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#11

Analysis of Transit Alternatives

HONOLULU RAPID TRANSIT PROJECT
PRELIMINARY ENGINEERING & EVALUATION PROGRAM
PHASE II

DEPARTMENT OF TRANSPORTATION SERVICES
CITY AND COUNTY OF HONOLULU

DMJM
DANIEL, MANN, JOHNSON, & MENDENHALL

ANALYSIS

OF

TRANSIT ALTERNATIVES

HONOLULU RAPID TRANSIT PROJECT
PHASE II

Prepared For

DEPARTMENT OF TRANSPORTATION SERVICES

CITY & COUNTY OF HONOLULU

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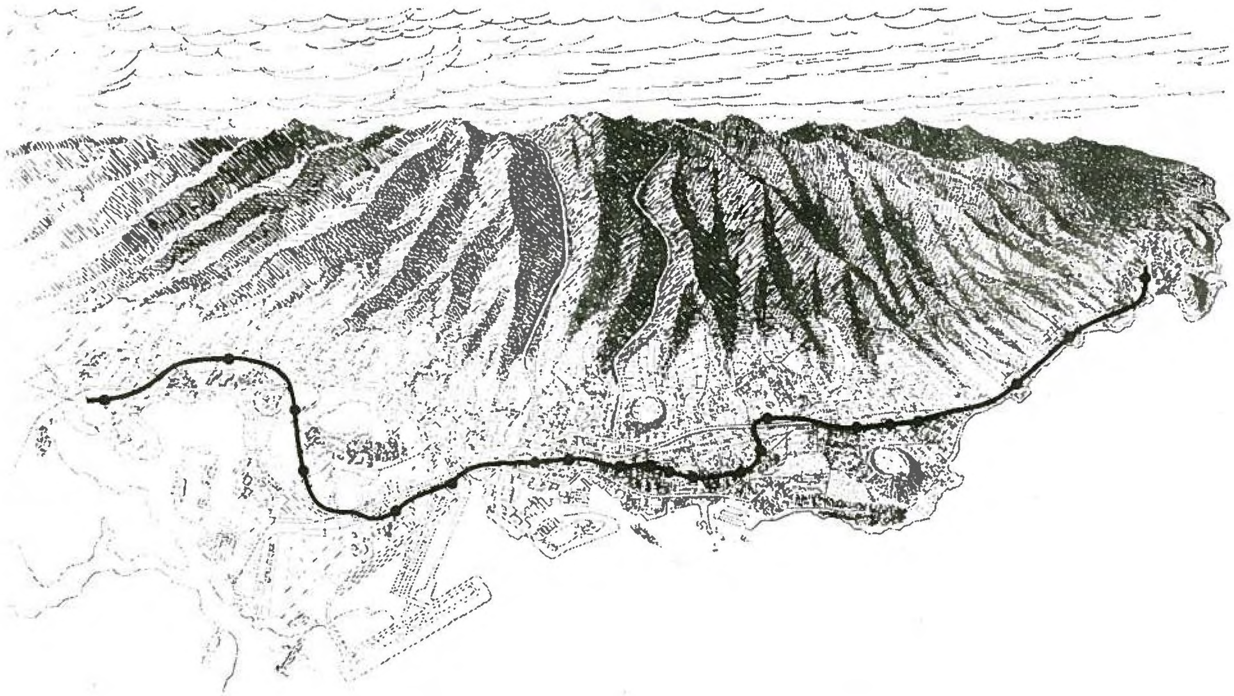
SUMMARY

Comprehensive transportation planning for Honolulu has been underway for some 10 years, beginning in 1965. While many questions have been posed and answered during this planning process, a few critical questions have continually been addressed in a successfully more detailed form. This report on analysis of transit alternatives provides the most current and detailed answers to four principal questions:

- How best can future transportation needs of Honolulu be met?
- What vehicle system would best serve the area's needs and desires?
- How soon would the system be needed?
- How extensive should the initial increment of the system be?

In order to answer each of the above questions, a systematic and comprehensive analysis of alternative courses of action available to the area was conducted. This summary presents in a succinct manner the conclusions reached as to what alternative best serves the transportation needs of the island. In addition, this report has been developed to meet the requirements of UMTA's policy statement on major mass transportation investment.



1. HOW BEST CAN FUTURE TRANSPORTATION NEEDS BE MET?

Beginning in 1965, a major step towards meeting the increasingly critical transportation needs on Oahu was made when the Oahu Transportation Study (OTS) was undertaken to establish a long-range, comprehensive transportation plan for the area. This study considered two basic alternative transportation plans - a fixed facility rapid transit system coupled with the completion of the committed highway facilities, and an all-bus system operating on an expanded system of streets and highways. The study concluded and recommended that since rapid transit could attract large numbers of passengers, a new high-capacity highway facility in urban Honolulu would not be needed and therefore, a rapid transit system be included in all long-range planning for Oahu.

As the result of the Oahu Transportation Study and other subsequent studies, government officials, professional planners, and citizens have become increasingly aware of the fact that Honolulu cannot afford such an environmentally disruptive facility as a new freeway in the urban area. Accordingly, the official short- and long-range transportation plans for Oahu do not include any new highway facility in urban Honolulu. This is further supported by both the State's and the City's recommended policy statements as contained in their respective General Plan Revision Program documents.

Since 1971, the City and County of Honolulu has been actively planning a rapid transit system which has been supported and endorsed by the State. Recent studies have consistently borne out the earlier conclusions reached that:

- a modern rapid transit system would be highly attractive,
- a rapid transit system would be acceptable to the communities and would conform to both federal and local policies on energy conservation and environmental preservation,
- a rapid transit system will be supportive of the area's growth and development policies, and
- a rapid transit system would be a sound investment by providing social and economic benefits to the island which would amount to over twice the cost.

2. WHAT SYSTEM WOULD BEST SERVE THE AREA'S NEEDS AND DESIRES?

All forms of transit systems were analyzed as possible solutions to the long-range transportation needs of the area. Low-capital intensive improvements including buses on streets in mixed traffic and on reserved bus lanes of existing facilities were tested for feasibility. A waterborne system consisting of ocean-going hydrofoils supplemented by canal boats were also considered. For land-based systems, busways, PRT system, light rail, and fixed guideway were the primary candidates.

The analyses showed that low capital intensive improvements utilizing buses on existing facilities could not meet the long-range travel needs of the area without providing additional new highway facilities. The waterborne system was found not to be the appropriate transit system for Honolulu, since it cannot penetrate the various major activity centers as directly as the land-based systems. A modified PRT system was analyzed and found to provide comparable service as conventional rapid transit systems but at a much higher cost. Therefore, it was determined that the three appropriate systems to conduct detailed analysis on, were the 7-mile busway system, various length light rail system, and the fixed guideway system.

Four different lengths of 7, 14, 23, and 28 miles were analyzed for the light rail transit system. Three different lengths of 7, 14, and 23 miles for the fixed guideway system were also analyzed. A very comprehensive and detailed comparative evaluation of the three alternative systems were conducted and the results of selected key measures considered are tabulated below.

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</table>

Note: Numbers in parenthesis (1) show ranking of alternatives based on how well they met the objective
*Practical capacity for busways are unknown and assumed to be less than for guided systems

The findings and conclusions of this comparative evaluation are summarized as follows:

a. The busway alternative had higher cost, inferior characteristics relative to environmental factors, and limited system capacity. It was therefore ruled out as an appropriate system for Honolulu.

b. The light rail transit alternative was found to adequately meet the basic requirements by providing grade separated facilities in the urban core area of Honolulu. It was determined that due to the high volume transit demand combined with the lack of suitable streets to accommodate at-grade trackwork, system staging by way of providing lower cost at-grade facilities initially would not be feasible. Therefore, various lengths of this concept were developed and tested including the 7- and 14-mile length of wholly grade separated facilities supported by feeder buses and the 23- and 28-mile lengths of combined grade-separated and non-grade-separated facilities in streets and highways, also supported by feeder buses. It was concluded that the system lengths limited to grade-separated facilities and supported by feeder buses were superior to those lengths with both grade-separated and non-grade-separated facilities with additional support by feeder buses.

c. All three lengths of the fixed guideway system analyzed have grade-separated guideways and supported by feeder buses. It was concluded that the fixed guideway system would adequately meet the basic transportation requirements for Honolulu. In comparing comparable lengths of grade-separated light rail and fixed guideway systems, it was found that for any individual qualitative or quantitative measure used in the evaluation, only a slight difference existed between the systems. However, it was concluded that, although the differences were small for individual measures, the fixed guideway showed a definite superiority for nearly all of the measures related to service, community disruption, preservation of the environment, and costs.

d. With an all grade-separated guideway, it was determined that light rail vehicle and conventional rail vehicle would be essentially comparable in cost and operating characteristics. Accordingly, in comparing steel wheel, steel rail systems with the rubber-tired fixed guideway system, the following major factors were the key determinants in the selection:

- In order to serve the highly developed urban Honolulu area in the most economical manner, only limited use of underground or subway configuration is proposed. Most of the system is proposed to be above ground on aerial structures in order to maintain the system cost at an affordable level for the island.

- The aerial guideway route locations were carefully selected with full community participation and input for minimizing dislocation of residents and businesses and adverse impacts on the environment. The requirements were to provide aerial structures with minimum obtrusiveness and a vehicle system that would cause minimum noise and vibration intrusions to the community.

- The horizontal and vertical alignments selected for the guideway requires grades of up to 8% for transition between underground and aerial configurations in order to minimize dislocation of residents and businesses. The use of lower grades would require modifications to the alignments which would result in higher cost as well as greater number of business dislocation.

- In one segment of the system route, a sustained grade of over 5% is required using the above ground configuration. If this grade were to be reduced, a change in either horizontal or vertical alignment would be necessary affecting both cost and relocation requirements.

- If segments of the system route with proposed aerial guideway configuration are found not to be acceptable to the local community due to larger structures or higher noise levels, more of the system route may be required to be placed underground with resulting higher cost which may place the project beyond the financial capabilities of the island.

The conclusion reached on the vehicle system is the result of a very thorough and comprehensive evaluation of social, economic, and environmental considerations conducted with assistance from the community. The recommendation is for a medium size, rubber tired fixed guideway vehicle system which was found to best meet the needs and desires of the island.

3. HOW SOON WOULD THE SYSTEM BE NEEDED?

Although the fixed guideway system was proven to be needed to meet the long-range (1995) travel demands of the area, it remained to be seen as to how soon it would be needed. The near-term study year of 1985 was selected as providing a reasonable lead time to implement a major capital facility.

The study analyzed various forms of low capital intensive improvements to obtain greater efficiency and capacity on existing facilities. To this end, various forms of bus operations were defined in conjunction with street and highway improvements for automobiles. The study approach was to optimize both modes relative to existing facilities and determine if adequate capacity would exist to meet the projected travel demand in 1985.

The continuation of the existing bus system on existing streets and highways, referred to as the baseline system, and an expanded bus system utilizing reserved bus lanes with various traffic engineering improvements on the street and highway system, referred to as the transportation system management (TSM) system, were carefully developed and tested. The 14-mile fixed guideway system was selected to represent the capital intensive alternative for this analysis. The results of this analysis are represented in terms of volume/capacity ratios at critical screenlines taken through existing streets and highways as tabulated below.

VOLUME/CAPACITY RATIO AT LEVEL OF SERVICE "D"

	BASELINE			TSM			14-MILE FIXED GUIDEWAY		
Screenline Locations	Daily Volume	Equiv. Daily Capacity	V/C	Daily Volume	Equiv. Daily Capacity	V/C	Daily Volume	Equiv. Daily Capacity	V/C
Kapalama Canal	266,400	234,700	1.14	251,800	234,700	1.07	246,500	234,700	1.05
Nuuanu Canal	308,200	275,600	1.12	290,800	275,600	1.06	288,700	275,600	1.05
Punchbowl Street	365,700	309,300	1.18	347,800	302,700	1.15	336,900	319,100	1.06
Ward Avenue	352,400	300,200	1.17	333,500	290,200	1.15	324,100	306,500	1.06

VOLUME/CAPACITY RATIO AT LEVEL OF SERVICE "E"

	BASELINE			TSM			14-MILE FIXED GUIDEWAY		
Screenline Locations	Daily Volume	Equiv. Daily Capacity	V/C	Daily Volume	Equiv. Daily Capacity	V/C	Daily Volume	Equiv. Daily Capacity	V/C
Kapalama Canal	266,400	284,200	0.94	251,800	284,200	0.89	246,500	284,200	0.87
Nuuanu Canal	308,200	323,800	0.95	290,800	323,800	0.90	288,700	323,800	0.89
Punchbowl Street	365,700	361,200	1.01	347,800	353,900	0.98	336,900	372,100	0.91
Ward Avenue	352,400	351,100	1.00	333,500	340,000	0.98	324,100	358,200	0.90

Based on the results of this analysis, the following conclusions were reached:

a. The baseline system representing the continuation of the existing bus and highway systems will result in demand exceeding available capacity before 1985.

b. The expanded bus system, under an overall transportation system management (TSM) alternative, would utilize reserved bus lanes and attract higher ridership than the baseline bus system. However, based on the projected transit ridership, the diversion to transit would not be sufficient to substantially reduce automobile volumes to alleviate congestion. In fact, by 1985, the streets and highways would be operating at or near maximum capacity without sufficient capacity available for contingency in the event the actual volume should exceed projected volumes.

c. When the forecasted 1985 volume for travel demand exceeds the planning and design capacity (Level D) of the streets and highways by 15% and is at or near the maximum capacity (Level E), there is no doubt that additional new capacity is justified and urgently needed.

d. With 1985 less than 10 years away and the projected travel demands based on conservative assumptions, the resulting travel demand/capacity forecast makes the transportation outlook for Honolulu critical unless implementation is initiated immediately.

4. HOW EXTENSIVE SHOULD THE INITIAL INCREMENT OF THE SYSTEM BE?

The proposed 23-mile fixed guideway system is planned to be constructed in stages. Incremental guideway sections beginning with a basic 7-mile "core" segment have been thoroughly analyzed and they include lengths of 8 miles, 12 miles and 14 miles as potential initial increments for construction. The analysis was conducted based on the study year of 1985 and a 5-year period to 1990.

The basic "core" system is the 7-mile fixed guideway system from the Keehi Lagoon Park area to the University of Hawaii campus area with incremental extensions thereto for the 8-mile, 12-mile, and 14-mile length alternatives. Each incremental extension was carefully planned to achieve maximum accessibility at the termini as well as providing the best transit service possible to the areas traversed by the guideway. For each alternative length, a feeder bus system was provided to support the guideway system. The following summarizes the principle findings and conclusions.

a. System Attractiveness

A modern well planned and designed fixed guideway system provides the ultimate in public transit service which is far superior to a bus system. Therefore, with each added length of guideway facility, both additional new riders and riders diverted from buses will increase the ridership volume on the fixed guideway system. Additionally, the accessibility to terminal stations which varies with different length guideways will also have a significant impact on the ridership volume. The table below shows the estimated ridership volumes in 1985 for the four guideway lengths.

	Guideway Length			
	7-Mi.	8-Mi.	12-Mi.	14-Mi.
Daily Ridership	193,600	196,100	212.200	227,600
Increase Over 7-Mi. Length	-	+ 2,500	+18,600	+34,000
Percent Increase	- -	1.3%	9.6%	17.6%

The above table shows the relative attractiveness of the different guideway lengths. The 14-mile guideway length is found to attract the most ridership and has the highest percent increase for added increment of length.

b. Total Annual Cost Analysis for Total Transit System

The previous paragraph presented the findings of relative system attractiveness on the fixed guideway only. Since the proposed fixed guideway system is supported by an island-wide network of feeder buses, the guideway and buses must be treated as a single integrated system in a total transit system analysis.

The longer guideway systems require fewer feeder buses since certain bus routes would be replaced by the guideway extension. In comparing the total transit systems, the cost trade-off is between the higher capital cost/lower operating cost of the longer guideway length and the lower capital cost/higher operating cost of the shorter guideway length. The total annual cost per ride for the alternatives for 1985 are shown below.

	Guideway Length			
	7-Mi.	8-Mi.	12-Mi.	14-Mi.
Total Annual Cost (Million)	$61.92	$62.67.	$63.81	$66.23
Total Annual Patronage (Million)	95.31	96.04	98.54	102.31
Total Annual Cost/Ride	$0.650	$0.653	$0.648	$0.647

The results of this analysis shows that the total annual cost per ride is the lowest by a very small amount for the system with the 14-mile guideway based on constant 1975 dollars. However, since the capital cost portion of the total cost remains unaffected by future inflation while the operating cost is subject to increases due to inflation, the system with the longer guideway with its lower operating cost will have a distinct advantage for the local region. As an example, by assuming a 7% escalation rate on the operating costs, the 14-mile guideway system would provide a $50 million savings to the island over the 7-mile guideway system. Again this analysis shows the superiority of the longer 14-mile guideway length over the shorter lengths.

c. Costs and Benefits Analysis for Total Transit System

The previous analysis considered capital and O&M costs and patronage volumes to derive costs per ride for comparison purposes. This analysis considers those quantifiable benefits resulting from travel time savings and automobile ownership and operating cost savings. The longer the fixed guideway length, the shorter the overall transit trip time which results in greater time savings than with a shorter fixed guideway length. Also the higher volume of transit patronage with the longer length fixed guideway system results in greater automobile cost savings. The results of this analysis shows the longer guideway systems with higher benefit/cost ratios than the shorter system as shown in the table below.

DESCRIPTION	1985				1990			
	7-Mi.	8-Mi.	12-Mi.	14-Mi.	7-Mi.	8-Mi.	12-Mi.	14-Mi.
Total Net Annual Cost ($ Million)	29.05	29.80	30.94	33.36	39.08	39.30	40.20	42.03
Total Annual Benefits ($ Million)	32.27	32.50	34.99	37.63	48.69	49.23	52.20	55.95
BENEFIT/COST RATIO	1.11	1.09	1.13	1.13	1.24	1.25	1.30	1.33

The above table shows that all alternative lengths have benefit/cost ratios higher than 1.0 which implies that they would all be sound public investments even prior to 1985. It further shows that the longer 12- and 14-mile lengths are better investments than the shorter 7- and 8-mile lengths in 1985 with the 14-mile length being the best in 1990.

To further substantiate the above, an incremental benefit/cost analysis was conducted by comparing the two shortest lengths with each other, picking the better of the two and comparing it to the next longer length, and repeating the process to the longest length. In the comparison, the longer length must show a benefit/cost ratio of greater than 1.0 to be better than the shorter length with the results shown in the table below.

DESCRIPTION	1985			1990		
	8-Mi. Vs. 7-Mi.	12-Mi. Vs. 7-Mi.	14-Mi. Vs. 12-Mi.	8-Mi. Vs. 7-Mi.	12-Mi. Vs. 8-Mi.	14-Mi. Vs. 12-Mi.
Incremental Costs ($ million)	0.75	1.89	2.42	0.22	0.90	1.83
Incremental Benefits ($ million)	0.23	2.72	2.64	0.53	2.97	3.75
BENEFIT/COST RATIO	0.31	1.44	1.09	2.45	3.30	2.05

The 14-mile length alternative was found to be clearly superior to all other alternative lengths as shown above, and in all other aspects as previously described, and therefore it is recommended as the initial increment of construction.

CHAPTER I

INTRODUCTION

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A. PURPOSE OF REPORT

The purpose of this report is to present, in one document, the processes followed and the technical conclusions reached regarding a rapid transit system for Honolulu. It has been prepared in specific response to the U. S. Department of Transportation's policy on making "Major Urban Mass Transportation Investments", as published in Draft Form in docket 75-04 of the Federal Register of August 1, 1975.

In preparing this report, it is recognized that planning for rapid transit in Honolulu has taken place over a period of time, beginning with a major Island-wide transportation study in 1967. Throughout the course of this work, political leaders, business leaders, and citizen groups have continually participated in the studies and have, in various ways, indicated support and endorsement of the technical conclusions reached. However, at the outset, it should be pointed out that while numerous public meetings have been held during the course of the program on these technical conclusions, final decisions must await acceptance of an Environmental Impact Statement and the outcome of final public hearings.

While many questions have, of course, been addressed during the last eight years, five principle questions have received particularly close study in successively more detailed form. These questions are:

1. Does Honolulu need a fixed facility rapid transit system?

2. Where should it be located?

3. What type of rapid transit system would best serve the area's needs and desires?

4. How soon would the system be needed?

5. How extensive should the initial system be?

Well documented and plausible answers to these questions are required by decision-makers in the City and County of Honolulu, the State of Hawaii, and the U. S. Department of Transportation, in order for the rapid transit program--the largest single public works program ever undertaken in Honolulu--to move forward. In answering these questions, Honolulu has thoroughly analyzed all feasible alternatives to each question, both in terms of cost-effectiveness as transportation solutions; and in terms of the non-quantifiable measures of effectiveness toward strengthening attainment of the Island's social, environmental, and community goals. These analysis were conducted with a view toward both the short range impacts (1985) and the long range impacts (1995).

Hopefully, this report captures the 10-year history of analyzing these questions. The remaining portion of Chapter I outlines the history of transportation and transit planning on the Island in order to give the reader some perspective of the detailed processes followed.

Chapter II provides an overview of current and future growth on the Island, both in terms of people and their transportation needs. This chapter also attempts to lay out in summary form the generally accepted land use and transportation goals of the Island as a framework within which public officials have made and will make decisions regarding alternative courses of transportation and related actions.

Chapter III presents a documentation of the analysis of the existing transportation system to meet current and future travel needs. It also describes and compares the alternative courses of action which could lead to solutions of this problem. These courses are principally to construct additional freeways, to considerably upgrade the existing bus transit system, or to do some combination of these. The conclusion documented in this chapter, both in terms of cost-effectiveness, and in terms of reinforcing established and future development, and community acceptance, would be to construct a high level rapid transit system in urban Honolulu as a backbone for a greatly improved Island-wide transit system.

Chapter IV builds on this case by illustrating the steps which have been taken in recent years by local and state governments to continue to maximize the use and effectiveness of the present street, highways, and bus system. Despite this action, the gap between demand and capacity continues to widen.

Given this condition, Chapter V analyzes various alternative locations for a backbone rapid transit system in terms of both transportation service and compatibility with other community goals. It concludes with a recommendation which is believed to provide a sound balance between maximum transportation service, minimum residential and non-residential dislocation, and maximum support of established development goals.

Chapter VI then looks at a series of alternative transit vehicle systems which by proper design might be able to satisfy the transportation requirements of the Island within the context of its non-transportation goals. Various alternative transit systems are screened and three are fully analyzed with respect to service and cost-effectiveness within the context of these goals. A selection of a vehicle system is documented.

Chapter VII evaluates various alternative systems including a low capital cost solution on a near-term basis to determine when a major capital investment must be made in Honolulu. A low capital cost system, referred to as the transportation systems management alternative, relies principally on improving existing systems by employing various traffic engineering techniques to increase both efficiency and capacity. This evaluation then provides the necessary data for determining how long the area can go without investing in a major new transportation facility.

Chapter VIII assesses the short-term requirements regarding the length of the system. The effect here is to document the results of studies conducted primarily to assure the cost-effectiveness over time of transit investments. This chapter concludes with a recommended length of the fixed guideway system over the short-term (1985) which establishes the initial increment of the fixed guideway system for implementation.

Great care has been exercised in this report to summarize a process which has occupied the time of public officials, citizens, and technicians over a number of years. In order to make the report coherent and concise, many details have been omitted, and while every effort has been made to produce a report which can stand on its own merits on the major points, substantial use is made of reference material which has been prepared over this long period of time. These references are all on file in Honolulu and with UMTA in Washington.

B. HISTORY OF TRANSPORTATION AND TRANSIT PLANNING

Since World War II it has been relatively clear that Oahu's population density and geography would require new high capacity transportation services. Studies conducted by the Hawaii Department of Highways in the late 1940's and 1950's concluded that three high capacity freeways would provide substantial relief through the 1970's (H-1, H-2 and H-3). These eventually became the principle elements in Hawaii's Interstate Highway Program. In the 1960's, however, as construction got underway for these facilities; as the impacts of such construction became clearer from experiences in San Francisco and elsewhere, and as the population growth began to exceed official forecasts, both the State and the City, with the financial support of the Federal government began a series of concentrated studies of the situation. Beginning with the preparation of the General Plan of the City and County of Honolulu, studies were initiated which began to show the need and value of an alternative to the expanded highway system. Adopted by the City Council after considerable public discussion and debate, the General Plan laid the foundation for further studies of the transportation system and established some general principals and goals which should guide the development of such a system.

In the mid-1960's, the State and the City, with Federal financial assistance, undertook the Oahu Transportation Study, partly to satisfy Federal transportation planning requirements but mostly to begin the detailing of the parameters of a long term solution to the Island's transportation problems. This program re-examined the population and employment growth potential of the Island and based on new forecasts of such activity, prepared a comprehensive assessment of the present and projected transportation deficiencies on the Island. It concluded that additional transportation capacity would be needed in the 1980's to satisfy these deficiencies.

This study evaluated two basic alternatives, one an all-bus system operating in mixed traffic over an expanded freeway system, and the other a fixed-guideway system of the "trunkline/feeder" type. It also defined a feasible corridor and set some preliminary limits of the system at Pearl City on the west and Hawaii Kai on the east. Alternative technologies and alignments were not explored in detail.

With respect to timing, it concluded that a grade-separated fixed-guideway system should be developed as a long-term solution and that expansion of the existing bus system should be undertaken in the short term. Basically the high costs of an expanded highway system and its social and environmental consequences led to such a recommendation. Accordingly, additional studies of a high-capacity public transit system began in 1971, by which time the City and County of Honolulu began acquisition of private bus carriers and embarked on a substantial expansion and modernization program.

At the same time, studies proceeded on the fixed guideway program. The Preliminary Engineering Evaluation Program, Phase I (PEEP I) included evaluation of mode, technology, corridor, length, and alignment alternatives. As in OTS, the need for a high-capacity system was demonstrated in the urban corridor. The line-haul/feeder was tentatively selected as the most appropriate technology in light of the volumes anticipated by 1995. Other technologies, however, were studied in some depth and included bus-on-busway and waterborne vehicles operating offshore and in canals with a feeder bus system.

Alternative corridors were looked at again and included a makai and mauka corridor in the urban area and a trans-Koolau corridor to Windward Oahu. The makai (near the sea) corridor was selected in preference to the mauka (inland) corridor, and patronage and cost estimates showed that only one of two could be justified. The trans-Koolau corridor did not prove to be justified in light of high costs and limited patronage.

Length of corridor was again re-tested in several alternatives, the longest of which extended from Kailua on the Windward side, around Koko Head, through the urban area, branching at Waiawa, with one branch extending to Wahiawa and the other to Waianae on the Leeward side of the Island. The shortest segment was 12 miles in length from Halawa to University, and the network selected was a single line in contrast to the branched line recommended by OTS. The selected technology was a rubber-tired, high-platform, medium-sized trainable transit car on a grade-separated fixed guideway with on-line stations supplemented with feeder and express buses.

An additional evaluation was made of alternatives involving the PEEP I system, bus-on-busway, waterborne, and an automatic small-vehicle system with off-line stations. With respect to the busway system, a number of operating alternatives were considered, including platooning and station bypassing. With respect to the automatic small-vehicle system, a network was designed to serve the same corridor but in a way which capitalized on the unique features of such systems. The system consisted of 33 miles of two-way guideway and 77 stations. An independent analysis of patronage was employed to compare the automatic system with the PEEP I recommendations. In addition to providing a means for comparing the two systems, this estimate of patronage also confirmed the estimates made by the regional travel and modal split models in PEEP I.

Thus, by early 1972, a broad spectrum of alternatives had been evaluated ranging over several corridors, technologies, system configurations, alignments, and lengths. A draft environmental impact statement, prepared at the conclusion of PEEP I, had been published, and comments had been received from numerous agencies, organizations, and individuals. The recommended system at that time was the rubber-tired, high-platform, fixed guideway with on-line stations and a supplementary bus network of local, feeder, and express routes covering the entire island of Oahu. The fixed guideway was proposed to extend from Pearl City to Hawaii Kai, a total length of 22 miles. Even so, there were a number of organizations and individuals who believed that other technologies could be used either as the primary system or as supplementary sub-systems.

Additionally, although the PEEP I study had evaluated many detailed alignment alternatives, the number of relocations required by the proposed alignment was high in light of the shortage of low- and moderate-cost housing in Honolulu. Accordingly, Phase II of the Preliminary Engineering Evaluation Program (PEEP II) examined a greater range of system lengths and alignments, the feasibility of off-line stations, and mixed-mode systems. The supplementary systems vary in some details but provide comparable levels of service in terms of schedule frequency, coverage, and travel time. As a result of PEEP II, several previous decisions on general locations, length, and vehicle system were verified. In addition, a more precise alignment was established which minimized relocation and disruption. This alignment was engineered in a preliminary way, stations were located and designed, and relocation, management and financial plans were prepared. An initial program to satisfy the Island's short range needs was determined. These were presented to both the City Council and the State Legislature for endorsement. General endorsement was forthcoming and preliminary applications were made in early 1975 for Federal financial assistance for final engineering, right-of-way acquisitions and construction.

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CHAPTER II

BASIS FOR TRANSPORTATION PLANNING

A. GOALS, OBJECTIVES, AND CRITERIA

1. Introduction

As pointed out in Chapter I, planning for transportation and transit has been actively pursued in a comprehensive manner in Honolulu for some 10 years. Early in this program, a research was conducted of various planning documents containing specific goals and objectives reflecting the area's policy to ensure coordinated physical development of the Island.[1/] Recognizing that planning is a rational process for formulating and meeting objectives, the objectives chosen by the area should be used in development, testing, and evaluation of alternative transit decisions.

The physical development of an area is normally guided by a master plan of the city or region which is based upon economic, employment, and population studies of the area. The plan reflects estimates of future population based on economic and employment evaluations, allocation of land uses, determination of community facility needs, and transportation demands for the area. The land use element of the plan allocates land to various uses in compliance with the zoning code and the transportation element is not only planned to serve but to promote the land use pattern.

The specific objectives are usually listed separately for land use and transportation planning purposes. However, it should be emphasized that land and transportation are interdependent; and, therefore they cannot be separated. The separate listing of the specific objectives is done only for convenience of organization and presentation.

In the development of a transportation system, some measures must be applied in order to test the feasibility of a particular plan. Test and evaluation normally involve quantitative and qualitative evaluation of the degree to which a plan meets development objectives or criteria. Through this process, alternative transportation plans can be tested and evaluated such that a comparison can be made to aid in the selection of the most feasible and desirable alternative.

The purpose of this section is to outline those basic goals and objectives adopted by the area and define more specific transportation and transit development objectives together with a set of criteria relatable to each objective. These criteria are then used to facilitate their application in the decision-making process.

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2. Goals and Objectives for Oahu

General goals and objectives for Oahu have been formulated through many studies and programs conducted by public and private agencies and organizations in the recent past with the aid of various community and citizen groups. The General Plan of the City and County of Honolulu adopted in 1964 included a statement of objectives.[2/] Transportation goals and objectives were developed and used in 1967 in the Oahu Transportation Study.[3/] General goals were prepared in the same year and recommended to the State of Hawaii by the Citizen's Advisory Committee. In 1970 the Advisory Committee of the Governor's Conference on the Year 2000 submitted general goals for the whole state in the decades ahead. In the publication, "Issues, Goals and Objectives for the Seventies and Beyond",[4/] the Mayor of the City and County of Honolulu outlined the administration's goals for the future.

In May of 1970 the Oahu Development Conference, a private organization, proposed Transportation Goals and Policies for Oahu dealing with both general and specific transportation objectives. In October of the same year the City Planning Department in a Status Report of The General Plan Revision Program[5/] reviewed the effectiveness of Objectives, Sub-Objectives, Standards and Principles of the General Plan of 1964 and suggested alternative definitions of objectives at the highest level of the program structure hierarchy. In general, each of those programs has produced consistent sets of goals and objectives for Oahu.

The relevant sets of goals and objectives used in guiding development on the island are summarized as follows:

a. General Goals of the Oahu General Plan: The General Plan of the City and County of Honolulu, adopted in 1964, which, together with its subsequent amendments forms the basis of this study, sets forth the City's policy for the long-range comprehensive physical development of Oahu. The General Plan consists of a map of Oahu and a statement of development objectives, standards, and principles with respect to the most desirable use of land, soil, density of population, the transportation system, public facilities and utilities, public housing projects, and such other matters which may be of benefit to the City. The plan is based upon studies of physical, social, economic and governmental conditions and trends.

The General Plan is designed to assure the coordinated development of the City and County of Honolulu and to promote the general welfare and prosperity of its people. The broad goals of the General Plan are set forth as follows:

1) To develop a wholesome, convenient, and attractive living environment.

2) To preserve and maintain significant historic sites, scenery and natural assets of the Island of Oahu.

3) To foster and create a favorable economic climate in agriculture, commerce, industry, defense and tourism.

4) To establish this island as a unique showplace of democracy, where all ethnic and social groups live together graciously and harmoniously in a "Spirit of Aloha".

5) To promote better citizen understanding in the planning program and participation in the planning process.

b. Transportation Objectives of the Oahu General Plan: The transportation objectives set forth in the General Plan are primarily concerned with a balanced transportation system to provide a set of facilities for convenient, safe, quick and economic movement of people and goods between various points within Oahu in harmony with the various land use patterns it serves. The transportation development objectives as adopted are stated as follows:

1) These facilities should enable a person to travel from any point in the region to any other point within reasonable travel time by one or more modes of transportation.

2) The entire system should be a combination of facilities which will provide the greatest efficiency and service to the community with the least overall expenditure of the resources.

3) The systems should be designed to prevent accidents as much as possible.

4) The systems should be designed as an integral part of and complementary to land use patterns.

c. The Oahu Transportation Study: Working within the framework of goals for comprehensive planning as set forth in the General Plan, the Oahu Transportation Study applied these basic goals in the development of a transportation plan for Oahu. The specific objectives adopted for the transportation plan were formulated through the efforts of technical and citizen advisory committees involving various citizen and business group participation in the decision-making process.

The Oahu Transportation Study identified major transportation planning objectives which are summarized as follows:

1) Ease of Movement

2) Integration of the Transportation System with Land Use

3) Availability of Variety of Modes of Travel

4) Preservation of Oahu's Beauty and Amenities

5) Safety

6) Balanced Transportation System

d. Supplemental Goals and Objectives of the City and County: In "Issues, Goals and Objectives for the Seventies and Beyond", the Administration of the City and County of Honolulu has identified various issues confronting the City. Transportation is included as one of the central issues with the goal for the development of an efficient, balanced transportation system that will offer alternative choices for the transportation of individuals and goods that will be consistent with the other elements and goals of the community in design and function.

Under that broad goal, the following specific objectives are outlined with programs already underway towards accomplishing certain objectives:

1) An efficient and safe street and highway system.

2) A convenient island-wide transit system that will encourage all people to use it and which should eventually be fare-free - beginning first for senior citizens and students, then for everyone.

3) A modern, highly attractive rapid transit system that will provide service to major centers of employment, education and recreation in urban areas.

4) Substantial reduction of the traffic accident rate.

5) Reduction of the vehicle ownership growth rate.

6) Participation of industry and community groups and partnership with the State and Federal governments in planning, financing and implementation.

All of the state goals and objectives of the State and City and County agencies as well as community and civic groups continually bring into focus the basic goals and objectives of the General Plan and the Oahu Transportation Study. They are primarily concerned with a balanced transportation system, improved mobility, reducing travel time and accident exposure, and minimizing costs and disruptive effects upon communities and natural resources.

3. Use of Goals and Objectives in the Transit Planning Process

As stated previously, the purpose of researching the area's goals and objectives was to assist in developing a framework within which various alternatives regarding public transit could be compared so that recommendations on technical basis could be made.[1/] The obvious parallels in the goals and objectives established at various periods and by various governmental levels and private groups with respect to transportation, clearly set the stage for such a framework. However, to relate these to the current transit program and to facilitate their application to the development, testing, and evaluation of alternative transit decisions, requires a set of measurable criteria relating to each goal and objective.

