without emphasis on coal, per se. In addition, the rankings for fuel consumption have all been penalized by 50%, emphasizing the impact of increased manuevering required for spotting smaller barges. The appropriate analysis is for the environmentally sensitive perspective, thus testing a "technology innovation vs. environment" scenario. The results are as shown below:

State	Policy Vector of Alternatives	Value Vector
1	1	27.0593
2	3	36.2653
3	4	41.1048
4	9	19.8862
5	2	17.1263

The results are quite different from those of the initial environmental perspective, yielding solutions similar to that of the initial economic development scenario. Given the origin-destination demands, due to shifted harbor development transitions, alternative 1 (sites 1,2,5) is recommended for state 1, to maximize local general cargo dock

Table 11

Altered $[P_{1j}]^k$ Matrices Reflecting the

Impact of LASH BARGE Technology

TRANSITION PROBABILITY MATRIX FOR ALTERNATIVE 1

.100	.100	.600	.050	.150
050	.200	.200	.350	.200
050	.100	.650	.050	.300
050	.0	.0	.950	.0
050	.0	.0	.350	.600

TRANSITION PROBABILITY MATRIX FOR ALTERNATIVE 2

.050	.250	.250	.200	.250
050	.200	.250	.250	.250
050	.200	.250	.250	.250
050	.0	.0	.950	.0
050	.0	.0	.900	.050

TRANSITION PROBABILITY MATRIX FOR ALTERNATIVE 3

.050	.050	.350	.150	.400
050	.050	.0	.350	.550
050	.150	.300	.100	.400
050	.0	.0	.950	.0
050	.0	.0	.200	.800

TRANSITION PROBABILITY MATRIX FOR ALTERNATIVE 4

.200	.150	.300	.100	.250
050	.200	.200	.350	.200
050	.200	.250	.250	.250
050	.0	.0	.950	.0
050	.0	.0	.950	.0

TRANSITION PROBABILITY MATRIX FOR ALTERNATIVE 5

.100	.100	.150	.500	.150
050	.050	.100	.700	.100
050	.050	.100	.700	.100
050	.0	.0	.950	.0
050	.0	.0	.950	.0

TRANSITION PROBABILITY MATRIX FOR ALTERNATIVE 6

.100	.150	.150	.450	.150
050	.100	.100	.650	.100
050	.100	.100	.650	.100
050	.0	.0	.950	.0
050	.0	.0	.950	.0

TRANSITION PROBABILITY MATRIX FOR ALTERNATIVE 7

.300	.050	.350	.030	.270
300	.300	.200	.0	.200
300	.0	.400	.003	.0
100	.0	.300	.300	.300
100	.005	.0	.004	.0

Table 11 (cont.)

TRANSITION PROBABILITY MATRIX FOR ALTERNATIVE 8

.100	.0	.750	.0	.150
100	.200	.300	.100	.300
100	.0	.600	.100	.200
100	.0	.100	.700	.100
100	.0	.200	.0	.700

TRANSITION PROBABILITY MATRIX FOR ALTERNATIVE 9

.050	.0	.700	.0	.250
050	.200	.100	.550	.100
050	.0	.400	.0	.550
300	.0	.0	.700	.0
050	.0	.0	.250	.700

delivery for North Riverfront and Tri-Cities, with through fleeting served by site 5. Alternative 3 (sites 3,4,5) is recommended if in state 2, which recommends further additional capacity for local dock delivery at 3 and 4 to open up the Chesley-Arsenal Island development potential, along with through fleeting at site 5. If state 3 obtains, alternative 4 (sites 5,6) is recommended, adding through capacity and potentials for coal service at 6. If full port development and coal service exists as per state 4, further capacity is recommended at sites 1, 2, 4 comprising alternative 9, again emphasizing local dock delivery for more intense general cargo movement. If state 5 obtains, alternative 2 (sites 1,2,5,6) is recommended, allowing some future potential for coal service at Kaskaskia, along with emphasis on addition of further capacity for the large general cargo potential of the North Riverfront and Tri-Cities.

Versatility of the Model

Although this model has been developed and tested on the St. Louis Metropolitan Port, the technique and resulting computer software is generalizable to any inland or deep water port experiencing fleeting or harbor congestion problems. It is necessary for the port authority to organize its land use, commodity flow projections, harbor traffic volume data, tug operations costs, and environmental impact data into a format which allows them to describe likely future states of harbor development. These states, in conjunction with proposed alternatives, and their impacts can be structured and analyzed by the Markovian evaluation technique illustrated herein.

This chapter has demonstrated the management model's capabilities over a wide array of viewpoints and data input alterations. The next chapter will articulate conclusions from the research and potential areas of further investigation.

CHAPTER VI

CONCLUSIONS - NEED FOR FURTHER RESEARCH

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This chapter will format the major conclusions on the research approach and major findings of the case study evaluation of the Bi-State Regional Port, and offer suggestions for logical future research to enhance the state of the art.

Conclusions

It is appropriate to document what this research has achieved. Specifically, it has:

1) Organized the major port operational problem of fleeting into a management framework.
2) Developed a comprehensive data base on land use plans and port development efforts, commodity flow forecasts and likely local dock fleeting origin-destination patterns for the St. Louis harbor to the year 2000.
3) To the extent possible, it has gathered information on opinions with respect to environmental data and impacts related to fleeting.
4) Engaged in dialogue and interviews with fleeters and terminal operators, establishing a data base on prices, operational priorities, opportunities and desire for co-operation among the fleeting community.
5) Limited, if any, fleeter mutual co-operation can be expected due to the highly competitive free enterprise nature of their business. As such, the only viable operational alternative

tested was a common dock delivery boat, freeing all other boats for through tow fleeting activity. This results in reduction in fuel consumption, which was incorporated in the sensitivity analysis.

6) Formatted and demonstrated a Markovian decision theory model for management of long range fleeting planning in the St. Louis area with respect to siting and limited operational alterations. The model adequately accommodate the following:

   a) Uncertainty of commodity flow data and port land use plans.

   b) The relationship between fleeting alternatives and likely port development patterns.

   c) Subjective or actual measured environmental and cost data, as an input to evaluation matrices.

   d) Incorporation of various viewpoints in the decision process (development vs. environment, compromise positions etc.).

   e) Development of meaningful fleet siting conclusions for all of the above viewpoints, and reasonable sensitivity analysis for capital cost alterations, improved energy efficiency through common dock delivery boat fleeter cooperation, and changes in cargo and land use patterns that are potential by the use of LASH barges in the inland river fleet.

7) The Markovian decision theory management model demonstrated herein can be generalized for use at any inland or deep water port in the nation with their particular operational, cost,

commodity flow, land use and environmental data. Thus, a significant advance in the state of the art has been achieved.

Need for Further Research

As in any research effort, the activity yields further insight into the problem, revealing new areas of research which would complement the current study effort, and/or further the state of the art. Based on this research effort, the following are concluded to be areas of significant further research needs and opportunities:

1) The most striking need is specific research on environmental effects with regards to fleeting. All of the environmental attributes suffer from no documentation of specific fleeting impacts. A highly structured research approach to this matter should be undertaken immediately.

2) A much better data base on daily fleeting movements in and out of each site is desirable to adequately record volumes, capacity, usage ($\frac{V}{C}$), and origin-destination patterns in the context of port commodity flow. Due to the private sector nature of fleeting operations and site leasing, this data is unlikely to be made available by each individual fleeter. However, its availability would immensely aid long run facility planning accuracy.

3) Some research documentation is needed on levels of improved fleeting capacity and turn-around time as related to total terminal operations, thus illustrating the relationship to land side transportation services and developing potential measures of improved port terminal productivity as related to fleeting.

4) Closely related to the above, interaction with port and terminal delay research work, illustrating detailed intra-harbor travel time delay and cargo transfer delay, and their relationship to terminal productivity.

5) A review of key export commodities (grain, coal) and the potential for improved export position by virtue of adequate fleeting services of these commodities at the key port of St. Louis, or other congested ports.

6) The combining of the above research with a comprehensive port development capital budgeting model - relating fleeting development sites and harbor states to comprehensive time-staged harbor investment programs. Washington University is currently beginning such a project with MARAD.

In final conclusion, this research effort has formatted a meaningful fleeting management model, tested it on the highly relevant port of Metropolitan St. Louis, and presented it in a form generalizable and usable at any inland or deep water port in the nation with their particular operational, cost, commodity flow, land use and environmental data. In so doing, detailed knowledge about fleeting operations has been procured, and meaningful new areas of research have been discovered to pursue which will further enhance the state of the art.

BIBLIOGRAPHY

BIBLIOGRAPHY

American Commercial Barge Line Company. Inland Waterway Mileage Guide.

American Waterway Operators, Inc. Big Load Afloat. American Waterway Operators, Inc., Washington, D.C. 3rd printing - 1973.

Public Affairs Office, U.S. Army Corps of Engineers. Efficiency and Benefits of Inland Navigation. Public Affairs Office, U.S. Army Corps of Engineers, Washington, D.C. 1975.

U.S. Army District, Corps of Engineers, St. Louis, Mississippi River St. Louis Harbor Evaluation Report. April 1978.

East-West Gateway Coordinating Council. Port of Metropolitan St. Louis Appendix A: Profile of the Port, 1975. Prepared for U.S. Department of Commerce, Maritime Administration. May 1976.

East-West Gateway Coordinating Council. Port of Metropolitan St. Louis Appendix B: Commodity Market Analysis. Prepared for U.S. Department of Commerce, Maritime Administration. May 1976.

East-West Gateway Coordinating Council. Port of Metropolitan St. Louis Appendix C: Port Operations Analysis. Prepared for U.S. Department of Commerce, Maritime Administration. May 1976.

East-West Gateway Coordinating Council. Port of Metropolitan St. Louis Atlas. Prepared for U.S. Department of Commerce, Maritime Administration. May 1976.

Franco, J.J. Shoaling Conditions, St. Louis Harbor, Mississippi River, Hydraulic Model Investigation. U.S. Army Engineer Waterways Experiment Station, Hydraulics Laboratory. Vicksburg, Mississippi. November 1972.

Hymson, Edward B. "Analysis of Rail-Water Price Competition." Transportation Research Record 635, Transportation Research Board. 1977.

Jordan, P.R. "Fluvial Sediment of the Mississippi River at St. Louis, Missouri." United States Geological Survey Water Supply Paper 1802. 1965.

Jordan, P.R. Summary and Analysis of Sediment Records in Relation to St. Louis Harbor Sedimentation Problem. U.S. Geological Survey, Water Resources Division, 1968.

Illinois Statutes. House Bill No. 404 Approved June 10, 1911. Statutes of 1912, pp. 115-122.

A.T. Kearney, Inc. Recommendations for the Development of the Port of Metropolitan St. Louis to the Year 2000 - Executive Summary. Prepared for East-West Gateway Coordinating Council, St. Louis, MO. April 1977.

A.T. Kearney, Inc. Recommendations for the Development of the Port of Metropolitan St. Louis to the Year 2000 - Final Report. April 1977.

A.T. Kearney, Inc. Study of the Port of Metropolitan St. Louis, Phase II - Appendix H: Marked Research Findings. March 1977.