Table II-1 presents in summary form the general framework which was used. It first presents the list of major goals and objectives, then presents the criteria used to measure relative attainment of these by various alternatives, and then illustrates the selected criteria used for evaluation of specific set of alternatives. Within the framework of this table, more detailed discussions are presented in later chapters.

TABLE II-1: GOALS, OBJECTIVES AND CRITERIA

Transportation Goals Oahu General Plan	Transportation Goals Oahu Transportation Study	Transit Development Objectives PEEP I and II	Transit Development Criteria for Alternatives Analysis	Applicable Criteria for Specific Alternative Analysis: Route Location	System Type	System Length
1. Provide transportation facilities to enable travel from any point in the region to any other point within reasonable travel time by one or more modes	1. *Provide transportation facilities for ease of movement throughout Oahu; and provide a variety of modes of travel which will best serve the different requirements of the community	1. Improve accessibility by serving and interconnecting existing and future urbanized areas of Oahu	a. Availability & coverage	—	✓	✓
			b. Average trip time	✓	✓	✓
			c. Service reliability	—	✓	✓
			d. Rider convenience	✓	✓	✓
			e. Rider comfort	✓	✓	✓
2. A transportation system which will provide the greatest efficiency and service to the community with the least overall expenditure of resources	2. Provide a balanced transportation system which will result in optimum service with the least public expenditure	2. *Provide a balanced transportation system of transit and highways	a. System patronage	✓	✓	✓
			b. System capacity	✓	✓	✓
		3. *Minimize expenditure of resources and disruption to community	a. Consumption of land	—	✓	✓
			b. Displacement of residents	✓	✓	✓
			c. Displacement of businesses	✓	✓	✓
			d. Reduction of comm. amenities	✓	✓	✓
			e. Disruption to future dvlpmt.	✓	✓	✓
			f. Disruption to local circulation	✓	✓	✓
			g. Disruption - constr. activity	—	✓	✓
			h. Savings in energy	—	✓	✓
			i. Technical risk	—	✓	✓
3. A transportation system to be designed as an integral part of and complementary to land use policies	3. Integration of the transportation system with land use	4. Support land use and development policies	a. Support regional development	✓	✓	✓
			b. Support comm. development	✓	✓	✓
4. *Preserve and maintain significant historic sites, scenery and natural assets of Oahu	4. Preserve Oahu's beauty and amenities	5. Preserve environment	a. Reduction air pollution	✓	✓	✓
			b. Noise level	✓	✓	✓
			c. Visual intrusion	✓	✓	✓
			d. Vistas	✓	✓	✓
			e. Historic sites	✓	✓	✓
5. Safety	5. Safety	6. Safety	a. Reduce accident exposure	—	✓	✓
			b. Security	—	✓	✓
6. **Provide a transportation system which will provide the greatest efficiency and service to the community with the least overall cost	6. **Provide a balanced transportation system which will result in optimum service at the least cost to the public	7. Provide the most economical system which best meets all other objectives	a. Total annual cost	✓	✓	✓
			b. Cost per trip	—	✓	✓
			c. Benefit-cost ratio	—	✓	✓
*Stated as one of the general goals **Stated separately from 2 to differentiate between expenditure of resources and least cost	*Combines Goals 1 & 3 of OTS **Stated separately from 2 to differentiate between expenditure of resources and least cost	*Goal 2 stated as two separate objectives				

B. POPULATION AND EMPLOYMENT FORECASTS

The unique geography and topography of the Island of Oahu have, throughout the island's history, greatly influenced land use development including residential and economic growth and the transportation network. Development of Oahu has been conditioned largely by the geographic constraint imposed by the Koolau and Waianae Mountain Ranges and the constraint on urbanization imposed by the State's land use law. Urban development has been restricted primarily to a relatively narrow level area along the southern Leeward Coast of the Island as shown in Figure II-1. This area has developed considerably higher in density in the past several decades, creating a need for more intensive transportation facilities. The following discussion describes the assumptions and methodology used to prepare population and employment forecasts which were used as the basis for patronage projections for the rapid transit and other alternative systems.

1. Assumptions and Methodology

The Honolulu Rapid Transit Program incorporates various policy directives and assumptions agreed to by the Oahu Transportation Planning Process representing the planning and transportation agencies of the City and County of Honolulu and the State of Hawaii and advised by the Citizens and Technical Advisory Committees. The Citizens Advisory Committee is made up of representatives from professional business and civic organizations and the Technical Advisory Committee is made up of members from various City and State agencies. Among the most significant policy directives and planning assumptions which were agreed upon by this process was:

a. That the year 1995 would be utilized as the base projection year for transportation purposes.

b. That medium range population forecasts and employment forecasts developed by the State Department of Planning and Economic Development (DPED) in 1971 for the year 1995 would be utilized for transportation planning purposes.

2. Population Forecasts

The DPED forecasts were used as the basis from which to assess the urban and environmental planning opportunities and patronage associated with the development of a refined transit system. The DPED long term growth projections were prepared in 1971 and are based upon medium growth assumptions; that is that population trends on Oahu will gradually converge with "Series D" national fertility projections and the same level

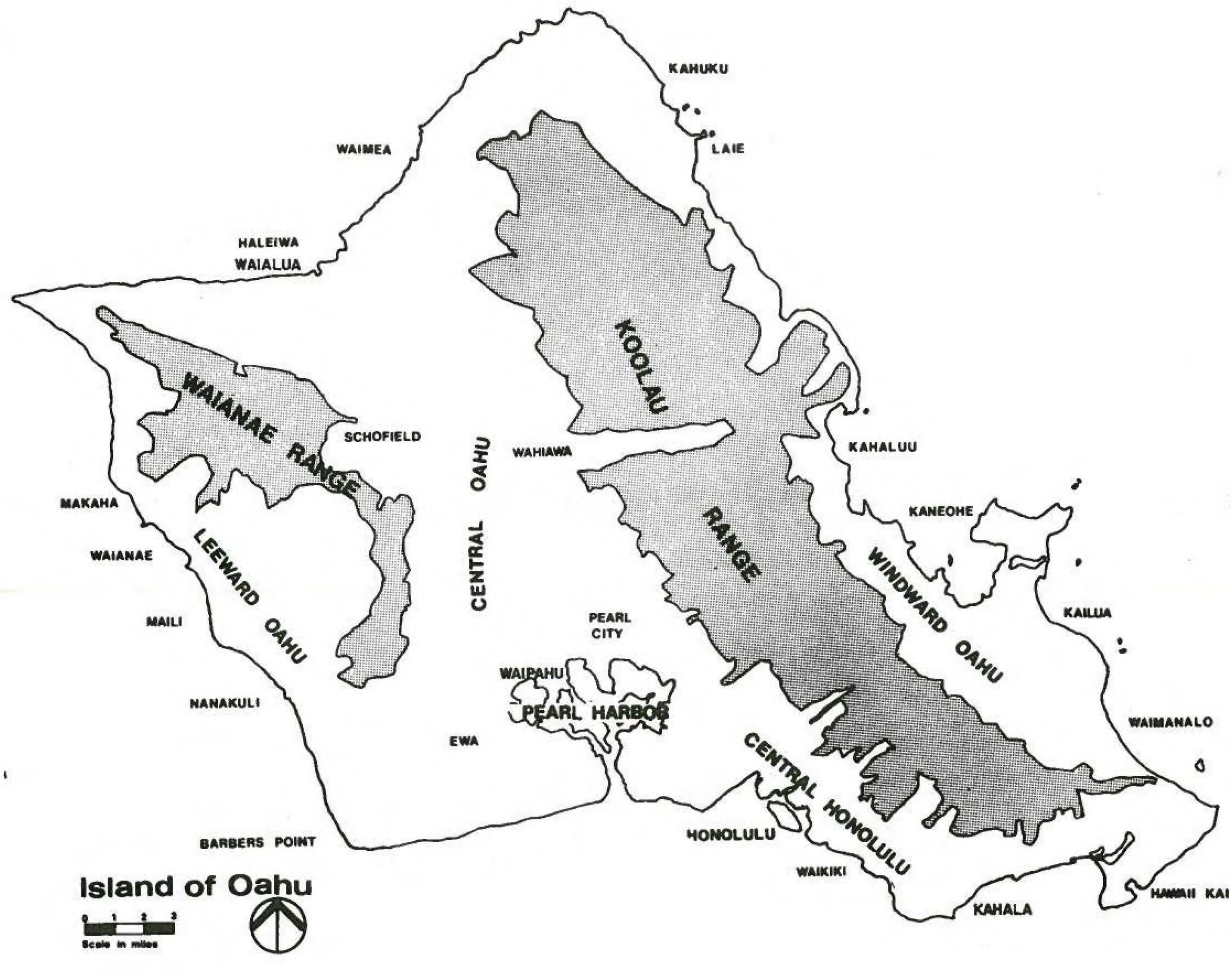

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FIGURE II-1

of net in-migration as in the 1970-1970 period.[6] These long range projections for the City and County of Honolulu are summarized in Table II-2.

TABLE II-2

POPULATION FORECAST SUMMARY

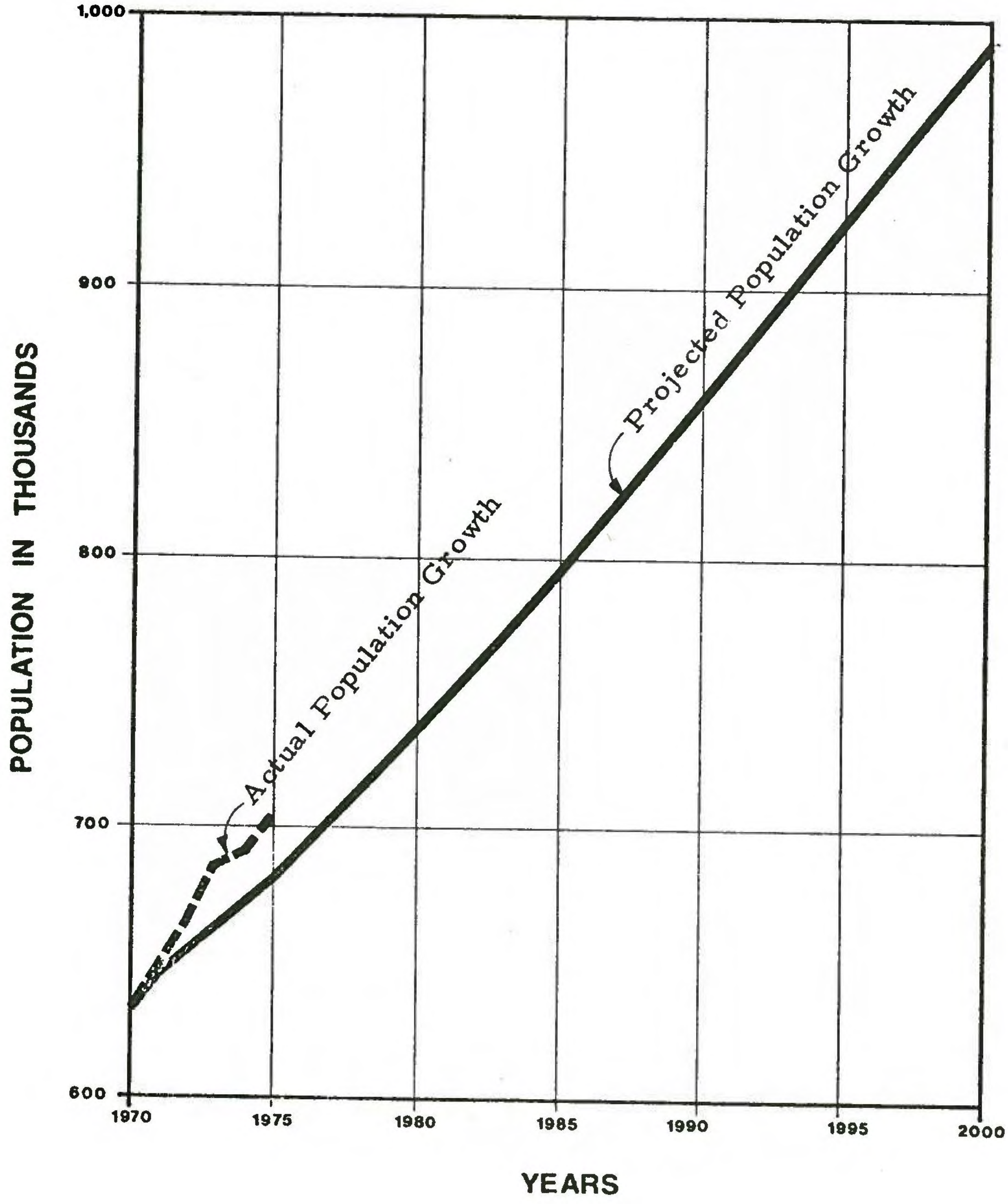
YEAR	POPULATION
1970	630,500
1975	680,000
1980	735,000
1985	795,000
1990	859,000
1995	924,000
2000	990,000

3. Comparison of Population Forecasts and Experience

Although DPED projections forecasted population growth rates on Oahu to gradually approach those of the nation, in fact, since Statehood, Hawaii's population growth rate has been about twice that of the nation and approximately 94% of the new residents have located on Oahu.[7]

The City and County of Honolulu had an estimated resident population of 704,500 as of July 1975, compared with 680,000 which was forecasted for 1975. (See Figure II-2) Between 1970 and 1974, population increased 9.6% and the housing inventory increased 15.8%. By district, recent population growth has been most rapid in Ewa (19%) and slowest in urbanized Honolulu; i.e. the area between Red Hill and Makapuu Point. Increases in the housing inventory by district followed a similar pattern, ranging from 10% in Waialua and 11% in Honolulu to 33% in Ewa.[8] These estimates were based on 1970 census statistics, official population estimates by county for the post censal years and official records of construction and demolition for 1970-1974.

Population projection updates prepared by DPED similarly document the rapidity of population growth in Hawaii and they confirm that population projections which were prepared in earlier years are conservative. The most recent DPED projections, prepared in 1974, indicate that by 1995, the population of Oahu may well approach 965,000 versus the 924,000 projected in 1971 and used in this study.



ISLANDWIDE POPULATION GROWTH

FIGURE II-2

Therefore, the observed growth rate and recent projections indicate that the transportation demand and transit patronage forecasts used in this program based on the 1971 projections should prove to be conservative.

4. Employment Forecasts

Employment projections used in this study were also developed by DPED through application of their economic model. In order to specify the required levels of economic activity, the economic planning model simulates, through a series of mathematical expressions, the key relationships among the many components of the economy and thereby "recreates" the primary forces that affect the pattern and nature of the economy's growth. These basic (or structural) relationships, which themselves are assumed to change over time, provide the basis for predicting the future required growth pattern.

An important output of the model is a projection of employment stratified by standard industrial classification code for 5 year increments. This data, together with population and dwelling unit projections is input to the land use model. The results of the DPED forecast of employment produced for this study are summarized in Table II-3 below.

TABLE II-3

EMPLOYMENT FORECAST SUMMARY [9/]

YEAR	TOTAL EMPLOYMENT
1970	315,780
1975	333,000
1980	375,000
1985	419,000
1990	464,700
1995	515,700

5. Comparison of Employment Forecasts and Experience

Rapid population growth has occurred primarily because of expansion in three of Hawaii's basic economic sectors; tourism, military expenditures and Federal non-defense grants which, in turn, have stimulated growth throughout the rest of the economy. As indicated in Table II-4 below, the State has experienced fairly rapid growth in employment and has maintained relatively low unemployment rates. But competition for jobs, especially professional jobs is becoming increasingly intense.

TABLE II-4

HISTORICAL EMPLOYMENT GROWTH AND UNEMPLOYMENT RATES[10]

Years	Annual Growth Rate of Employment (Percent Increase)	Unemployed as Percent of Total Labor Force
1965-70	5.4	2.6 min - 3.5 max
1970-71	2.4	4.4
1971-72	3.3	2.3
1972-73	4.6	7.1
1973-74	1.5	6.5

Recognizing this historical growth rate, the projections used in this study which reflect an average annual growth of approximately 2% between 1970 and 1995 appear reasonable. They also reflect a slight increase in labor participation rate, a trend that is also historically correct.

C. PRESENT AND FUTURE LAND USE

1. Assumptions and Methodology

It is a generally accepted fact that there is a complex relationship between transportation and future land use. Regional transportation facilities will influence the patterns, types, and densities of future land uses within the entire region and vice versa, and transportation facilities must be planned and designed to reflect existing and projected land use.

In recognition of these inter-relationships a Land Use Model was developed by the Oahu Transportation Study. The model is currently maintained and operated by the Oahu Transportation Planning Program and was used to project future land uses for this study. The Land Use Model takes the outputs of the Economic Model described earlier and allocates new jobs and population to census tracts. Employment is allocated depending on its type and on the land use allowed under the General Plan. Thus, allocations are made to census tracts which have land available for the specific purpose. Dwelling units and population are similarly assigned by the Land Use Model. The model provides 29 items of information for each census tract in five-year increments. Input to the Land Use Model was derived from the 1964 General Plan.

The following section discusses the land use inputs to the model and evaluates their validity in light of the land use classification changes which have occurred in Oahu since 1964.

2. Land Use Model

The land use planning basis for the development of patronage forecasts of the Honolulu Rapid Transit Program is the General Plan of 1964 of the City and County of Honolulu. Since 1964 two major factors have influenced the development of the General Plan. They are the State Land Use District classification system and the General Plan Revision Program.

Land uses designated in the General Plan were based upon the State of Hawaii Land Use Districts as designated in August 1964. This land use classification system designates all land in the State into urban, rural, agricultural or conservation lands. In the City and County of Honolulu, changes in the General Plan follow changes in

State Land Use Districts. The table below summarizes the State land use classification changes which have occurred since 1964, on Oahu:

TABLE II-5

LAND USE CLASSIFICATION CHANGES 1964-1975[11/]
(Acres)

	Urban	Rural	Agricultural	Conservation	Total
August 1964	75,700	0	158,200	151,400	385,300
August 1969 (After completion of 5-year Comprehensive Review)	82,592.9	0	145,906.1	156,801.0	385,300
March 1974	84,093.4	0	144,285.7	156,920.9	385,300
February 1975 (After completion of 2nd 5-year Comprehensive Review)	85,186.5	0	145,205.9	154,907.6	385,300

This summary of land use classification changes indicates that few new areas have been redesignated for urban use since 1964; this in turn suggesting that land use projections used in this study, produced in 1971 and based on the 1969 data, are still essentially reliable in 1975.

3. Future Land Use

The other major influence on the reliability of the Land Use Model is the current City and County of Honolulu General Plan Revision Program (GPRP). As part of the City's GPRP, three basic alternative growth policies have been developed. The three basic development policies are described below:

- Intensive Development - Characterized by the restriction of future development to within the present urban boundary as defined by the General Plan adopted in 1964 and as revised since that date. This restriction would have the effect of limiting or slowing both the population and economic growth of the island. Under this policy, it is assumed that Central Honolulu would continue to be the primary employment and government center of the island.

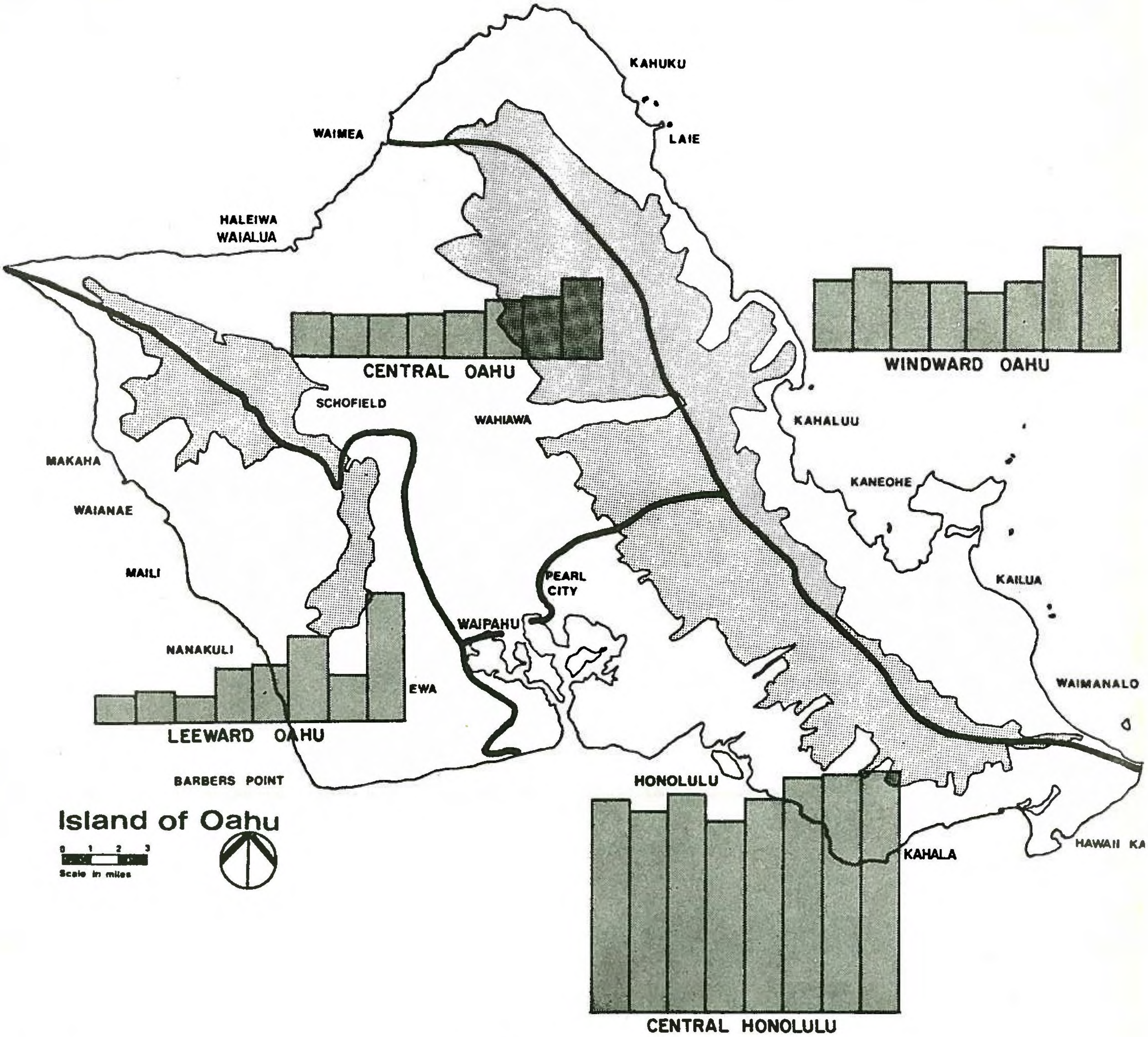
- Moderate Expansion - Characterized by the restriction of development within the present urban boundary with the possible exception of providing land outside the urban boundary to meet the housing needs of low and moderate income families. The employment pattern remains essentially the same as in the Intensive Development alternative with Central Honolulu being the primary employment and governmental center.

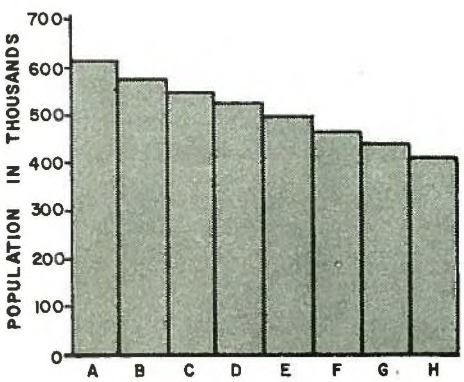
- Directed Growth - Characterized by the requirement that sufficient capacity be provided for residential and non-residential urban uses in programmed developments. These developments can occur through the expansion of the urban boundary. The amount of agricultural land released for urban use is dependent upon the programmed development of these new communities. These new communities are for all families of all income levels. The critical characteristics of this alternative is that non-residential land which could support substantial employment centers is provided.

Under each of the basic policies, variations in the development pattern were defined and considered for various levels of population which essentially determine holding capacity of the development patterns. The island-wide population levels considered ranged from 924,000 to 1,398,000.

The alternative selected by the Chief Planning Officer of the City and County and recommended by him for adoption is the policy of "Directed Growth." In that alternative, future growth would be directed into the Ewa-Pearl City-Aiea-Central Honolulu corridor.

While these land use policy changes may in fact have great significance over the long term on the future shape of development on Oahu, up to the 924,000 population level, any of the three basic development alternatives emphasizes development in existing urbanized areas. This emphasis can be seen in Figures II-3 and II-4 which shows the distribution of the projected population and employment for the various alternative policies developed by the Department of General Planning[12] and the distribution of the 1995 projections used in the PEEP study.[13] In comparing the GPRP and PEEP projections at the 924,000 population level, there would be a slight shifting of population into the Ewa district with the implementation of either the "Moderate Expansion" or "Directed Growth alternative policies, but the location of employment areas would





A. 1995 PEEP
(924,000 POPULATION LEVEL)

B. INTENSIVE DEVELOPMENT, SCHEME A
(924,000 POPULATION LEVEL)

C. INTENSIVE DEVELOPMENT, SCHEME B
(924,000 POPULATION LEVEL)

D. MODERATE EXPANSION
(924,000 POPULATION LEVEL)

E. DIRECTED GROWTH
(951,000 POPULATION LEVEL)

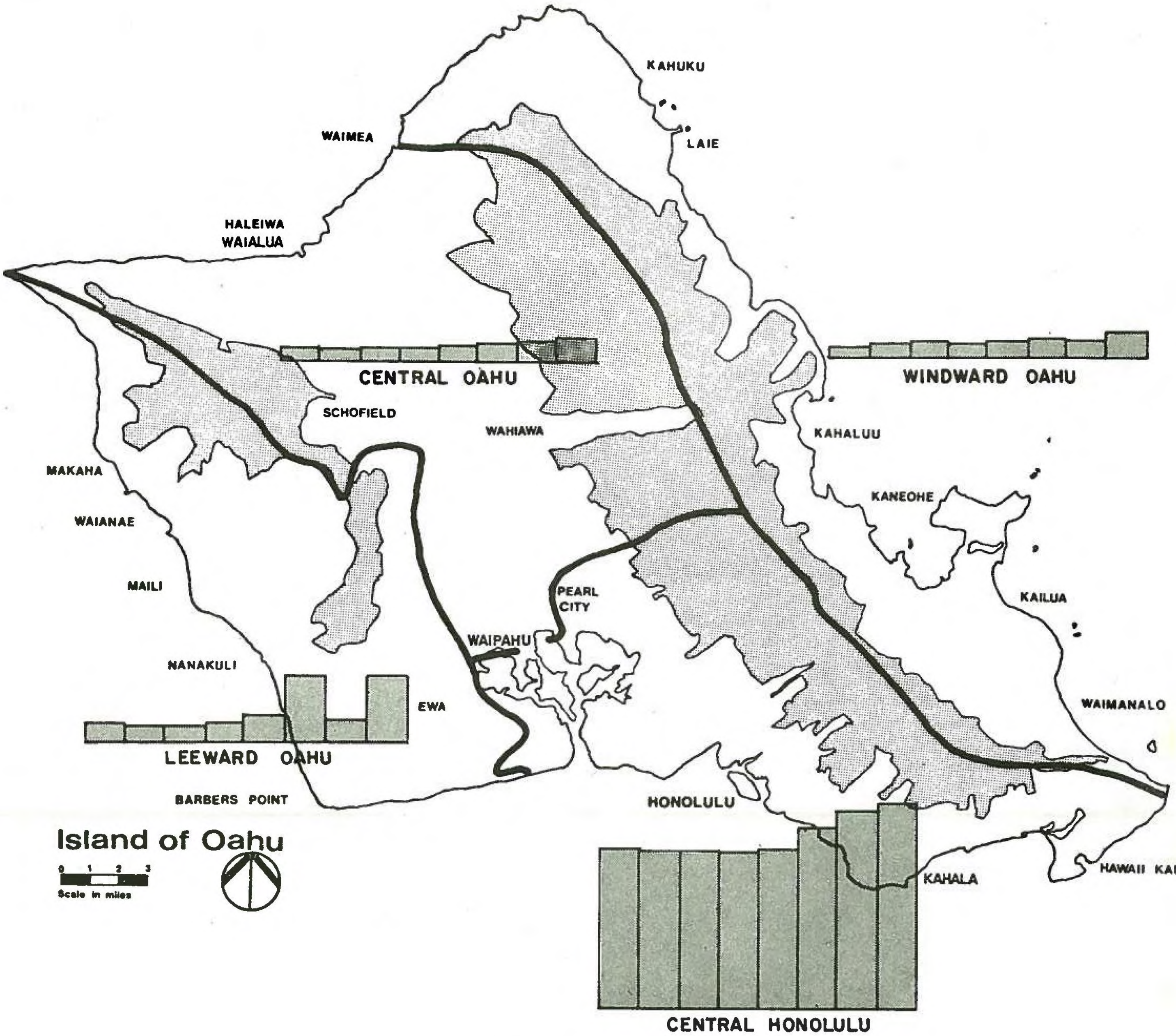
F. DIRECTED GROWTH
(1,157,000 POPULATION LEVEL)

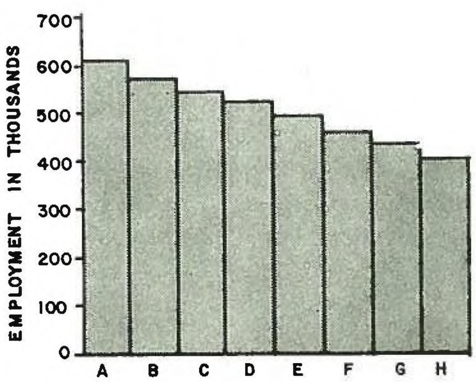
G. INTENSIVE DEVELOPMENT
(1,158,000 POPULATION LEVEL)

H. DIRECTED GROWTH
(1,398,000 POPULATION LEVEL)

ISLAND-WIDE POPULATION DISTRIBUTION
BASED ON ALTERNATIVE DEVELOPMENT POLICIES

FIGURE II-3





A. 1995 PEEP (924,000 POPULATION LEVEL)

B. INTENSIVE DEVELOPMENT, SCHEME A (924,000 POPULATION LEVEL)

C. INTENSIVE DEVELOPMENT, SCHEME B (924,000) POPULATION LEVEL)

D. MODERATE EXPANSION (924,000 POPULATION LEVEL)

E. DIRECTED GROWTH (951,000 POPULATION LEVEL)

F. DIRECTED GROWTH (1,157,000 POPULATION LEVEL)

G. INTENSIVE DEVELOPMENT (1,158,000 POPULATION LEVEL)

H. DIRECTED GROWTH (1,398,000 POPULATION LEVEL)

ISLAND-WIDE EMPLOYMENT DISTRIBUTION
BASED ON ALTERNATIVE DEVELOPMENT POLICIES

FIGURE II-4

remain the same, concentrated in the urban Central Honolulu area. At higher population levels, both population and employment is projected to increase in this Central Honolulu region. The major thrust of the General Plan, therefore, continues to be complete development of the existing urbanized corridor with gradual diversification of jobs and population into the outer areas of Oahu. Furthermore, all of these development policies retained the importance of the existing urban area of Central Honolulu. As will be seen in Chapter III, if the proposed transit improvements through this area are warranted at the 924,000 population level projected for use in this study, they will be even more important under any of the development patterns if a higher population is obtained.

The emphasis of rapid transit planning is to provide increased mobility to and within the highly urbanized core from all areas of the Island of Oahu. Increased urbanization within this core in the short term and gradual development of outer areas over the long term are in conformance with the expressed policies of the Honolulu Rapid Transit Program and with all planned transportation facilities associated with it.

D. TRAVEL FORECASTS

1. Assumptions and Methodology

The overall travel forecasts and subsequent patronage estimation procedures employ conventional sequential modeling techniques which take into account population and employment characteristics together with locational factors, land use, and characteristics of the transportation system. The total process involves seven (7) major models: Economic; Land Use; Car Ownership; Trip Generation; Trip Distribution; Modal Split; Assignment. Figure II-5 illustrates the sequencing of these models, basic input data and the output of each.

The models were developed in conjunction with the Oahu Transportation Study (OTS).3/ They are, with the exception of the Economic Model, currently maintained and operated by the Oahu Transportation Planning Program (OTPP) as successor to OTS. The Economic Model is maintained and operated by the State Department of Planning and Economic Development (DPED). These agencies made the models available for this study and provided much of the input information.

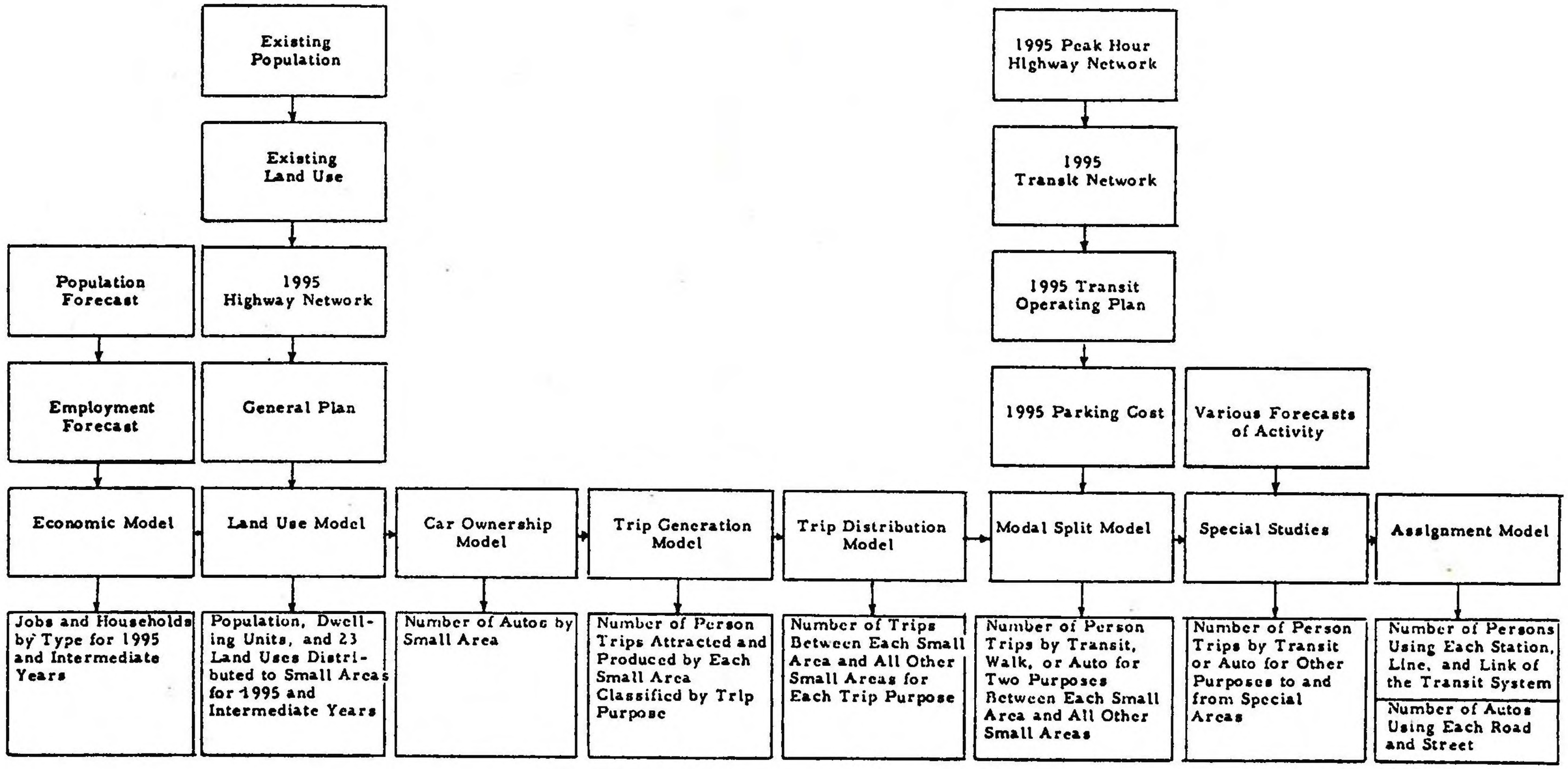
The Economic and Land Use models which produced the population, employment and land use data crucial to transportation planning have previously been discussed. From the transportation planning aspects, the important facts relative to their output are:

a. They reflect not only present trends of development but the specific long range policies of the study area in terms of land use, and

b. that the population and employment projections used, if anything, may be considered conservative when compared to actual observed growth rates in the immediate past.

The net result of these facts is that resulting trip distribution patterns reflect both policy decisions and current patterns and that the total future trip generation market (population and employment) is not overstated.

The following discussion describes the transportation aspects of this model sequence and the basic underlying assumptions and data. Important assumptions made in this portion of the process include:



GENERALIZED MODEL RELATIONSHIPS FOR TRANSIT PATRONAGE FORECASTS

FIGURE II-5

a. The street and highway system would include all existing and committed facilities including completion of H-1, H-2, and H-3. The resulting highway network was used in patronage estimating for all alternatives.

b. Kalanianaole Highway would not be further widened in the section between Kahala Mall and Hawaii Kai Drive. This assumption limited the capacity of that route to a definable and constant value and dictated the further assumption that all person trip movements in this corridor which could not be accommodated within the resulting capacity limit would use transit.

c. Manoa Campus of the University of Hawaii would be limited to an enrollment of 25,000 and Waikiki would be limited to a total of 27,000 hotel rooms. These assumptions placed limiting values on certain trip types to be analyzed in special studies.

2. <u>Forecasts</u>

After determining economic, demographic and land use variables and projections, determination of total person trips and their distribution between geographic areas was the next step in the transportation planning sequence. This involved 3 of the models illustrated in Figure II-5: car ownership, trip generation; and trip distribution.

a. Car Ownership: Access to or availability of an automobile is a significant variable in both the number of total person trips made (trip generation) and the mode of travel used (mode split). In the person-trip generation equations developed by OTS, car ownership appears as an independent variable in nearly all homebased trip productions. Therefore, it is necessary to be able to forecast future car ownership.

The OTS developed a car ownership model based on origin-destination studies which related car ownership to household income. For this study, OTPP operated the OTS model to project car ownership for 1980 and 1995 in each census tract based on the projected number of households in each of three income ranges forecasted by the Land Use Model. Table II-6 shows the result of that forecast and the historical trend of cars per household.

TABLE II-6

HISTORIC & PROJECTED AVERAGE CARS PER HOUSEHOLD

Year	Cars Per Household: Honolulu Urban Area	Cars Per Household: Non-Urban Areas
1960	1.01	1.11
1970	1.15	1.11
1980	1.27	1.21
1995	1.30	1.32

While these values indicate that auto-ownership will continue to increase, they appear reasonable when compared to observed mainland conditions. Columbus, Ohio in 1960 showed auto-ownership of 0.97 while Los Angeles County, a heavily auto oriented region, showed ownership of 1.42 in 1967. The projections for Honolulu appear in the mid-range of these observed conditions.

b. Trip Generation: The Trip Generation Model forecasts the number of daily trips produced in and attracted to each census tract. Because of the variation of land uses in each census tract and of trip production and attraction rates by trip purpose, trip generation was also stratified by purpose and each purpose calculated separately.

The Trip Generation Model was developed by OTS using statistical regression analysis techniques applied to socio-economic and land use characteristics related to the number of trip productions and attractions determined by origin-destination studies for specific trip purposes. In their development of the generation equations, all identifiable variables that could logically be related to the frequency of trip production or attraction by trip purpose were tested. Only those which had a significant effect on the generation were retained in the final equations. Trips were stratified by six (6) trip purposes:

- Home-based work
- Home-based shopping
- Home-based social-recreation
- Home-based school
- Home-based other
- Non-Home-based

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In this program, OTPP operated the OTS model and the output was analyzed for conformance to results of recent home interview studies on Oahu and to results of similar studies on the mainland. In the OTS study and in the 1971 home interview, the ratio of 1.30 trips per job was found--a ratio which conforms to findings of Mainland studies. This consistent ratio of trips to jobs thus enabled the results of the Trip Generation Model to be checked. It was concluded that the model had over-predicted work trips by a relatively small amount and the results were therefore adjusted downward. With the adjustment, the total trips and trips per capita appeared reasonable, and no further adjustments were made.

c. Trip Distribution: The concluding step in the forecast of total travel was the determination of total person trip interchange between geographic areas, or trip distribution. The Trip Distribution Model is a gravity-type model developed and calibrated for Oahu by OTS. Primary model inputs are the productions and attractions produced by the trip generation model and an empirically derived time factor expressing the separation of zones. The model deals with each trip purpose separately and was calibrated by OTS on the basis of origin-destination studies. The model as calibrated produced excellent correlation between observed and predicted trip interchange values by trip purpose.

Prior to input into the Trip Distribution Model, trip totals as forecasted by the trip generation model on a census tract base were further refined to traffic analysis zones. These traffic analysis zones are subdivisions of census tracts and were used to provide more precise allocations of trips to the highway and transit networks in subsequent steps. There are 159 such zones. The model distributes the trips to these zonal pairs on the basis of person trips and produces what is called a person trip table, one for each trip purpose. The OTS model was operated by OTPP for this study producing trip tables for 1980 and 1995. These trip tables represent the basic travel forecasts and were used in subsequent testing of each transit alternative.

Again, because of the somewhat conservative nature of the population and employment forecasts, the direct relationship of land use projections to policy and current trends, and the excellent results obtained in the calibration of the travel forecasting models, the resulting trip tables may be accepted as representing the future trip distribution and demand with a high degree of confidence. If anything, the total travel demand forecast may be conservative.

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Table II-7 presents a summary of daily and peak hour projections for 1995 by purpose.

3. Mode Choice and Network Assignment

The concluding steps in the transportation planning process were the determination of choice of mode (mode split) and the travel volume on each portion of the respective transportation system (assignment). These steps are a function of the total travel forecast and the relative attractiveness of competing modes. Each of the transit alternatives considered was subjected to these steps in the analysis and the resulting output used to evaluate each alternative. Since these steps are sensitive to the specific combination of modes expressed as system networks, only the general and common factors will be discussed here. Each alternative and its results will be discussed in more detail in subsequent sections.

A primary assumption necessary to perform these steps for the alternatives was that the street and highway system including travel speed and capacity would be the same for all alternatives regardless of transit system. This assumption has the distinct advantage of producing transit performance forecasts on a directly comparable basis since each system to be examined and evaluated would compete with alternatives on an equal basis. The only variable being the relative attractiveness of the transit system itself.

a. Mode Split: The mode split (or mode choice) model developed by OTS is a post-distribution, interchange type model which forecasts transit use as a percentage of total trips based on the independent variables of autos per dwelling unit at the production end, the travel time difference by transit for the interchange and average 9-hour parking cost at the destination end. As in prior models, calibration was based on observed mode split determined by origin-destination surveys.

Autos per dwelling unit input to the model uses the output of the car ownership model described earlier. The travel time difference is equal to the "equivalent" transit time* minus the auto time

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*Equivalent transit time includes time spent walking, waiting or transferring (termed "excess time") and estimated running time. In calculating this factor, "excess time" is kept separate from "running time" and multiplied by 2.5 because people tend to "weight" the excess time heavily in their selection of mode. The 2.5 value has been determined through analysis of origin-destination studies in such places was Washington, D. C. and Calgary, Ontario by statistical linear regression techniques which related the proportion of total trips by transit to identifiable variables including running time and excess time. These calibrated equations indicated that "excess time" was from 2.5 to 3.0 times as important as running time.

TABLE II-7 1995 TRAVEL PROJECTION[14/]
TRIP PURPOSE DISTRIBUTION

PURPOSE	DAILY: TOTAL PERSON TRIPS	DAILY: % OF TOTAL TRIPS	P.M. PEAK HOUR: PEAK HOUR PERSON TRIP	P.M. PEAK HOUR: % OF TOTAL TRIPS
HOMEBASE WORK	673,600	20.4	108,580	29.5
HOMEBASE SHOP	456,200	13.8	53,020	14.4
HOMEBASE SOCIAL/ RECREATIONAL	857,400	25.9	90,400	24.6
HOMEBASE OTHER	383,700	11.6	41,150	11.2
SCHOOL	288,000	8.7	28,840	7.8
UNIVERSITY OF HAWAII	33,400	1.0	3,610	1.0
NON-HOMEBASE	615,700	18.6	42,350	11.5
TOTAL	3,308,000	100.0	367,950	100.0

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between origin-destination pairs and is determined by summing the various network link times for travel between zone pairs. Thus, this variable is a direct function of the transit and highway systems as specified in the respective networks.

Parking cost variables were determined initially on the basis of the number of parking stalls available, the 9-hour parking rate and the occupancy rate for each type of parking available. Since this is an important variable in the mode-split estimation, special care was exercised in developing 1980 and 1995 parking costs for this study. In addition to the original parking cost surveys conducted by the original OTS, recent studies of parking cost in selected areas for 1972 and 1973 were used. Costs determined in these various studies was plotted against employment and a linear relationship identified generally similar in any employment area. Because of the linearity of this historical plot, it was assumed to continue in the future and parking costs were adjusted accordingly.

The other variable entered into the model was the person trip table. The trip tables outputted by the distribution models were combined into two basic tables each with distinct differences in propensity to use transit. These were Home-based work and Home-based non-work (a combination of Home-based shopping, Home-based social-recreation and Home-based other). Home-based school and Non-Home-based trips have unique transit related characteristics and were handled independent of the mode-split model as part of the special studies step. Special analyses were made for school trips, trips to and from the Manoa Campus of the University of Hawaii, and for Punahou School. Model output consists of the modal split for (1) home-based work trips and (2) home-based non-work trips. Thus, the model produces four trip tables--two for transit trips and two for auto trips.

Transit and auto trip tables were created with the results of the mode split runs. Average daily transit and auto trip tables were formed by combining the respective trip tables for each purpose into one table for each mode. The peak-hour trip tables were developed by multiplying the daily trip table for each directional trip purpose by appropriate peak period factors. Each trip purpose was further disaggregated into home-to-destination and destination-to-home trips to enable application of the appropriate directional peak-period factor.

b. Assignment and Network Coding: The highway and transit systems largely determine how trips are made and what routes are taken. Thus, it was necessary to develop the 1980 and 1995 highway and transit system and describe their operating characteristics. The 1980 and 1995 highway systems were prepared by OTPP. They were assumed to be the same for all of the transit alternatives.

Computer processing requires that these transportation systems be encoded in a certain manner for use in both mode split and assignment. The method is to represent the system as a series of lines (links), points denoting intersections or stations (nodes), and centroids, denoting the approximate center of activity for each traffic analysis zone. Each link is described by its length, travel time or speed, and certain other characteristics. After network description is encoded for machine processing, the computer makes all necessary calculations to determine the travel time by transit and highway for the more than 25,000 zone-to-zone movements.

The daily and peak-hour trip tables were "loaded" onto their respective networks to obtain the trip assignments. The transit assignments form the basis of the patronage estimates of this report. The highway assignments were examined for overly-congested roadways which would require special analysis.

The resulting transit assignments for each alternative were then used to evaluate the performance of each and to determine the fleet requirements, operating costs, etc. Subsequent sections of this report deal in more detail with these individual results.

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CHAPTER III

FUTURE TRANSPORTATION NEEDS AND SOLUTIONS

A. ISLAND-WIDE DEVELOPMENT AND TRAVEL CHARACTERISTICS

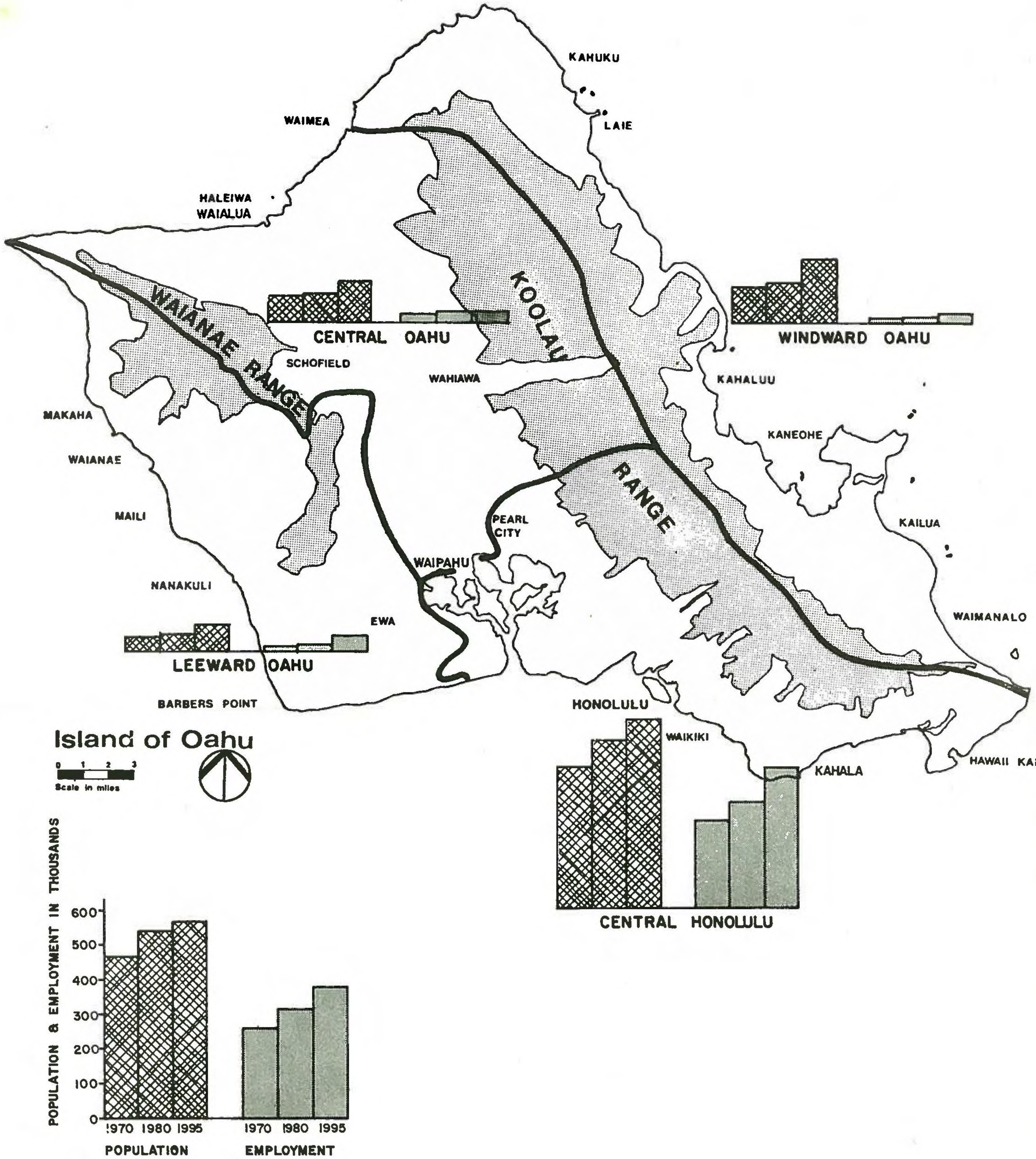
1. Development Characteristics

The Island of Oahu, due to its geography and topography, can be divided into four distinct regions; (1) Central Honolulu located on the leeward side of the Koolau Range, (2) Central Oahu located in the central plains between the Koolau and Waianae Ranges, (3) Windward Oahu located on the windward side of the Koolau Range, and (4) Leeward Oahu located on the leeward side of the Waianae Range. The development of the island has been greatly influenced by the geographic constraints imposed by the Koolau and Waianae Mountain Ranges and the constraints imposed by the State's land use law. Figure III-1 shows the 1970, 1980 and 1995 distribution of population and employment on the Island of Oahu. The highly urbanized Central Honolulu region is projected to continue as the center of population and employment on the Island of Oahu in the future.

The most densely urbanized district within Central Honolulu stretches from Pearl Harbor to Diamond Head. It is composed of many small urban concentrations which are strongly linked in function to the urban core of Honolulu. This dense urban district contains most of the island's industry, business, and government facilities and is the focus of major social, cultural, educational and recreational activities.

The urban district is approximately twelve miles long and two to three miles wide, with numerous developments extending into the valleys and ridges of the Koolau Range. It is characterized by a relatively narrow band of densely developed residential, commercial and industrial land uses. Development is generally most intense between the H-1 (Lunalilo) Freeway and the ocean, a distance of approximately one mile.

The suburban areas of the urban Honolulu district on the eastern end include developments adjacent to the Kalanianaole Highway extending to Hawaii Kai and on the western end developments in the Pearl City-Waipahu area, all located in the Central Honolulu region. In the outlying regions, the principal communities are located in the Leeward region from Ewa to Waianae, the Central region from Waipahu to Wahiawa, and the Windward region, including Kaneohe, Kailua and Waimanalo. Land use forecasts indicate that the pressures of continuing housing demand will intensify the development in the urban



ISLAND-WIDE POPULATION & EMPLOYMENT GROWTH DISTRIBUTION

FIGURE III-1

Honolulu as well as generate more new growth in the outlying regions.

2. Travel Patterns

Development of Oahu, like that of most mainland urban regions, reflects the automobile orientation of the past several decades. The island was developed in relationship first, to the early road system, which was replaced by highways and ultimately by the interstate system.

In 1972 there were 1,230 miles of paved streets and highways on Oahu. The existing and planned Federal interstate highway system (H-1, H-2, H-3) which comprises approximately 52 miles of freeways on Oahu, is scheduled for completion by 1980. (See Figure III-2.) It will provide improved access to urban Honolulu from the Leeward, Central, and Windward regions of Oahu. With concentrations of government, commerce and tourism, located in urban Honolulu, the existing segment of the H-1 (Lunalilo Freeway) will be heavily used and will become the critical link in the interstate system. The H-2 freeway is presently under construction, and will extend from Pearl City to Wahiawa. The H-3 Freeway, when completed, will provide another link from the Kailua-Kaneohe area to urban Honolulu.

The travel pattern of urbanized Oahu is similar in intensity to that of many intermediate sized metropolitan regions in the United States, in that, the primary urban travel corridors radiate from the urban core. In the eastern direction, the corridor follows Kalanianaole Highway to Hawaii Kai. In the northern direction, the trans-Koolau corridor serves the Windward region. In the western direction beyond Halawa, the H-1 Freeway-Kamehameha Highway corridor, extends to the Pearl City area, where it bifurcates into two corridors serving the Central and Leeward regions. These three primary corridors funnel all traffic flows into the relatively narrow east-west movement channel of the Honolulu urban core. Due to the preponderance of employment and major activity centers concentrated in the urban core 350,000 to 400,000 average daily auto trips are projected for this main corridor by 1995.

In this urban core, there are several destination points in addition to the Central Business District (CBD). The most significant destinations are the Ala Moana Center, the Waikiki area, and the Hickam-Pearl Harbor military complex, with considerable importance given to the other points such as the University of Hawaii and the Honolulu International Airport. These major destination points form a geo-

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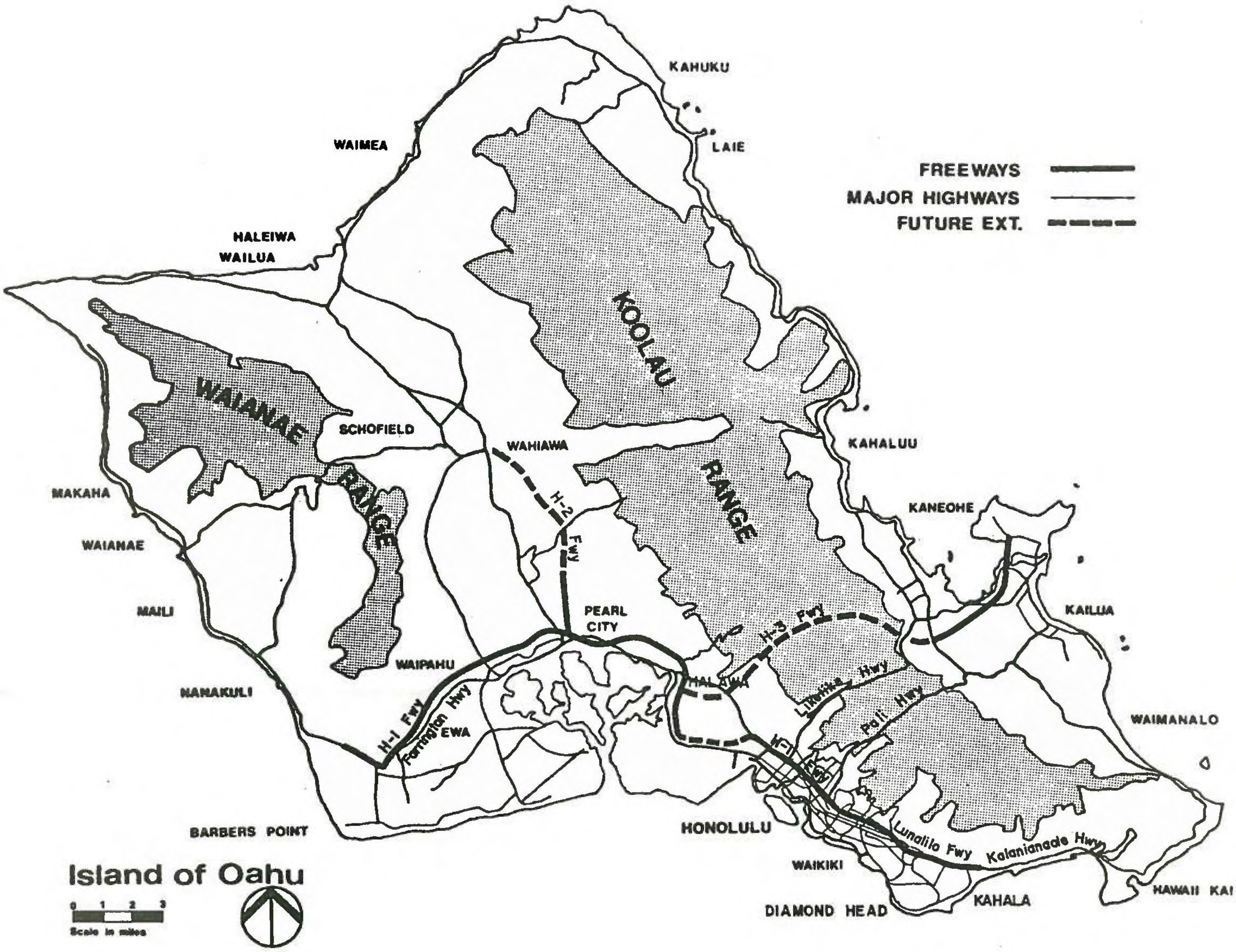

HIGHWAY NETWORK - ISLAND OF OAHU

FIGURE III-2

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graphically linear corridor pattern, beginning with the military complex on the eastern corridor end, followed by the airport, the CBD and Civic Center, the Ala Moana center, and the Waikiki-University area as the corridor proceeds eastward.

The residential areas are characterized by density types: high density developments in the urban core, low-to-medium densities in the suburban areas and predominantly low density developments in the outlying districts. Within a ten mile radius of the CBD are located the major suburban communities of Hawaii Kai, Pearl City-Waipahu, and, in the Windward region, Kaneohe-Kailua. Within a radius of twenty to thirty miles are located the more distant communities of Wahiawa and Waianae in the Central and Leeward regions, respectively.

Travel on Oahu, as measured by automobile ownership and vehicle miles traveled has increased by about seventy-five percent during the past decade. Proportionally this is a much greater increase than the twenty percent increase in population. Due to the increase in labor participation rate, work trips have also increased more rapidly than the population. The very rapid increase in overall travel has created a great demand for additional street and highway capacities. The development patterns of urban Oahu and their transportation demands are beginning to overtax the principal travel corridors with the major impact on the critical high-volume corridor in the urban core.

3. Accessibility To Urban Honolulu

The outlying regions of Oahu are planned to be served by modern highways and freeways providing easy access to urban Honolulu. The H-1, H-2, and H-3 Freeways will serve the Leeward, Central, and Windward communities, respectively, and are all supplemented by one or more highways in the major travel corridors.

The Leeward and Central regions contain suburban and rural communities scattered over a large area. The rural communities are generally small and are typical of low density development. A relatively high percentage of the population in these communities fall into the lower income category.

In the Windward region are located the larger suburban communities of Kaneohe and Kailua. These communities are predominantly low to medium density developments for middle income families. On the southeastern end of this region is the semi-rural community of Waimanalo which has a relatively high percentage of lower income population.

With existing and committed highways and freeways providing fast and direct routes to central Honolulu, accessibility from these outlying regions is good and capacity is ample to accommodate future travel demands. As previously stated, these outlying regions have communities with higher percentages of low income households than is typical in other parts of Oahu. Consequently, there are more transit dependent households in these outlying communities but the dispersed pattern of development and its relatively small population poses certain economic constraints on the provision of more frequent service. The existing transit service provides bus routes to each of these low income areas with buses operating at minimum headways of 5-10 minutes during peak periods and at maximum headways of 20-30 minutes during off peak periods.

B. CHARACTERISTICS OF THE URBAN HONOLULU CORRIDOR

1. Land Use

In Chapter II, forecasts of growth in population, employment, and travel demand for the Island of Oahu which formed the basis for transit planning were presented. A more detailed review of the forecasted growth and changes in urban Honolulu is presented in the following section.

Within the Central Honolulu region, from Pearl City to Hawaii Kai which is the span of the proposed transit corridor, past and forecasted population and employment are shown in Table III-1.

TABLE III-1

CENTRAL HONOLULU SHARE OF POPULATION AND EMPLOYMENT

	Population	% of Total Island	Employment	% of Total Island
1970	407,600	65%	259,000	82%
1980	483,500	66%	309,000	82%
1995	545,500	59%	404,000	78%

The forecast indicates that there will be continued growth in both population and employment within urban Honolulu. However, in 1995, the percentage of population in urban Honolulu relative to the entire island drops from 65% to 59%. This percentage shift reflects the pressure for more urban land in the outlying areas as a result of both policy direction and the fact that the current urbanized area can accommodate increases only through reuse of existing developed land.

The employment forecasts indicate increased growth with only a slight decline in percentage of the total located in urban Honolulu. This forecast reflects the continued growth forecasted in government, tourism and service types of employment in the Honolulu core area. Notable increases in employment are forecasted to occur in the following locations:

TABLE III-2

MAJOR URBAN EMPLOYMENT AREAS

Districts	Employment 1970	1980	1995
CBD - Civic Center	52,400	64,400	83,100
Waikiki	18,800	23,700	39,800
Ala Moana-Ward	18,600	20,000	29,800
Kakaako	16,500	19,400	26,300
Kalihi-Iwilei	30,300	39,200	52,800
Airport	14,800	17,400	21,000
Pearl Harbor-Hickam	40,200	41,600	40,900

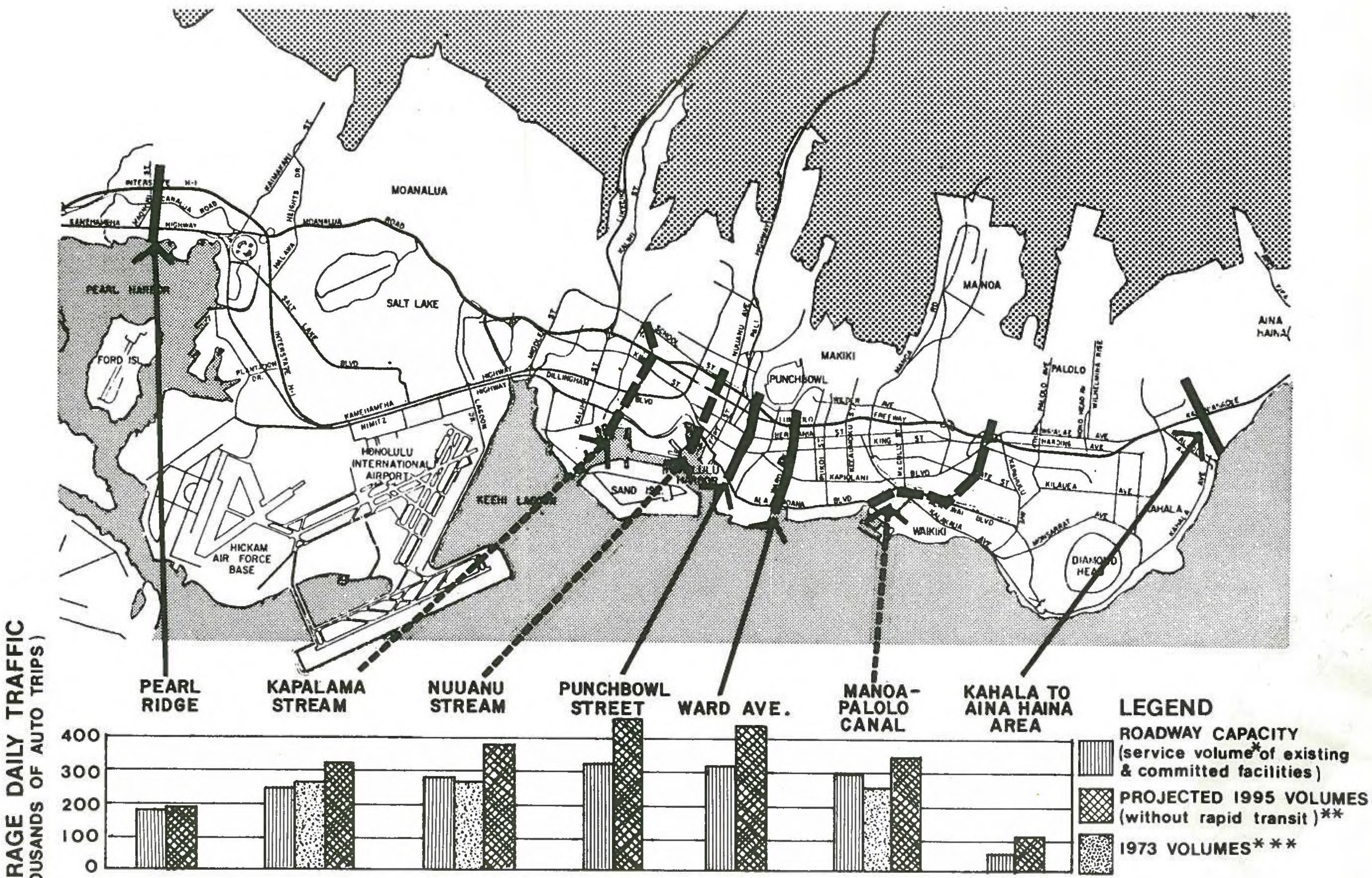
The above projected employment will reinforce the continued growth and importance of the urban core and the attendant increase in travel demand. Adequate transportation facilities which are required for the efficient movement of goods and people to support these activities is vital to the economic well being of the entire State.

2. Corridor Demand

The most critical transportation corridor on the Island of Oahu is the narrow east-west corridor spanning from Middle Street to the Diamond Head area. No new highways or freeways are contemplated and recent studies conducted under the TOPICS[15] and National Transportation Need Study[16] programs forecasted a serious deficiency in transportation capacity in this corridor.

Within this urban corridor, which continues to grow at a rapid rate, a comparison of traffic volumes versus capacity was made. An analysis of the screenlines on either side of the CBD-Civic Center area indicates an available capacity of some 280,000 vehicles per day on the western side and approximately 320,000 on the eastern side, based on a level of service "D". (See Figure III-3). The 1973 volumes through these screenlines are approaching or have reached their available capacities. Based on travel demand forecasts, in 1995 the volume will exceed capacity by an average of approximately 100,000 autos per day. Converting the daily auto trips to peak hour auto trips would result in approximately 6,000 autos per hour in each direction; the equivalent of at least a new 6-lane freeway carrying 2,000 autos per hour per lane. It is clear from this analysis that, even today, congestion is heavy and will be more severe in the future and the question then is how to relieve this situation.

PRELIMINARY ROADWAY CAPACITY & VOLUME



* AT LEVEL OF SERVICE D.

** ASSUMES A BASELINE BUS SYSTEM IN OPERATION.

*** SOURCE :" TRAFFIC SUMMARY - 1973," STATE DEPARTMENT OF TRANSPORTATION.

FIGURE III-3

C. STUDY OF TRANSPORTATION ALTERNATIVES

1. The Oahu Transportation Study

In 1967 a major step towards meeting the increasingly critical transportation needs on Oahu was made when the Oahu Transportation Study (OTS) was undertaken to establish a long range, comprehensive transportation planning process.[3/] This effort coordinated all other comprehensive planning efforts of the State and the City and County. In addition to the development of a transportation planning process, the study recommended a long range transportation plan, oriented toward relieving the heavily congested streets and highways on the island.

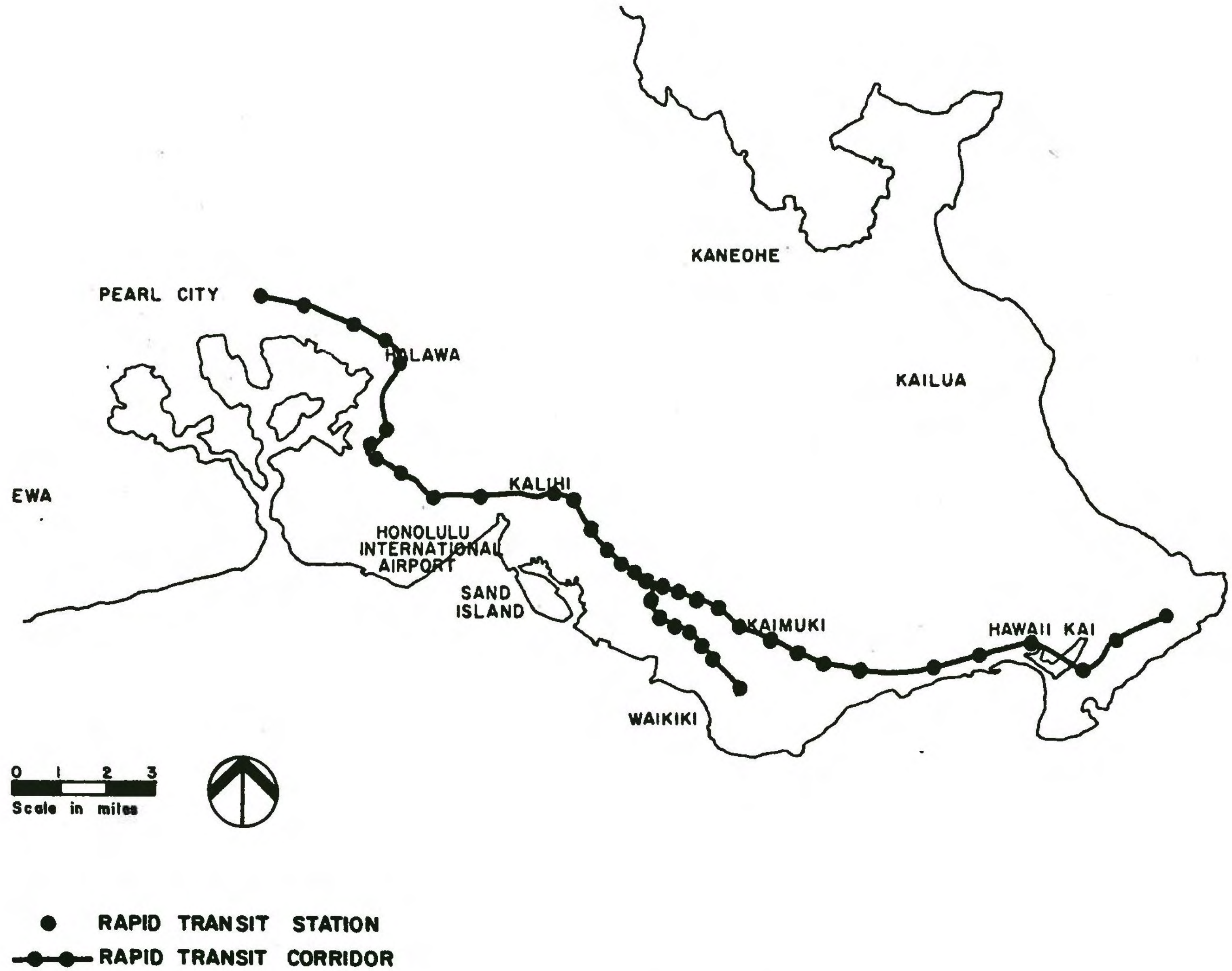
The OTS developed two basic alternative transportation systems for testing. One was oriented toward a fixed facility transit mode (System No. 1), as shown in Figure III-4, coupled with completion of the committed highway facilities. The other was oriented toward an all bus system operating on an expanded system of streets and highways (System No. 2). Route locations and service criteria were based upon the travel patterns and volumes indicated by a 1960 origin and destination study and projected 1985 travel.