A.T. Kearney, Inc. and East-West Gateway Coordinating Council. Study of the Port of Metropolitan St. Louis, Appendix I: Industrial Development Sites Selected for Regional Emphasis. March 1977.

Lang, Don and Yarjani, Bigan. "Waterway Channels - Inland Water Transportation" Working Paper, CE 500-2. Washington University. November, 1976.

Lengyel, Barbara Wilson. "Inland Navigation Simulation Model." Transportation Research Record 704, Transportation Research Board. 1979.

Marcus, Henry S. et al. Federal Port Policy in the United States. MIT Press, Cambridge, MA. 1976.

Public Affairs Office, Mississippi River Commission and U.S. Army Engineers Division, Corps of Engineers. Mississippi River Navigation. U.S. Army Corps of Engineers, Vicksburg, Mississippi. December 1975.

National Research Council, Panel on Future Port Requirements of the United States, Maritime Transportation Research Board. Port Development in the United States. Maritime Transportation Research Board, Washington, D.C. 1976.

Paley, Cynthia W. "The Mississippi River Navigation System and Locks and Dam 26." Working Paper, Washington University. February 1976.

Scott, C.H. and Stephens, H.D. "Special Sediment Investigations - Mississippi River at St. Louis, Missouri 1961-63." United States Geological Survey Water Supply Paper 1819-J. 1966.

Smith, Robert Leo. Ecology and Field Biology, 2nd ed. Harper and Row. New York. 1974.

Southern Illinois Metropolitan and Regional Planning Commission. Alton and Southern Land Use Analysis. Prepared for Southwest Regional Port District. June 1977.

Southwestern Illinois Metropolitan and Regional Planning Commission. Development Plan for Granite City Army Installation Excess Property, Granite City, Illinois. Prepared for Illinois Department of Transportation and Tri-City Regional Port District. July 1979.

Southwestern Illinois Planning Commission. Tri-City Regional Port District Development Plan. Prepared for Tri-City Regional Port District. December 1978.

Sverdrup, Parcel and Associates, Inc. A Port Development and Land Use Study for the Port District of St. Louis, St. Louis, Missouri. December 1976.

Tippetts-Abett-McCarthy-Stratton. Mid-America Ports Study - Volume I-XIX, Maritime Administration, U.S. Department of Commerce, June 1979.

Winsett-Simmonds, Consterdine & Jacobs, Inc. and Metropolitan Engineering Co. Waterways - Jefferson County, Missouri. Prepared for Jefferson County Port Authority. 1978.

APPENDIX A

MARKOVIAN DECISION THEORY

APPENDIX A

MARKOVIAN DECISION THEORY

A. Expected Reward of a Policy

The expected reward $v_i(n)$ from a set of staged decisions (policy), given a starting point (i) is defined by the recurrence relationship

$$v_i(n) = \sum_{j=1}^{N} p_{ij}\{r_{ij} + v_j(n-1)\} \qquad i = 1,2,\ldots N,\ n = 1,2,\ldots$$

By defining q_i, the expected reward from the next stage transition, given the starting state i

$$q_i = \sum_{j=1}^{N} p_{ij} r_{ij} \qquad i = 1,2,\ldots N$$

the recurrence relationship can be written in the form

$$v_i(n) = q_i + \sum_{j=1}^{N} p_{ij}\ v_j(n-1) \qquad i = 1,2,\ldots N,\ n = 1,2,\ldots$$

As an example, suppose our problem contained two states, with matrices

$$R = \begin{bmatrix} 9 & 3 \\ 3 & -7 \end{bmatrix} \qquad P = \begin{bmatrix} .5 & .5 \\ .4 & .6 \end{bmatrix}$$

Then, after computing

$$q = \begin{bmatrix} 6 \\ -3 \end{bmatrix}$$

the recurrence relationship can be used to construct the values in the following table:

TOTAL EXPECTED REWARD AS A FUNCTION OF STATE
AND NUMBER OF STAGES REMAINING

n =	0	1	2	3	4	5
$v_1(n)$	0	6	7.5	8.55	9.555	10.5555
$v_2(n)$	0	-3	-2.4	-1.44	-0.444	0.5556

B. Gain of an Ergodic Process

The gain (g) of an ergodic process can be found from

$$g = \sum_{i=1}^{N} \pi_i q_i$$

where q_i is the expected immediate return in state i and π_i is the steady state probability of state i. The gain can be visualized as the return per transition of the process.

C. The Policy Iteration Method

Expected total return is defined as

$$v_i(n) = q_i + \sum_{j=1}^{N} p_{ij} v_j(n-1) \qquad i = 1,2,\ldots N,\ n = 1,2,\ldots$$

As n increases, $v_i(n)$ asymptotically approaches the line

$$v_i(n) = ng + v_i$$

for the ergodic process (where g is the gain and v_i is the axis intercept). If the system is run for a large number of stages one can use

$$\sum_{j=1}^{N} p_{ij} = 1 \qquad \text{to develop the relationship}$$

$$g + v_i = q_i + \sum_{j=1}^{N} p_{ij}v_j \qquad i = 1,2,\ldots N$$

which is a set of N simultaneous linear equations with N+1 unknowns (N v_i's and one g). Setting $v_N = 0$ allows solution of the system for g, the expected (relative) gain of a policy. By comparing gains for the set of possible policies, the optimal policy can be determined.

If an optimal policy exists up to stage n, the best alternative in the ith state at stage n+1 can be found by maximizing the function

$$q_i^k + \sum_{j=1}^{N} p_{ij}v_j{}^k(n)$$

over all alternatives (k) in the ith state. Using the results obtained in the last section for large n, substitute

$$v_i(n) = ng + v_i$$

and obtain the test quantity

$$q_i^k + \sum_{j=1}^{N} p_{ij}{}^k v_j$$

with respect to the alternatives in the ith state. In summary: for each state i, find the alternative k that maximizes the test quantity using the relative values determined under the old policy. The alternative k now becomes d_i, the decision in the ith state. A new policy has been determined when this procedure has been performed for every state. The iteration cycle is as follows:

VALUE-DETERMINATION OPERATION

Use p_{ij} ad q_i for a given policy to solve

$$g + v_i = q_i + \sum_{j=1}^{N} p_{ij} v_j \qquad 1 = 1,2,\ldots N$$

for all relative values v_i and g (by setting $v_N = 0$).

POLICY IMPROVEMENT ROUTINE

For each state i, find the alternative k* that maximizes

$$q_i^k + \sum_{j+1}^{N} p_{ij}^k v_j$$

using the relative values v_i of the previous policy. Then k* becomes the new decision in the ith state, q_i^{k*} becomes q_i and p_{ij}^{k*} becomes p_{ij}.

The process can begin in either of the boxes. If value determination is selected as the starting point, an initial policy must be selected. If policy improvement is to start, then a starting set of values is necessary. If nothing else is a priori better, it is convenient to start in policy improvement with all $v_i = 0$. The optimal policy is reached when two successive iterations are identical in policy chosen. In our examples above, we are given the following data:

State	Alternative	Transition Probabilities		Rewards		Expected Immediate Return
i	k	p_{i1}^k	p_{i2}^k	r_{i1}^k	r_{i2}^k	q_i^k
1	1	.5	.5	9	3	6
	2	.8	.2	4	4	4
2	1	.4	.6	3	-7	-3
	2	.7	.3	1	-19	-5

Step 1: Set $v_1 = v_2 = 0$ and enter policy improvement routine

Step 2: It chooses maximum immediate returns, giving

$$d = \begin{bmatrix} 1 \\ 1 \end{bmatrix} \qquad P = \begin{bmatrix} .5 & .5 \\ .4 & .6 \end{bmatrix} \qquad q = \begin{bmatrix} 6 \\ -3 \end{bmatrix}$$

Step 3: Entering the value determination routine:

$$g + v_1 = 6 + .5v_1 + .5v_2 \quad \text{and}$$

$$g + v_2 = -3 + .4v_1 + .6v_2$$

By setting $v_2 = 0$ we solve and obtain

$$g = 1 \qquad v_1 = 10 \qquad v_2 = 0.$$

Step 4: Applying the policy improvement routine:

State	Alternative	Test Quantity
i	k	$q_i^k + \sum_{j=1}^{2} p_{ij}^k v_j$
1	1	$6 + .5(10) + .5(0) = 11$
	2	$4 + .8(10) + .2(0) = 12^*$
2	1	$-3 + .4(10) + .6(0) = 1$
	2	$-5 + .7(10) + .3(0) = 2^*$

yields

$$d = \begin{bmatrix} 2 \\ 2 \end{bmatrix} \qquad p = \begin{bmatrix} .8 & .2 \\ .7 & .3 \end{bmatrix} \qquad q = \begin{bmatrix} 4 \\ -5 \end{bmatrix}$$

Step 5: Repeating the process:

$$g + v_1 = 4 + .8v_1 + .2v_2$$

$$g + v_2 = -5 + .7v_1 + .3v_2$$

yielding $v_2 = 0$ $\qquad g = 2 \qquad$ $v_1 = 10$

Step 10: As one can see, the computations will be identical, and will yield the same results. Then we have reached two successive identical policies, implying that this is the optimal policy:

$$d = \begin{bmatrix} 2 \\ 2 \end{bmatrix}$$

APPENDIX B

SOFTWARE DOCUMENTATION

MARKOVIAN DECISION THEORY

Program Explanation

The following Markovian Decision Theory program was developed for the National Aeronautics and Space Administration in past works performed by Haefner. (66) (67) This decision theory approach has become a highly useful solution approach to the evaluation of multi-dimensional regional transportation investments. It enables the qualified users to rigorously examine a set of feasible transportation investments in light of the uncertainty of real world processes and in the projections of future regional development. Figure B.1.1 is a flowchart presentation of the computer software implementation of the solution technique, as described in Chapter IV. Table B.1.1 is next presented as a variable list of the software program. Section B.2 follows as the computer software listing.