An analysis of these two alternatives was conducted including a modal split analysis. The results of this analysis indicates nearly 340,000 daily passengers for the fixed facility system and some 280,000 daily passengers for the all bus system. The higher patronage volume of the fixed facility system required less streets and highway to meet future travel demand and hence resulted in less total transportation cost than the all bus system. Based on 1967 prices, the cost of the combined fixed facility transit system and planned streets and highway improvements was estimated at $580 million as compared to over $700 million for the all bus system alternative with its attendant requirement for additional streets and highways.

In addition to cost considerations, the study also analyzed various social, economic, and community factors relative to the two alternative systems. The result of this analysis was in support of System No. 1 or the fixed facility transit for the following reasons:

a. It produces a significantly higher level of service.

b. It has a much greater potential for influencing the shape and pattern of the future community.



OTS RAPID TRANSIT CORRIDOR

FIGURE III-4

c. It affords a practical method of alleviating traffic congestion in the concentrated areas of Honolulu and is potentially a practical alternative to a second major freeway through an intensely developed area.

d. It affords the greatest potential for adequately accommodating the heavy tourist movements to and from the airport anticipated in the near future.

e. It provides the most predictable transportation mode in terms of travel time.

f. Coupled with existing highway facilities plus some improvement in the central areas, it affords a transportation capacity adequate to meet the estimated 1985 travel demands and beyond.

g. It provides an alternative to the requirement for extensive parking facilities in the urban areas and therefore promotes a more productive use of high value land area.

The Oahu Transportation Study concluded that the planned highway improvements should go forward and that plans should also be developed for an improved rapid transit system which would be required by 1985. It also concluded that rapid transit can attract large numbers of passengers which could influence the requirements for highways. The OTS had the foresight to conclude, as early as 1968, however, that a high-capacity roadway in Central Honolulu would not meet with general public accpetance. The study therefore recommended that a rapid transit system be adopted in all long-range plans for Oahu.

2. Review of An Expanded Bus Transit System

The previous section discussed the results of the OTS Study conducted on basic transportation alternatives consisting of an all-bus system operating on streets and highways and a high level rapid transit system. The study concluded that a rapid transit system is not only more cost-effective due to the reduced need for additional highway improvements but that it provided other social, environmental, and community benefits which the all-bus transit system could not match. This section presents a more detailed discussion of various implications related to an all-bus transit system.

In the earlier sections of this Chapter, the travel demands on an island-wide basis and for Central Honolulu were presented. The critical capacity deficiency in the street and highway system on either side of the downtown area was shown to require a minimum 6-lane freeway by 1995. As early as 1967, the OTS pointed out that any new freeway in Central Honolulu would not be acceptable to the community. Today, it is recognized by government officials, professional planners, and citizens that Honolulu cannot afford such an environmentally disruptive facility as a new freeway in urban Honolulu. Both the State's and the City's recommended policy statements as contained in their respective General Plan Revision Program for Oahu reflect this view.

Various means of meeting future long-range travel needs through application of transportation systems management improvements to existing systems were further explored. In the previous section, it was shown that the future corridor demand was such that the existing and committed facilities and improvements could not handle the projected 1995 travel volume by merely continuing with the existing modes of travel. As the next logical step, a greatly expanded bus system was defined and tested. This system incorporated various transportation system management (TSM) improvements including the assignment of reserve bus lanes on major transit routes.

The expanded bus or TSM system, by utilizing reserved lanes on both streets and highways, provided faster trip time for buses as compared to the existing bus system and was therefore able to attract substantially more ridership. In 1995, it was estimated that some 110 million passengers would be attracted and that over 900 buses would be required.

During the peak hour, nearly 200 buses in each direction will pass through the downtown area. This will require at least 2 exclusive lanes in each direction to accommodate this number of buses. The reduction in roadway capacity by eliminating 2 lanes through the critical downtown area would result in the demand volume exceeding maximum capacity by a sizable amount. In addition to the foregoing, the degradation of the downtown environment through increased air and noise pollution by several hundred buses per hour would be significant. Thus, both environmental considerations and physical constraint of downtown streets combine to limit the feasibility of continued expansion of the bus system as the long term solution for Honolulu. A more complete description of the expanded bus system and the analyses conducted are presented in Chapter VII.

D. STUDY OF TRAVEL DEMAND BASED ON ALTERNATIVE DEVELOPMENT POLICIES

In the analysis of the "Benefits" and "Costs" to the community associated with each of the alternative development policies and their impact on the existing transportation facilities, the Department of General Planning in their General Plan Revision Program (GPRP) assumed an existing transportation system containing a highway network which included all primary facilities that exist today and H-1, H-2, and H-3 Freeways.[18/] In addition, a high-capacity rapid transit facility between Pearl City and Hawaii Kai with supporting feeder and express bus service was assumed fully operational.

To investigate the impact of the alternative development policies on the highway network, several strategically located cordons or corridor "screenlines" were established and an auto volume to capacity analysis was conducted at these screenlines. The capacities or service volumes used were based on level of service C or D.[19/] Facilities in urban areas were generally assigned service volumes at the D level, while facilities in rural areas were assigned service volumes at the C level.

Each screenline volume was calculated by totaling the individual volumes projected for each roadway through which the screenline passes. The service volumes through each screenline were calculated similarly. A tabulation of the results of the volume versus capacity or service volume (V/C ratio) analysis for each of the six alternative development patterns (all with a high-capacity rapid transit system with attendant express and feeder bus service assumed operational) are given in Table III-3.

As can be seen in Table III-3, the street capacities are generally adequate at the 924,000 population level except in the Kalanianaole Highway corridor. Further it can be observed that streets in the urban core for populations greater than 1,000,000 would be highly congested and inadequate to meet the demand without additional facilities provided.

For population in excess of 1,157,000 and more specifically for 1,398,000 as tested, the development patterns under the Directed Growth policy shifts both population and employment to outer areas in order to develop holding capacity. While this policy naturally reduces travel demand in the critical central areas of Honolulu compared to the Intensive Development option at comparable population levels, travel demand is still substantially above that produced with the DPED projected population of 924,000 used in this study.

TABLE III-3: SCREENLINE VOLUME TO CAPACITY ANALYSES

Screenline	Service Volume (Autos)	924,000 Population Level: Intensive Development Scheme A* Volume (Autos)	V/C	Intensive Development Scheme B* Volume (Autos)	V/C	Mod. Expansion Volume (Autos)	V/C
Pearl Ridge	192,000	175,000	0.91	165,000	0.86	181,000	0.94
Liliha Street	278,000	251,000	0.90	254,000	0.91	251,000	0.90
Ward Avenue***	369,000	324,000	0.88	340,000	0.92	323,000	0.88
Kahala-Aina Haina	60,000	83,000	1.38	71,000	1.18	72,000	1.20

Screenline	Service Volume (Autos)	1,157,000 Population Level: Intensive Development** Volume (Autos)	V/C	Directed Growth Volume (Autos)	V/C	1,398,000 Population Level: Directed Growth Volume (Autos)	V/C
Pearl Ridge	192,000	223,000	1.16	227,000	1.18	204,000	1.06
Liliha Street	278,000	332,000	1.19	290,000	1.04	315,000	1.13
Ward Avenue***	369,000	441,000	1.20	381,000	1.03	403,000	1.09
Kahala-Aina Haina	60,000	96,000	1.60	79,000	1.32	84,000	1.40

*Scheme A consisted of meeting anticipated housing demand based on the maximum number of low density dwelling units. Scheme B consisted of the maximum number of high density dwelling units to meet housing demand.

**Housing demand would consist of the maximum number of high density dwelling units. Supply of low density residential land was insufficient to support the maximum number of low density dwelling units.

***Includes all minor streets up to and including Prospect Street.

In addition to studies of projected vehicular traffic volumes, the Department of General Planning developed transit ridership volumes for both the rapid transit and feeder-express bus services. A compilation of these volumes for each of the defined alternatives is shown in Table III-4. It was estimated that the peak hour, peak link rapid transit volumes would vary between 20,000 to 30,000 passengers in one direction. The variation is basically due to the difference in population levels. The table indicates that, in general, the Intensive Development policy will place a somewhat heavier requirement upon both the arterial and highway network and mass transit systems through the urban corridor at comparable development levels.

In terms of the transportation policy analysis for the various development policies the findings were as follows:

- With a high capacity rapid transit system complementing the existing and planned streets and highways, the combined capacity would generally meet the demand of a population level of 924,000 for all three of the alternative development policies; Intensive Development, Moderate Expansion and Directed Growth.

- The travel demand is not significantly affected in the urban core by different development alternatives up to the population level of 924,000.

The recommended policy statement contained in the General Plan Revision Program is: "Demand for transportation services within the Central Honolulu, East Honolulu, and Pearl Harbor corridors should be met primarily through the provision of rapid transit services and feeder systems as appropriate, with limited highway improvements."[5/]

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TABLE III-4

PROJECTED TRANSIT TRIPS FOR ALTERNATIVE DEVELOPMENT POLICIES

	Total Daily Trips	Daily Transit Trips	Daily Rapid Transit Trips
Intensive Development			
Population Level I Scheme A	3,361,300	484,500	345,000
Population Level I Scheme B	3,361,300	497,000	348,200
Population Level II	4,194,350	597,300	424,100
Moderate Expansion			
Population Level I	3,361,300	489,400	343,900
Directed Growth			
Population Level II	4,196,600	583,050	393,300
Population Level III	4,994,500	644,500	417,900

Note: Population Level I - 924,000
PopulationLevel II - 1,157,000
Population Level III - 1,398,000

E. CONCLUSIONS AND RECOMMENDATIONS

Based on these studies, it is concluded that a high level rapid transit system would best meet the future travel demand in Central Honolulu. This conclusion is supported by the results of studies which considered the following:

- the ability of existing and planned facilities to satisfy present and future travel demands
- the ability of various forms of transit to attract patrons
- the ability of transportation systems to best meet land use and environmental goals of the area

First, from a total travel standpoint, the existing street and highway system is heavily congested, particularly in the urban core sections. Almost all major city streets and freeways are presently operating at a level of service "D" during peak hour in the urban core with no new freeways planned in those areas. Therefore, at the present time, there is a crucial need for additional transportation capacity in the urban core areas of Honolulu. The City and County and the State have cooperated in several traffic engineering, parking, and bus operational improvement programs to fully maximize the use of the present system. Despite this, the problem remains and it will worsen, of course, as time goes on.

Population was projected to rise by 17% by 1980 to a level of 735,000 and by 50% by 1995 to a level of 924,000 from the base year of 1970. Already in 1975, the forecast has been exceeded by nearly 5%. The same general situation exists in terms of employment. In terms of trip making and existing and planned transportation capacity, there is no question that new facilities are needed now, and that they will be increasingly utilized immediately when available. The density of population and resulting relocation problems, environmental problems, and energy considerations prohibit additional freeway capacity, a decision which was made locally, prior to the current general nationwide view on this matter.

The question then becomes, can some other mode of transportation accommodate the transportation needs? Our analyses have shown conclusively that transit can indeed satisfy this need. In early 1971 the City and County of Honolulu assumed bus transit operation on the island. The patronage on this system has increased dramatically since that time from 17 million annual passengers in 1971, to over 35 million passengers in 1974, and about 45 million expected in 1975. These increases have

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been attributed to various innovative programs instituted by the City including express bus services, contra-flow bus lanes, reserved bus lanes, etc. Based on the conservative population and employment forecasts described above, we have projected greater transit ridership in 1985 and in 1995. Exclusive of tourist patronage, we conservatively estimate that a well located and designed high level rapid transit system can generate 100 million passengers a year by 1985, and nearly 150 million by 1995. This projection is quite consistent with the present experience with the bus system, when one accounts for the differences in levels of services, particularly as further congestion builds on the highway system.

These forecasted transit patronage volumes would match the expected travel demand which cannot be accommodated by the existing transportation system due to capacity limitations. Providing a system less than a high level rapid transit system, such as the expanded bus system which would attract about 100 million passengers in 1995, would not be sufficient to meet future demands without building additional new freeways.

Finally, we have discussed earlier about the population and employment growth of the island. While many geographical features, such as mountain ranges and water tend to channel this growth into certain locations, the construction of a high level rapid transit system, in concert with present and future growth and development policies, will do much to ensure that this growth is served by adequate transportation and that the growth takes place at the proper locations.

There are other reasons as well why investments can safely be made, and should be made in rapid transit in Honolulu.[20/] Environmentally, Honolulu is a sensitive area which must be protected, both for its residents and for the sake of one of its principal industries--tourism. Investments in public transit such as those proposed will have a positive impact on air and noise pollution, and in addition, have less serious negative environmental impacts than major investments in new highway facilities. Then, too, from an energy conservation standpoint, which is especially crucial because of the geographical separation of Honolulu from energy sources, an investment in a sound rapid transit system will have impacts on energy conservation which would save the area over 10 million gallons of fuel per year.

Another important consideration is transit service to various national defense installations on Oahu. These facilities and supporting military housing areas are important generators of trips which were recognized in determining the system route. Improved transit service will benefit

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not only the resident population working in defense facilities but also military personnel and their dependents.

Without question, then, there is a demonstrated need for new transportation facilities in the urbanized areas of Honolulu at the present time. This need will increase significantly over time and it can be satisfied well by a high level rapid transit system. This system will attract significant patronage so that it would be a sound investment which is in accord with and promotes the land use and environmental goals of the Island. Honolulu has demonstrated through its existing bus system that it can and is indeed attracting high transit patronage at a level of about 50 trips annually per population unit, a level about that of Chicago. This high level is sufficient to justify a major expenditure in rapid transit now and over the long term.

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CHAPTER IV

MANAGEMENT OF EXISTING TRANSPORTATION SYSTEM

A. GENERAL

An important element of effective urban transportation planning is the examination of the possibilities of using low-cost, short-term transportation actions to optimize use of existing systems. A conclusion of Chapter III was that all possible steps should be taken in this area. This is especially important when consideration is being given toward the commitment of a large amount of capital for a long-term project. Currently, the City is striving to optimize the use of its existing transportation capacity and is taking steps to reduce travel demands wherever possible.

For the purpose of discussion, improvements in the management of existing transportation systems are discussed in three broad categories:

- Management of Existing Street and Highway System
- Improvement of Existing Transit System
- Measures to Reduce Vehicular Travel

This chapter discusses the low capital, short-term transportation programs which have been attempted and are planned for the City and County of Honolulu. The magnitude of each project and their effectiveness is also discussed.

B. MANAGEMENT OF EXISTING STREET AND HIGHWAY SYSTEM

The City and County of Honolulu and the State of Hawaii have implemented several measures to improve total vehicular flow on Oahu. These measures have varied from minor signalization improvements at intersections to reserving lanes on freeways for high-occupancy vehicles.

1. Improved Signal System

The City and County of Honolulu have continually maintained a program of monitoring and upgrading its traffic signals. The traffic demand at major intersections is carefully reviewed to ensure that signal phasing and timing optimizes these facilities. This is especially true at the more complex intersections. The City and County has embarked on a program of signal modernization and upgrading of traffic control equipment which will encompass 203 intersections over a period of three years.

2. One-Way Streets, Reversible Lanes, Restricted On-Street Parking

Traffic engineering experience has indicated that there are several means of increasing street capacity within the existing right-of-way and without major capital expenditures. One of these which has been extremely successful is the one-way street program. The circulation pattern for the entire area from downtown to Waikiki is designed around the concept of one-way streets. The Waikiki area is an example with Kalakaua Avenue and Ala Wai Boulevard forming an east-west one-way couplet. All the mauka-makai (north-south) streets in this area are one-way streets. Because many of these streets are narrow, the one-way street system allows on-street parking without sacrificing street capacity.

A program of peak-hour parking restrictions has been implemented in Honolulu. This has increased the peak-hour capacity of streets without affecting the off-peak parking capacity of certain areas. This is especially important on streets which are in areas with a high concentration of commercial establishments and are important routes for commuters to the downtown and Waikiki areas.

A third major program is the use of reversible lanes. This has been implemented on two streets in Honolulu--Kapiolani Boulevard and Ward Avenue. The two center lanes on Kapiolani Boulevard between Kaimuki and South Street are used in this manner during peak hours allowing four lanes inbound (ewa) and two outbound (kokohead) during the AM peak and four outbound and two inbound during the PM peak.

This same concept is utilized on Ward Avenue between Kinau Street and Kapiolani Boulevard.

3. Ramp Metering and Freeway Surveillance

Consultants to the State of Hawaii Department of Transportation has recently completed a study[21] to evaluate the origin and destination of the users of the Lunalilo Freeway. This study was conducted to determine what measures could be implemented to monitor and control the volume of traffic on the freeway by ramp metering. This would help divert short trips off of the freeway and provide the long trip users with improved traffic flow. The results of this study are currently under review by the State.

4. Flexible Work Hours

The City and County of Honolulu allows its employees to vary their work hours in an effort to spread the peak period commuting over a greater period of time. City and County employees are allowed to start as early as 6:00 AM and as late as 9:00 AM with a corresponding variance at the end of the day to allow for an 8-hour work day. This is a program which would require more universal implementation (e.g., State and Federal employees) before it could significantly improve city-wide traffic conditions. The City program has been in existence since 1973 and affects 1,600 employees.

5. Bike Lanes and Bikeways

Accommodation of bicyclists on the streets and highways in Honolulu have been provided in certain areas. Bike lanes have been implemented on University Avenue, between Metcalf Street and Kapiolani Boulevard. Bike lanes have also been provided along Kalanianaole Highway, between Lunalilo Home Road in Hawaii Kai to Ainakoa Avenue near Kahala. These bike lanes have improved the safety of bicyclists and the operation of automobiles on these roadways by providing reserved lanes for bicycles and thereby reducing the conflicts between automobiles and bicycles.

Currently, a master plan of bikeways[22],[23] in Honolulu is being prepared by the City and County of Honolulu and State of Hawaii. This plan is primarily located in the central area of Honolulu. The plan is intended to provide a safe and convenient network of bikeways for Honolulu residents for work and school use as well as for recreation.

6. Carpool Lanes

Carpool lanes have been instituted on two critical highways - on Kalanianaole Highway using a contra-flow lane jointly with buses and Moanalua Road on normal-flow lanes also used jointly with buses. Both highway carpool lanes are well used by automobiles carrying 3 or more occupants with resulting time savings during peak hours.

7. Other Improvements

Improved street illumination along major traffic arteries provides not only improved pedestrian safety but also greater comfort and convenience to traffic moving during hours of darkness. The City and County of Honolulu continually reviews existing street illumination levels to determine areas of deficiencies and non-conformance to current standards and criteria and implements programs to remedy these deficiencies. Such programs include the conversion of mercury vapor lamps to high pressure sodium lamps to increase the illumination levels at certain busy intersections along two major east-west arteries, King Street and Kapiolani Boulevard.

Also, the City endeavors to improve existing street capacity and operation through programs of re-channelization of major streets and intersections. Such programs include the re-striping of Dillingham Boulevard in the Kalihi-Palama area, Ward Avenue in the Kakaako area, and Kuhio Avenue in Waikiki, to provide left turn lanes and improve the flow of through traffic on these streets.

C. IMPROVEMENT OF EXISTING BUS SYSTEM

Improvements to the existing bus system can be categorized into two general areas: those improvements which are related to fares, routes, and schedules, and those which are related to improving the flow of buses on the streets and highways.

1. Fares, Routes, and Schedules

Despite increasing costs for the operation and maintenance of the system, the City and County of Honolulu has maintained its policy of a flat fare (25 cents), free transfer bus system. All discussions related to changes in fare policy have been directed toward the lowering of fares to a possible free-fare system. This philosophy of providing bus service at a low cost to passengers has been a significant factor in the continual increase in the patronage.

Several routes have been added since the integration of the system into an Island-wide bus system. The most significant additions include the Hawaii Kai Express, the Windward Express and the Wahiawa Express (See Figure IV-1). Schedules have been improved to the point of reducing headways on some heavily patronized routes to three minutes. The City and County of Honolulu Department of Transportation Services is continually monitoring and updating the transit plan to reflect changes in demand and usage. The improvement program, which is fully documented in the "Short-Range Bus Plan for Oahu (1975-1980 inclusive)"[24/] includes the following elements:

- A substantial increase to the existing bus fleet from 350 buses currently to 400 by 1978.
- New bus routes and revisions to existing routes.
- Improvement of bus stops including benches, shelters, and signs.
- Provision for park-and-ride facilities in suburban areas.
- A positive marketing program to disseminate route and schedule information to the public.
- Modern coaches with air-conditioning and public address system.
- Provisions for reserved-lane bus service on major highways.

Major Improvements to Existing Bus Operations

- Express Bus from Hawaii Kai
- Express Bus from Windward
- Express Bus from Wahiawa

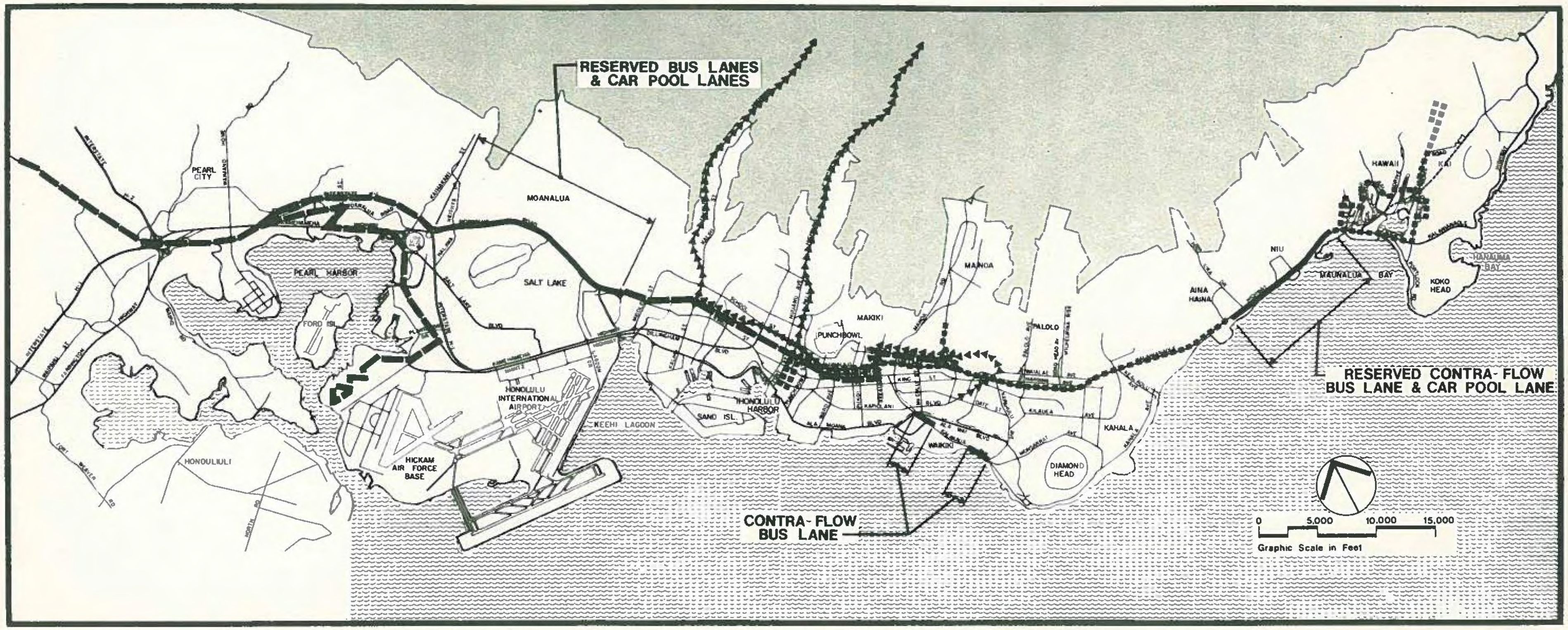

FIGURE IV-I

2. Improvements to Flow of Buses

The most notable improvement is the implementation of several express and semi-express bus routes. The Hawaii Kai express bus route was implemented by utilizing the concept of the contra-flow bus lane (see Figure IV-1). An outbound (kokohead) traffic lane on the Kalanianaole Highway is reserved for inbound (ewa) express buses during the AM peak period. The Hawaii Kai express has been in operation since 1973 and has a daily patronage of 1,300, very near its capacity based upon existing bus availability. Recently the use of the contra-flow bus lane has been expanded to include carpoolers.

Two other programs are currently being employed in Honolulu to improve the service provided by buses. These are:

- The use of contra-flow lane on a portion of Kalakaua Avenue between Kapahulu Avenue and Ala Wai Boulevard to allow local buses to travel ewa-bound. This affects 4 routes and 41 buses per hour during the peak hour. (See Figure IV-1).

- Reserving the center lane in each direction on Moanalua Freeway for buses and carpools between Halawa Heights Road and Puuloa Road. Currently the lane averages over 600 vehicles per hour during the two-hour peak period. (See Figure IV-1).

The short-range bus plan for Oahu includes an extensive system of bus lanes and busways to service the express and semi-express routes during the next six years. These include:

- Kalanianaole Highway from Lunalilo Home Road to Kahala Mall--possibly an at-grade one-way busway with median openings at ten major intersections and the use of signal preemptive devices aboard the buses to assure good signal progression.

- H-1 from Kahala Mall to Kapiolani Interchange--exclusive bus lanes.

- Pali Highway from Castle Junction to CBD--contra-flow bus lanes.

- TH-3 from Likelike Interchange to Halawa Interchange--bus lanes.

- H-1 from Waiawa Interchange to Halawa Interchange--exclusive bus lanes.

In addition to the above, a new route is planned to serve the primary transportation corridor in urban Honolulu and basically follows the proposed rapid transit route. The description of this route and required improvements are as follows:

- Kamehameha Highway from Waiawa Interchange to Middle Street--exclusive bus lanes in outside lanes on each side of the highway. Bus bays will be constructed off-line to permit buses to pass stopped vehicles and preemptive devices aboard buses will improve signal progression.

- Dillingham Boulevard from Middle Street to North King Street-contra-flow bus lanes with use of signal preemptive devices.

- Hotel Street from River Street to Richards Street--exclusively for buses and commercial vehicles.

- King Street from Richards Street to Kapiolani Boulevard--exclusive bus lane in right-hand lane.

- Beretania Street from Alapai Street to Richards Street--exclusive bus lane.

- Kapiolani Boulevard from King Street to Kalakaua Avenue--exclusive bus lane in right-hand lane in peak-period direction during peak period.

D. MEASURES TO REDUCE VEHICULAR TRAFFIC

The City and County of Honolulu and the State of Hawaii have both implemented programs to reduce vehicular travel primarily by encouraging higher occupancy in existing modes. This includes greater bus usage and increasing passenger occupancy in private automobiles. Some of the measures are intended to reduce automobile traffic in specific areas. One such program is the limitation on the amount of public parking facilities provided in the downtown area to encourage use of buses and fringe lots. The program is designed to provide parking facilities outside of the downtown core to free these streets for pedestrians and buses.

The other major program which has been attempted in Honolulu is the carpooling program. Early in 1974 the State of Hawaii Department of Transportation implemented a carpool matching program. Questionnaires were distributed throughout the Island of Oahu through banks, post offices, and other highly-frequented locations. For carpooling purposes the Island was divided into a grid pattern of zones. Anyone interested in participating in the carpooling program was asked to respond to the questionnaire and to indicate the location of his home, place of work, and the times when he traveled between these two points. Approximately 5,000 responses were received. Of these, only 150 were provided with the names of three persons whose work trip characteristics were compatible with their own. No follow-up was performed to determine how many of these 150 were successfully matched and formed a carpool.

Over the recent past there has been considerable interest on the part of federal officials, and others as well, over controlling the indiscriminate use of the automobile. Environmental and energy related concerns have formed the basis for this interest which already existed in Honolulu primarily due to its unique environment and total dependency on outside energy source. In this regard, the following actions are underway or being proposed in the current legislative session as auto disincentive measures on the island.

1. The creation of an auto free zone in the CBD-Civic Center area.

2. Increase driver age from 15 to 17.

3. Prohibit student parking at public schools and provide more school buses.

4. Institute user charges for all on-campus parking.

5. Moratorium on parking facilities in select areas.

6. Enforced staggered work hours.

7. Increase parking fees charged to government employees.

8. Carpool incentive plans for government employees.

9. Energy tax levy on auto based on weight.

10. Increase auto registration fee based on engine displacement.

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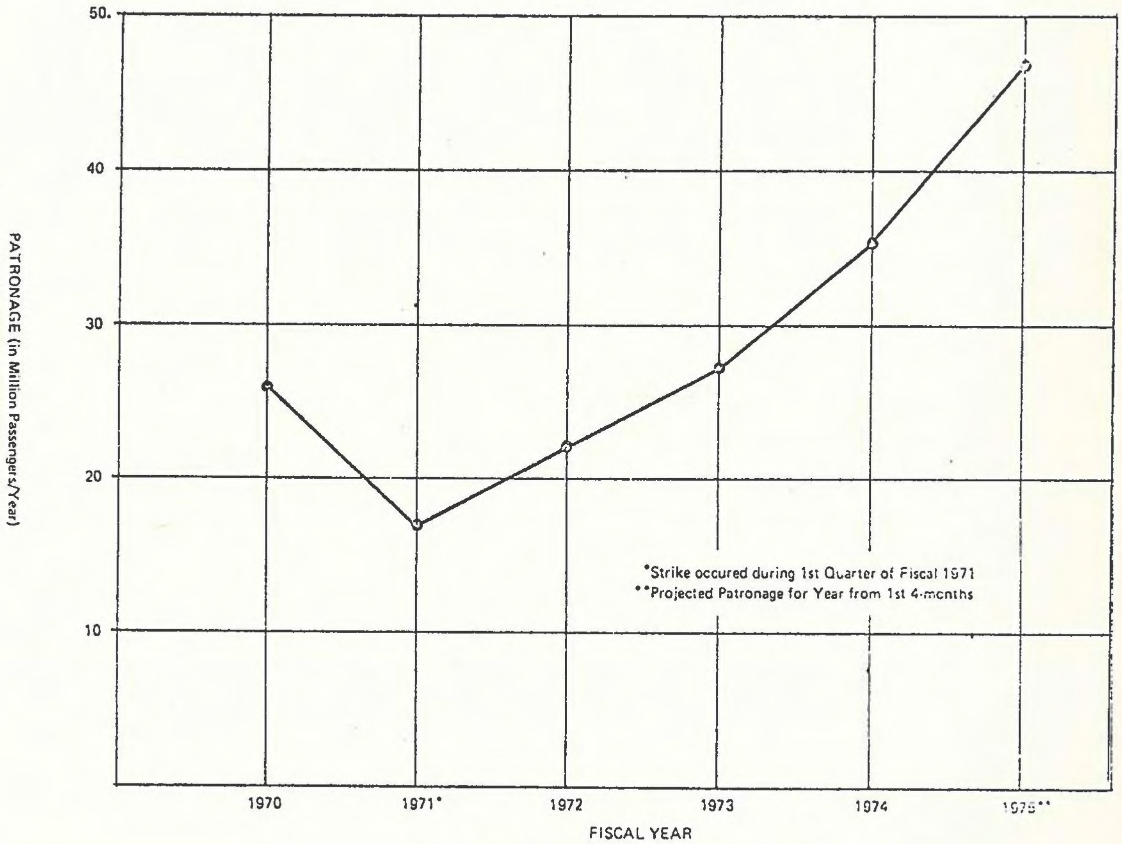
E. SUMMARY AND CONCLUSIONS

It is difficult to determine precisely how successful any one of these programs have been because of the interrelationship between them. For example, a multitude of factors affect transit patronage and therefore make it impossible to estimate how much of the patronage increase on lines serving Waikiki can be attributed to the contra-flow bus lane on Kalakaua Avenue. The Hawaii Kai express is, of course, a definitive improvement since no such service existed prior to its implementation.

But nevertheless, three general conclusions can be drawn. First, in relation to transit patronage, the bus improvements have been generally successful. Figure IV-2 shows what has happened to transit patronage since the City and County of Honolulu took over the several private systems and began the program of improvements described herein. The 200% increase in transit patronage over a five year period of time is a basic reason why local officials are so confident that a fixed facility rapid transit system will be successful in Honolulu.



TREND IN PASSENGERS ON THE BUS

FIGURE IV-2

Regarding the street improvements, the situation is not as clear. About the best that can be said is that the improvements which have been made have kept pace with the general increase in vehicular traffic and that congestion has not worsened significantly.

Finally, it also seems clear that in the use of the existing facilities, both the transit system and the street and highway system are continuing to be maximized with the improvements already implemented and those scheduled for implementation in the very near future. With the projected growth in travel demand combined with possible limitations on additional improvements remaining, it is inevitable that additional new transportation capacity must be provided. In the latter part of this report, an evaluation is presented to determine when this new transportation capacity is required.

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CHAPTER V

RAPID TRANSIT ROUTE LOCATION ANALYSIS

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A. GENERAL

Having established in Chapter III that a high level, grade separated rapid transit system was needed in Honolulu, both in the near term and over the long term, the planning process now becomes one of generally locating the facility within the urban fabric of the city. Clearly to get the most usage, it should be located where the population and employment are located today. Then too, one must consider the development potential of the location and its ability to reinforce the declared development goals of the Island. These two factors must then be balanced by relocation, environmental problems and by cost factors. The objective, of course, is to find that location which represents a reasonable balance of all of these.

One of the initial steps in long-range transportation planning is the development of an area-wide system network which is compatible with future growth and land use policies, environmentally acceptable, and practical to implement. A long-range, island-wide transit network was defined to serve and interconnect the various urbanized regions of the island.[25] All outlying districts would have transit corridors located in existing highway corridors that feed into the primary Central Honolulu corridor. The basic transit network in Central Honolulu would consist of a single line that could meet the projected travel demand to 1995 and beyond. A second parallel line was identified on the urban core area to complement the initial single line system whenever it is justified by future demand.

The primary transportation corridor in Central Honolulu, from Pearl City to Hawaii Kai, is located in a narrow plateau constrained by the ocean on one side and the mountains on the other. Located within the corridor are all of the major activity and employment centers which are the primary traffic generators on Oahu. One of the basic requirements for a successful rapid transit system is to provide fast and convenient service to major destination areas of the region. The proposed rapid transit system should therefore be planned to serve as many of these activity centers as possible in the most direct manner with appropriately placed stations for ease of accessibility, consistent with land use and development goals, relocation and environmental factors, and with minimum cost.

Given the above, the first step in the route location process was an extensive data gathering program. Land use plans, zoning ordinances and maps, traffic data, development plans and studies, economic data, population and demographic data and any other pertinent data were collected and reviewed. This provided the basis for defining the limits of the rapid transit corridor and the identification of alternative routes. After an initial screening and elimination of least desirable alternatives, the remaining routes were subjected to a thorough comparative evaluation.