Figure B.1.1

Flowchart Description, Markovian Decision Theory, Policy Iteration Solution Technique

MAIN PROGRAM

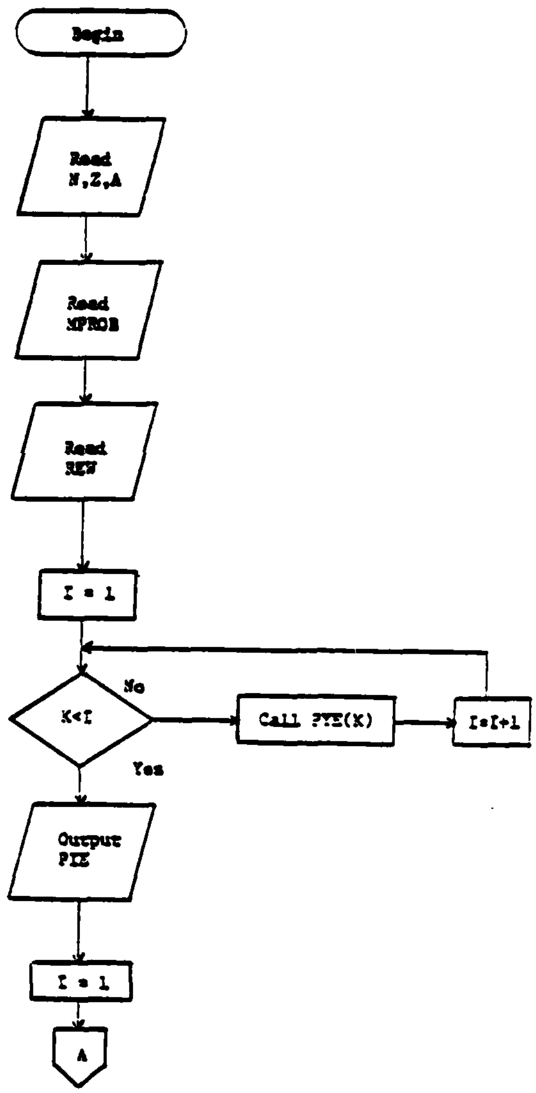
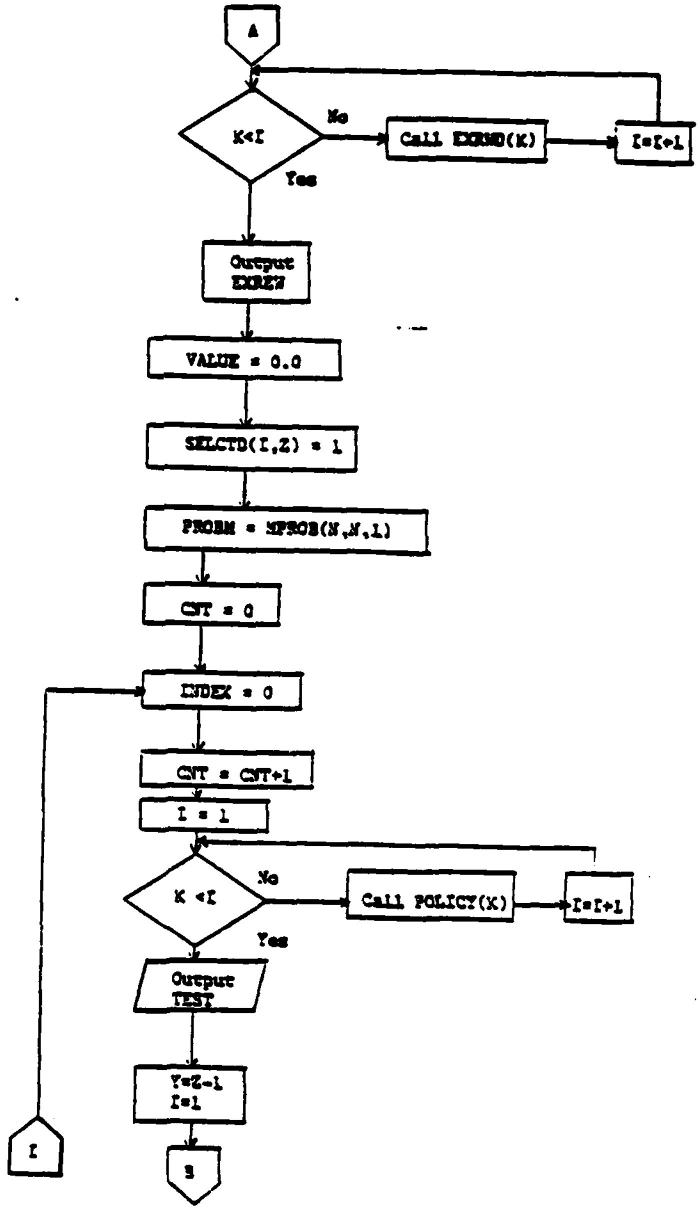


Figure B.1.1
(Continued)



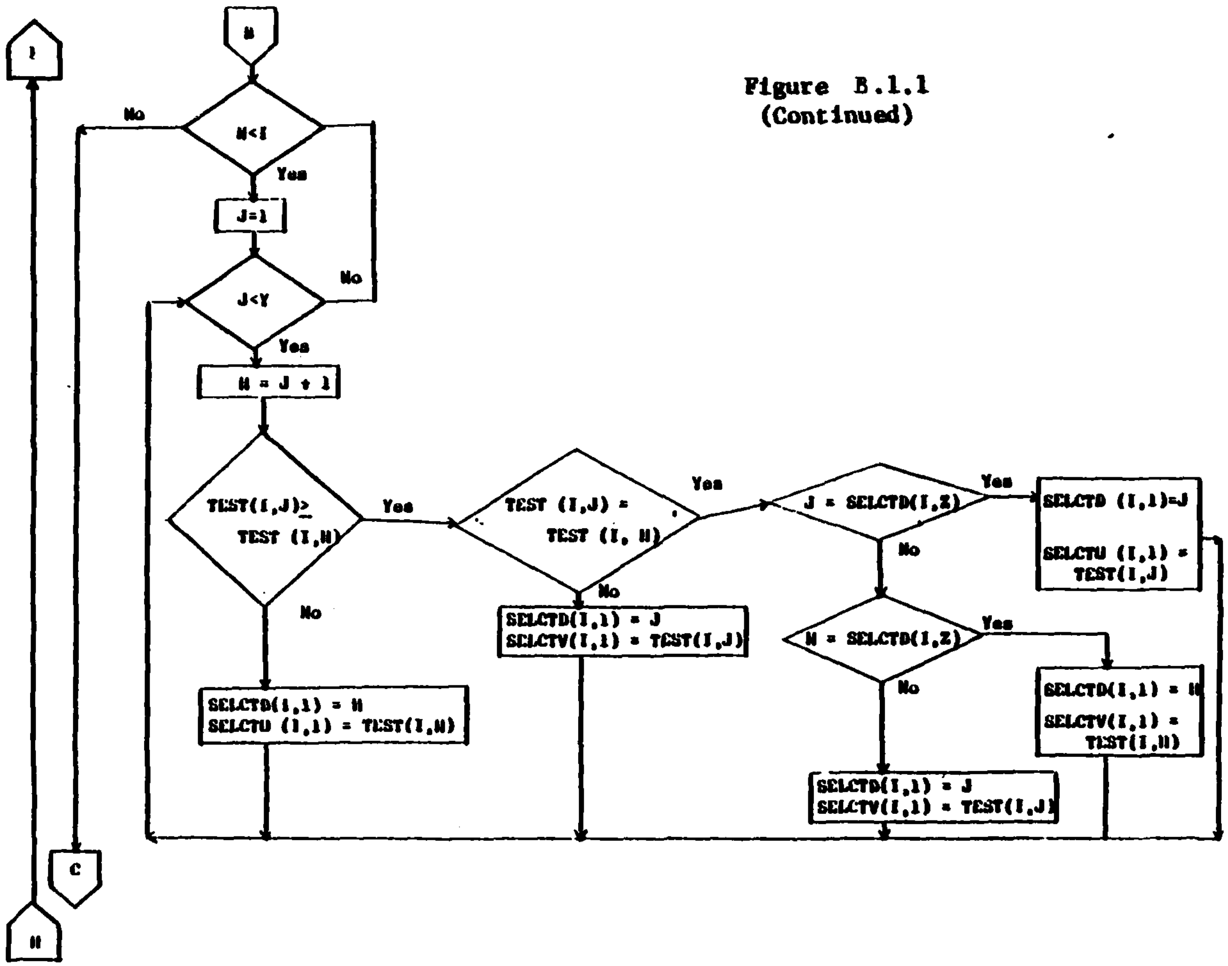


Figure B.1.1
(Continued)

Figure B.1.1
(Continued)

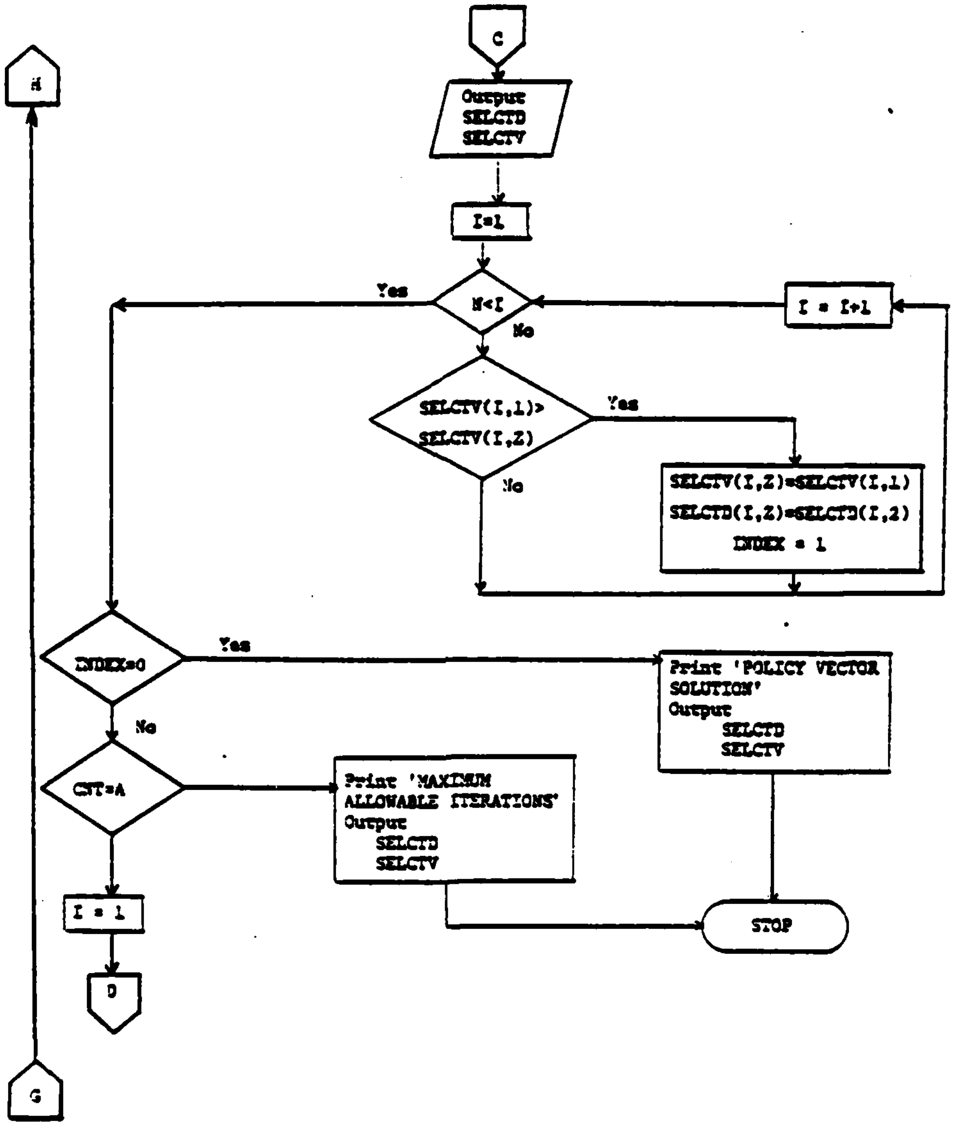


Figure B.1.1
(Continued)

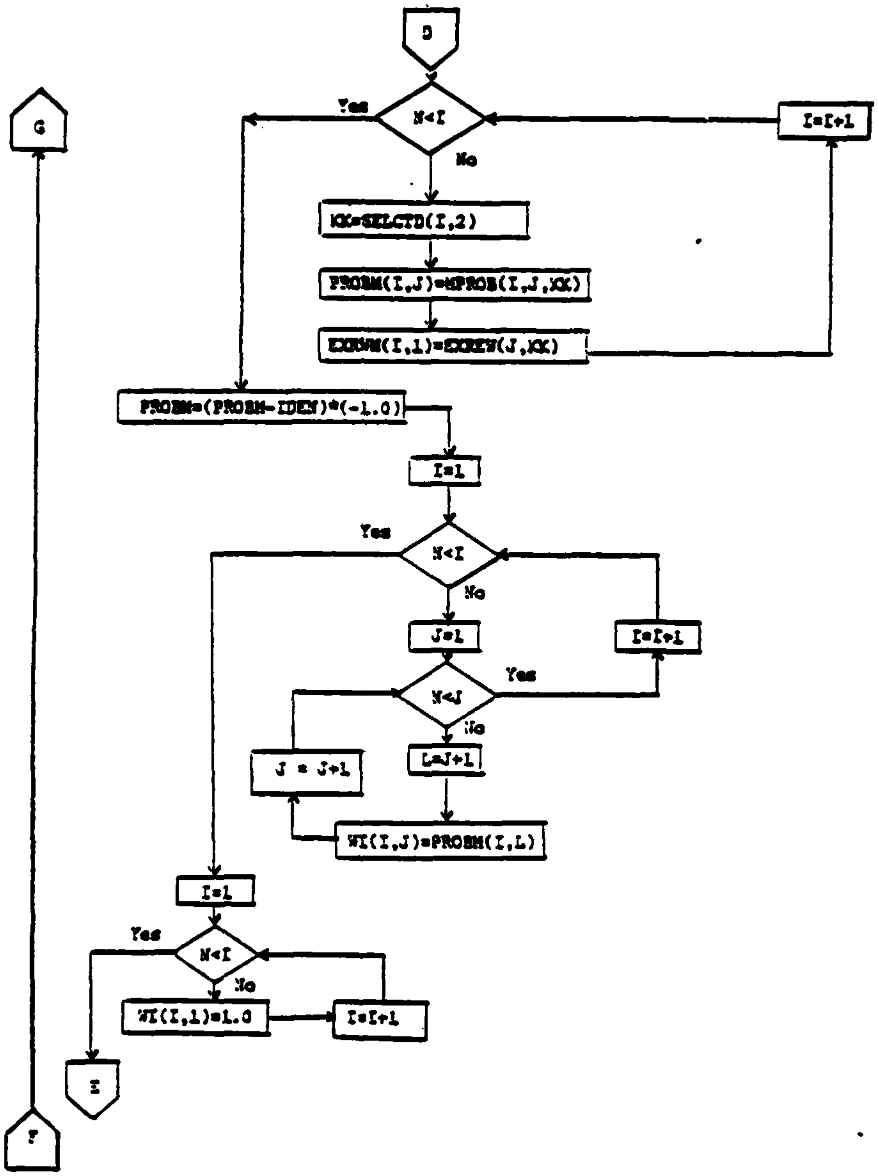


Figure B.1.1
(Continued)

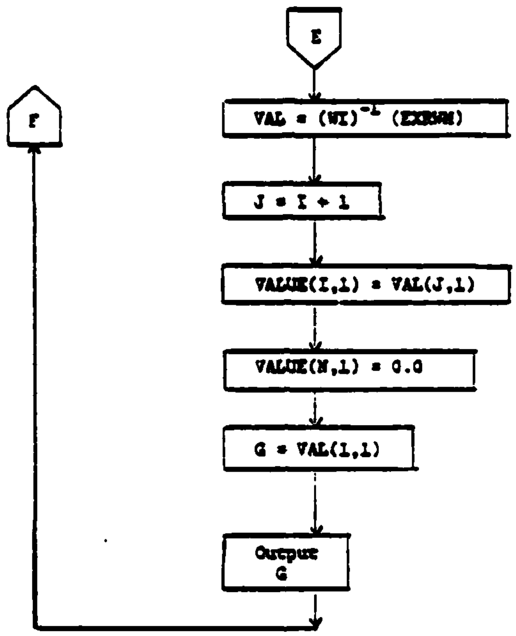


Figure B.1.1
(Continued)

Subroutine PYE

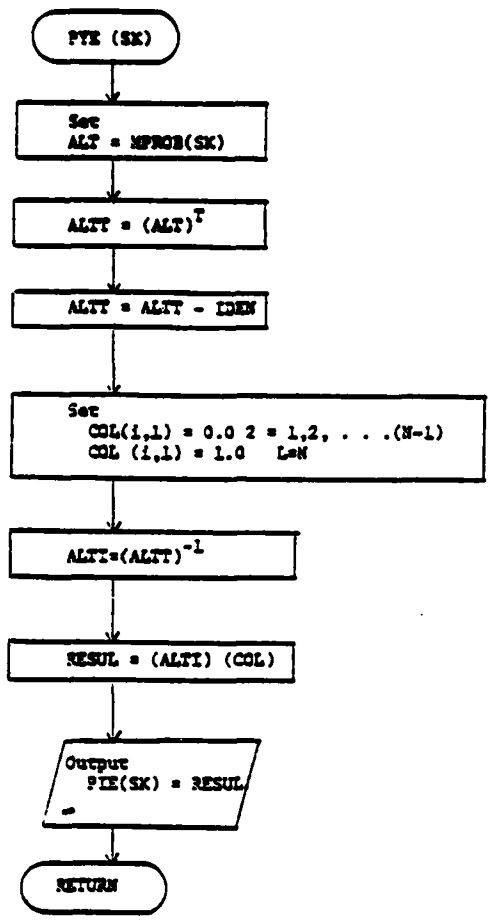


Figure B.1.1
(Continued)

Subroutine EXRWD

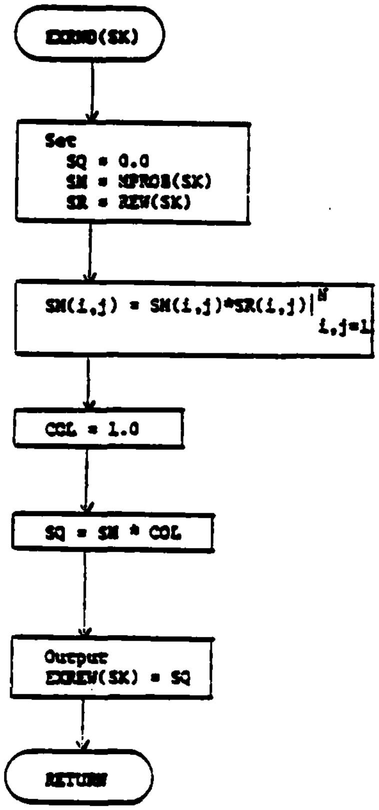


Figure B.1.1
(Continued)

Subroutine POLICY

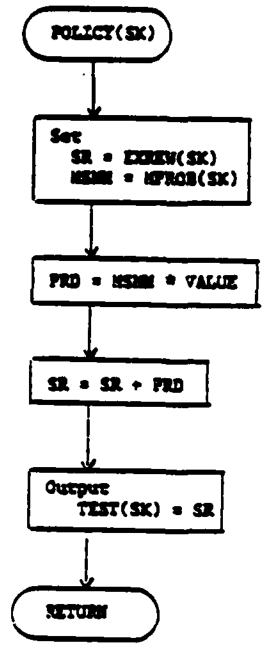


Table B.1.1

Main Program, common

N	Number of system states, $0<N\leq 25$
Z	Number of alternatives, $0\leq Z\leq 10$
A	Maximum number of allowable iteration cycles
MPROB	Matrix of single step transition probabilities, (NxNxK)
REW	Matrix of transition rewards, (NxNxK)
PIE	Matrix of Steady State probabilities, (NxK)
EXREW	Matrix of expected immediate Rewards, (NxK)
VALUE	Matrix of state value, v_i, (Nx1)
SELCTD	Matrix of decisions, d_i, (Nx2) where, for i - 1, 2, . . .N d(i,1) = new decision, state i d(i,2) = old decision, state i
SELCTV	Matrix of maximum test quantity values, (Nx2), where for i = 1, 2, . . .N SELCTV(I,1) = new maximum test value SELCTV(I,2) = old maximum test value, previous iteration
PROBM	Matrix of modified transition probabilities for the policy improvement operation (NxN)
CNT	Iteration number
INDEX	information variable indicating if at least one element of the policy vector has been changed since the last iteration 0 = no change 1 = change
TEST	Matrix of test quantity values, policy improvement operation (NxZ)

Table B.1.1
(Continued)

EXRWM	Matrix of modified expected rewards, (Nx1)
IDEN	Identity matrix, (NxN)
WI	Work matrix (NxN)
VAL	Work matrix (Nx1)
G	System gain

Subroutine PYE

ALT	Matrix of single step transition probabilities, (NxN)
COL	Work matrix, (Nx1)
RESUL	Matrix of steady state probabilities, (Nx1)

Subroutine EXRWD

SQ	Work matrix, (Nx1)
SM	Matrix of single step transition probabilities, (NxN)
SR	Matrix of transition rewards, (NxN)
COL	Work matrix, (Nx1)

Subroutine POLICY

SR	Matrix of expected rewards, (Nx1)
MSMM	Matrix of single step transition probabilities