The evaluation of alternative route alignments, station locations, and auxiliary facility locations were accomplished in two phases, i.e. the two phases of the Preliminary Engineering and Evaluation Program (PEEP I and PEEP II). The first full-scale evaluation was conducted in PEEP I using a thorough and rigorous comparative evaluation methodology.[26] PEEP II studies later refined routes recommended in PEEP I and established more detailed route alignments and station locations. In fact the PEEP II refinement was successful in reducing by three quarters the relocations originally caused by the alignments first selected in PEEP I.

B. BASIS FOR ROUTE EVALUATION

The approach adopted for the evaluation of routes was to provide a balance between the tangible elements of cost and the intangible elements of community disruption, aesthetic qualities, convenience and comfort of service, etc. To provide the balance for the evaluation process, a set of evaluation criteria was defined which was relatable to the basic goals and objectives described in Chapter II. The criteria developed and used specifically for this route evaluation process are shown in Table V-1.

The evaluation of factors were separated into tangible and intangible groups which were weighted equally in terms of importance, i.e. 50% for tangible and 50% for intangible. The tangible factors were primarily related to costs including capital cost, right-of-way and relocation cost, and property tax loss.

The intangible factors are listed in Table V-2, along with the relative weights for each factor. The weights reflect the composite opinion of a panel of professional planners and representatives of various community groups who assisted the planning staff on the evaluation of alternatives. The results of course reflected a wide range of opinions. However, to overcome this wide divergence of opinion a computer program was utilized to measure the sensitivity of each factor to changes in their relative weights or values. In addition to this analytical process, due consideration was given to desires and requests of various governmental agencies, private organizations, and citizens of the Honolulu area through several hundred meetings held with interested community residents and their leaders all along the corridor.

Upon selection of the most desirable route, station sites were further evaluated to determine optimum station placement along the selected route. The basic parameters used in evaluating station locations were similar to criteria used for route evaluation but with special emphasis on the following factors:

- Maximum service to area
- Beneficial impact on adjacent properties
- Convenient access to arterial and local streets
- Maximum interface with feeder bus routes
- Availability of proper vehicle parking site, where needed

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- Least physical constraints to users
- Compliance with civil engineering design criteria (not on excessive curves, grades, etc.)
- Proper spacing between stations (average about one mile; less in urban core, more in outlying areas)

TABLE V-1

ROUTE EVALUATION FACTORS

TRANSIT DEVELOPMENT OBJECTIVE	ROUTE PLANNING EVALUATION FACTORS
OBJECTIVE 1	
a. Availability & coverage	- NA* (same as 2.a.)
b. Travel time	- Length of line
c. Service reliability	- NA
d. Rider convenience	- Station site & accessibility
e. Rider comfort	- Curvature & grade - Passenger acceptability
OBJECTIVE 2	
a. System patronage	- Service to origins - Service to destinations
b. System Capacity	- System line extendability - System carrying capacity
OBJECTIVE 3	
a. Consumption of land	- NA (same as 3.a. and b.)
b. Displacement of residents	- Displacement of residents
c. Displacement of businesses	- Displacement of businesses
d. Reduction of comm. amenities	- Physical identify of community
e. Disruption to future dvlpmt	- Character of adjacent property
f. Disruption to local circulation	- Local traffic impact - Constraints to freeway - Constraints to arterial streets
g. Disruption from const. activities	- NA (same as 3.f.)
h. Consumption of energy	- NA (same as 1.a.)
i. Technical risks	- NA
OBJECTIVE 4	
a. Support regional dvlpmt	- Enhance dvlpmt. potential - Reinforce present plan
b. Support comm. dvlpmt	- Relation to comm. planning goals - Urban design potential

*NA - Not Applied

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TRANSIT DEVELOPMENT OBJECTIVE	ROUTE PLANNING EVALUATION FACTORS
OBJECTIVE 5	
a. Air pollution	- Air pollution
b. Noise level	- Noise
c. Visual intrusion	- Natural beauty
d. Vistas	- Natural beauty
e. Historic sites	- Urban environmental quality
OBJECTIVE 6	
a. Reduction in accident exposure	- NA
b. Security	- NA
OBJECTIVE 7	
a. Total cost	- Construction cost - ROW acquisition cost - Tax losses
b. Cost per ride	- NA
c. Benefit-cost ratio	- NA

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TABLE V-2

WEIGHTING OF INTANGIBLE FACTORS IN PEEP I ROUTE PLANNING

Factors				Total Weight
I.	Service			
	4.	Service to Origins		40
		a.	Population Centers	
		b.	Concentrations of Labor Force	
		c.	Low-Income Areas	
	5.	Service to Destinations		
		a.	Employment	
		b.	Business/Shopping	
		c.	Institutional/Cultural	
		d.	Recreation	
II.	Impact			
	6.	Local Impact		48
		a.	Relation to Community Planning Goals	
		b.	Urban Design Potential	
		c.	Relocation of Resident	
		d.	Relocation of Businesses	
		e.	Effect upon Physical Identity of Community	
		f.	Effect upon Character of Adjacent Property	
		g.	Local Traffic Impact	
	7.	Corridor Impact		
		a.	Enhances Development Potential	
		b.	Reinforces Present Planning Goals	
	8.	Environmental Aspects		
		a.	Noise Levels	
		b.	Air Pollution	
		c.	Retention of Natural Beauty	
		d.	Retention of Urban Environment Quality	
III.	Design			
	9.	Physical Design		8
		a.	Curvature and Grades	
		b.	Station Sites and Accessibility	
		c.	Length of Line	
		d.	Passenger Acceptability	
	10.	Transit System Expansion Capability		
		a.	Extensions	
		b.	Carrying Capacity	
IV.	Constraints			
	11.	Constraints to Transportation		4
		a.	Freeways	
		b.	Arterial Streets	
			Total for Intangible Factors	100

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C. ROUTE PLANNING ANALYSIS

For purposes of evaluation, the 23-mile corridor was divided into nine segments, each containing several alternative route locations. These transit corridor segments are shown in Figure V-1. PEEP I considered a segment through Waikiki which was subsequently eliminated because the high cost of constructing a spur or branch line was not justified. The analysis considered both horizontal and vertical alignments in the development of alternative routes. The vertical alignments or configurations included aerial, at-grade, and subway. Also considered, but not shown in the alternatives, are the alternative locations considered for the transit yard and shop site. Several locations were examined and it was concluded that the proposed site at Keehi Lagoon was far superior to any alternative site. Using the factors described in Table V-2 and their relative weights, each alternative was developed to the point where comparative evaluations could be made. The evaluation process was accomplished with the assistance of both public and private citizen groups.

One of the purposes of the PEEP II program was to refine the selection of routes and station locations made in PEEP I. For some segments, new alternatives were defined and evaluated.[27/] These included the following:

- Segments 1-3 (Pearl City to Middle Street): evaluation of the feasibility of using the H-1 Freeway median
- Segment 4 (Kalihi-Palama): evaluation of using the middle of Dillingham Boulevard
- Segment 7 (McCully-Moiliili): evaluation of a whole new set of alternative routes between Waikiki and University stations
- Segment 8 (Kaimuki-Kahala): re-evaluation of the feasibility of using Lunalilo Freeway median

A key factor in the PEEP II evaluation was the elimination of the requirement that any street or highway facility used for rapid transit facilities must be replaced to its original capacity and condition. Otherwise, the criteria applied in PEEP II were similar to those applied in PEEP I with special attention given to relocation requirements.

Numerous alternative route locations and alignments were considered both in PEEP I and II. An initial screening process was conducted to reduce the number of alternatives to only those which were most viable and to a manageable number for detailed evaluation. In some cases a wide range of route locations were examined and deemed necessary to carry forward with the detailed evaluation stage, such as in the Kalihi-

Transit Corridor Segments

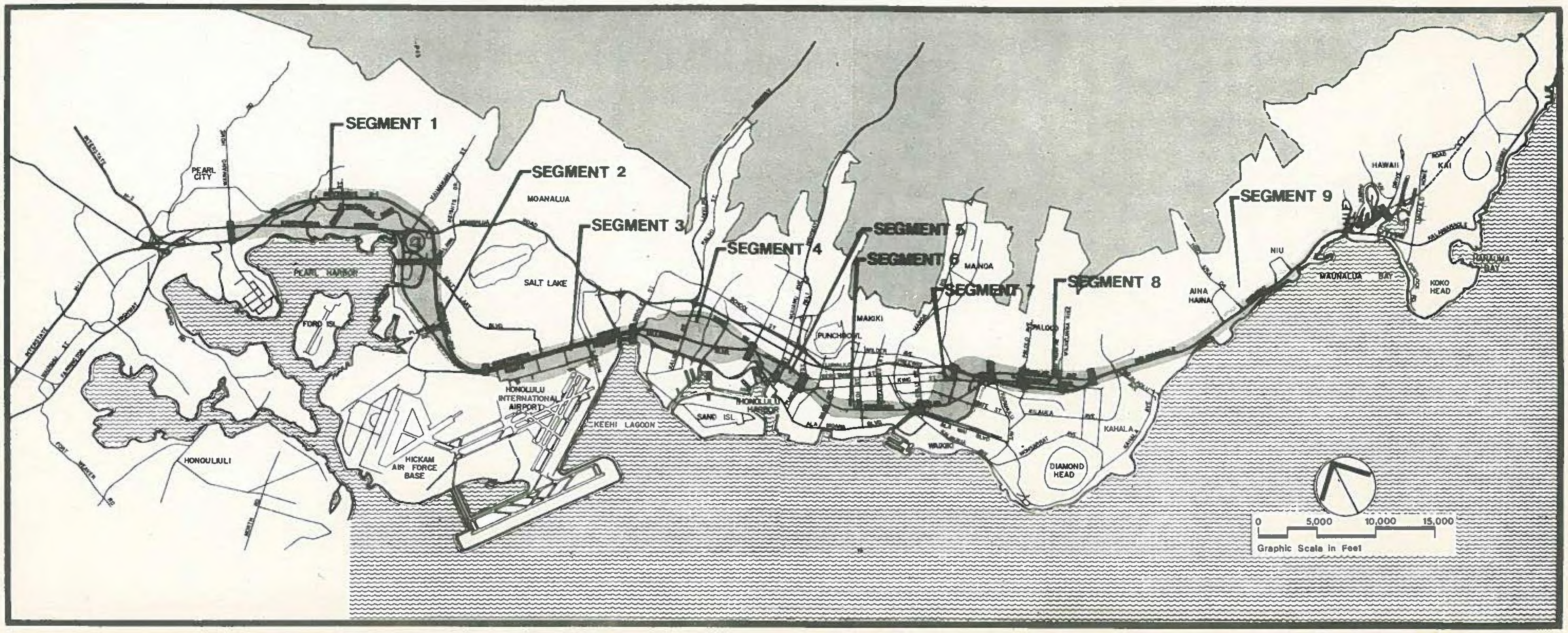

FIGURE V-1

Palama area which consisted of six alternative routes ranging in location from Nimitz Highway to King Street. In other cases, an equally wide range of locations were examined but it was possible to narrow the alternative route locations to a single general location with several different alignments. An example of this was in the Kakaako-Ala Moana area where the locations ranged from Ala Moana Boulevard to Lunalilo Freeway but the general Kapiolani Boulevard was determined to best serve the area with three alternative alignments selected for detailed evaluation.

After the initial screening process, the remaining routes or alignments were subjected to a thorough comparative evaluation as discussed earlier. These alternatives are described in Table V-3.

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TABLE V-3: RAPID TRANSIT ALTERNATIVE ROUTE ALIGNMENTS AND STATION LOCATIONS

Corridor	Alternative	Route Alignment	Route Configuration	Station Location	Station Configuration
Segment 1 - Pearl City-Aiea (Pearl City to Aloha Stadium)	•H-1 Freeway	Median of H-1 Freeway	Transit at grade with roadway	Pearl City - H-1 Freeway west of Lehua Avenue	Aerial
				Pearl Ridge - H-1 Freeway east of Kaonohi Street	Aerial
	Kamehameha Highway*	Median of Kamehameha Highway	Aerial	Pearl City - Kamehameha Highway west of Lehua Avenue	Aerial
				Pearl Ridge - Kamehameha Highway east of Kaonohi Street	Aerial
	OR&L R.O.W.	Oahu Railway & Land Co. RR R.O.W. (portion)	Aerial and Subway	Pearl City - West of Lehua Avenue at Third Street	Aerial
				Pearl Ridge - On OR&L Co. R.O.W. west of Aiea Kai Place	Aerial
Segment 2 - Halawa/Pearl Harbor (Aloha Stadium to Elliot Street)	•H-1 Freeway	Median of H-1 Freeway	Transit at grade with roadway	Halawa - H-1 Freeway at Halawa Heights Road	Aerial
				Pearl Harbor - H-1 Freeway north of new Plantation Drive	Aerial
	Kamehameha Highway	Along Kamehameha Highway on west side and then along south side of Nimitz Highway	Aerial	Halawa - Relocated Salt Lake Boulevard and Kamehameha Highway	Aerial
				Pearl Harbor - Nimitz Highway at Valkenburg Street	Aerial
	H-1 Freeway*	Cross stadium parking area and along H-1 on west side and then along south side of Nimitz Highway	Aerial at stadium, at grade along H-1, then aerial	Halawa - Stadium site at relocated Salt Lake Boulevard	Aerial
				Pearl Harbor - Nimitz Highway at Valkenburgh Street	Aerial

• Proposed location
* Alternative recommended in PEEP I

Corridor	Alternative	Route Alignment	Route Configuration	Station Location	Station Configuration
Segment 3 - International Airport (Elliot Street to Keehi Lagoon)	•Aolele Street	From H-1 Freeway median to airport terminal, then following Aolele Street through northern edge of Keehi Lagoon Park	Aerial	International Airport - North of proposed parking garage Keehi Lagoon - Lagoon Drive and Aolele Street	Aerial Aerial
	H-1 Freeway	Median of H-1 Freeway	At grade with H-1	International Airport - Proposed H-1 Freeway near Rodgers Boulevard Keehi Lagoon - Proposed H-1 Freeway at Lagoon Drive	Aerial Aerial
	Aolele Street*	From Nimitz Highway and Elliot Street to Airport terminal, follows existing drainage ditch along Aolele Street through Keehi Lagoon and cross Nimitz Highway	Aerial, except at grade just west of Keehi Lagoon Park	International Airport - North of existing parking garage Keehi Lagoon - Lagoon Drive and Aolele Street	Aerial Aerial
	Aolele/Koapaka Streets	From Nimitz Highway and Elliot Street to airport terminal; Aolele Street then Koapaka Street at Lagoon Drive and through northern edge of Keehi Lagoon Park	Aerial	International Airport - North of existing parking garage Keehi Lagoon - Lagoon Drive and Koapaka Street	Aerial Aerial

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Corridor	Alternative	Route Alignment	Route Configuration	Station Location	Station Configuration
Segment 4 - Kalihi/Palama (Middle Street to River Street)	•Dillingham Blvd. (median)	Median of Dillingham Boulevard	Aerial then Subway before Iwilei Station	Kalihi - Dillingham Blvd., east of McNeill Street Iwilei - Between King Street and Dillingham Blvd. and Kaamahu Place	Aerial Subway
	King Street	Along North King Street	Aerial to Kalihi Stream, Subway along King Street	Kalihi - King Street between Kalihi Street & Mokauea St. Liliha - West of Liliha Street on King Street	Subway Subway
	Alokele Street	Along Alokele Street south of King Street	Aerial to Kalihi Stream, Subway through residential, Aerial across Kapalama Canal, Subway through Iwilei	Kalihi - East of Mokauea Street at Alokele Street Liliha - West of Dillingham Boulevard at Akepo Lane	Subway Aerial
	Dillingham Boulevard (South)*	Along south side of Dillingham Boulevard on private R.O.W.	Aerial to Dole Cannery, Subway through Iwilei	Kalihi - Dillingham Boulevard between Kalihi St. & McNeill St. Iwilei - Between King St. & Dillingham Blvd. and Kaamahu Place	Aerial Subway
	Nimitz Highway	Follow Nimitz Highway to Kapalama Canal, then OR&L RR R.O.W.	Aerial, then Subway through Iwilei	Kalihi - Kalihi Street & Nimitz Highway Iwilei - Just west of King Street and Iwilei Road intersection	Aerial Subway
	OR&L R.O.W.	Follow Oahu Railway & Land Co. RR R.O.W.	Aerial, then Subway through Iwilei	Kalihi - East of Kalihi Street at Hart Street Iwilei - Just west of King Street and Iwilei Road intersection	Aerial Subway

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Corridor	Alternative	Route Alignment	Route Configuration	Station Location	Station Configuration
Segment 5 - Chinatown, Downtown, Civic Center (River Street to Alapai Street)	•Hotel Street*	Follow Hotel Street through Chinatown, downtown, and Civic Center	Subway	Fort Street - Fort Street/Nuuanu Avenue at Hotel Street	Subway
				Civic Center - Just west of Kapiolani Boulevard Extension & King Street	Subway
	King Street	Follow King Street to Punchbowl Street, then onto Kapiolani Boulevard	Subway	Fort Street - Fort Street/Nuuanu Avenue at King Street	Subway
				Civic Center - Punchbowl Street and King Street	Subway
Segment 6 - Kakaako/Ala Moana (Alapai Street to Atkinson Drive)	•Waimanu/Kona Street	South of Kapiolani Boulevard along Waimanu Street and Kona Street	Subway to Dreier Street, then Aerial	Ward Avenue - Ward Avenue and Waimanu Street	Aerial
				Ala Moana - Keeaumoku and Kona Street	Aerial
	Kapiolani	Follow Kapiolani Boulevard	Subway	Ward Avenue - Ward Avenue & Kapiolani Boulevard	Subway
				Ala Moana - Keeaumoku Street and Kapiolani Boulevard	Subway
	Makaloa Street	Follow Kapiolani to McKinley High School then along Makaloa, then cross to Kona Street	Subway to McKinley High School, then Aerial	Ward Avenue - Ward Avenue and Kapiolani Boulevard	Subway
				Ala Moana - Keeaumoku Street at Makaloa Street	Aerial

Corridor	Alternative	Route Alignment	Route Configuration	Station Location	Station Configuration
Segment 7 - Moiliili/ University (Atkinson Drive to Kapahulu Ave)	oMB - Kapiolani/ University with Date and UH Quarry Stations	Middle of Kapiolani, middle of University Avenue past Freeway, easterly through UH & then along Waialae Road	Aerial	Waikiki - Between Kalakaua Avenue & McCully Street, north of Ala Wai Canal	Aerial
				Date Street - University Avenue and Date Street	Aerial
				University - UH Quarry	Aerial
	A - Kapiolani Boulevard	Middle of Kapiolani Boulevard to H-1 Freeway at Kapahulu Avenue	Aerial	Waikiki - Between Kalakaua Ave. and McCully Street, north of Ala Wai Canal	Aerial
				Kapiolani - On Kapiolani Blvd. between University & Date	Aerial
	B_1 - Kapiolani/ University/Old Waialae Road	Middle of Kapiolani, middle of University Avenue past Freeway, easterly through UH and then along Waialae Road	Aerial	Waikiki - Between Kalakaua Ave. and McCully Street north of Ala Wai Canal	Aerial
				University - University Avenue between King Street & H-1 Freeway	Aerial
	B_2 - Kapiolani/ University/South of H-1	Same as B_1 but turns east at King Street then over and into the median of H-1	Aerial	Waikiki - Between Kalakaua Ave. and McCully Street north of Ala Wai Canal	Aerial
				University - Between King Street and H-1 east of University Ave.	Aerial
	C - Isenberg/ UH/Old Waialae Road	Kapiolani to Isenberg, north to King Street, northeast to UH then east along Waialae Road	Aerial	Waikiki - Between Kalakaua Ave. and McCully Street north of Ala Wai Canal	Aerial
				Isenberg Street - South of King St. on Isenberg Street	Aerial
				University - On UH property east of Varsity Circle	Aerial

NOTE: Five other routes were evaluated in PEEP I and rejected prior to the evaluation of the above five in PEEP II. These were Manoa-Palolo Drainage Canal, Ala Wai Canal/University Avenue (subway), Kapiolani/University (subway), Kapiolani/University (aerial), and a private right-of-way across Coolidge and Hausten Streets.

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Corridor	Alternative	Route Alignment	Route Configuration	Station Location	Station Configuration
Segment 8 - Kaimuki/Kahala (Kapahulu Avenue to Kahala Mall)	•Middle of Lunalilo Freeway (Grade)	Middle of Freeway	At-grade	6th Avenue - On Freeway west of 6th Avenue	At-grade
				Koko Head - On Freeway west of Koko Head Avenue	At-grade
				Kahala - Kahala Mall on Freeway near Hunakai Street	At-grade
	Waialae Avenue	Along Waialae Avenue	Subway in Waialae Avenue and then Aerial over the Freeway to Kahala Mall	6th Avenue - 6th Avenue & Waialae Avenue	Subway
				Koko Head - Koko Head Avenue and Waialae Avenue	Subway
				Kahala - Kahala Mall at Kilauea Avenue	Aerial
	North of Lunalilo Freeway*	Private R. O. W. along northern edge of Freeway and crosses Freeway near Waialae Avenue to Kahala Mall	Aerial with a small portion in Subway under Koko Head Avenue	6th Avenue - 6th Avenue & Lunalilo Freeway (north)	Aerial
				Koko Head - Koko Head Avenue & Lunalilo Freeway (north)	Subway
				Kahala - Kahala Mall at Kilauea Avenue (south)	Aerial
	Median of Lunalilo Freeway (Aerial)	Median of Freeway	Aerial	6th Avenue - Above Lunalilo Freeway east of 6th Avenue	Aerial
				Koko Head - Koko Head Avenue at Lunalilo Freeway	Aerial
				Kahala - Kilauea Avenue at Freeway	Aerial
	South of Lunalilo Freeway	Private R. O. W. south of Freeway	Aerial	6th Avenue - 6th Avenue and Lunalilo Freeway (south)	Aerial
				Koko Head - Koko Head Avenue & Freeway (south)	Aerial
				Kahala - Kahala Mall at Kilauea Avenue (south)	Aerial

Corridor	Alternative	Route Alignment	Route Configuration	Station Location	Station Configuration
Segment 9 - Kahala/Hawaii Kai (Kahala Mall to Hawaii Kai)	•Kalanianaole Highway (median)*	Median of widened Kalanianaole Highway	Aerial	Aina Haina - Kalanianaole Highway just east of West Hind Drive	Aerial
				Niu - Kalanianaole Highway near Halemaumau Street	Aerial
				Hawaii Kai - Between Ainahou St. and Keahole Street south of Hawaii Kai Drive	Aerial
	Kalanianaole Highway (South)	Along south side of Kalanianaole Highway	Aerial	Same locations as Kalanianaole Highway (median) above	

NOTE: Three alternatives were not considered for full evaluation: north of Kalanianaole Highway; along the slopes of the Koolaus; and off-shore reef.

D. CONCLUSION AND RECOMMENDATIONS

The route selection recommendations are summarized below. A more detailed discussion of the results is provided in various technical reports published during both PEEP I[26] and PEEP II.[27]

Segments 1-2 (Pearl City to Pearl Harbor): PEEP I recommended a route generally following the median of Kamehameha Highway from Pearl City to Aloha Stadium and then along the side of the proposed H-1 Freeway and Nimitz Highway, with stations located at Pearl City, Pearl Ridge, Aloha Stadium, and Pearl Harbor. PEEP II recommended the use of the median of the H-1 Freeway throughout these segments with stations located in the same four general areas but within the freeway. The primary reason for the revised recommendation was the lower cost and lesser environmental impact.

Segment 3 (Airport): The route and station locations through the airport area are substantially the same in the PEEP I and PEEP II recommendations except that the revised route would enter the airport area from the median of the proposed H-1 Freeway. The airport station, mauka of the parking garage, and Keehi Lagoon station will be connected by an alignment running along Aolele Street. While a route remaining in the H-1 Freeway would have a lower capital cost, the proposed route would provide direct service to the airport without the need for a supplementary system.

Segment 4 (Kalihi-Palama): PEEP I recommended a route on a private right-of-way along the makai side of Dillingham Boulevard, with stations at Kalihi Street and Iwilei. The proposed route selected in PEEP II by the consultants and community representatives would locate the fixed guideway above the center of Dillingham Boulevard in order to reduce the amount of relocation and total cost. The Kalihi station would also be placed one block farther east in order to separate it from Kalihi-Kai Elementary School.

Segment 5 (Chinatown-Downtown-Civic Center): The proposed route, placing the guideway in a subway under Hotel Street with stations at Fort Street and the Civic Center, was recommended in PEEP I and reaffirmed in PEEP II. The route was chosen primarily on the basis of cost and the location of future growth.

Segment 6 (Kakaako-Ala Moana): The proposed route running generally makai of Kapiolani Boulevard along Waimanu Street and Kona Street was recommended in PEEP I and confirmed in PEEP II. The key factors were lower cost, slightly better service characteristics, and greater development potential compared to the other alternatives.

Segment 7 (Moiliili-University): The recommended route was selected in PEEP II after an extensive evaluation of five routes, with considerable community input. The recommended route would contain two stations and thus provide direct service to the University and Moiliili residential areas (Date Street). This route is similar to a route initially evaluated in PEEP I except for the two station locations and the use of the middle of Kapiolani Boulevard rather than private right-of-way along the south and north side. The PEEP I recommendation for a route which would have traversed residential areas of Moiliili along Coolidge and Hausten Streets rather than up the middle of University Avenue was rejected primarily because of the amount of relocation and other negative community impacts.

Segment 8 (Kaimuki-Kahala): PEEP I recommended a route following mauka of the Lunalilo Freeway on a private right-of-way, with stations located at 6th Avenue, Koko Head Avenue, and Kahala Mall. The proposed route using the middle of the freeway (requiring the use of the two center lanes) has similar station locations and was recommended in PEEP II to reduce relocation, costs, negative visual effects, and noise impacts.

Segment 9 (Kahala-Hawaii Kai): The PEEP I studies initially projected insufficient patronage to justify placement of a fixed guideway facility in the Kalanianaole corridor. Subsequently, based on a City-State agreement for an integrated transportation strategy which would generate more transit ridership, it was recommended that the fixed guideway facility be extended from Kahala to Hawaii Kai. Based on an evaluation of alternative routes which was similar to that conducted in other segments, the route recommended in PEEP I would follow the median of a widened Kalanianaole Highway, with stations at Aina Haina, Niu, and Hawaii Kai. PEEP II reaffirmed this selection on the basis of lower cost, relocation, and environmental impact, compared to the alternative route makai of the highway.

Auxiliary Facilities: The yard and shop site at Keehi Lagoon was selected in PEEP I on the basis of its large area, central location, accessibility to the route, and minimal relocation or development impact. No other available large area could be found to meet these requirements.

The recommended route location provides a good balance between maximizing transit service and attainment of community objectives and minimizing relocation and cost. It will provide a high level of service, and hence attractiveness, by serving various population centers and all major activity and employment centers on Oahu. In these centers are concentrated most of Central Honolulu's existing and future employment opportunities which represent 80% of the total island-wide employment. On the origin end of the trip in addition to direct service to various population centers, a full coverage feeder bus service is provided to make transit service available to all urbanized areas on the island. At the same time, through judicious alignment studies and excellent use of existing transportation rights-of-way, approximately 170 residential units and 180 business units are displaced based on the use of a guided rapid transit system. This is accomplished with only a short section of tunnel in the heart of downtown Honolulu, helping to reduce costs.

Although a great deal of deliberate analysis has gone into the selection of the recommended route location, from a great number of alternatives and with public involvement, the Environmental Impact Statement and public hearings have yet to be completed. Through this final step of the planning process, a full review of the technical conclusions reached will be made.

CHAPTER VI

LONG-RANGE ALTERNATIVE SYSTEMS EVALUATION

07

A. BACKGROUND OF TRANSIT PLANNING STUDIES

As discussed in Chapter I, various transit planning studies for Honolulu have been conducted which dealt with basic transportation alternatives beginning with the 1967 Oahu Transportation Study extending through PEEP II. The results of these studies are all in accord relative to the need for an exclusive, grade separated rapid transit system to meet the near-term and long-term travel needs of the island as was described in Chapters III and IV. The route evaluation process described in Chapter V led to the selection of a recommended route for an exclusive, grade separated transit system. With the need and location established, a deliberate process of selecting a transit system which would best satisfy the transportation goals and objectives of the island is the subject of this chapter.

Various alternative vehicle systems were examined over the past 8-10 years in Honolulu with many of the systems discarded as non-appropriate for Honolulu. Those systems which seemed appropriate were reviewed and then subjected to further detailed analysis as described in this chapter.

B. PEEP I ALTERNATIVES STUDIED

In order to determine the type of rapid transit system most suitable for Honolulu, various alternative systems were examined and comparisons made as part of the PEEP I program completed in late 1972.[28] Although the initial emphasis in the PEEP I program was directed at re-evaluating the recommendations of the prior OTS program for a grade separated rapid transit system, it was also necessary to examine a broader range of alternative concepts. In that context, the study analyzed busway, fixed guideway, and waterborne alternatives which took into consideration various technical, economic, social, and environmental factors.[29]

A low capital intensive system that basically extended the current bus service level to 1995 was defined and used as the baseline system. The baseline bus system assumed use of the existing streets and highways. Its operating characteristics were comparable with current bus operations. The 1972 patronage volume was extrapolated to 1995 to reflect growth in population and total trips projected for the island. This resulted in a patronage volume of 188,000 passengers per day. Use of this system as a baseline provided the basis for measuring certain performance characteristics of the alternative systems selected for evaluation.

A bus rapid transit concept developed and evaluated in detail was a busway system. The busway facilities utilized exclusive, grade separated roadway for providing high speed line-haul service. Two exclusive busway lengths of 22 and 19 miles were analyzed.

The waterborne concept which was evaluated utilized 250 passenger ocean-going hydrofoils to provide high speed line-haul service. It was assumed that feeder services would be provided by either buses or by a combination of canal boats and buses. The analysis was made on two patronage basis: patronage volume equivalent to the fixed guideway system and patronage volume based on modal split analysis.

The fixed guideway concept analyzed was based on a 22-mile system with 20 stations. An island-wide network of local and express buses was provided to complement the fixed guideway, trunk line system. The result of the comparative cost analysis of these systems is summarized in Table VI-1.

Of the three basic alternative concepts studied - busway, waterborne, and fixed guideway, the waterborne concept was found to be the least cost-

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TABLE VI-1: SUMMARY OF ALTERNATIVES ANALYSIS - PEEP I

	FIXED GUIDEWAY	BUSWAY		WATERBORNE		
		A	B	1-A	1-B	1-C
LINE HAUL LENGTH (MI.)	22	22	19	22	22	22
NO. STATIONS	20	20	18	13	7	7
DAILY PASSENGER VOLUME	484,000*	484,000**	471,000***	484,000**	226,000*	185,000*
ANNUAL PASS. VOL. (MILLION)	146.2	146.2	142.3	146.2	68.3	55.9
FAST LINK VEHICLES	405	458	416	224	75	43
CAPITAL COST ($ MILLION)	577.8	537.7	483.2	935.7	377.0	244.9
ANNUALIZED CAP. COST ($ MILLION) (30 YRS. @ 4%)	33.4	31.1	27.9	54.1	21.8	13.2
ANNUAL O&M ($ MILLION)						
FAST LINK	17.0	23.6	20.4	76.6	25.4	14.6
FEEDER	19.0	19.0	20.0	16.9	8.5	7.4
TOTAL	36.0	42.6	40.4	93.5	33.9	22.0
TOTAL ANNUAL COST ($ MILLION)	69.4	73.7	68.3	147.6	55.7	36.2
COST/PASS. TRIP (¢)	47.5	50.4	48.0	101.0	81.6	64.8

* BASED ON MODAL-SPLIT ANALYSIS (PEEP I)

** ASSUMED PATRONAGE SAME AS FIXED GUIDEWAY

***PATRONAGE ESTIMATE BASED ON MANUAL DERIVATION

Note: All costs based on 1972 dollars.

effective. Because the waterborne system cannot penetrate the main activity centers as well as the land based concepts, it provides a lower level of service. This is reflected by the comparative patronage volumes. The high operating and maintenance costs of the hydrofoil system result in a cost per trip that is much higher than the land based systems. Accordingly, this waterborne concept was determined to be inferior to the other concepts and dropped from further analysis.

The 19- and 22-mile busway systems were analyzed using both standard 40 foot buses and a combination of standard buses and large articulated buses operating as captive vehicles on the busway. A special travel demand forecast for the system was not made for this analysis since the level of service was assumed to be nearly comparable to the fixed guideway system. Later studies in PEEP II indicated this was not precisely correct in that the fixed guideway patronage is slightly higher than the busway patronage. The location of the route and stations for the busway were essentially the same as the fixed guideway system. The operating characteristics of the busway system were found to be nearly comparable with the fixed guideway system. The busway had a slightly lower average trip speed but had the advantage of eliminating transfers for certain bus routes. However the no-transfer advantage was assumed to be offset by the greater schedule reliability and greater attractiveness of the fixed guideway system. It was therefore concluded that, although the cost and service characteristics between the busway and fixed guideway were nearly comparable, the fixed guideway had the overall advantage in terms of environmental and community factors. These factors were air pollution, noise level, visual impact, and dislocation of residents and businesses, all as fully described in the Draft Environmental Impact Statement, Honolulu Rapid Transit Preliminary Engineering Evaluation Program, September 1972, Volume 2.[29/]

Also during PEEP I, a review of the dual-mode and PRT transit systems was conducted to determine their feasibility for application in Honolulu.[30/] Two of the overriding factors against the dual-mode and PRT concepts were the unavailability of demonstrated hardware and the lack of proven operational experience; therefore they were rejected.

After completion of the PEEP I study, the City and County of Honolulu and the State of Hawaii jointly sponsored a study of an automatic rapid transit (ART) system and a review of the busway alternative study which was completed under PEEP I. The study defined and analyzed the ART operating characteristics, the network and travel characteristics, and economic and environmental factors.[31/] A comprehensive review of the previously described busway alternative analysis including review of the physical design, operating concept, and costs was conducted to determine the validity of the analysis and if any improvements could be made to the system.

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The separate study conducted for the automated rapid transit (ART) system found that it had about equal attractiveness as the fixed guideway based on the best current predictions of the system operating characteristics. The ART system analyzed consisted of over 33 miles of two-way guideway with 77 stations as compared to the 22-mile, 20 station fixed guideway system. The cost of the ART system was about 15% higher than the fixed guideway system in both capital cost and annual operation cost.

This operating cost did not include train and station attendants for the ART while the fixed guideway system did. The fixed guideway system could, if so desired, be operated without train attendants and also without station attendants as on the Lindenwold Line System in Philadelphia. If the estimates were made on the same basis relative to the attendants, the O&M cost for the fixed guideway system would be significantly lower than for the ART system.

Relative to the attractiveness of the ART system, it was concluded that under the most favorable assumptions regarding operating speed, with greater attendant risks at particularly higher speeds, the ART would have a slightly greater patronage potential than the fixed guideway only during peak periods. Based on this study, the City and State agreed to reject the ART system from further consideration.

Relative to the busway review, this joint study concluded that the cost of busway alternative could possibly be reduced with greater use of highway facilities. Accordingly, the City and State agreed to proceed with transit planning in Honolulu based on further studies of the fixed guideway and busway.

C. ALTERNATIVES SELECTED FOR DETAILED STUDY

The extensive study and re-study of transit system requirements described briefly in earlier chapters and sections of this report had produced several significant conclusions. Very briefly they may be summarized as follows:

- A greatly expanded bus system with various transportation systems management (TSM) improvements was found to be incapable of increasing the carrying capacity of the existing roadways to meet the 1995 travel demand. It was therefore concluded that an all-bus system without exclusive, grade separated facilities would not be a viable long-range alternative in Honolulu.

- The waterborne alternative was found to provide a lower level of service with attendant lower patronage volume and have a higher cost per passenger trip than the land-based alternatives and therefore rejected from further consideration as the primary transit mode for Honolulu.