Section B

Software Listing,

Markovian Decision Theory

```
//GC@POLCY JOB (65590,1385,2),'LEE HUTCHINS',CLASS=G,TIME=(,50)
/*ROUTE  PRINT REMOTE13
//A EXEC IMSLSPGO
//FORT.SYSIN DD *
      INTEGER N,Z,A,Y,H,KK,C,D,B
      REAL MPROB,IDEN
      DIMENSION IDEN(25,25)
      DATA IDEN/625*0./
      REAL PIE
      INTEGER CNT,INDEX
      INTEGER SELCTD
      DIMENSION WINV(25,25),W2(25,25)
      DIMENSION SELCTD(25,2)
      DIMENSION SELCTV(25,2)
      DIMENSION PROBM(25,25)
      DIMENSION EXRWM(25,10)
      DIMENSION WI(25,25)
      DIMENSION WV1(25,1)
      DIMENSION WV2(25,1)
      DIMENSION VAL(25,1)
      DIMENSION FMT1(18)
      DIMENSION FMT2(18)
      COMMON/BLIST/MPROB(25,25,10),REW(25,25,10),PIE(25,10),
     1EXREW(25,10),TEST(25,10),VALUE(25,1),N,FMT(18),FMT3(18)
      DATA SELCTD/50*0/,SELCTV/50*0./
      READ (5,1) N,Z,A
      READ (5,8) FMT1
      READ (5,8) FMT2
    1 FORMAT (3I4)
      PRINT 2,N
    2 FORMAT('0','NUMBER OF SYSTEM STATES',2X,I4)
      PRINT 3,Z
    3 FORMAT('0','NUMBER OF ALTERNATIVES',2X,I4)
      PRINT 4,A
    4 FORMAT('0','MAXIMUM NUMBER OF ITERATIONS',2X,I4)
      READ (5,FMT1) (((MPROB(I,J,K),J=1,N),I=1,N),K=1,Z)
      READ (5,FMT2) (((REW(I,J,K),J=1,N),I=1,N),K=1,Z)
      READ (5,8) FMT
      READ (5,8)FMT3
    8 FORMAT (18A4)
      CNT=0
      INDEX=0
      DO 7 M=1,N
      IDEN(M,M)=1.0
    7 CONTINUE
      DO 20 K=1,Z
      IF (K.EQ.1) CALL PYE(K)
      IF (K.EQ.2) CALL PYE(K)
      IF (K.EQ.3) CALL PYE(K)
      IF (K.EQ.4) CALL PYE(K)
      IF (K.EQ.5) CALL PYE(K)
```

```
      IF (K.EQ.6) CALL PYE(K)
      IF (K.EQ.7) CALL PYE(K)
      IF (K.EQ.8) CALL PYE(K)
      IF (K.EQ.9) CALL PYE(K)
      IF (K.EQ.10) CALL PYE(K)
   20 CONTINUE
      DO 25 K=1,Z
      PRINT 26,K
   26 FORMAT('0','STEADY STATE PROBABILITIES,ALTERNATIVE',2X,I3)
      DO 27 I=1,N
      PRINT 28,I,PIE(I,K)
   28 FORMAT('0',2X,'STATE',2X,I3,4X,F9.6)
   27 CONTINUE
   25 CONTINUE
      DO 30 K=1,Z
      IF (K.EQ.1) CALL EXRWD(K)
      IF (K.EQ.2) CALL EXRWD(K)
      IF (K.EQ.3) CALL EXRWD(K)
      IF (K.EQ.4) CALL EXRWD(K)
      IF (K.EQ.5) CALL EXRWD(K)
      IF (K.EQ.6) CALL EXRWD(K)
      IF (K.EQ.7) CALL EXRWD(K)
      IF (K.EQ.8) CALL EXRWD(K)
      IF (K.EQ.9) CALL EXRWD(K)
      IF (K.EQ.10) CALL EXRWD(K)
   30 CONTINUE
      DO 32 K=1,Z
      PRINT 33,K
   33 FORMAT('0','EXPECTED REWARD,ALTERNATIVE',2X,I3)
      DO 34 I=1,N
      PRINT 35,I,EXREW(I,K)
   35 FORMAT('0',2X,'STATE',2X,I3,4X,F11.4)
   34 CONTINUE
   32 CONTINUE
      CNT=0
      DO 39 I=1,N
      VALUE(I,1)=0.
      SELCTD(I,2)=1
      SELCTV(I,2)=0.
      DO 38 J=1,N
      PROBM(I,J)=MPROB(I,J,1)
   38 CONTINUE
   39 CONTINUE
   31 INDEX=0
      CNT=CNT+1
      DO 40 K=1,Z
      IF (K.EQ.1) CALL POLICY(K)
      IF (K.EQ.2) CALL POLICY(K)
      IF (K.EQ.3) CALL POLICY(K)
      IF (K.EQ.4) CALL POLICY(K)
      IF (K.EQ.5) CALL POLICY(K)
```

```
      IF (K.EQ.6) CALL POLICY(K)
      IF (K.EQ.7) CALL POLICY(K)
      IF (K.EQ.8) CALL POLICY(K)
      IF (K.EQ.9) CALL POLICY(K)
      IF (K.EQ.10) CALL POLICY(K)
   40 CONTINUE
      PRINT 49,CNT
   49 FORMAT('0','ITERATION NUMBER',2X,I3)
      DO 48 K=1,Z
      PRINT 47,K
   47 FORMAT('0','TEST QUANTITY,POLICY IMPROVEMENT,ALTERNATIVE',2X,I3)
      DO 46 I=1,N
      PRINT 45,I,TEST(I,K)
   45 FORMAT('0','STATE',2X,I3,4X,F11.4)
   46 CONTINUE
   48 CONTINUE
      Y=Z-1
      DO 99 I=1,N
      SELCTD(I,1)=1
      SELCTV(I,1)=TEST(I,1)
      DO 98 K=1,Y
      H=K+1
      IF (SELCTV(I,1).GE.TEST(I,H)) GO TO 97
      SELCTD(I,1)=H
      SELCTV(I,1)=TEST(I,H)
      GO TO 93
   97 IF (SELCTV(I,1).EQ.TEST(I,H)) GO TO 96
      GO TO 93
   96 IF (K.EQ.SELCTD(I,2)) GO TO 95
      IF (H.EQ.SELCTD(I,2)) GO TO 94
      SELCTD(I,1)=K
      SELCTV(I,1)=TEST(I,K)
      GO TO 93
   95 SELCTD(I,1)=K
      SELCTV(I,1)=TEST(I,K)
      GO TO 93
   94 SELCTD(I,1)=H
      SELCTV(I,1)=TEST(I,H)
      GO TO 93
   93 CONTINUE
   98 CONTINUE
   99 CONTINUE
      PRINT 43
      DO 44 I=1,N
      PRINT 19,I,SELCTD(I,1),SELCTV(I,1),SELCTD(I,2),SELCTV(I,2)
   19 FORMAT ('0',29X,I3,3X,I3,5X,F11.4,4X,I3,4X,F11.4)
   43 FORMAT ('0','POLICY IMPROVEMENT SUMMARY',2X,'STATE',3X,
     1'NEW ALT',3X,'NEW VALUE',3X,'OLD ALT',3X,'OLD VALUE')
   44 CONTINUE
      DO 50 I=1,N
      IF (SELCTV(I,1).GT.SELCTV(I,2)) GO TO 52
      GO TO 51
```

```
52 SELCTV(I,2)=SELCTV(I,1)
   SELCTD(I,2)=SELCTD(I,1)
   INDEX=1
   GO TO 51
51 CONTINUE
50 CONTINUE
   IF (INDEX.EQ.0) GO TO 100
   IF (CNT.EQ.A) GO TO 101
   DO 60 I=1,N
   KK=SELCTD(I,2)
   DO 61 J=1,N
   PROBM(I,J)=MPROB(I,J,KK)
   EXRWM(I,1)=EXREW(I,KK)
61 CONTINUE
60 CONTINUE
   DO 72 I=1,N
   DO 71 J=1,N
   PROBM(I,J)=-(PROBM(I,J)-IDEN(I,J))
71 CONTINUE
72 CONTINUE
   DO 80 B=1,N
   DO 81 C=2,N
   D=C-1
   WI(B,C)=PROBM(B,D)
81 CONTINUE
80 CONTINUE
   DO 82 I=1,N
   WI(I,1)=1.0
82 CONTINUE
   CALL LINV1F (WI,N,25,WINV,0,W2,IER)
   CALL VMULFF (WINV,EXRWM,N,N,1,25,25,VAL,25,IER)
   DO 89 C=2,N
   B=C-1
   VALUE(B,1)=VAL(C,1)
89 CONTINUE
   VALUE(N,1)=0.
   PRINT 88,VAL(1,1)
88 FORMAT ('0','SYSTEM GAIN,G',2X,F11.4)
   DO 87 I=1,N
   PRINT 86,I,VALUE(I,1)
86 FORMAT ('0','STATE',2X,I3,3X,'VALUE',2X,F11.4)
87 CONTINUE
   GO TO 31
100 PRINT 102
102 FORMAT ('0','POLICY VECTOR SOLUTION')
   GO TO 103
101 PRINT 104
104 FORMAT('0','MAXIMUM ALLOWABLE ITERATIONS')
   GO TO 108
103 PRINT 107
107 FORMAT ('0','STATE',3X,'POLICY VECTOR',4X,'VALUE VECTOR')
```

```
      DO 105 I=1,N
      PRINT 106,I,SELCTD(I,2),SELCTV(I,2)
  106 FORMAT ('0',2X,I3,9X,I3,8X,F11.4)
  105 CONTINUE
      GO TO 110
  108 DO 109 I=1,N
      PRINT 43,I,SELCTD(I,1),SELCTV(I,1),SELCTD(I,2),SELCTV(I,2)
  109 CONTINUE
  110 CONTINUE
 9999 STOP
      END
      BLOCK  DATA
      COMMON/BLIST/MPROB(25,25,10),REW(25,25,10),PIE(25,10),
     1EXREW(25,10),TEST(25,10),VALUE(25,1),N,FMT(18),FMT3(18)
      REAL MPROB
      DATA MPROB/6250*0./,REW/6250*0./,PIE/250*0./,EXREW/250*0./,
     1TEST/250*0./
      END
      SUBROUTINE PYE(SK)
      COMMON/BLIST/MPROB(25,25,10),REW(25,25,10),PIE(25,10),
     1EXREW(25,10),TEST(25,10),VALUE(25,1),N,FMT(18),FMT3(18)
      DIMENSION ALT(25,25),ALTT(25,25)
      REAL MPROB
      INTEGER SK
      REAL IDEN
      DIMENSION IDEN(25,25),COL(25,1),W1(25),ALTI(25,25)
      DIMENSION RESUL(25,1)
      DATA IDEN/625*0./,ALTT/625*0./,ALTI/625*0./
      WRITE (6,7) SK
    7 FORMAT ('0','TRANSITION PROBABILITY MATRIX FOR ALTERNATIVE',I3)
      WRITE (6,FMT) ((MPROB(I,J,SK),J=1,N),I=1,N)
      DO 15 K=1,N
      DO 16 L=1,N
      ALT(K,L)=MPROB(K,L,SK)
   16 CONTINUE
   15 CONTINUE
      WRITE (6,8) SK
    8 FORMAT ('0','REWARD MATRIX FOR ALTERNATIVE',I3)
      WRITE (6,FMT3) ((REW(I,J,SK),J=1,N),I=1,N)
      DO 19 I=1,N
      DO 20 J=1,N
      ALTT(I,J)=ALT(J,I)
   20 CONTINUE
   19 CONTINUE
      DO 30 K=1,N
      IDEN(K,K)=1.0
   30 CONTINUE
      DO 22 I=1,N
      DO 21 J=1,N
      ALTT(I,J)=ALTT(I,J)-IDEN(I,J)
   21 CONTINUE
   22 CONTINUE
```

```
      DO 17 K=1,N
      ALTT(N,K)=1.0
   17 CONTINUE
      DO 40 K=1,N
      COL(K,1)=0.
   40 CONTINUE
      COL(N,1)=1.0
      CALL LINV1F(ALTT,N,25,ALTI,0,W1,IER)
      CALL VMULFF(ALTI,COL,N,N,1,25,25,RESUL,25,IER)
      DO 18 K=1,N
      PIE(K,SK)=RESUL(K,1)
   18 CONTINUE
      RETURN
      END
      SUBROUTINE EXRWD(SK)
      COMMON/BLIST/MPROB(25,25,10),REW(25,25,10),PIE(25,10),
     1EXREW(25,10),TEST(25,10),VALUE(25,1),N,FMT(18),FMT3(18)
      DIMENSION SM(25,25)
      DIMENSION SR(25,25),COL(25,1),SQ(25,1)
      REAL MPROB,EXREW,SM,SR,COL,SQ
      INTEGER SK
      DATA SQ/25*0./
      DO 33 L=1,N
      DO 32 M=1,N
      SM(L,M)=MPROB(L,M,SK)
      SR(L,M)=REW(L,M,SK)
   32 CONTINUE
   33 CONTINUE
      DO 35 J=1,N
      DO 34 K=1,N
      SM(J,K)=SM(J,K)*SR(J,K)
   34 CONTINUE
   35 CONTINUE
      DO 36 J=1,N
      COL(J,1)=1.
   36 CONTINUE
      CALL VMULFF(SM,COL,N,N,1,25,25,SQ,25,IER)
      DO 38 K=1,N
      EXREW(K,SK)=SQ(K,1)
   38 CONTINUE
      RETURN
      END
      SUBROUTINE POLICY(SK)
      COMMON/BLIST/MPROB(25,25,10),REW(25,25,10),PIE(25,10),
     1EXREW(25,10),TEST(25,10),VALUE(25,1),N,FMT(18),FMT3(18)
      DIMENSION MSMM(25,25)
      DIMENSION SR(25,1),PRD(25,1)
      INTEGER SK
      DO 40 I=1,N
      DO 41 J=1,N
      MSMM(I,J)=MPROB(I,J,SK)
```

```
 41 CONTINUE
 40 CONTINUE
    DO 42 J=1,N
    SR(J,1)=EXREW(J,SK)
 42 CONTINUE
    CALL VMULFF(MSMM,VALUE,N,N,1,25,25,PRD,25,IER)
    DO 44 I=1,N
    SR(I,1)=SR(I,1)+PRD(I,1)
 44 CONTINUE
    DO 43 J=1,N
    TEST(J,SK)=SR(J,1)
 43 CONTINUE
    RETURN
    END
/*
//LKED.SYSLMOD DD UNIT=DISK,VOL=SER=WU0400,DISP=(NEW,CATLG),
// DSN=WU65RM.GRAVLOAD(MARKOV),SPACE=(TRK,(5,2,1))
//
```

APPENDIX C

FLEETING STATISTICS

PERMITTED FLEETING - footage corrected, $W_A = 200'$

Permit #	Footage	Capacity (Barges)	Low-Water Capacity (0.7C)
785	450' p	11	8
1159	500' p	18 p	9
911	1,200'	30	21
1040	3,500' p	51 p	36
1320	900' p	23	16
920	3,500' p	90 p	63
1281	800' p	20	14
125	1,000' p	25	18
270	1,400' p	35	25
830	1,200' [1]	30	21
1005	500'	13	9
1288	1,325'	36 p	25
581	700' p	18	13
1309	-	5 p	4
235	3,100' p	78 p	55
1312	-	45 p	32
1285	1,900' p	25 p	18
1308	-	45 p	32
1307	-	45 p	32
1306	-	35 p	25
1299	-	12 p	8
1194	13,200'	50 p	35
1318	8,448'	50 p	35
		Σ 790	Σ 554

p - specified by permit

1 - permitted footage 4,000', navigational blockage near dock prohibits full utilization

GRANDFATHER-CLAUSE FLEETING - footage corrected, $W_A = 200'$

Permit #	Footage	Capacity (Barges)	Low-Water Capacity (0.7C)
(16)			
(15)	6,000'	150	105
(14)	1,000'	25	18
(13)	1,000'	25	18
(12)	450'	11	8
(11)	3,700'	93	65
(10)	1,700'	43	30
(9)	2,100'	53	37
(8)	4,000'	100	70
(7)	2,150'	54	38
(6)	500'	13	9
(5)	750'	19	13
(4)	1,300'	33	23
(3)	500'	13	9
(2)	600'	15	11
(1)	2,000'	50	35
		Σ 697	Σ 489

APPENDIX D

ENVIRONMENTAL INFORMATION

Equal Opportunity Employer

July 3, 1980

Dear

The Bi-State Development Agency is undertaking a fleeting analysis within the Port of Metropolitan St. Louis. The work is being done by Dr. Lonnie Haefner of Washington University, and the purpose of the analysis is to identify the amount of existing fleeting, project the amount of fleeting needed in the future, and identify future fleeting sites within the metropolitan port.

In order to assist us in a balanced analysis, we would like to receive from you any documented research papers which help to identify the impact fleeting has on the environment. Whether or not you have or know of any documented research papers, we would still appreciate receiving from your agency the evaluation criteria being used or considered in evaluating proposed or potential fleeting areas and the reasons why you feel the criteria are important.

In addition, the study is utilizing a decision-making model to narrow the potential alternative sites to a few most feasible. The model takes into account a number of variables both economic and environmental. These variables are displayed on the attached sheet. We would appreciate your evaluation of the importance of these factors in considering potential fleeting areas. Please place an importance weighting on each of these variables insuring that the total weighting of the variables does not exceed 100 points. We urge you to approach this from a practical standpoint, keeping in mind that this will assist us in attempting to identify the importance which should be given to these variables in arriving at a fleeting site decision.

We appreciate your assistance and cooperation in our fleeting analysis and would like to receive your response by July 25, 1980. If you have any questions or would like to discuss this request further, please contact Mr. Wayne Weidemann of my staff (314-231-9185).

Bi-State Development Agency
Port of Metropolitan St. Louis
411 North Seventh Street, 11th Floor
St. Louis, Missouri 63101/314/231-9185

We look forward to your input.

Sincerely,

John D. Booth, P.E.
General Manager of Development

JDB:jp
Attachment

cc: Dr. Lonnie Haefner
Charles G. Houghton
Wayne E. Weidemann
John Kilker

Importance Weighting of Decision-Making Variables for Selecting Fleeting Sites

Variable	Importance Weighting
Cost (everything but maintenance and operation)	
Economic Value Added (to the Region)	
Maintenance Expense (to maintain site)	
Fish and Wildlife	
Flora and Fauna	
Noise (from fleeting operation)	
Water Quality	
Energy Consumption (by fleeting operation)	
Breakaway Safety (of fleeting site)	
Total	100 Points Maximum

WAYNE

MISSOURI DEPARTMENT OF CONSERVATION

MAILING ADDRESS:
P.O. Box 180
Jefferson City, Missouri 65102

STREET LOCATION:
2901 North Ten Mile Drive
Jefferson City, Missouri 65101

Telephone 314/751-4115
LARRY R. GALE, Director

July 10, 1980

Mr.John D. Booth, P.E.
General Manager of Development
Bi-State Development Agency
Port of Metropolitan St. Louis
411 No. Seventh St., 11th Floor
St. Louis, Missouri 63101

Dear Mr. Booth:

Thank you for the letter requesting our input into the fleeting analysis being conducted by your agency. The Missouri Department of Conservation by constitutional authority is vested with the responsibility of managing and conserving the fish, wildlife and forest resources of the state. With regard to these resources on the Mississippi River, this responsibility is magnified by court decree which established that the water and the bed of navigable streams are public resources.

Our Department staff is comprised of fish and wildlife biologists, foresters and other similar professionals. As such, we would not feel qualified to place an importance weighting on economic variables for selecting fleeting sites and have therefore chosen not to complete the form entitled "Importance Weighting of Decision-Making Variables for Selecting Fleeting Sites".

The following criteria are used by our Department to evaluate impacts of proposed or potential fleeting areas on fish, wildlife and forest resources:

a. Habitat Diversity -
   Numerous studies have documented that channelization of a river or stream can reduce fish and wildlife resources between 50 and 75 percent. This loss is attributable to a quantitative decrease in habitat as well as a loss of quality of remaining habitat. A most important qualitative loss is habitat diversity -- water of varying depths and velocities and different types of substrate. The law of diminishing returns places added value to habitat remaining

Missouri Department Of Conservation

Mr. John D. Booth
July 10, 1980
Page Two

on the channelized Mississippi River. This should be an important consideration in siting fleeting areas. Shorelines and areas in and around dike fields with small and large side channels provide the most diverse habitat in a channelized river system.

b. Special or Unique Habitats -
An effort is made to determine the presence or close proximity of a fleeting area to such unique habitats as a heron rookery, mussel bed or large side channel. Adverse impacts to such areas can vary from human disturbance to possible physical disruption.

c. Water Quality -
Fleeting areas may impact water quality, a matter of great public concern, in two ways. First, it is well documented that tug boat prop wash can disturb the bottom sediments thereby increasing river bottom scour with an increase in suspended solids. Of even greater concern is the factor of barge cleaning and washing. Through personal communication with fleeting company operators, my staff have learned that large volumes of various commodities of varying toxicity may be entering the river through this practice. Your assistance in our gaining a better understanding of materials and volume disposed of would help us better evaluate the long-term significance of this practice. Until that time, we assume this is a problem and therefore prefer that fleeting areas are located away from productive, diverse fish and wildlife habitats.

We appreciate having the opportunity to comment. Members of my staff are available to further discuss these matters with you. When completed, we would certainly be interested in receiving a copy of the results of the analysis.

Sincerely,

Larry R. Gale

LARRY R. GALE
DIRECTOR

ENCLOSURE

July 16, 1980

Mr. Carey W. Burch
Environmental Planning Division
Versar, Inc.
6621 Electronic Drive
Springfield, Virginia 22151

Dear Mr. Burch: Re: St. Louis Harbor Study

As per our meeting on July 1, 1980, enclosed please find the completed matrices for computing factor weights for use in the referenced study. As stated in the March 4, 1980 letter from Larry Gale to Colonel Dacey, we believe this procedure is satisfactory for a cursory biological evaluation of the 29 potential harbor sites within the St. Louis Harbor. Additional studies may be necessary to complete the EQ account required by Principles and Standards for those sites deemed most suitable for development.

We appreciate the opportunity to work with you on this effort. Please do not hesitate to contact me should you have any questions or comments.

Sincerely,

NORMAN P. STUCKY
ENVIRONMENTAL COORDINATOR

NPS:jct
Enc.

Norm and I prepared this together. He was supposed to send it out with both our names.

ASSIGNMENT OF GENERAL HABITAT ANALYSIS FACTOR WEIGHTS

BASED ON THE RANKED PAIRWISE COMPARISON TECHNIQUE

	FACTOR	A	B	C	D	E	J		SUM	FACTOR WEIGHT
		ASSIGNMENT OF IMPORTANCE VALUES								
A	TERRESTRIAL HABITAT VALUE	–	.5	.5	1	1	1		4.0	
I	WOODY EDGE	.5	–	.5	1	1	1		4.0	
C	AQUATIC HABITAT VALUE	.5	.5	–	1	1	1		4.0	
I	SHORELINE DEVELOPMENT	0	0	0	–	0	1		1.0	
I	DREDGE SPOIL DISPOSAL	0	0	0	1	–	1		2.0	
	(Dummy)									
							GRAND TOTAL			1.00

Procedure:

1. Compare Factor "A" with Factor "B." Assign a value of 1.0 to that factor perceived to be the more important and assign a value of 0.0 to the least important factor. If the two parameters are believed to have the same relative significance, assign a value of 0.5 to each.
2. Now compare Factor "A" with Factor "C", then "A" with "D" and so on down the list.
3. Then compare Factor "B" with all the other factors (don't compare "B" with Factor "A" - this has already been done).
4. Continue this comparative process with each of the remaining factors.
5. Determine totals for each factor and a grand total for all comparisons.
6. Divide the total score for a given factor by the grand total for that factor's weight.
7. State the major rationale used in assigning the relative importance values.