- The dual-mode and PRT systems were found to be lacking in available demonstrated hardware and proven operational experience to meet Honolulu's program schedule.

- The ART system was found to have only comparable patronage potential with the fixed guideway system but with higher costs which led to the rejection of this system.

With these conclusions and with more recent developments in transit vehicle systems, particularly the resurgent interest in Light Rail Transit, three basic approaches to meeting the long-range transportation needs of Honolulu were selected for further detailed analysis in PEEP II:

- A Minimum Length (7-Mile) Busway

- A Light Rail Transit (LRT) System

- A Fixed Guideway System

These alternatives were then developed for analysis and subsequent evaluation and for each alternative, an appropriate feeder and express bus system to produce comprehensive transit coverage and service was provided.

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Each system network and operating plan were carefully structured and designed to reflect the particular attributes of the system characteristics. For example, the busway system utilizing conventional bus equipment was planned to operate both on and off the busway to minimize passenger transfers. It was also provided with passenger stations located similarly to the other systems to make it as nearly comparable as the other systems in terms of passenger convenience and accessibility. The LRT system was designed to take advantage of its capability to operate in both exclusive and non-exclusive right-of-way and with and without grade separation.

Therefore, the three systems were structured to provide maximum advantage of the unique characteristics of each and yet to be directly comparable. These systems are described briefly in this section and summary results of the systems analysis presented. Alternative systems are shown on Figures VI-1, VI-2, and VI-3 and described very briefly below. More detailed discussion of these alternatives and their analyses may be found in Appendix A to this report as well as in the report titled "Alternative Transit Concepts Analysis."[32]

1. Basic Assumptions and Design Features

   a. Transit Corridor: A single corridor served by a single route alignment and set of station locations will produce the best balance between operational, service, minimal disruption and cost factors as established in the "Long Range Transit Plan" developed during PEEP I.[25]

   b. Route and Station Locations: Various alternative rapid transit routes and station locations have been thoroughly studied as described in Chapter V. A recommended route with the most desirable station spacing and location has been identified which considered service quality, minimum community disruption, and cost. This recommended route will therefore be followed by all alternative systems specifically between Halawa and Hawaii Kai. Between Pearl City and Halawa, either the H-1 Freeway route or the Kamehameha Highway route could be considered as appropriate to a given system. Any deviations from the recommended route would penalize any particular system in terms of patronage volume, community disruption and cost.

   c. Service Levels: Comparable level of local and express bus network and service was provided for each system. The supporting feeder bus system relative to level of service and coverage are therefore basically the same for the alternative systems with the only difference occurring in the interfacing of the bus routes

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Busway Transit System

RAPID TRANSIT STATIONS

1. Keehi Lagoon
2. Kalihi
3. Iwilei
4. C.B.D.
5. Civic Center
6. Ward Avenue
7. Ala Moana
8. Waikiki
9. Date Street
10. University

● Stations
━ Busway
●●●●●● Express Bus Route

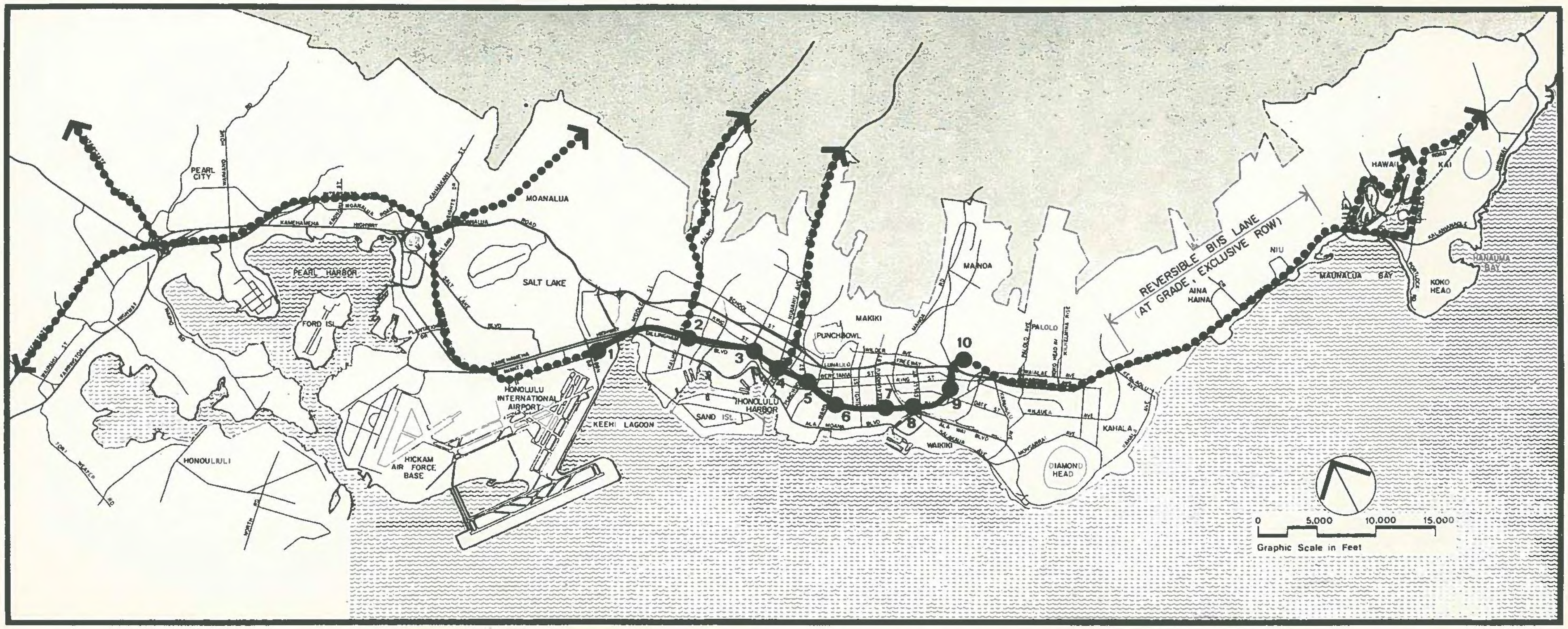

FIGURE VI-I

Light Rail Transit System

RAPID TRANSIT STATIONS

1. Pearl City
2. Waimalu
3. Pearl Ridge
4. Halawa
5. Pearl Harbor
6. Airport
7. Keehi Lagoon
8. Kalihi
9. Iwilei
10. C.B.D.
11. Civic Center
12. Ward Avenue
13. Ala Moana
14. Waikiki
15. Date Street
16. University
17. Sixth Avenue
18. Koko Head Avenue
19. Kahala
20. Waialae Iki
21. Aina Haina
22. Niu
23. Kuliouou
24. Hawaii Kai

- ● Stations
- ▬▬ Grade separated, Exclusive R.O.W.
- ■■■■■ At-Grade, Exclusive R.O.W.
- ||||||||| At-Grade in Mixed Traffic
- ●●●●●● Express Bus Route

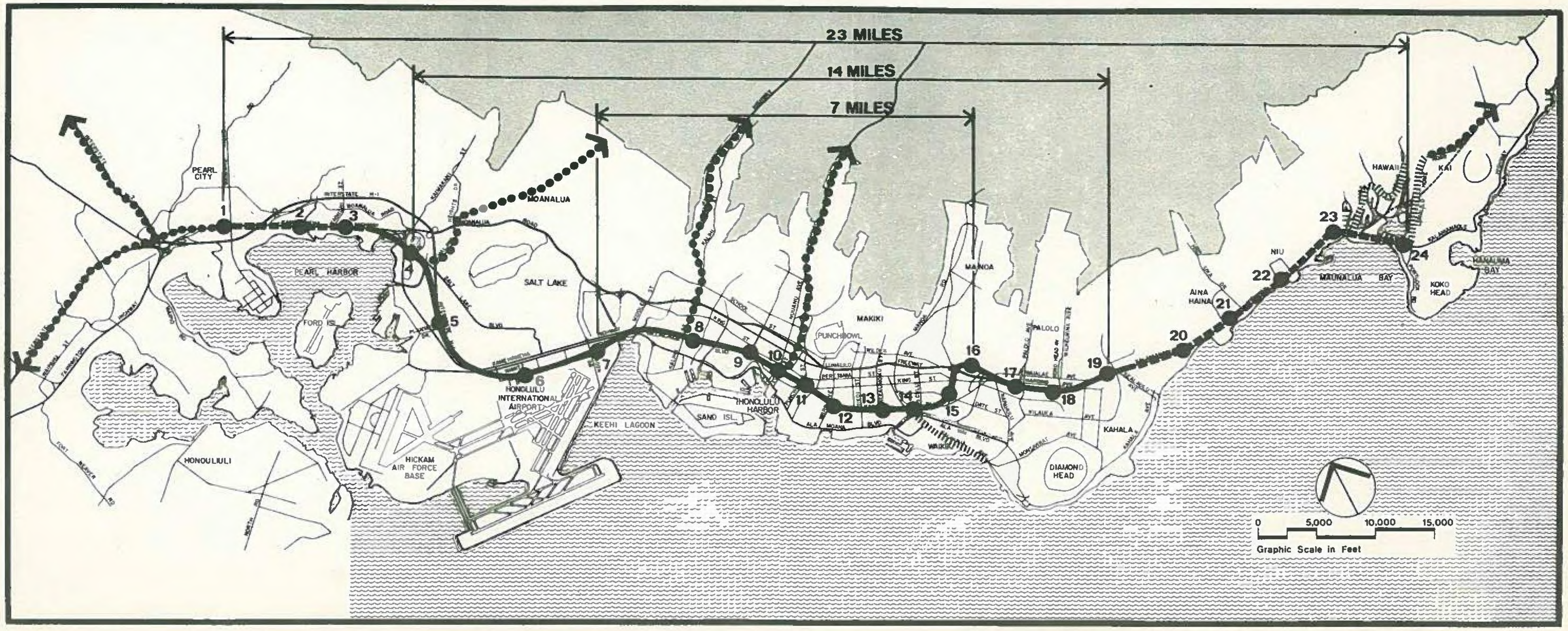

FIGURE VI-2

Fixed Guideway Transit System

RAPID TRANSIT STATIONS

1. Pearl City
2. Pearl Ridge
3. Halawa
4. Pearl Harbor
5. Airport
6. Keehi Lagoon
7. Kalihi
8. Iwilei
9. C.B.D.
10. Civic Center
11. Ward Avenue
12. Ala Moana
13. Waikiki
14. Date Street
15. University
16. Sixth Avenue
17. Koko Head Avenue
18. Kahala
19. Aina Haina
20. Niu
21. Hawaii Kai

● Stations
▬ Fixed Guideway
●●●●●● Express Bus Route

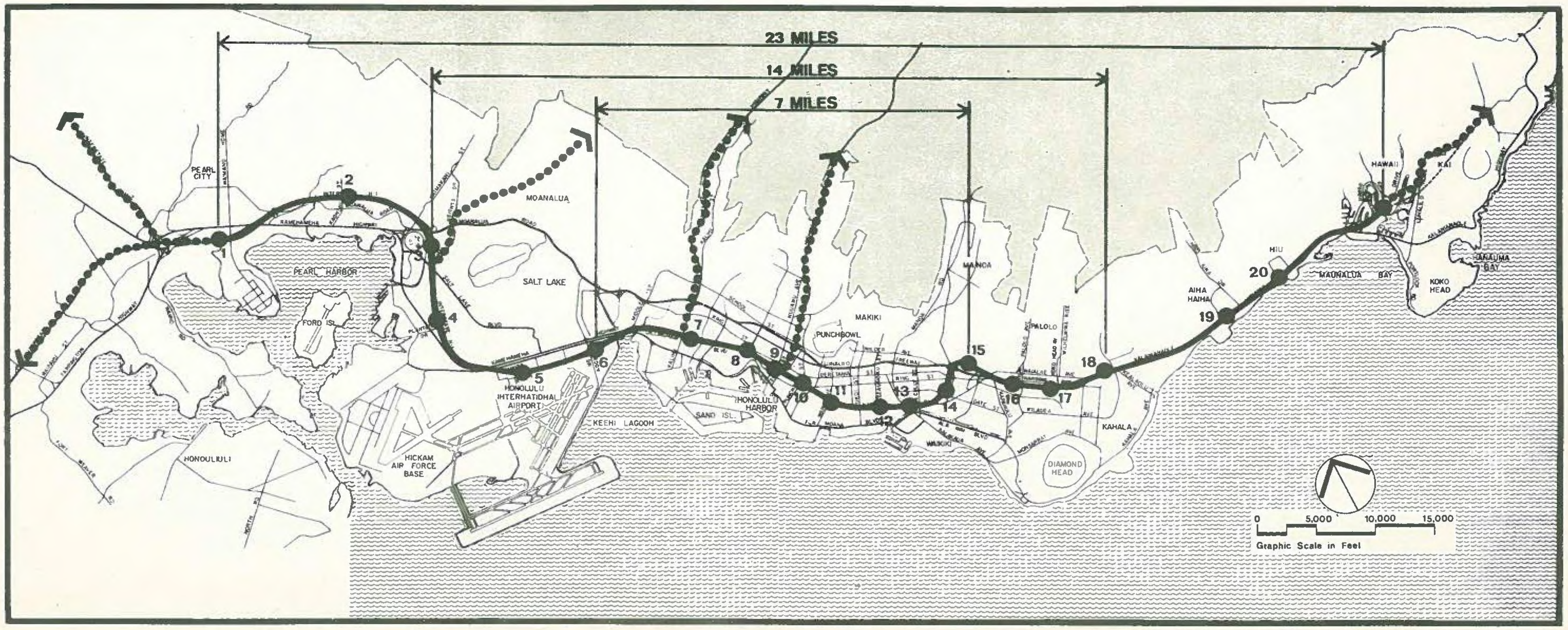

FIGURE VI-3

with the respective routes and station locations of each alternative system or system length. Similarly, all system alternatives assumed comparable frequency of service on the fixed segments.

d. Summary of Assumptions and Parameters: Basic assumptions and design features of the alternative systems and their attendant vehicles are summarized in Table VI-2.

2. <u>Systems Descriptions</u>

a. Busway: For the busway system, only a 7-mile length of exclusive, grade-separated right-of-way was analyzed. This is based on the fact that this system could utilize existing freeways beyond the 7-mile segment which would essentially be exclusive right-of-way without incurring the additional cost of building a separate busway facility. From the results of the busway system evaluation conducted in PEEP I, it was concluded that providing a longer separate busway facility is less cost effective than a shorter busway system which maximizes the use of existing freeway facilities.

b. LRT: A full 28-mile LRT system network was developed and analyzed which consisted of 14 miles of exclusive, grade separated right-of-way, 9 miles of exclusive but non-grade separated right-of-way, and 5 miles of double track route in streets operating in mixed traffic. (See Appendix B) To assure comparability, shortened alternatives were analyzed. These included a 23-mile system which eliminated the 5 miles of street operation; and the 7- and 14-mile lengths of all exclusive, grade separated right-of-way operation.

c. Fixed Guideway: The fixed guideway system, which is entirely on exclusive, grade separated right-of-way, was evaluated for 3 different lengths of 7, 14, and 23 miles. For each alternative system, the feeder bus system network was completely developed for the longest length and then those bus routes affected by the shortening of the guideway facility were appropriately modified.

3. <u>Summary Analysis of Alternative Systems</u>

After definition of the alternative systems, each was subjected to a rigorous analysis which included estimates of patronage through application of mode split models; estimates of capital cost reflecting all construction, rights-of-way, relocation, and transit vehicles and equipment; and estimates of operating costs reflecting total maintenance and operations of the system.

TABLE VI-2

SUMMARY OF DESIGN ASSUMPTIONS

Design Item	Busway	LRT	Fixed Guideway
• Route Location			
- Halawa & Hawaii Kai	Same	Same	Same
- Pearl City & Halawa	-	Kam Hwy	H-1 Fwy
• Bus Feeder System			
- Local bus coverage	Same	Same	Same
- Line haul route	Same	Same	Same
• Vehicle Operating Characteristics			
- Maximum speed	50 mph	50 mph	50 mph
- Acceleration rate	2.0 mphps	3.0 mphps	3.0 mphps
- Deceleration rate	1.5 mphps	2.6 mphps	2.6 mphps
• Frequency on Line-Haul Segment			
- Peak Hour	12 sec. *	2 min.	2 min.
- Base	40 sec. *	4 min.	4 min.
- Night	2 min. *	4 min.	4 min.

*Frequency at max. point on busway-includes local and express buses entering busway which do not stop at all stations

Design Item	Busway	LRT	Fixed Guideway
• Average Station Dwell Time	30 sec.	20 sec.	20 sec.
• Vehicle Capacity/ Area Per Passenger			
- Seated load	53	68	36
- Design Load	61/4.57 ft^2	100/4.57 ft^2	72/4.57 ft^2
- Crush Load	93/2.99 ft^2	154/2.99 ft^2	110/2.99 ft^2
• Train Length			
- Minimum	1	1	2
- Maximum	1	8*	10

*Assumes modest redesign of limiting factors will allow training more than present 4 car limit

Design Item	Busway	LRT	Fixed Guideway
• Special Features			
- On-line coupling & decoupling trained vehicles	-	Yes	No
- Vehicle operating on non-exclusive & non-grade separated Right-of-Way	Yes	Yes	No
- Short turn radius for street operation	Yes	Yes	No

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In estimating capital costs, unit prices for material and labor prevailing in Honolulu during late 1974-early 1975 were used as the basis for developing costs anticipated in 1975. A 10% contingency allowance was included for all costs and 13% applied to capital costs to cover administration and engineering. Similarly, the operating and maintenance costs were also developed in late 1974-early 1975 as shown in Table VI-3.* In addition to cost estimates, Table VI-3 presents a concise summary of selected analytical results. These and other statistics determined in the analysis are used in the evaluation of alternatives described in the next section.

*Subsequent to the development of operating costs shown in the table, a new labor agreement was reached in mid-1975 which increased labor rates and fringe benefits substantially over those projected. The net result of this new labor agreement was an increase in the operating cost by approximately 15% over those shown.

TABLE VI-3: SUMMARY OF ANALYTICAL RESULTS

SYSTEM	TRAVEL CHARACTERISTICS						OPERATING CHARACTERISTICS				COST	
	Total Daily Transit Trips	Mode Split (Total) %	Daily Trips on Gwy.	% Pk. Hr. Work Trips By Transit	Avg. Trip Length (Mi.)	Avg. Trip Time (Min.)	Vehicles Required (With Spares)		Vehicle Miles Operated Daily		Total Capital Cost ($1,000)	Annual Operating Cost ($1,000)
							Gwy.	Feeder	Gwy.	Feeder		
7-Mi. Busway	456,250	13.8	288,200	42.4	7.31	36.3	179	752	30,308	121,408	414,411	42,713
LRT												
28 Mile	474,520	14.4	358,750	44.6	7.22	32.4	410	443	79,515	71,645	712,289	41,480
23 Mile	474,520	14.4	353,700	44.6	7.21	32.3	325	477	75,530	75,910	646,537	40,313
14 Mile	473,300	14.3	306,900	44.2	7.26	33.7	198	580	45,840	94,260	529,321	38,428
7 Mile	459,300	13.9	277,300	42.8	7.19	35.2	109	774	23,580	124,605	406,808	43,355
Fixed Guideway												
23 Mile	490,000	14.8	332,600	46.0	7.50	31.6	421	493	111,495	78,390	647,900	40,861
14 Mile	473,300	14.3	306,900	44.2	7.26	33.7	264	580	64,225	94,260	517,318	38,055
7 Mile	459,300	13.9	277,300	42.8	7.19	35.2	161	774	34,335	124,605	398,676	43,294

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D. COMPARATIVE EVALUATION OF ALTERNATIVES

After the alternative systems were defined and analyzed, they were evaluated to determine the degree to which they met the transit development objectives described in Chapter II which were formulated to serve as the criteria for system selection. Since three alternative systems were selected and analyzed with two of the systems having optional lengths, the evaluation process included the following series of comparisons:

- Comparative evaluation of the short (7-mile) length of all three alternative systems.

- Comparative evaluation of the medium (14-mile) length of the LRT and fixed guideway systems.

- Comparative evaluation of the long lengths (23- and 28-mile LRT system and 23-mile fixed guideway system).

This series permits direct comparison of comparable lengths of alternative systems which provides a uniform basis for comparing alternatives as related to the qualitative objectives. However, for the cost objective, different lengths within each alternative and between alternatives can be appropriately compared.

In using the results of this comparative evaluation, one critical fact must be constantly kept in mind. That fact is simply that the detailed examination of alternatives has been made on systems which survived an iterative and recursive process of elimination using the same set of criteria and evaluation parameters throughout. The result is that systems producing wide variation or differences have already been weeded out and only subtle differences remain between systems. If this were not so, they would not have survived to the final detailed examination step.

For example, criteria related to Objective 2 - Balanced Transportation - has two measures which can be expressed in absolute terms: system patronage adequate to minimize the need for additional new highways and system capacity to accommodate that patronage level. Each system analyzed in detail was determined through prior iterations to be capable of reasonably meeting these criteria. Any others failing this test had already been dropped. Similar conditions resulted from application of the other criteria so that only the "best" alternatives remained.

That process combined with the fact that all systems evaluated represent "complete" transit systems wherein service levels and coverage are highly

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comparable, produces, as should be expected, highly comparable results. For example, as mileage of fixed guideway and LRT systems was cut back, it was replaced with express bus service and only subtle differences resulted.

In essence, any of the three remaining systems would each produce a reasonable level of transit service on Oahu. The ensuing discussion of system evaluation, therefore, is directed at identifying the best of the best and ultimate selection will hinge on a full range of considerations rather than some marked performance differences.

1. Evaluation Measures and Methodology

The basic transportation goals and objectives adopted by the area for development of transportation plans formed the basis for defining specific transit development objectives as shown in Table II-1. Complementing each specific objective is a set of standards or criteria established to use as a measure in testing and evaluating alternative systems. These criteria may be either tangible (monetary terms) or intangible. The intangible criteria may be either quantitative (absolute) or qualitative (comparative).

Patronage in Objective 2 or Travel Time in Objective 1 are absolute measures in that specific values can be determined. Rider comfort in Objective 1, on the other hand, is an example of a comparative measure since it can only be related on a better-equal-worse basis when compared to competing alternatives.

Similarly, certain absolute measures are more appropriately treated as comparatives. An example of such a measure is minimizing the displacement of residents. No desirable value can be realistically assigned and its application, therefore, must be a comparative one in which the alternative system resulting in the lowest number of displacement is deemed to best meet the criteria.

Therefore Objectives 1 through 6 containing both absolute and comparative measures are all treated as comparatives. Objective 7 related to cost is the only one that is totally tangible and will therefore be treated separately from the others.

Objectives 1 through 6 are classified as qualitative objectives with no standardized techniques available to combine all measures into a single overall measure. They also relate to a wide variety of service, community, environmental, and social factors which further complicates the synthesizing process. In order to overcome this problem, a simplified approach was used by ranking the alternatives in the order of how well they were able to meet the objective. The further ranking of objectives based on their relative importance was not done due to the highly subjective nature of this process. However, as part of the total evaluation process, a sensitivity test was made to determine if the application of varying values would have any effect on the final composite ranking of the systems.

Objective 7 which specifically relates to cost is stated as "a transportation system which will provide the greatest efficiency and service by meeting all other objectives at the lowest cost possible." Accordingly, this objective contains 3 tangible cost measures: total cost, cost per passenger trip, and benefit-cost ratio. The total cost including capital and operating costs provides a measure for total public investment required of each system. The cost per passenger trip provides a means of combining total cost with system attractiveness and usage into a single measure. The third measure involves the benefit-cost analysis which quantifies benefits and relates it to cost as a method of evaluating returns on public investment.

It is pointed out that many of the qualitative objectives and their measures are directly or indirectly reflected in the benefits computed for the benefit-cost analysis. Benefits are based on transit ridership volumes for which in turn, reflects the quality of service provided by the various alternative systems. On the cost side of the ledger, various community related measures such as consumption of land and displacements are included as part of the total cost. However, since there are various secondary benefits or costs associated with certain measures which are explicitly accounted for in the benefit-cost analysis, the separate evaluation of those qualitative objectives would not be considered as double counting.

2. Comparative Analysis of Alternative Systems

Table VI-4 shows the results of the series of comparative analysis of all alternatives as listed in the beginning portion of this section. While most of the entries in the table are self-explanatory, the following additional explanation and comments are provided to insure uniform interpretation of each objective and criteria measure.

TABLE VI-4: COMPARISON MATRIX FOR ALTERNATIVE SYSTEMS

	Short 7-Mile Length			Medium 14-Mile Length		Long 23 & 28 Mile Length		
	Busway	LRT	Fixed Guideway	LRT	Fixed Guide.	23-Mile LRT	28-Mile LRT	23-Mile F.G.
OBJECTIVE 1								
a. Availability & coverage	Same	Same	Same	Same	Same	Same	Same	Same
b. Avg. trip time (min.)	36.3	35.2	35.2	33.7	33.7	32.3	32.4	31.6
c. Service reliability	(2)	(1)	(1)	Same	Same	(2)	(2)	(1)
d. Rider convenience	(1)	(2)	(2)	Same	Same	(2)	(1)	(2)
e. Rider comfort	(2)	(1)	(1)	Same	Same	Same	Same	Same
OBJECTIVE 2								
a. System patronage (million)	137.8	138.7	138.7	142.9	142.9	143.3	143.3	148.0
b. System capacity	*	Same	Same	Same	Same	Same	Same	Same
OBJECTIVE 3								
a. Consumption of land (acres)	42	21	20	23	22	36	36	32
b. Displacement of residents (units)	233	152	148	166	162	179	179	167
c. Displacement of businesses (units)	257	168	164	187	183	194	194	184
d. Reduction of community amenities	Same	Same	Same	Same	Same	Same	Same	Same
e. Disruption to future dvlpmt.	Same	Same	Same	Same	Same	Same	Same	Same
f. Disruption to local circulation	Same	Same	Same	Same	Same	(2)	(3)	(1)
g. Disruption from constr. activities	Same	Same	Same	Same	Same	(1)	(2)	(1)
h. Savings in energy (million gal/yr.)	10.0	8.5	8.9	8.5	9.4	5.0	4.8	8.5
i. Technical risk	(3)	(1)	(2)	(1)	(2)	(1)	(1)	(2)
OBJECTIVE 4								
a. Support regional dvlpmt.	Same	Same	Same	Same	Same	Same	Same	Same
b. Support comm. dvlpmt.	Same	Same	Same	Same	Same	Same	Same	Same
OBJECTIVE 5								
a. Reduction Air pollution (tons/yr.)	2,970	3,240	3,260	4,110	4,150	4,120	4,140	4,930
b. Noise level (dBA)	86-88	77-81	77	77-81	77	77-81	77-81	77
c. Visual intrusion	(3)	(2)	(1)	(2)	(1)	(2)	(2)	(1)
d. Vistas	(2)	(3)	(1)	(2)	(1)	(1)	(1)	(2)
e. Historic sites	Same	Same	Same	Same	Same	Same	Same	Same
OBJECTIVE 6								
a. Reduce accident exposure	Same	Same	Same	Same	Same	(2)	(2)	(1)
b. Security	Same	Same	Same	Same	Same	Same	Same	Same

OBJECTIVE 7	Busway		LRT (7-Mile)		Fixed Guideway (7-Mile)		LRT (14-Mile)		Fixed Guide. (14-Mile)		23-Mile LRT		28-Mile LRT		23-Mile F.G.	
Interest Rates	4%	10%	4%	10%	4%	10%	4%	10%	4%	10%	4%	10%	4%	10%	4%	10%
a. Total annual cost ($ Million)	77.43	96.90	76.98	96.17	76.41	95.21	77.38	102.60	76.26	101.01	85.73	116.66	90.73	124.84	86.51	117.48
b. Cost per trip	56.2¢	70.3¢	55.5¢	69.3¢	55.1¢	68.6¢	54.1¢	71.8¢	53.4¢	70.7¢	59.8¢	81.4¢	63.3¢	87.1¢	58.5¢	79.4¢
c. Benefit-cost ratio	2.24	1.50	2.28	1.55	2.31	1.58	2.40	1.47	2.47	1.51	2.06	1.24	1.87	1.13	2.19	1.32

Note: Numbers in parenthesis (1) show ranking of alternatives based on how well they met the objective
*Practical capacity for busways are unknown and assumed to be less than for guided systems

Objective 1 - Improve Accessibility by serving and interconnecting existing and future urbanized areas of Oahu. This objective relates to improved transit service to all areas of the island and to all segments of its population. Criteria measures are:

- Availability and coverage relates to reasonable accessibility to transit at both ends of the trip for all residents (coverage) and to the frequency of service (availability).

- Trip time reflects the door-to-door trip time and is expressed as a system average in minutes.

- Service reliability relates to the assurance of completing a trip within a scheduled time. As such it includes vehicle reliability against in-service failure, schedule reliability against missed connections at transfer points and schedule adherence in terms of arrival and departure times.

- Rider convenience measures the perceived ease of using the vehicle and transit system. As such it includes minimum number of transfers, ease of fare collection through automatic collection rather than on-board exact fare systems, boarding and alighting ease (curb-side vs. raised platform), sheltered waiting areas, etc.

- Rider comfort recognizes the overall ride quality of the vehicle system including climate control, noise levels, vibrations, jerk rate, etc.

Objective 2 - Provide a balanced transportation system of transit and highways. This objective is directed toward offering a high quality transit service which will attract sufficient ridership to minimize the need for added highways in the urban area of Honolulu. Criteria measures are:

- System patronage expressed as the total annual patronage estimated for each system.

- System capacity reflects the ability of the transit vehicle system(s) to accommodate maximum projected patronage within prescribed loading standards at the maximum load points on the system.

Objective 3 - Minimize expenditure of resources and disruption to the community. This objective relates to the area of secondary social and economic cost as a result of consumption of or disruption to the community or its resources and amenities as differentiated from direct financial costs. Measures are:

- Consumption of land expressed as the total number of acres required for rights-of-way (excluding existing street and freeway rights-of-way) to implement the system and its ancillary facilities including stations and vehicle storage areas.

- Displacement of residents expressed as the total number of residential dwelling units taken.

- Displacement of businesses reflects total business establishments taken.

- Reduction of community amenities relates to the use of existing public facilities such as parks, etc. for other purposes supportive of the transit system.

- Disruption of future development reflects the usability of adjacent land for its intended purpose after development of the transit system.

- Disruption of local circulation reflects street closures or loss of street capacity as a result of transit system development.

- Disruption from construction activities is a measure of local impact resulting from construction activities. It includes such factors as traffic disruption, dust and noise, reduced access to street frontage, etc. These impacts are short-term impacts applicable only during construction periods.

- Savings in Energy Consumption reflects the net savings in energy used resulting from savings by diverted motorists less that consumed by the transit system itself expressed in millions of gallons of fuel.

- Technical risk is a function of the degree to which any combination of vehicle system and operating concept may assure workability.

Objective 4 - Support land use and development policy. This objective relates to the development of a transit system which can aid in directing growth and development as desired and expressed through stated policies. Its measures are:

- Support regional development is a reflection of the extent to which deployment of a particular transit system supports overall regional planning.

- Support community development is a measure of the same factors at the neighborhood or community level such as around a station or within an identifiable community such as Moiliili.

Objective 5 - Preserve environment. This objective relates to the preservation or enhancement of Oahu's unique environment. Its measures are:

- Reduction in Air Pollution reflects the net reduction which results from diverted motorists who use transit less the air pollution contributed by the transit system itself expressed in tons of total pollutants.

- Noise level indicates the amount of noise produced by the transit vehicle system(s) expressed in decibels (dbA) produced at operating speeds 50 feet from the vehicle.

- Visual intrusion reflects the size or mass of the transit structures or the visual "clutter" that results from their introduction into the existing vistas. It assumes that all structures would be carefully and sensitively designed for harmony with surrounding developments to minimize intrusion.

- Preservation of vistas is a function of the vertical alignment and the mass of the transit structures with respect to blocking existing views.

- Preservation of historic and scenic sites is a function of route location with respect to identified historic or scenic places.

Objective 6 - Safety. This objective relates to the safety of the transit user with respect to on-board accidents, boarding and alighting accidents, etc. and to non-users in terms of conflict with the transit vehicle either as a pedestrian or motorist. Its measures are:

- Reduce accident exposure reflects primarily the exclusivity of the transit rights-of-way but also includes operational characteristics such as jerk rate which could produce falls on-board by standing passengers.

- Security reflects the personal well-being of the transit patron while riding on or waiting for the transit vehicle.

Objective 7 - Provide the most economical system which best meets all other objectives. This objective deals with the overall cost effectiveness and financial demands of the system. Its measures are:

- Total annual cost which includes total capital, operating and maintenance costs associated with building and operating the system expressed in total annual costs. Operating costs were based on the 1995 system operations and reflected full operation and maintenance of vehicles and transit facilities. Capital costs were annualized over a 30 year period at interest rates of 4% and 10% to determine if different rates would influence the relative ranking of the alternatives.* Since there are many common elements of cost in the alternatives, costs were developed on a comparative basis to obtain the highest degree of uniformity in costs between alternatives. (See Appendix A.)

- Cost per trip is a measure of cost effectiveness relating total annual cost to patronage.

- Benefit-cost ratio is a measure of economic effectiveness of the alternatives in terms of public benefits accruing from expenditure of public funds. Benefits used in this analysis reflected only user and non-user travel benefits to present a conservative measure and to avoid inclusion of simple transfer benefits. A detailed description of assumptions and methodology used in calculating the benefits are presented in Appendix C.

3. Comparative Evaluation and Selection Process

The final selection of a recommended system from among the alternatives is predicated on the overall ability of each system to meet the specific transit development objectives. As the first step in the system selection process, a comparative evaluation was made according to the extent each system met each criteria. Where numerical terms were developed, the ranking was readily determined based on a simple comparison of the numerical values. Where only qualitative terms were applicable, the alternative systems were ranked based

*It should be noted that the various interest rates did not alter the relative ranking between system alternatives. However, within the LRT and fixed guideway systems the lowest cost per passenger value shifted from the 14-mile system to the 7-mile at the 10% interest level reflecting the impact of higher construction cost.

on a relative comparison of how well the criteria was met as was fully described in the previous section.

Examination of the comparative analysis table bears out the earlier statement that few if any compelling differences are evident between alternatives for any individual criterion or objective. However, taken as a whole, the set of objectives and criteria demonstrate a clear and consistent pattern of superiority of the fixed guideway alternatives. Table VI-5 presents a summary of the rankings for each comparative analysis and illustrates this superiority.

By examination, it can be readily seen that the fixed guideway alternative received by a wide margin more top rankings than the other alternatives. Accordingly, any assignment of reasonable values to the objectives based on the relative importance would not change the ranked order of the alternatives.