NOTE: The final comparison with a dummy factor assures that no real factor has a weight value of 0.0.

ASSIGNMENT OF AQUATIC HABITAT ANALYSIS FACTOR WEIGHTS BASED ON THE RANKED PAIRWISE COMPARISON TECHNIQUE

FACTOR	A	B	C	D	E	F	J			SUM	FACTOR WEIGHT
	ASSIGNMENT OF IMPORTANCE VALUES										
MAIN CHANNEL	—	0	0	0	0	0	1			1	
MAIN CHANNEL BORDER	1	—	0	.25	.25	.25	1			2.75	
BACK WATERS	1	1	—	.75	.75	.75	1			5.25	
LAKES & PONDS	1	.75	.25	—	.25	.25	1			3.5	
TRIBUTARIES	1	.75	.25	.75	—	.75	1			4.5	
TAIL-WATERS	1	.75	.25	.75	.25	—	1			4	
(Dummy)											
									GRAND TOTAL		1.00

Procedure:

1. Compare Factor "A" with Factor "B." Assign a value of 1.0 to that factor perceived to be the more important and assign a value of 0.0 to the least important factor. If the two parameters are believed to have the same relative significance, assign a value of 0.5 to each.
2. Now compare Factor "A" with Factor "C", then "A" with "D" and so on down the list.
3. Then compare Factor "B" with all the other factors (don't compare "B" with Factor "A" - this has already been done).
4. Continue this comparative process with each of the remaining factors.
5. Determine totals for each factor and a grand total for all comparisons.
6. Divide the total score for a given factor by the grand total for that factor's weight.
7. State the major rationale used in assigning the relative importance values.

NOTE: The final comparison with a dummy factor assures that no real factor has a weight value of 0.0.

X

ASSIGNMENT OF TERRESTRIAL HABITAT ANALYSIS FACTOR WEIGHTS

BASED ON THE RANKED PAIRWISE COMPARISON TECHNIQUE

	FACTOR	A	B	C	D	E	F	J			SUM	FACTOR WEIGHT
		ASSIGNMENT OF IMPORTANCE VALUES										
A	SAND/MUD FLATS	—	0	0	.5	1.	0	1			2.5	
B	BRUSH LANDS	1	—	0	0	1	0	1			3.0	
C	BOTTOMLAND FORESTS	1	1	—	.75	1	.25	1			5.0	
D	AGRICULTURAL LANDS	.5	1	.25	—	1	.25	1			4.0	
E	DEVELOPED LANDS	0	0	0	0	—	0	1			1.0	
F	WETLANDS	1	1	.75	.75	1	—	1			5.5	
G												
H												
I												
J	(Dummy)											
										GRAND TOTAL		1.00

Procedure:

1. Compare Factor "A" with Factor "B." Assign a value of 1.0 to that factor perceived to be the more important and assign a value of 0.0 to the least important factor. If the two parameters are believed to have the same relative significance, assign a value of 0.5 to each.
2. Now compare Factor "A" with Factor "C", then "A" with "D" and so on down the list.
3. Then compare Factor "B" with all the other factors (don't compare "B" with Factor "A" - this has already been done).
4. Continue this comparative process with each of the remaining factors.
5. Determine totals for each factor and a grand total for all comparisons.
6. Divide the total score for a given factor by the grand total for that factor's weight.
7. State the major rationale used in assigning the relative importance values.

NOTE: The final comparison with a dummy factor assures that no real factor have a weight value of 0.0.

LE. Steidemann ✓

Illinois Department of Transportation

Division of Water Resources
2300 South Dirksen Parkway/Springfield, Illinois/62764

July 14, 1980

Mr. John D. Booth, P.E.
General Manager of Development
Bi-State Development Agency
411 N. Seventh St.
St. Louis, Missouri 63101

Dear Mr. Booth:

This replies to your letter of July 3 concerning the fleeting study for the Port of Metropolitan St. Louis.

We do not maintain a library nor have we made a literature search for research papers on the environmental impact of fleeting. I suggest you review literature searches made for the following studies:

1. GREAT's I, II, and III.

2. UMRBC Mainstem Level B

3. UMRBC Master Plan

The Waterways Experiment Station is another possible source.

Site selection variables, or criteria, are very important. The tentative list you provided can be greatly improved. However, scoring will not work.

There are different ways to categorize criteria. I suggest the following:

1. Suitable for fleeting - a group of criteria that describes the most desirable characteristics of a fleeting site.

2. Undesirable for fleeting - a group of criteria that describes undesirable characteristics of fleeting sites.

3. Fatal flaw - a group of criteria any of which would rule out a site.

Mr. John D. Booth
Page 2
July 14, 1980

4. Variable - a group of those criteria, such as cost, which vary among sites and should be "minimized" or "optimized."

Very few criteria are susceptible to scalar measure, such as a 0 to 100 points scoring system. Suitable, undesirable, or fatal flaw criteria can be treated as "present" or "not present" or, alternatively, "applicable" or "not applicable." For some of these criteria it may be possible to attach a "high," "medium," or "low" value.

Dollars are, of course, a scalar. Economic efficiency is served by minimizing the cost of fleeting. Fleeting cost is the main "variable" criterion. The main investment costs are real estate interests (or rent) and installation of mooring facilities. The main operating cost which varies from site to site is towing to and from the docks being served. Other variables which affect costs differently at different sites include:

1. Type of mooring facilities: anchor barge, cells, shoreside deadmen, etc.

2. Frequency and amount of maintenance dredging.

3. Proximity to tug base - the additional cost of running to and from the fleet.

4. Size of fleet.

5. Utilization of fleet capacity.

Costs can provide an objective scalar to the degree all relevant costs are estimated and placed on a comparable basis. Investment and recurring costs should be converted to an equivalent annual value using an appropriate discount rate. The discount rate can be the minimum attractive rate of return for the industry or the interest cost of financing as a surrogate.

It would be useful to separately estimate the fixed and variable costs of fleeting per barge. Fixed costs would be all the investment and site operation and maintenance costs required to develop a site and have it ready-to-serve. This can be divided by the average annual number of barges served to find "fixed" cost per barge. The "variable" cost per barge is the weighted mean cost of towing to and from the docks being served. The most economically efficient sites minimizing the cost per barge, i.e., the sum of fixed and variable costs.

Cost analysis also helps determine an economic level of fleet capacity. The fleet capacity factor, average daily use divided by capacity, directly affects fixed cost. Greater utilization of

Mr. John D. Booth
Page 3
July 14, 1980

capacity lowers fixed cost. But greater utilization may require use of more distant fleets at higher variable cost. This kind of analysis can indicate when it is worthwhile to develop new fleet capacity.

These costs are preferable criteria to those tentatively selected as: "cost," "maintenance expense," and "energy consumption." The criterion "fish and wildlife" is not distinguishable from "flora and fauna." "Water quality" is meaningless without some qualifying terms, such as, cargo spillage.

It is not customary to calculate "economic value added" for an intermediate service such as transportation. But, even if calculated, it is not obvious why it would differ among locations in the same region. Cost minimization as described earlier is an appropriate economic criterion for transportation.

Here are some criteria I suggest for identifying suitable sites:

1. Water depth - 11 to 13 feet at normal low water and at least nine feet at extreme low water.

2. Bottom stability - depth is self-maintaining so maintenance dredging is avoided.

3. Exposure - free of unusual exposure to high winds, high waves, high velocity current, and ice movement.

4. Proximity - close to docks, terminals or tow interchange locations being served.

5. Shoreland use - shoreline vacant of waterfront activities with compatible zoning or present land use.

Here are some criteria for identifying undesirable site characteristics:

1. Water access - interferes with existing docks, fleets, marinas.

2. Navigation - interferes with vessel transit through channels, bridges, locks, and harbors.

3. Other water uses - interferes with recreation or commercial fishing.

4. Compatibility - incompatible shoreland use or zoning.

5. Dredging - requires dredging to maintain depth.

Mr. John D. Booth
Page 4
July 14, 1980

Here are some fatal flaws:

1. Critical habitat - encroachment on habitat of rare or endangered species.

2. Historic preservation - interferes or encroaches on designated historic or cultural landmark.

3. Public lands - encroaches on or utilizes property controlled by a public agency for public purposes: parks, memorials, preserves, sanctuaries, etc.

4. Safety - proximate land or water activities or uses present unacceptable risks of fire, explosion, contamination, collision, or other serious accidents.

The main variables are site acquisition, costs, mooring facilities installation costs, site capacity, and towing. These can be reduced to a single comparable cost, such as, dollars per barge served.

I am sure many more criteria can be identified. Those suggested here are just the first that come to mind. Information on screening criteria can be assembled on suitable maps to readily identify the best sites while avoiding the worst. From there on cost is the main factor and will require site planning, design, and cost estimating work. Least cost sites may involve some undesirable characteristics which should be considered in trade-off analysis.

It is a pleasure to provide you these views on fleeting site selection. Do not hesitate to call upon us for assistance.

Sincerely,

Bruce Barker

Bruce Barker, P.E.
Chief, Bureau of Program Development

BB:mam

D-15

Stayne - 383.

Illinois Department of Conservation

life and land together

605 WM. G. STRATTON BUILDING • 400 SOUTH SPRING STREET • SPRINGFIELD 62706
CHICAGO OFFICE – ROOM 100, 160 NO. LASALLE 60601
David Kenney, Director • James C. Helfrich, Assistant Director

July 17, 1980

RECEIVED
DEVELOPMENT COMPANY
JUL 24 1980
BI-STATE DEVELOPMENT AGENCY
ST. LOUIS, MO.

Mr. John D. Booth
General Manager of Development
Bi-State Development Agency
Port of Metropolitan St. Louis
411 North Seventh Street, 11th Floor
St. Louis, MO 63101

Dear Mr. Booth: John,

Thank you for your letter of July 3 concerning the fleeting analysis that Bi-State Development Agency plans to conduct within the Port of Metropolitan St. Louis. We are most interested in the proposal study, and I hope you will keep us informed as work progresses.

I have checked with my staff regarding the availability of the information requested in your letter. While we have been deeply involved in the fleeting issue, I can offer you little by way of documented research into the effects of fleeting on the environment. As you know, the St. Louis District, Corps of Engineers, prepared an environmental assessment for several fleeting areas in the St. Louis Harbor last winter. This would appear to be the only study that has been conducted on the subject to date. Obviously, there is a great need for more work in this area.

As regards the evaluation criteria employed by this agency in reviewing fleeting areas, these are not the sort of easily definable criteria that would lend themselves to inclusion in your study. In our advisory role to the Corps of Engineers, we typically receive public notices for proposed new fleeting areas. These are reviewed by staff of our Divisions of Fisheries, Wildlife, Forestry and Planning, and a judgement is made as to the potential impacts of the activity on the environment. This is based on probable disturbances to known populations of fish and wildlife and their habitats, water quality, sedimentation rates, and so forth. Because so little information exists concerning the precise environmental effects of fleeting, our recommendation to the Corps is based, of necessity, on the experience and judgement of our staff.