TABLE VI-5: SUMMARY OF RANKINGS

	7-Mile Bus.	7-Mile LRT	7-Mile FG	14-Mile LRT	14-Mile FG	23 Mi. LRT	28 Mi. LRT	23 Mi. FG
OBJECTIVE 1								
a. Availability & coverage	-	-	-	-	-	-	-	-
b. Avg. trip time (min.)	2	1	1	-	-	2	3	1
c. Service reliability	2	1	1	-	-	2	2	1
d. Rider convenience (transfers per trip)	1	2	2	-	-	2	1	2
e. Rider comfort	2	1	1	-	-	-	-	-
OBJECTIVE 2								
a. System patronage	2	1	1	-	-	2	2	1
b. System capacity	2	1	1	-	-	-	-	-
OBJECTIVE 3								
a. Consumption of land (acres)	3	2	1	2	1	2	2	1
b. Displacement of residents (units)	3	2	1	2	1	2	2	1
c. Displacement of businesses (units)	3	2	1	2	1	2	2	1
d. Reduction of community amenities	-	-	-	-	-	-	-	-
e. Disruption to future dvlpmt.	-	-	-	-	-	-	-	-
f. Disruption to local circulation	-	-	-	-	-	2	3	1
g. Disruption from constr. activities	-	-	-	-	-	1	2	1
h. Savings in energy (million gal/yr.)	1	3	2	2	1	2	3	1
i. Technical risk	3	1	2	1	2	1	1	2
OBJECTIVE 4								
a. Support regional dvlpmt.	-	-	-	-	-	-	-	-
b. Support comm. dvlpmt.	-	-	-	-	-	-	-	-
OBJECTIVE 5								
a. Reduction Air pollution (tons/yr.)	3	2	1	2	1	3	2	1
b. Noise level (dBA)	3	2	1	2	1	2	2	1
c. Visual intrusion	3	2	1	2	1	2	2	1
d. Vistas	2	3	1	2	1	1	1	2
e. Historic sites	-	-	-	-	-	-	-	-
OBJECTIVE 6								
a. Reduce accident exposure	-	-	-	-	-	2	2	1
b. Security	-	-	-	-	-	-	-	-
OBJECTIVE 7								
a. Total annual cost	3	2	1	2	1	1	3	2
b. Cost per trip	3	2	1	2	1	2	3	1
c. Benefit-cost ratio	3	2	1	2	1	2	3	1
No. of Firsts	2	6	15	1	11	4	3	15
No. of Seconds	6	10	3	11	1	14	10	4
No. of Thirds	10	2	0	0	0	1	6	0

E. SUMMARY OF FINDINGS AND CONCLUSIONS

The results of the comparative evaluation of the alternative systems presented herein formed the basis for selecting and recommending a system for implementation. Although the evaluation and selection procedure was previously discussed in detail, it is worth summarizing some of the key factors which led to the selection of the recommended system.

1. Busway Conclusions

The busway system, although reasonably meeting all objectives, provided the least relative compliance with the various objectives of all alternative systems evaluated. The busway system utilizing individually driven vehicles powered by internal combustion engines has inherent disadvantages in providing quality service, minimizing community disruptions, and reducing environmental impacts comparable to the electrically propelled and trainable vehicles of the guided systems.

In addition, the busway system provides no cost advantage over the guided systems at the patronage levels projected for Honolulu. In fact the 7-mile busway system has a higher operating and maintenance cost per passenger carried than the guided systems reflecting the labor intense feature of bus operation which will also be more susceptible to labor rate escalation than the guided systems. In summary, the busway system is found to be generally inferior to the guided systems in terms of service, community disruption, preservation of the environment, cost effectiveness, and probable limitations in capacity and therefore should be dropped from consideration.

2. LRT vs. Fixed Guideway Conclusions

Based on the results of the comparative evaluation, the LRT and fixed guideway systems were both judged to adequately meet the basic requirements of overall system attractiveness and desired system capacity together with various other qualitative objectives. A review of the comparative values, given in numerical and qualitative terms, applied to the measures identified with various objectives, indicates only a slight difference between the two systems. However, the fixed guideway system shows a definite superiority, however slight for each measure, in terms of the number of measures in which it ranked higher than the LRT system. This superiority is reflected in nearly all objectives related to service, community disruption, and preservation of the environment.

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Relative to the cost objective, for comparable lengths with all grade separated routes, the total capital and operating costs are essentially the same. In comparing the 23-mile length system, the LRT with partial grade separated routes has a slightly lower total capital and operating cost than the fixed guideway system. However, because of its slightly lower system operating speed resulting from the at-grade service in Kalanianaole and Kamehameha Highway medians, the LRT attracts less passengers which then results in a slightly higher cost per passenger carried. The longer 28-mile LRT system was found to have both higher total cost and higher unit cost per passenger carried than the 23-mile fixed guideway system.

From the results of this comparative evaluation, the 2 guided systems were found not to differ significantly relative to the various measures used. Since the two systems have similar performance characteristics, they are rated as having equal service quality capabilities. The primary difference is in the physical characteristics of the vehicles. The LRT vehicles being larger and heavier, requires larger aerial guideway structures. Where partial grade separated routes are considered for the LRT system, the requirement for overhead trolley wires increases the visual intrusion. With the guideway structure proposed to be preponderantly in aerial configuration through the urban Honolulu core, the above features are considered to be a critical factor in this environmentally sensitive area.

One additional factor of importance which was not included as one of the comparative measures is the grade climbing capability of the systems. Sustained grades of 5% to 6% are encountered in the Kaimuki area and any future crossing of the Koolau Range would also require a grade of approximately 6%. Although the steel wheeled LRT system can negotiate these grades, they would require the systems to be operated at slower rates of acceleration and deceleration and lower operating speeds than the fixed guideway system thus resulting in reduced quality of service and higher capital and operating costs.

In summary, the fixed guideway system is concluded to possess those essential qualities to best meet the overall objectives defined for transit development. Although the advantage shown for any single measure may be slight, they collectively indicate the overall superiority of the fixed guideway as the long-range transit system for the area and combine to produce a recommendation for adoption of a 23-mile fixed guideway system.

3. System Staging Potential

As part of the development of the alternative systems, the potential of each system for staged development was analyzed by considering several different lengths for implementation. A further examination was made of staged development by initially beginning with a lower level of service which could be upgraded at a later date to a higher level system. An example of this would be to provide an at-grade LRT system located in existing streets or other available rights-of-way which would require a lower capital investment as compared to a fully grade separated LRT system.

A review of this potential for staged development using the LRT system was found to be difficult due to the lack of suitable streets or other available ROW for locating the tracks of the LRT system. This is especially true in the downtown area where the travel demand is the greatest but where transportation facilities are most lacking. In Honolulu, the critical need is in the urban core area where it has been determined that a full grade separated, high level system is critically needed to meet the forecasted demand. Due to the unavailability of suitable rights-of-way and the immediate need for a high level service, the provision of an at-grade LRT system as the initial staged development would be economically unsound. (See Appendix B)

In those instances where initial construction of a grade separated transit system cannot be justified by demand volume in the near-term or even prior to 1995, it will be extremely difficult to justify the construction cost associated with at-grade trackage compared to bus service. While the capital cost is substantially less than for a grade separated facility, it is also substantially above that necessary to operate conventional buses on a preferential treatment basis. At the same time, the capacity of the LRT in this mode of operation is limited by train length (probably 2-car maximum) due to an at-grade crossing of intersecting streets. It is also restricted in speed by safety considerations at these same at-grade crossings.

Under these conditions, the continued use of buses on corridors or routes, other than the primary east-west corridor in the urban core would be the most cost effective form of transit service until a higher level system can be justified. With buses utilizing existing streets and highways and with plans underway to provide more reserved bus lanes, the bus system cannot be surpassed by any form of an at-grade system as the interim or short-range transit solution for Honolulu.

As a result, it is concluded that no advantage can be assigned to either LRT or fixed guideway systems from a staging viewpoint. Either system can reasonably be staged to meet Honolulu requirements. Therefore, staging is not a factor in ultimate system selection and the previously discussed conclusion to select the fixed guideway holds.

4. Vehicle Conclusions

In the evaluation of alternative systems, the vehicle system assumed for the fixed guideway alternative was a medium capacity, rubber-tired vehicle. In concluding upon a recommendation for fixed guideway, the issue that requires discussion pertains to the type of wheels - rubber tire versus steel. Based on studies conducted during the course of the program, it was found that the conventional heavy rail, steel wheel system and the medium capacity, rubber-tired system were quite similar in many respects.

Basically, a fully grade separated LRT system has essentially the same physical and operating characteristic as the heavy rail system. Other than for the difference in the car design and the location of the propulsion power system, i.e. third rail versus overhead trolley wire, these two systems can be designed to provide similar operating characteristics as well as fixed facilities including guideway and station structures. The comparative evaluation presented in this chapter between the LRT and the fixed guideway systems would be applicable as well to a comparison between heavy rail and fixed guideway.

As mentioned repeatedly in this chapter, the real difference between the LRT and fixed guideway is quite small when each individual measure is examined separately. Even in the cost measures, the difference is relatively small with the final conclusion and recommendation based on that fact that the fixed guideway can better meet more of the measures, however slight the difference may be for each measure, as specifically applied to the Honolulu condition and environment.

Although all U.S. systems have eventually decided upon steel wheel systems, the completion of new rubber-tired systems in Montreal, Mexico City and Sapporo (Japan), and in airports in Tampa, Seattle-Tacoma, and Dallas-Fort Worth, has provided the industry with sufficient design and operating experience in recent years to lead us to the conclusion that a rubber-tired system can be designed and built for Honolulu.[33/] While not entirely without risk with any new system, the knowledge and experience gained from these rubber-tired vehicle systems and those proven automatic train control systems used by both rubber-tired and steel wheel vehicle systems, the overall risk is minimized.

The selection of a medium capacity, rubber-tired vehicle system is supported by a number of considerations unique to Honolulu.

a. The need for quiet operation: Housing in Honolulu commonly involves "open window" construction with natural air conditioning provided by the trade winds. Additionally, high land costs have resulted in very high densities in the corridor which the system will traverse. Because the system will, for the most part, be built within existing major streets and highways, the noise produced by rubber-tired vehicles will be very similar to the ambient noise within the corridor. The alignment of the system, selected to minimize relocations in a "land short" island includes curve radii which would result in flange noise from steel-on-steel operation, a sound unknown on Oahu today and distinctly different from the ambient noise in the corridor.

b. The need for grade climbing capability: The terrain in the corridor involves negotiating sustained grades of five per cent which could only be avoided by tunneling, heavy grading, or high trestling. With almost daily rainfall, the suitability of steel-on-steel for such operations would entail operations at lower acceleration and deceleration rates and operating speeds whereby schedule reliability and minimum headway would not be at the same level as the rubber-tired vehicle system. Grades of 8% for short distances to achieve vertical alignment transition from subway to aerial guideway are required to minimize dislocation and community disruption. Moreover, if the system is ultimately extended across the Koolau Mountains to Kailua and Kaneohe, sustained grades of six per cent under wet track conditions will be required. Thus the rubber-tired vehicle was prefered for this reason as well.

c. The need for light weight vehicles: The size of the vehicle was based on the patronage estimates which indicated that peak demand of approximately 20,000 persons per hour in one direction by 1995 would require a medium-capacity system. With vehicles of this size, lighter weight aerial structures to minimize visual intrusion, can be used for the guideway. Additionally, existing highway structures can accommodate this vehicle weight without major modification and attendant cost as would be required with steel wheel systems.

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d. Compatibility of systems not a factor: There are no existing or planned steel rail systems on Oahu so that there is little or no likelihood that compatibility of systems will become an issue as it has in some Mainland cities and in many foreign countries where commuter rail systems could become parts of an expanded system.

e. Community acceptance: Public sentiment repeatedly expressed is overwhelmingly in favor of a rubber-tired system, principally because of the nature of the sound such a system would create as contrasted with a steel-on-steel system.

F. RECOMMENDATION FOR VEHICLE SYSTEM SELECTION

The findings and conclusions resulting from the evaluation of alternative systems indicated that both the light rail and fixed guideway transit systems would adequately meet the basic requirements for Honolulu. However, through this comprehensive evaluation process, it was found that the fixed guideway system would provide certain features which are more compatible with and hence more desirable for the unique environment of Honolulu. As part of this evaluation process, citizen and community participation and input were solicited and received and they are reflected in the results of the evaluation.

Based on the results of the very comprehensive evaluation conducted on the various alternative systems, the medium size, rubber tired fixed guideway system is recommended for Honolulu. Some of the primary issues which support this recommendation may be summarized as follows:

1. In order to properly and directly serve the highly developed urban Honolulu area in the most economical manner, only limited use of underground or subway configuration is proposed. Most of the system is proposed to be above ground on aerial structures in order to maintain the system cost at an affordable level for the island.

2. The aerial guideway route locations were carefully selected with full community participation and support for minimizing dislocation of residents and businesses and adverse impacts on the environment. The requirements were to provide aerial structures that are unobtrusive and a vehicle system that would cause minimum noise and vibration intrusions to the community.

3. The horizontal and vertical alignments selected for the guideway requires grades of up to 8% for transition between underground and aerial configurations in order to minimize dislocation of residents and businesses. The use of lower grades would require modifications to the alignments which would result in higher cost as well as greater number of business dislocation.

4. In one segment of the system route, a sustained grade of over 5% is required using the above ground configuration. If this grade must be reduced, a change in either horizontal or vertical alignment would be necessary affecting both cost and relocation requirements.

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5. If segments of the system route with proposed aerial guideway configuration are found not to be acceptable to the local community due to larger structures and higher noise levels, more of the system route may be required to be placed underground with resulting higher cost which may place the project beyond the financial capabilities of the island.

The conclusion reached on the vehicle system is the result of a very thorough and comprehensive evaluation of social, economic, and environmental considerations conducted with assistance from various community groups. Therefore, it is recommended that the medium size, rubber tired fixed guideway vehicle system be selected as best meeting the needs and desires of the island.

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CHAPTER VII

NEAR-TERM ALTERNATIVE SYSTEMS EVALUATION

A. GENERAL

Previous chapters have discussed long-range transportation needs and solutions and include the evaluation of alternative systems to meet these needs with the conclusion reached that a grade separated, high capacity transportation facility was justified. A fixed guideway rapid transit system was determined to best meet the long-range needs of the island.

This chapter will present the near-term evaluation of alternative solutions including the baseline bus and transportation systems management (TSM) alternatives. A study period of 1985 to 1990 was selected as the basis for conducting an evaluation of two basic types of alternative solutions - the low capital intensive systems (baseline bus and TSM) and the high capital intensive systems consisting of various grade-separated systems.

The previous chapter presented a detailed evaluation of various forms of grade-separated rapid transit systems. The findings and conclusions were that a fixed guideway system was the most cost-effective solution and supported by a favorable benefit-cost ratio on a long-term basis. Since this chapter will deal with those same high capital intensive systems but on a near-term basis, the fixed guideway alternative which was found to be superior to other alternatives will be used in this evaluation.

The objectives of this evaluation is to determine to what extent low capital intensive improvements can meet future transportation needs and at what point in time should major capital investment be made for additional new transportation facilities. As mentioned above, a study period of 1985 to 1990 was selected with the earlier date established as a reasonable lead time to implement a major capital cost facility if it is needed.

B. EXISTING AND PLANNED SHORT-RANGE TRANSPORTATION SYSTEMS

1. Existing Street and Highway System

As in most larger urban areas, the street and highway system in the urban core near the central business district or downtown area is the most critical in terms of providing adequate capacity to meet current and future travel demands. In Honolulu, the highly urbanized area lying between Pearl Harbor and Diamond Head generates and attracts most of the trips on the island. Because this area is sandwiched between the ocean and the Koolau Mountain Range, urban Honolulu has developed into a true linear city of only a mile to one and one-half miles in width. Within this narrow width, the major east-west travel movement is served by a single 6-lane interstate freeway and 4 principal urban arterials which are fed by a network of minor local streets.

Because of the dense developments existing in the area, both the State and City have agreed that this area cannot tolerate a new major highway facility. The disruption to the communities and the adverse environmental impacts of an additional highway facility would be unacceptable to the residents of the area. Accordingly, improved transportation systems management programs have been and are continually being instituted as previously described in Chapter IV. By aggressively instituting a variety of systems management programs, the area has been able to improve both capacity and efficiency of existing facilities. Although new improvements are continually being implemented, the opportunity for new improvements which will significantly improve traffic conditions are diminishing. Therefore, the purpose of this analysis is to determine the extent of additional low-capital intensive improvements and when some form of major new facility will be required to meet the growing travel demand.

2. Existing Bus System

With the recent addition of some 80 new buses, the City's bus fleet now totals 350 relatively late model coaches. The City has also started on the development of two new bus yard and maintenance facilities capable of accommodating up to a total of 500 buses when completed.

The City has an enviable record of a highly successful and efficient bus operation. For FY 74-75, approximately 45 million trips were made on the City's transit system consisting of a fleet of less than 280 buses. It is estimated that over 50 million transit trips will be made during FY 75-76 due to the increase in the fleet size.

3. Short-Range Bus Improvement Program

The City's recently completed study entitled, Short-Range Bus Plan for Oahu (1976 - 1981 inclusive), outlines the future plans, implementation program, and cost of the Honolulu bus system for the six year period. It serves as the most recent document for implementing the short-range transit improvement program in Honolulu.

The plan consists of several phases to be implemented during the six-year period. The first phase involves the expansion and modernization of the fleet in 1976 to a total of 350 vehicles. The second phase will occur with the expansion of the bus fleet to 400 vehicles in 1978. The third phase will begin with the expected opening of the fixed guideway rapid transit system in the early 1980's.

In addition to the modernization and expansion of the bus fleet, various other complementary improvements are also planned as follows:

- New bus routes and revisions to existing routes.
- The establishment of new preventative maintenance and bus parking facilities at the present Honolulu Division.
- Improvement of bus stops including benches, shelters, and signs.
- Provisions for reserved-lane bus service on major highways.
- Special electronic equipment to monitor and improve bus service.
- Provision for park-and-ride facilities in suburban areas.
- A positive marketing program to disseminate route and schedule information to the public.

4. Baseline Bus System

A baseline bus system for 1980 was defined and used as the null alternative in the comparative analysis of alternative systems. Based on the current short-range program which calls for the expansion of the bus fleet to some 400 buses in 1978, a fleet of 450 buses was established as being appropriate to provide transit service in 1980, comparable to that existing today. It was further estimated that some 65 million trips would be accommodated on the baseline system.

It was assumed that the baseline system would be comparable to the Phase One operating plan under the City's Short-Range Bus Program. Since the Phase Two plan reflects certain modifications of the current operating plan in anticipation of the fixed guideway system, the Phase One plan was deemed to be more appropriate as the basis for the baseline system.

The baseline system would then be the continuation of today's bus operations but with an increased fleet size, and hence service, to meet future transit demands based on increasing population and total travel on this island up to 1980. Currently, the total transit trip volume represents slightly less than 8% of the total person trips made on the island. The estimated 65 million transit trips of the baseline system would represent slightly over 9% of the total projected person trips made on the island in 1980. This small increase in transit diversion in 1980 reflects the slightly better service provided by the increase in fleet size over that existing today.

This baseline system was used both as the null alternative in measuring benefits of various alternative systems considered and as one of the low capital intensive alternatives evaluated in this study. For the latter evaluation, the baseline bus system was maintained at a fleet of 450 buses based on the assumption that this would provide the maximum number of peak hour buses that could be accommodated in the downtown streets without making major capital improvements to the street and highway system.

It should be pointed out that the main constraint to any expansion of the baseline bus system is the street capacity in the downtown area which assumes the use of curb lanes in mixed traffic. If greater number of buses were to be operated, it would tie-up two lanes of the street and thus reduce the available roadway capacity remaining for automobiles. This condition would not permit the maximum utilization of existing roadway capacity and therefore the limitation of the bus fleet to 450 vehicles.

C. THE TSM ALTERNATIVE PLAN

1. General

The TSM alternative plan is based upon maximizing the use of existing street and highway facilities for both automobiles and transit. The transit system under this plan would be an all-bus system with expanded and improved service to be provided without large capital investments. The bus transit system would therefore be structured to utilize existing facilities through various transportation systems management techniques and methods.

As previously described, urban Honolulu is served by only a few major streets and highways which are currently operating at or near capacity. Various systems management programs have already been instituted and with great success in obtaining both improved capacity and efficiency. The objective of this plan is to further improve the carrying capacity of the existing facilities through greater utilization of transit combined with additional improvements for private automobiles.

The bus transit plan must therefore provide a fine balance relative to the joint use of the street facilities by both buses and automobiles. An unbalanced system that improves the transit system at the expense of the automobiles whereby the overall system capacity is reduced would not serve the basic objective of this plan. Accordingly, a transit plan that maximizes the use of the assigned facilities was assumed.

2. Bus System Network and Patronage Estimate

Honolulu has well established existing bus routes that have and are providing excellent service to the communities it serves as proven by the large patronage volume. Under the TSM alternative, a comparable bus network was defined and supplemented with expanded service in new areas with growth potential. Various outlying suburban areas currently served by limited express service was reinforced with increased service by providing additional buses. Express bus routes currently operating in mixed traffic were carefully reviewed for operation in reserved or contra-flow lanes to improve trip time. Local services in congested urban core areas were also carefully studied and provided with reserved normal flow or contra-flow lanes to improve on operating speeds and therefore, level of service.

A complete bus system network was defined for modal split analysis.

A system that would attract approximately 70 million passenger trips annually and requiring a fleet of some 500 buses in 1980 resulted from this analysis. In 1995, it was estimated that some 110 million passenger trips annually could be attracted, with over 900 buses required to accommodate this demand.

The bus system would consist of 40 routes served by local buses and cover approximately 465 route miles. Another 14 routes covering some 240 route miles would be served by express buses. Table VII-1 gives a list of all local and express bus routes and the total number of vehicles required to accommodate the projected passenger volume for 1980 and 1995. The 1985 and 1990 bus requirements were obtained by interpolating the 1980 and 1995 data.

It should be pointed out that the primary constraint in operating the TSM bus system occurs in the downtown area where only a limited number of streets are available for bus routes. In areas outside the downtown area, it is assumed that various forms of TSM improvements would be made to improve bus service including the use of reserved or exclusive bus lanes on highways. In Honolulu, the primary problem is not in the line haul operations from the suburban or outlying areas, but in the collection-distribution operations in the downtown area. Therefore, the remaining portion of this chapter will be addressed to the TSM operations in the downtown area.

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TABLE VII-1

EXPANDED BUS SYSTEM
ROUTE DESCRIPTION AND NUMBER OF VEHICLES REQUIRED

ROUTE NO.	ROUTE DESCRIPTION	MAX. VEH. REQUIRED 1980	MAX. VEH. REQUIRED 1995
LOCAL BUSES:			
1	LUNALILO HOME ROAD-UMI LOOP	6.0	9.0
2	HAHAIONE VALLEY-UMI LOOP	8.5	11.8
3	AINA HAINA-UMI LOOP	6.4	9.3
4	KAHALA MALL-UMI LOOP	16.9	24.3
5	KAPAHULU-LILIHA	17.9	33.8
6	KAPIOLANI-MIDDLE STREET	27.4	50.8
7	KAHALA MALL-AALA	13.9	19.7
8	AALA-NAVY SUPPLY	0.6	0.8
9	NAVY DISPENSARY-AALA	7.8	9.7
10	NUUANU-PUNAHOU-WAIKIKI	37.6	76.4
12	MANOA-WAIKIKI	6.2	8.9
13	WOODLAWN-PAUOA	9.0	13.7
14	KALIHI SHUTTLE	5.2	8.3
15	WAIKIKI-HICKAM	17.7	37.5
16	WAIKIKI-CBD	10.4	19.2
17	PALOLO-AALA	17.4	25.2
18	KALIHI (KAM IV)- ALEWA	1.9	2.0
19	FOSTER VILLAGE-UMI LOOP	6.2	11.3
20	TRIPLER TO UMI LOOP	1.5	1.9
21	ST. LOUIS-MAUNALANI	7.1	9.1
24	PACIFIC HGTS.-AMC	2.7	3.2
25	AIEA HGTS.-AMC	6.0	9.7
26	PACIFIC PALISADES	4.5	7.3
27	CBD-HIC SHUTTLE	0.4	0.4
30	RED HILL-UMI	0	0
32	PEARL CITY	5.9	8.3
33	WAIPAHU	4.5	7.8
34	MAKAHA-NANAKULI-AMC	4.8	8.3
35	IROQUOIS POINT-WAIPAHU-CBD-AMC	11.5	18.4
36	WAIMANALO-KEOLU-KAILUA-CBD-AMC	5.5	11.0
37	WINDWARD COMM. COLL.-KAILUA-CBD-AMC	0.6	0.6
38	LANIKAI-KAILUA	1.3	2.0
39	CIRCLE ISLAND	11.7	35.8
40	CIRCLE ISLAND	9.5	16.1
41	LUALUALEI HMSTD-LUALUALEI NAVAL BASE	0.2	0.3
42	MAKAHA-WAIANAE VALLEY	1.1	1.5
43	MAKAKILO-CAMPBELL SHUTTLE	1.1	4.8
44	MAKAKILO-BARBER'S PT-EWA-WAIPAHU	3.0	4.9
46	WAHIAWA HTS.-GLEN AVENUE	1.3	1.6
49	UMI-CBD (Continuation of Lines 1, 2, 3)	0.9	1.1
	Total	302.1	525.8

ROUTE NO.	ROUTE DESCRIPTION	MAX. VEH. REQUIRED 1980	MAX. VEH. REQUIRED 1995
EXPRESS BUSES:			
1	MAKAHA-MAILI-CBD	13.4	27.5
2	MAILI-NANAKULI-CBD	9.0	14.0
3	MAKAKILO-CBD	3.4	13.0
4	MILILANI-CBD	2.9	7.8
5	WAHIAWA-CBD	12.0	15.4
7	WAIMANALO-CBD	7.4	23.1
8	KANEOHE-KALHI	18.8	25.8
9	KAILUA-CBD	15.1	26.0
11	KAHALUU-KALIHI-CBD	18.8	36.4
13	HEEIA-KALIHI-CBD	20.4	33.7
15	LUNALILO HOME ROAD-CBD	1.9	3.6
16	HAWAII KAI DRIVE-UH	5.9	19.8
17	HAWAII KAI DRIVE-CBD	15.1	46.5
18	PEARL CITY-CBD	7.1	12.6
	Total	151.2	305.2

TOTAL FLEET REQUIREMENTS

	1980	1985	1990	1995
Feeder Buses	302	377	452	526
Express Buses	151	202	253	305
Total	453	579	705	831
10% Spares	45	58	71	83
Total Fleet	498	637	776	914

3. Bus Operating Plan

In operating the bus system, the critical area was determined to be in central Honolulu and more specifically the CBD-Civic Center area. Nearly one-half of all local bus routes, or a total of 18 routes, directly serve the CBD-Civic Center area in the east-west direction and 13 of the 14 express bus routes also serve the CBD-Civic Center area from both north-south and east-west directions as shown in Figures VII-1 and VII-2. Table VII-2 shows the number of buses operating during peak hour on major bus routes at various critical locations in and near the central Honolulu area.

The three critical locations, due to the large number of local buses in 1985, are as follows:

- On Hotel Street at Fort Street Mall - 137 buses per hour
- On King and Beretania Streets at Punchbowl Street - 111 buses per hour
- On King and Beretania Streets at Ward Avenue - 75 buses per hour

A total of 166 express buses per hour will be routed into the CBD-Civic Center area from the north. Since this volume is too large to be accommodated on one street, they are divided between two north-south streets, Bishop Street and Nuuanu Avenue. The number of local and express buses required to operate in downtown Honolulu are sufficiently large to require careful and detailed analysis of street patterns and capacities which follows.

The two primary east-west streets serving the CBD-Civic Center area are King Street and Beretania Street both one-way streets and together forming a one-way couplet. In the CBD-Civic Center area, both King Street and Beretania Street has a maximum of 6 lanes either existing or planned. For purposes of this analysis, it was assumed that all planned street widenings along King and Beretania Streets would be constructed and the planned number of lanes available.

Currently the buses serve the Civic Center area on Beretania Street and King Street and the CBD on Hotel Street which is a 2-way street. Hotel Street is master-planned to be converted into a pedestrian mall by eliminating all forms of vehicular traffic including buses. However for purposes of this analysis, it is assumed that Hotel Street could be used as a restricted bus street by modifying it to have a 24-ft. roadway

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TABLE VII-2

BUSES PER PEAK HOUR IN DOWNTOWN HONOLULU

	NO. OF PEAK HOUR BUSES			
	1980	1985	1990	1995
LOCAL BUSES				
Hotel Street at Fort Street Mall	111	137	163	188
King-Beretania at Punchbowl Street	92	111	130	150
King-Beretania at Ward Avenue	61	75	89	104
Kapiolani Blvd. at Ward Avenue	27	34	41	49
Nimitz Hwy. at Liliha Street Extension	36	45	54	64
School Street at Liliha Street	35	45	55	66
EXPRESS BUSES				
Total Buses on North-South Streets	127	166	205	245

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and a 13-ft. sidewalk on either side. With the estimated number of buses per hour operating through the CBD area, the use of Hotel Street is mandatory to achieve any reasonable level of transit service without seriously restraining auto travel through the area.

In the Civic Center area, the buses would necessarily have to operate on King Street and Beretania Street since there are no other streets of required width or location to adequately serve the area. With the estimated volumes, curb bus lanes would be required with either normal flow or contra-flow operation.

The total number of express buses entering the CBD-Civic Center area is 166 which is too large to be accommodated on a single street. Therefore, the express buses would be divided between two streets - Nuuanu Avenue and Bishop Street - for entering the CBD from the north and Bethel Street and Alakea Street for the reverse movement as shown in Figure VII-2. An equal split between these two routes would result in some 80 buses per hour for each route which would require a curb bus lane to be provided on all of the 4 streets. To serve the Civic Center directly, some of the buses on the Bishop-Alakea route could utilize Punchbowl Street as shown in Figure VII-2. This route on Punchbowl Street with buses flowing in the northeast direction would require a contra-flow curb bus lane since the flow of traffic is in the southwest direction.

4. Bus Operations and Lane Capacity Analysis

All local and express buses serving the downtown area would operate on bus-only lanes. The local buses operating on King Street and Beretania Street, which are one-way streets, will operate on either normal flow curb bus lanes or contra-flow curb bus lanes. There are many facets that enter into the merits of one concept over the other. However, it appears that both lane capacity and operating speed are about the same and therefore it is assumed that the selection of one concept or the other would not affect this analysis.

The east-west movement through the CBD area will be on Hotel Street which will be converted to an exclusive bus street. The total right-of-way width is 50 feet and currently improved with a 40-ft. roadway and 5-ft. sidewalks. This sidewalk width is too narrow to accommodate the anticipated loading and unloading of bus passengers. Therefore the proposed busway would be limited to two lanes with 24 feet total width in order to provide a 13-ft. wide sidewalk.

Outside of the downtown area, the bus routes on Kapiolani Boulevard and Ala Moana Boulevard, located in the easterly direction, will operate in mixed traffic since the number of buses per hour would not justify reserved bus lanes. Similarly, in the westerly direction from the downtown area, the bus volume on Nimitz Highway, Dillingham Boulevard, King Street, Vineyard Boulevard and School Street do not justify the use of reserved bus lanes.

A detailed review of existing street conditions on King Street and Beretania Street in the Civic Center area, between Richards Street and Ward Avenue, indicates some difficulties in operating a reserved bus lane. As part of the improvements to the street and highway network under the TSM alternative, Alapai Street was assumed to be improved such that it could accommodate the traffic destined to the freeway or to Vineyard Boulevard. This would allow Punchbowl Street to be converted into a one-way street in the southwest direction, between the freeway and Nimitz Highway. With these improvements, it would eliminate the existing right turn movement on to Punchbowl Street from Beretania Street and make bus operation on a normal flow curb bus lane simpler on Beretania Street. But conflicts may arise with right-turns onto Alapai from Beretania Street. On the other hand, a contra-flow curb bus lane on Beretania Street would conflict with the left-turn movements onto Punchbowl Street.

A contra-flow curb bus lane on King Street encounters some difficulties at the intersection with Alapai Street. A normal flow curb bus lane also encounters right turn conflicts at Punchbowl Street and Kapiolani Boulevard. Furthermore, an eastbound contra-flow lane on Beretania Street would create problems for those buses on the Kapiolani Boulevard route. Therefore, it is concluded that either normal flow or contra-flow would encounter problems on both King Street and Beretania Street. Accordingly, for purposes of this analysis, a selection has not been made and furthermore it was determined that neither lane capacity nor vehicle speed would be affected.

The maximum capacity of a single bus lane with on-line curb bus stops is 100-120 buses per hour, both observed and theoretical.[34/] Although it has been reported that between 120 and 160 buses have been observed in operation, there are many factors that influence lane capacity. For example, a theoretical 120 buses per hour or 1/2 minute headway assumes a 20-second dwell time and a 10-second bus stop/clearance time with perfect headway geometrics, which mean that buses must operate within these time limits to maintain the 1/2 minute headway. Of course, this is difficult to achieve, if not impossible, with manual operations and merging of bus routes from different streets. Although the maximum capacity of 120 buses per hour is theoretically possible and has been actually observed, it can only occur under ideal conditions.

One critical factor is the dwell time which is primarily based upon the number of boarding and alighting passengers. At 2 seconds per passenger, the above mentioned 20 second dwell time would permit only 10 persons to board or alight from a bus. Some buses at certain heavy loading or transfer points could take much longer and hence require longer headway than the 1/2-minute allowed to attain the 120 buses per hour capacity. Overcrowded buses also have a tendency to require longer dwell time since it is more difficult and time-consuming to board or alight from a bus with completely filled aisle space.

In reference to the latter point on overcrowded buses, the design loading used in determining the peak hour bus volume was an average of 70 passengers per bus on a 50-seat bus. This implies that in order to achieve an average of 70 passengers per bus, some buses may have as many as 80-90 passengers which results in a seriously overcrowded condition. Under this assumed loading condition, the maximum capacity of 120 buses may be difficult, if not impossible, to achieve in actual operations. However, if a lower loading figure were used, there would be a correspondingly greater number of buses per hour required and therefore in either case, the maximum lane capacity may be exceeded.

In 1985, an estimated 137 buses per hour, each way, would be operating on Hotel Street based on a maximum average loading of 70 passengers per bus. For purposes of this analysis, it is assumed that this exclusive bus street would be able to accommodate this volume.

On King-Beretania Streets at Punchbowl Street, the estimated number of buses per hour is 111. This volume is also considered to be higher than the practical maximum for desirable bus lane operations, under either normal flow or contra-flow operation.[17/] Difficulties in restricting turns by other vehicles may make any volume in excess of 80 buses per hour a highly optimistic capacity. In summary, it is pointed out that the bus volumes estimated to be operating in the downtown area on curb bus lanes and on bus streets would exceed realistic maximum volumes that can reasonably be handled under the conditions as described.

D. COMPARATIVE EVALUATION

1. General

The comparative evaluation of alternative systems on near-term basis, 1985 and 1990, is based upon the comparison of the low capital intensive alternatives, represented by the TSM alternative and the baseline bus system, and the capital intensive alternative represented by the 14-mile fixed guideway rapid transit system. As mentioned earlier, since the fixed guideway system was concluded to be the best solution to meeting the long-term transportation needs of the island, it is used to represent the high capital intensive, grade-separated rapid transit alternative. The 14-mile length is used since, as will be shown in the next chapter, it would be the most cost-effective initial segment of the system to implement.

Although various evaluation measures were considered for the long-range alternative systems analysis, there are two measures which are paramount in this evaluation. They are the street and highway system volume to capacity ratio and the benefits and costs analysis. The first establishes the feasibility of the low capital intensive alternative in terms of their physical capability in meeting travel demand. If, for example, the TSM alternative cannot adequately meet travel demand in 1985, it would not be a viable alternative and therefore any further evaluation would not be necessary. However, if it can meet the 1985 travel demand, then it should be analyzed for its relative benefits and costs and compared with the other alternatives.

2. Analysis of the Volume to Capacity Ratio

In order to evaluate the traffic conditions that would exist on the street and highway network under the various transit alternatives, a volume to capacity analysis was conducted. This analysis consisted of, first, the establishment of several traffic cordons or corridor "screenlines." These "screenlines" were generally established along geographical features such as streams, rivers, canals, or streets which cut across the major transportation corridor. Then, the relationship of the total projected traffic demand on the various streets and highways crossing each screenline to the total roadway capacity available to accommodate this demand was developed.

Street and highway capacities are given in terms of daily traffic capacities based on the roadway network and appropriate capacity assignments as obtained from the Oahu Transportation Planning Process (OTPP), until recently, the official regional planning body for the island. The capacities obtained from OTPP are actually service volumes associated with a particular level of service. The Highway Research Board's "Highway Capacity Manual-1965," defines level of service as "a term which, broadly interpreted, denotes any one of an infinite number of differing combinations of operating conditions that may occur on a given lane or roadway when it is accommodating various traffic volumes....From the viewpoint of the driver, low flow rates or volumes on a given lane or roadway provide higher levels of service than greater flow rates or volumes on the same lane or roadway. Thus, the level of service for any particular lane or roadway varies inversely as some function of the flow or volume, or of the density." There are generally six levels of service which are:

- Level of Service A which describes a condition of free flow, with low volume and high speeds, and with speeds controlled by drivers' desires, speed limits and physical roadway conditions.