Regarding the Importance Weighting of Decision Making Variables, I would be hesitant to compare fish and wildlife values and water quality with such disparate categories as maintenance expense and breakaway safety. Naturally, we would prefer that all fleeting activity avoid areas of biological importance such as side channels, mussel beds, and riparian woodlands.

A weighted ranking of economic and safety factors, however, is outside our area of expertise.

Please feel free to call on me if I or my staff can be of further assistance.

Sincerely,

David Kenney

DK:RWS:gm

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VII
324 EAST ELEVENTH STREET
KANSAS CITY, MISSOURI - 64106

RECEIVED
DEVELOPMENT COMPANY
JUL 30 1980
BI-STATE DEVELOPMENT AGENCY
ST. LOUIS, MO.

JUL 25 1980

John D. Booth, P.E.
General Manager of Development
Bi-State Development Agency
Port of Metropolitan St. Louis
411 North Seventh Street, 11th Floor
St. Louis, Missouri 63101

Dear Mr. Booth:

Our Agency does not have any documented research papers which help to identify the impact fleeting has on the environment.

All of the economic and environmental factors displayed on the attachment of your July 3, 1980, letter are important. We have marked water quality and fish and wildlife high because we believe they are not being given adequate consideration. Movement of tows and spillage of cargo can have a serious effect on water quality, fish, and wildlife.

Mr. Robert Koke, Chief, 404 Program, has worked with the St. Louis District Corps of Engineers on the problems with locating fleeting areas in the St. Louis Harbor. Please keep him informed as your study progresses.

Thank you for giving us an opportunity to comment on the study.

Sincerely yours,

Kathleen Q. Camin, Ph.D.
Regional Administrator

Attachment

Importance Weighting of Decision-Making Variables for Selecting Fleeting Sites

Variable	Importance Weighting
Cost (everything but maintenance and operation)	10
Economic Value Added (to the Region)	10
Maintenance Expense (to maintain site)	10
Fish and Wildlife	15
Flora and Fauna	10
Noise (from fleeting operation)	10
Water Quality	15
Energy Consumption (by fleeting operation)	10
Breakaway Safety (of fleeting site)	10
Total	100 Points Maximum

cc: H. Heideman

United States Department of the Interior

FISH AND WILDLIFE SERVICE
ROCK ISLAND FIELD OFFICE (ES)
1830 SECOND AVENUE
ROCK ISLAND, ILLINOIS 61201
Com: 309-788-3991/3925
FTS: 360-9217/9274

IN REPLY REFER TO:

July 2?, 1980

RECEIVED
DEVELOPMENT COMPANY
JUL 28 1980
BI-STATE DEVELOPMENT AGENCY
ST. LOUIS, MO.

Mr. John D. Booth, P.E.
General Manager of Development
Bi-State Development Agency
411 North Seventh Street, 11th Floor
St. Louis, Missouri 63101

Dear Mr. Booth:

Thank you for your July 3 letter requesting our input into your fleeting analysis for the Port of Metropolitan St. Louis.

We are not aware of documented research papers that address the impact of fleeting on the environment. There are numerous papers, however, that address dredging impacts that would be appropriate to the subject where such action is necessary to develop the fleeting site or to maintain adequate depth at the site in the future. The disturbance of bottom materials and resuspension of sediments caused by propeller wash from tow boats during the movement of barges at the fleeting area would cause impacts similar to those of deposition of dredge spoil at the site to a varying degree.

The enclosed listing shows our concerns (criteria) relative to impacts that occur with the development, operation and maintenance of barge fleeting areas. These concerns are considered very important since there are significant adverse impacts caused to fish and wildlife resources in addition to the competition for and conflicting uses of the river surface.

We do not feel that we have the available expertise in this field office to address the economic, energy and safety variables listed on the evaluation sheet attached to your letter. Therefore, we have not attempted the importance weighting of decision-making variables for selecting fleeting sites. Our analysis would be biased toward protection of fish and wildlife resources and of the environment and would be of little use to you in your analysis.

We appreciate the opportunity to provide comments to you. Please feel free to contact this office if we can provide assistance.

Sincerely yours,

Thomas M. Groutage
Field Supervisor

Enclosure

cc: MO Dept of Conservation
MO Dept. of Natural Resources
IL Dept. of Conservation (Lutz, Conlin)
U.S. Environmental Protection Agency (Chicago, Kansas City)
IL Environmental Protection Agency
Corps of Engineers - St. Louis District

Com: 309-788-3991/3925
FTS: 360-9217/9274

August 3, 1979

Lt. William Hines
2nd Coast Guard District, Rm. 410
1430 Olive Street
St. Louis, Missouri 63103

Dear Lt. Hines

This responds to your request for information on the concerns of the Fish and Wildlife Service with fleeting areas. No formal set of criteria exist by which to judge establishment of fleeting areas. Until recently, each fleeting area has been assessed individually as to its impacts on the environment. An effort is now underway in the St. Louis District Corps of Engineers to study the cumulative impacts of many fleeting areas in one locality as well as the individual impacts.

The following attached list of concerns is not intended to be comprehensive. Should you need further information, please contact this office.

Sincerely yours

Thomas M. Groutage
Field Supervisor

Attachment
RO

1. Effects of propeller wash from tow boats used to jockey barges on the following:

   a) bed scouring
   b) resuspension of sediments and including toxic material contained therein
   c) spawning beds, nursery habitat
   d) rooted aquatic vegetation
   e) shoreline erosion (including muskrat dens)
   f) benthos communities

2. Effects of physical presence of and human disturbance at fleeting areas on:

   a) wading bird, shorebird and waterfowl activity
   b) water access and usability by sport and commercial fishermen
   c) primary production (aquatic)
   d) disposal of dredge spoils in environmentally least damaging locations
   e) shoreline erosion
   f) aquatic and riparion furbearer use, habits, etc.

3. Decreased water quality resulting from toxic and organic material in barges caused by:

   a, spills, seepage, etc.
   b) cleaning out barges

4. Potential for breaking loose from mooring and potential damage to docks, boats and recreational water-users resulting from same.

5. Dredging needs to maintain adequate depth, including frequency of dredging and impacts on fish and wildlife.

MISSOURI DEPARTMENT OF NATURAL RESOURCES
P.O. Box 176 Jefferson City, Missouri 65102 (314) 751-4422

July 29, 1980

RECEIVED
DEVELOPMENT COMPANY
AUG 4 - 1980
BI-STATE DEVELOPMENT AGENCY
ST. LOUIS, MO.

Mr. John D. Booth, P.E.
General Manager of Development
Bi-State Development Agency
Port of Metropolitan St. Louis
411 North Seventh Street, 11th Floor
St. Louis, Missouri 63101

Dear Mr. Booth:

We appreciate the opportunity to assist you in your fleeting analysis study. However, this Department lacks some of the basic information necessary to answer all the evaluation.

The form you enclosed, "Importance Weighting of Decision-Making Variable for Selecting Fleeting Sites", appears very similar in concept to an analysis this Department, in conjunction with the Department of Conservation, performed for the St. Louis Harbor Study, 29 - Site Evaluation (Attachment). This study is being conducted under the auspices of the St. Louis District, Corps of Engineers (Mr. David Gates). If you find the evaluation criteria for port development and fleeting areas too disparate, please inform us of the differences and we will fill out the portions of the forms in which we have expertise accordingly.

Thank you for the opportunity to coordinate.

Sincerely,

DEPARTMENT OF NATURAL RESOURCES

Fred A. Lafser
Director

FAL:hmp

cc: Department of Natural Resources, DEQ

Attachment

DEPARTMENT OF THE ARMY
ST. LOUIS DISTRICT, CORPS OF ENGINEERS
210 TUCKER BOULEVARD, NORTH
ST. LOUIS, MISSOURI 63101

REPLY TO ATTENTION OF

LMSOD-F

30 July 1980

Mr. John D. Booth
General Manager of Development
Bi-State Development Agency
Port of Metropolitan St. Louis
411 North Seventh Street, 11th Floor
St. Louis, MO 63101

RECEIVED
DEVELOPMENT COMPANY
AUG 5 - 1980
BI-STATE DEVELOPMENT AGENCY
ST. LOUIS, MO.

Dear Mr. Booth:

I have inclosed a completed copy of your questionnaire concerning the relative importance of nine variables which might be considered in the selection of fleeting sites in the St. Louis Harbor.

The "importance weightings" which we have assigned to the variables represent a composite of responses by elements of our Operations and Engineering staff. The heavy weighting which we have assigned to "breakaway safety" reflects the responses of our Operations staff. You might want to consider deleting this parameter from your list of decision-making variables by establishing a "go" or "no-go" screen for safety factors. This alternative could consist of establishing a safety "threshhold" level which would exclude extremely hazardous sites from consideration regardless of the apparent values of the site in terms of the other selection factors.

With respect to the remaining list of eight decision-making variables, we consider "noise" to be the most "site specific." In these few prospective fleeting sites located in the vicinity of residential areas, such as the Mount Pleasant-Bellerive Park area in south St. Louis, noise levels assume greater importance since fleeting operations often continue all night. In non-residential areas, noise levels are probably insignificant in the selection of fleeting sites.

The St. Louis District staff currently has no basis for concluding that fleeting operations adversely impact natural resources within the riverine environment, or in areas adjacent to the waterway. We are not aware of any studies performed, to date, that indicate "fish and wildlife," "flora and fauna," and "water qualit[illegible] impaired by fleeting operations. The relatively low values we ha[illegible] assigned to these decision-making variables

LMSOD-F
Mr. John D. Booth

30 July 1980

reflect our current and tentative judgment that these natural resources are probably not significantly impacted by fleeting operations. Our weightings should not be construed as a lack of concern for protection of these important resources. On the contrary, I would not hesitate to take actions to deny issuance of a fleeting permit on the basis of environmental damages.

In addition to the variables listed on your questionnaire, several other factors warrant consideration in the selection of prospective fleeting sites. If a fleet will be moored to an "anchor barge," areas immediately upstream of pipeline crossings should be avoided since anchors can slip, creating a serious hazard to the pipeline. In evaluating a prospective fleeting site, size of maximum fleet is also a factor to consider since some areas will accommodate a small fleeting operation but would be totally inadequate for a large fleet. Our final recommendation is that fleeting sites which are not normally affected by the Corps' dredging and disposal operations should be favored over those areas in which the navigation channel requires frequent dredging.

We would like to be informed of the final results of your fleeting analysis, and I would welcome any interim results which you feel we should consider in our regulatory actions.

Sincerely,

Robert J. Dacey

1 Incl
As stated

ROBERT J. DACEY
Colonel, CE
District Engineer

Importance Weighting of Decision-Making Variables for Selecting Fleeting Sites

Variable	Importance Weighting
Cost (everything but maintenance and operation)	11
Economic Value Added (to the Region)	12
Maintenance Expense (to maintain site)	11
Fish and Wildlife	10
Flora and Fauna	8
Noise (from fleeting operation)	4
Water Quality	6
Energy Consumption (by fleeting operation)	7
Breakaway Safety (of fleeting site)	31
Total	100 Points Maximum

LMED

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