- Level of Service B which is in the zone of stable flow, with operating speeds beginning to be restricted somewhat by traffic conditions, but drivers still being able to have reasonable freedom to select their speed and lane of operation.

- Level of Service C which is still in the zone of stable flow, but with speeds and maneuverability more closely controlled by the higher volumes and where most of the drivers are restricted in their freedom to select their own speed, change lanes, or pass.

- Level of Service D approaches unstable flow, with tolerable operating speeds being maintained, though considerably affected by changes in operating conditions, and where fluctuations in volume and temporary restrictions to flow may cause substantial drops in operating speeds.

- Level of Service E represents traffic operations at even lower operating speeds than in level D, with volumes at or near the maximum capacity of the roadway and where flow is unstable and stoppages of momentary duration can occur.

- Level of Service F describes forced flow operation at low speeds, where volumes are below capacity. These conditions usually result from queues of vehicles backing up from a restriction downstream.

For planning purposes, OTPP utilizes roadway capacities representing service volumes at either Level of Service C or D. For facilities

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located in urban areas, service volume at the D level are utilized, whereas facilities located in rural areas are assigned service volumes at the C level.

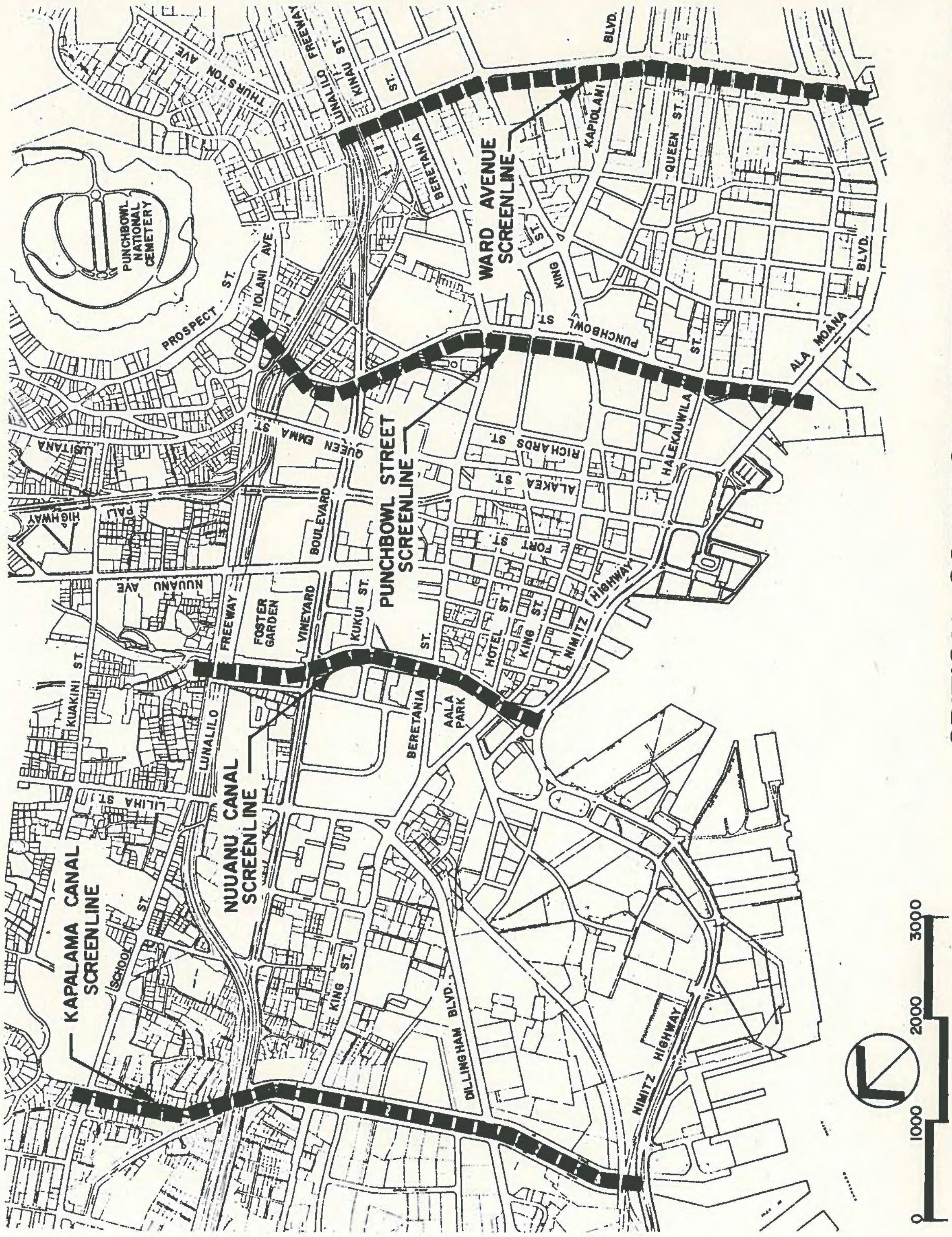
The roadway network on which the capacities or service volumes are based upon reflects the conditions to exist in 1980 and beyond which includes various future street widening and other system management improvements such as additional one-way street patterns not currently in existence.

The assigned daily capacities were obtained by first developing capacities for each facility based on the Highway Capacity Manual. These hourly capacities are then converted to daily capacities through a procedure which is in essence the inverse of developing the peak hour, peak direction traffic volumes from daily volumes. Therefore, the volume to capacity relationship or V/C ratio obtained from comparing daily volumes to daily capacity provides the same relationship for peak hour volumes and capacities.

Various screenlines were established along the transportation corridor between Pearl City and Hawaii Kai and the volume to capacity relationship developed for each of these screenlines. These screenline relationships were reviewed and a few critical ones were selected for more detailed evaluation. The location of the four critical screenlines selected as shown in Figure VII-3, represents areas where high volumes occur in and near downtown Honolulu.

Highway assignments were developed for the alternative systems for both 1980 and 1995 and through interpolation, volumes for 1985 and 1990 were obtained. The capacities (or service volumes at given levels of service) and projected volumes at the selected screenlines for 1985 are shown in Tables VII-3 and VII-4.

From Table VII-3 it can be readily discerned that the baseline system and the TSM alternative will have traffic demands exceeding the capacity at service level "D" by as much as 15% to 18% for the TSM and baseline systems respectively. For the fixed guideway alternative, since the traffic demand is only about 6% over the service capacity, the projected traffic would be operating within the range of service level "D", which provides tolerable operating speeds. Table VII-4 shows the V/C ratio obtained based on a capacity representing the service volume obtained at level of service E. As can be seen from the table, both the baseline and TSM systems have V/C ratios over or near 1.0, especially at the Punchbowl Street and Ward Avenue screenlines. Therefore, the street facilities passing through these screenlines would have traffic



CRITICAL CORRIDOR SCREENLINE LOCATIONS

FIGURE VII-3

TABLE VII-3: 1985 HIGHWAY NETWORK CAPACITY ANALYSIS: (CAPACITY @ LEVEL OF SERVICE D)

Screenline Locations	BASELINE			TSM			14-MILE FIXED GUIDEWAY		
	Daily Volume	Equiv. Daily Capacity	V/C	Daily Volume	Equiv. Daily Capacity	V/C	Daily Volume	Equiv. Daily Capacity	V/C
Kapalama Canal	266,400	234,700	1.14	251,800	234,700	1.07	246,500	234,700	1.05
Nuuanu Canal	308,200	275,600	1.12	290,800	275,600	1.06	288,700	275,600	1.05
Punchbowl Street	365,700	309,300	1.18	347,800	302,700	1.15	336,900	319,100	1.06
Ward Avenue	352,400	300,200	1.17	333,500	290,200	1.15	324,100	306,500	1.06

TABLE VII-4: 1985 HIGHWAY NETWORK CAPACITY ANALYSIS: (CAPACITY @ LEVEL OF SERVICE E)

Screenline Locations	BASELINE			TSM			14-MILE FIXED GUIDEWAY		
	Daily Volume	Equiv. Daily Capacity	V/C	Daily Volume	Equiv. Daily Capacity	V/C	Daily Volume	Equiv. Daily Capacity	V/C
Kapalama Canal	266,400	284,200	0.94	251,800	284,200	0.89	246,500	284,200	0.87
Nuuanu Canal	308,200	323,800	0.95	290,800	323,800	0.90	288,700	323,800	0.89
Punchbowl Street	365,700	361,200	1.01	347,800	353,900	0.98	336,900	372,100	0.91
Ward Avenue	352,400	351,100	1.00	333,500	340,000	0.98	324,100	358,200	0.90

operating in unstable flow conditions with volumes over or near the maximum capacities. It should be noted that the screenline analysis inherently assumes that the volume is proportionately distributed over all the facilities which passes through the screenline. In reality, certain facilities such as the interstate freeway would attract higher volumes than assigned and therefore would have higher V/C ratios than the other facilities.

The streets and highways under the baseline bus system has the highest V/C ratios at all screenlines resulting in intolerable congestion levels and the potential breakdown of the roadway network in the entire urban Honolulu area by 1985. The transit system would not be capable of relieving any of the congestion since it would be operating in mixed traffic under the same congested conditions. Therefore, this baseline system would not be capable of attracting more transit riders to provide greater people-moving capacity on existing facilities.

Under the TSM alternative, not only does the vehicular traffic on the streets and highways operate at undesirable conditions, but the expanded all-bus transit system also exceeds the assigned lane capacities for the number of buses required to carry the projected volumes of transit riders. Thus, where both street and highway capacity as well as the transit capacity are exceeded by the total travel demand, then this alternative falls far short of meeting the critical transportation needs of the region.

As stated earlier, the TSM alternative will have reserved bus lanes located in certain key streets in the CBD-Civic Center area with bus volumes that exceed even the absolute maximum lane capacity. If the "overcapacity" on the transit system were to be converted back to equivalent automobile trips, this would create a greater demand on the highway network through the already critical CBD-Civic Center area under the TSM alternative. Also, due to the relatively conservative population projection utilized in developing the projected travel demand on the island (as discussed earlier in Chapter II), the projected travel demand through the selected screenlines could be higher than those estimated and used in this analysis. Both of the above factors would contribute to greater traffic volumes through the screenline analyzed and force the V/C ratio for the screenlines at Punchbowl Street and Ward Avenue, shown in Table VII-4, to go over 1.0 and thereby making conditions on the roadway network even more intolerable. Therefore, it can be seen that there may be a high probability of demand exceeding capacity by several years prior to 1985 under the TSM alternative.

Even if the projected traffic demand through the two critical screenlines in the Civic Center area were to be realized as estimated in 1985, it is also projected that travel demand will grow at a rate of some 2% to 2-1/2% annually. Therefore, by 1986 or one year later, the traffic demand would definitely exceed the capacity or service volume based on a level of service E at these two screenlines. And with each additional year the traffic demand would increase and continue to worsen the unbearable condition that would already exist in 1985.

3. Benefits and Costs Analysis

Although the TSM alternative did not have the physical capacity to meet the 1985 travel demand, in urban Honolulu, a benefits and costs analysis was conducted for comparison with the 14-mile fixed guideway alternative. The baseline bus system was used as the basis for developing the benefits and the net costs for the TSM and fixed guideway alternatives. Both the costs and benefits are calculated for 1-year period in 1985 and 1990 and are not discounted to present worth. The TSM alternative has a benefit/cost ratio of 1.12 as compared to 1.13 for the 14-mile fixed guideway alternative in 1985 as shown in Table VII-5.

Although the TSM alternative has a substantially lower total net annual cost than the 14-mile guideway alternative, the latter has much higher total annual benefits due to the greater ridership volume that it attracts. The capital cost for the TSM alternative only reflects the cost of required buses and does not include any costs for developing the curb bus lanes and bus street. Furthermore, time savings to continuing motorists and commercial vehicles are not included which, if considered, would increase the benefit/cost ratio for both alternatives but favoring the 14-mile fixed guideway system. Thus the benefit/cost ratio difference could be greater than that shown.

The benefits and costs analysis shows that even though the capital investment is low for an expanded all-bus system, its operating and maintenance cost is relatively high when compared to the passenger volume carried. Therefore, this analysis supports the selection of the high capital intensive alternative as providing the greater economic benefits to the region and hence a justifiable public investment by 1985. The benefit/cost analysis shown for the TSM alternative in 1990, was developed for comparison purposes only. Since both automobiles and buses would be travelling on facilities that are considerably beyond their maximum capacities, the calculated benefits cannot represent actual benefits but it is shown merely for comparison with the 14-mile guideway system.

TABLE VII-5

COSTS AND BENEFITS ANALYSIS
($ MILLION)

	1985		1990	
	TSM	14-Mile Fixed Gwy.	TSM	14-Mile Fixed Gwy.
COSTS				
Annual Capital Cost				
Alternative System	6.27	35.16	7.55	37.42
Baseline Bus System	4.16	4.16	4.16	4.16
Net Annual Capital Cost	2.11	31.00	3.39	33.26
Annual O&M Cost				
Alternative System	38.70	31.07	46.73	37.48
Baseline Bus System	28.71	28.71	28.71	28.71
Net Annual O&M Cost	9.99	2.36	18.02	8.77
Total Net Annual Cost	12.10	33.36	21.41	42.03
BENEFITS				
Diverted Motorist Auto Savings				
Operating Cost	5.23	11.07	8.72	18.05
Parking Cost	1.77	4.12	3.27	6.88
Auto Ownership Cost	3.26	7.58	6.03	12.67
Addit. Auto Ins. Cost	0.14	0.34	0.27	0.57
Reduction in Fatalities	0.39	1.03	0.74	1.81
Subtotal	10.79	24.14	19.03	39.98
Time Savings				
Former Bus Users	2.76	12.87	3.11	14.76
Diverted Motorists	-	0.61	-	1.21
Subtotal	2.76	13.49	3.11	15.97
Total Annual Benefits	13.55	37.63	22.14	55.95
Benefit/Cost Ratio	1.12	1.13	1.03	1.33

E. SUMMARY OF FINDINGS AND CONCLUSIONS

The following summarizes the findings and conclusions of this evaluation:

1. The baseline system which is the continuation of the existing systems, i.e. highways and bus transit, will result in heavy and intolerable congestions on streets and highways which would be on the verge of a complete breakdown prior to 1985. The bus transit system would be ineffective in relieving the overloaded conditions of the streets and highways since it would also be operating in the same heavily congested traffic conditions. Therefore, a "do-nothing" alternative cannot meet the travel demands of 1985 and will result in a complete breakdown of existing streets and highways. Therefore, some form of new additional transportation capacity must be provided by 1985.

2. The TSM alternative, although requiring low capital investment, also fails to meet the needs of the 1985 travel demand with both the automobiles on streets and highways and the buses on reserved lanes operating on severely overloaded facilities. The required number of buses operating in the CBD-Civic Center area will exceed the practical capacities of the reserved bus lanes provided. The motorists on streets and highways will similarly face overloaded conditions such that even with the overall improvements provided under the TSM alternative, the system remains inadequate to meet the 1985 travel demands. This conclusion is further supported by the benefits and costs analysis. Even with its relatively low capital investments, the TSM alternative's benefit-cost ratio is less than that for the fixed guideway which implies that the latter is a better investment of public funds.

3. The 14-mile fixed guideway alternative has shown that it can attract or divert sufficient number of motorists to transit such that the streets and highways can continue to operate at reasonable levels. The economic justification for this investment is supported by the resulting benefit/cost ratio of 1.13 even as early as 1985 which is only a few years after its earliest opening date.

4. The near-term evaluation of the projected transportation conditions in the central Honolulu area in 1985 strongly supports the need for immediate implementation of a new high capacity transportation facility. The determination for this urgent need is based on the use of a conservative growth projection which is currently being exceeded by some 4% in terms of actual growth. In view of this, the need for additional transportation capacity could become critical even before 1985.

CHAPTER VIII

ALTERNATIVE LENGTHS EVALUATION

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A. GENERAL

With previous chapters presenting the conclusions reached for the need of a high level rapid transit system, its route location, and the type of system best suited for Honolulu, it remains to decide how much of the system to build initially. The recommended fixed guideway system was analyzed and planned for staged development by identifying various segment lengths of the full 23-mile system that are operationally viable. In identifying potential segment lengths for detailed evaluation, the primary consideration was location of terminal stations relative to accessibility by all modes of travel and availability of appropriate sites. The absolute minimum segment length considered to be operationally viable was from Keehi Lagoon Park to the University of Hawaii campus which comprises approximately 7.3 route miles. An extension of some 1 mile to this minimum segment to serve the Honolulu International Airport was selected as the second alternative segment length which results in approximately 8.4 route miles. A further extension to the 8.4 mile segment on its western end of some 3 miles to Halawa (Aloha Stadium) provides an excellent terminus for this segment length of 11.5 route miles. An extension of 2.5 miles on the eastern end to Kahala would provide a 14 route mile segment with an excellent terminus at both ends.

The four alternative segment lengths selected for detailed evaluation are shown in Figure VIII-1 and described below:

Segment Lengths	West Terminus	East Terminus
7 miles (7.3 mi.)	Keehi Lagoon Drive	University
8 miles (8.4 mi.)	Airport	University
12 miles (11.5 mi.)	Halawa	University
14 miles (14.0 mi.)	Halawa	Kahala

Any extensions beyond the 14-mile segment, based on patronage forecasts and costs for the early years, would not be economically justified. The maximum peak hour link volume, one way, for either of the outer segments in 1985 is estimated to be approximately 5,000 passengers. At this volume, a high level, grade separated guideway facility is not warranted especially where exclusive or reserve bus lanes can be provided in existing highway rights-of-way.

Alternative Segment Lengths

RAPID TRANSIT STATIONS

1. Pearl City	8. Iwilei	15. University
2. Pearl Ridge	9 Fort Street	16. Sixth Avenue
3. Halawa	10. Civic Center	17. Koko Head Avenue
4. Pearl Harbor	11. Ward Avenue	18. Kahala
5. Airport	12. Ala Moana	19. Aina Haina
6. Keehi Lagoon	13. Waikiki	20. Niu
7. Kalihi	14. Date Street	21. Hawaii Kai

- 1 ● Stations
- ▬▬ Aerial
- ııııııııııı At Grade
- ▬ ▬ ▬ Underground
- ●●●●●● Express Bus

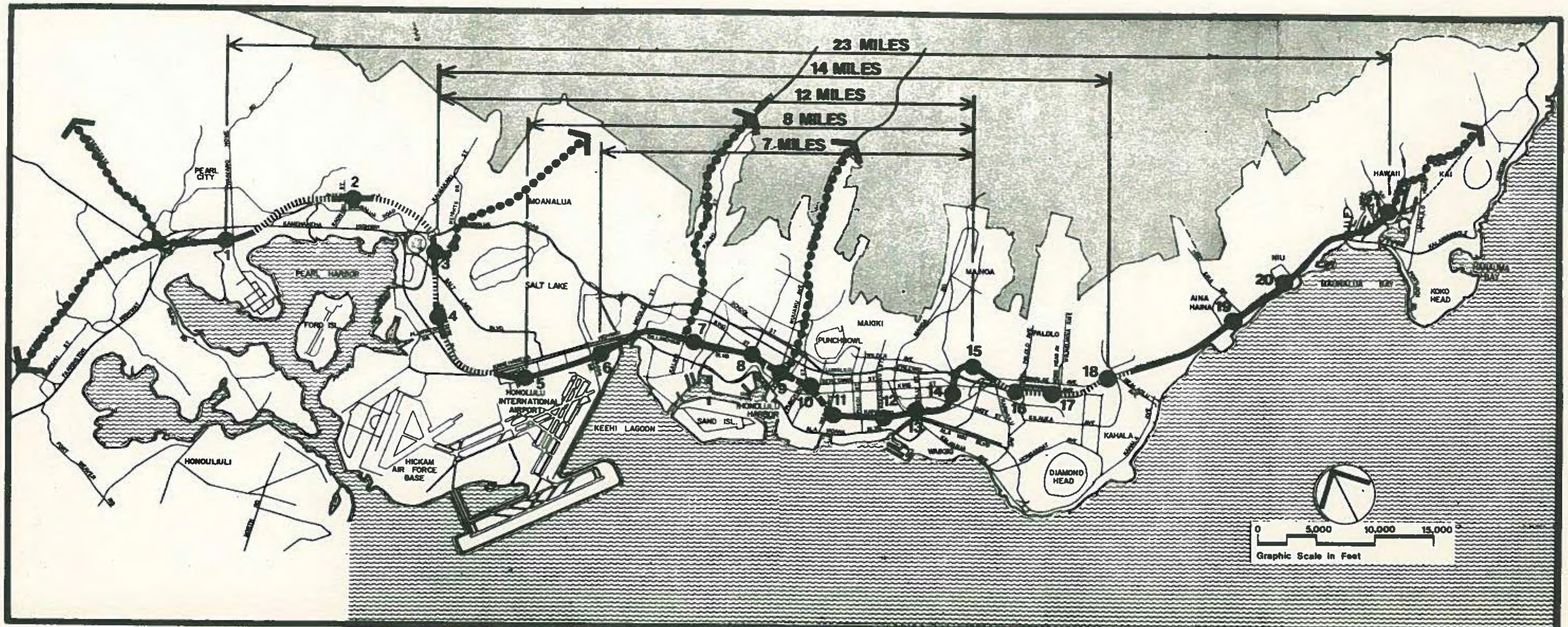

FIGURE VIII-1

B. ASSUMPTIONS AND METHODOLOGY

The purpose of this study is to develop an orderly process for the evaluation of alternative system lengths as the basis for selecting the initial segment for implementation. For the analysis, it was assumed that up to 5 to 6 years would be required to design and construct the initial segment thus placing the system in revenue service in the early 1980's. In order to provide several years of operation before the first system extension can be made, 1985 was selected as the basic study year and a 5-year period thereafter.

For purposes of this analysis, a 15 year study period from 1980 to 1995 was selected with relevant data developed for 5 year increments. The patronage and cost estimates were developed for the years 1980 and 1995 from which estimates for 1985 and 1990 were derived by interpolation.

Patronage estimates were developed for the 7, 12, and 14 mile segment lengths by computer processing of the modal split and trip assignment models. For the 8 mile segment length, the patronage forecasts were developed by manually adjusting trip assignment values for those portions of the system network modified from the 7 and 12 mile lengths. The resulting trip assignments for each alternative length system were used to evaluate its performance and to determine the vehicle requirements, operating costs, etc. for the fixed guideway and feeder bus system.

The alternative length systems were carefully analyzed in terms of terminal station location and its development to ensure efficient access for various modes of arrival. Each terminal station location was carefully studied and planned for accommodating access and transfer facilities for all modes. The location and facilities planned for each terminal station was used as the basis for developing the feeder bus network which served as input to the modal split and trip assignment model.

For comparative evaluation of alternative lengths, both quantitative and qualitative measures were applied as in the alternative systems evaluation. However, certain measures, such as system capacity, technical risk, and others, while meaningful when comparing one system vs. another, have little or no influence when applied to varying lengths of the same system. Therefore, only those measures which could be related to variation in system length and service have been used in this analysis.

C. ANALYSIS OF SYSTEM NETWORKS

The full 23-mile fixed guideway system would have terminal stations located in Pearl City and Hawaii Kai. Six express bus routes serving northern, central and leeward areas of Oahu utilizing the H-1 and H-2 Freeways, would interface at the western end of the system at the Pearl City Station. At the eastern end of the system, two express bus routes from the Waiamanalo and Kalama Valley areas would interface with the fixed guideway at the Hawaii Kai Station. All other bus routes serving these terminal stations would be local service. As the full 23-mile system is cut back into shorter segments, the express bus routes from outlying areas must travel farther to interface with the terminal stations that get progressively closer to the downtown area. Also those local buses serving stations that are eliminated by shortening the fixed guideway would be re-routed to the new terminal station which increases both their travel distance and the concentration of buses at the terminal station. The basic change in the overall system network to reflect alternative lengths is modifying the bus network to conform with each fixed guideway length. Essentially, total coverage and transit availability remain constant although mode and travel time may change.

As the system length was reduced on the western end, the express buses from the outlying areas were routed on the H-1 Freeway to Halawa (Aloha Stadium) Station to interface at this location for the 12- and 14-mile alternatives. For the 7 and 8 mile alternatives, these express buses were extended on the H-1 Freeway, leaving the freeway at the Pearl Harbor Interchange, with stops at Valkenburgh Road and at the airport, proceeding along Aolele Street to terminate at the Keehi Lagoon Station. Termination at the Keehi Lagoon Station was planned for both shorter length alternatives in order to minimize potential congestion occurring at the airport with the 8-mile length.

Local feeder buses operating in conjunction with the 12- and 14-mile segments serving the Pearl City-Pearl Ridge areas and westerly, were routed along the Kamehameha Highway and Moanalua Road to terminate at the Halawa Station. For the 7- and 8-mile alternatives, these feeder buses were routed to terminate at the Keehi Lagoon Station. The feeder bus routes serving the Halawa Heights-Foster Village and interfacing at the Halawa Station in the longer systems were modified to interface at the Keehi Lagoon Station for the 7- and 8-mile alternatives.

As system length was reduced on the eastern end, the two express bus routes from Waimanalo and Kalama Valley were routed on an exclusive bus lane in the middle of Kalanianaole Highway to terminate at the Kahala Station for

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the 14-mile segment. For the 12-, 8-, and 7-mile segments, these express buses were routed to continue on the Lunalilo Freeway in mixed traffic or reserved bus lane and terminated at the University Station.

For the 14-mile segment, 4 local bus routes originating from the Hawaii Kai, Niu and Aina Haina areas were routed in mixed traffic on Kalanianaole Highway to interface at the Kahala Station. For the 12-, 8-, and 7-mile segments, these 4 local bus routes were extended on local streets to interface at the Date Street Station. In addition, 5 other bus routes originating in areas between the University and Kahala and operating on the various local streets were re-routed to the Date Street Station with the 12-, 8-, and 7-mile alternatives.

Modifications and extensions to the feeder bus system for operation in conjunction with shortened guideway system lengths involve increases in bus-miles and bus-hours of operation and in the number of vehicles required to replace the guideway system. Conversely, with shortened guideway lengths, appropriate reductions in guideway vehicle miles and hours would occur.

D. PATRONAGE ESTIMATE

Patronage estimates were developed for the 7-, 12, and 14-mile segment lengths by computer processing of the modal split and trip assignment models. For the 8-mile segment length, patronage forecasts were developed by manual adjustments of trip assignment values to reflect those differences in the system network from the 7- and 12-mile lengths. These forecast volumes for 1995 were used in evaluating alternative system modes as described in the previous chapter.

For evaluating alternative lengths of the fixed guideway system, especially on a near-term basis for the year 1985, further refinements to the above developed patronage volumes were made. Certain special trips were not included in the trip generation model such as special activity trips to Aloha Stadium and U.S.S. Arizona Memorial in Pearl Harbor, general tourist trips, tourist trips to and from the airport.

Another important area where potential trips were not accounted for are those walk-in trips from areas adjacent to the fixed guideway stations. This is due to the fact that the currently established traffic analysis zones were too large to connect walk trip links to transit stations. In reviewing the affected traffic analysis zones, it was determined that potential walk-in trips were not reflected in certain station areas.

In addition to the above, the land use model does not accurately reflect potential high density development around station impact areas. This should also result in higher transit patronage from areas directly served by the fixed guideway stations.

The fixed guideway with supporting feeder bus system will provide improved and expanded service to the residents of Oahu. This could result in induced trips by both captive and modal choice riders. The superior service provided by the longer guideway length would induce greater numbers of these trips than the shorter guideway lengths.

A further refinement to the basic patronage estimates was made to adjust for any potential over-predictions from the modal split process. Two particular factors were identified which affected the predicted volumes. They were in the assigned trip time for local and express buses interfacing with the terminal station at the University. A detailed analysis of access to this terminal station was found to be difficult and time-consuming and hence appropriate time adjustments were made. Another area of potential over-prediction was identified as those short trips arriving at the terminal station by buses and then continuing on the fixed guideway system to the next station only. Based on the volumes of such trips predicted, it was assumed that the waiting time penalty of 2-1/2 factor may be too low for these short trips requiring the use of two modes.

Based on the above, the patronage estimates obtained from the modal split process were adjusted, both up and down, to more accurately reflect the ridership on each alternative system. (See attached Appendix D) These adjustments were made on a conservative basis and the adjusted daily patronage volumes for both total transit and fixed guideway only and vehicle requirements are shown in Table VIII-1. The estimated volumes show a continuing increase due to growing travel demand over time and higher attractiveness of longer guideway lengths such that by 1985, the 14-mile fixed guideway system would attract some 34,000 daily passengers more than on the 7-mile fixed guideway system.

TABLE VIII-1

DAILY PATRONAGE VOLUMES AND VEHICLE REQUIREMENTS

	1980	1985	1990	1995
7-Mile				
Total Transit	242,600	315,600	388,750	461,800
Fixed Guideway Only	150,500	193,600	236,650	279,800
Fixed Guideway Cars	81	107	130	161
Buses	345	488	631	774
8-Mile				
Total Transit	244,400	318,000	391,650	465,300
Fixed Guideway Only	152,600	196,100	239,650	283,200
Fixed Guideway Cars	95	126	144	178
Buses	329	466	603	739
12-Mile				
Total Transit	249,800	326,280	402,760	479,200
Fixed Guideway Only	162,600	212,200	261,700	311,100
Fixed Guideway Cars	113	150	185	221
Buses	283	402	521	639
14-Mile				
Total Transit	259,650	338,950	418,300	497,650
Fixed Guideway Only	175,650	227,550	279,500	331,250
Fixed Guideway Cars	134	176	219	264
Buses	255	363	471	580

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E. ANALYSIS OF QUALITATIVE MEASURES

As indicated earlier, the measures applicable to the evaluation of alternative lengths are necessarily different from measures applicable to alternative routes and alternative systems evaluation. Measures which are specifically applicable to alternative lengths evaluation have been identified and are analyzed and discussed in this section. Table VIII-2 shows the results of the evaluation in matrix form. The table is supplemented by the following narrative evaluation relative to each objective.

1. Objective 1. Improve Service

The basic availability and coverage of the transit system would essentially be the same for all lengths. Travel time, service reliability, rider convenience, and rider comfort would all improve with increased length due to faster average speed, higher equipment and schedule reliability, fewer transfers, and greater comfort on the fixed guideway system over the bus system. Consequently, the longer the system, the better this objective is met.

2. Objective 2. Balanced Transportation

System patronage volume becomes progressively higher with increased length due to the superior service characteristics of the fixed guideway system over the bus line haul system. Relative to system capacity, the fixed guideway system would have comparable capacities; however, there would be a total system capacity limitation on the 7-, 8-, and 12-mile lengths due to the interface problem at the eastern terminus for these lengths. Bus accessibility at the University Station terminus is poor and would constrain the number of buses that can be accommodated at this terminus.

3. Objective 3. Minimize Expenditure of Resources

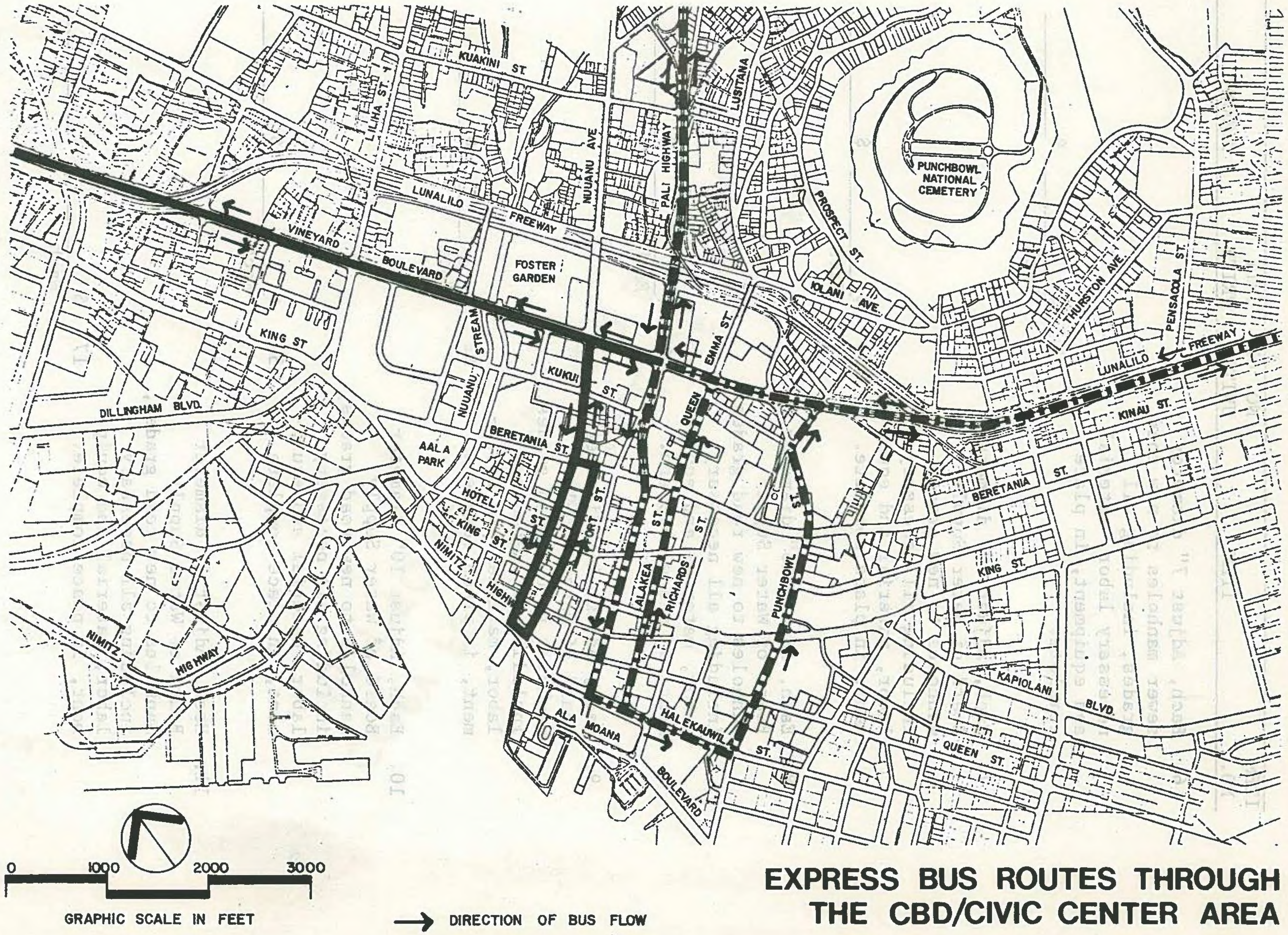
The consumption of land and displacements of residents and businesses are naturally greater with longer length systems. However, when a short system is extended at a later date, the impact caused by the extension could possibly be much greater at a later date due to additional development having taken place. Whatever difference that may exist between alternatives is relatively small and of short duration and therefore the alternatives are rated as being the same for these measures.

For measure d. - since there are no community facilities affected for alternative lengths longer than the 7-mile length, all alternatives are rated as being the same for this measure.

TABLE VIII-2: COMPARATIVE EVALUATION MATRIX

	7-Mile	8-Mile	12-Mile	14-Mile
OBJECTIVE 1				
a. Availability & coverage	Same	Same	Same	Same
b. Avg. trip time (min.)	35.2	35.2	34.5	33.7
c. Service reliability *	4	3	2	1
d. Rider convenience*	4	3	2	1
e. Rider comfort *	4	3	2	1
OBJECTIVE 2				
a. System patronage - 1985 (million/yr.)	95.3	96.0	98.5	102.4
b. System capacity*	2	2	2	1
OBJECTIVE 3				
a. Consumption of land (acres)	Same	Same	Same	Same
b. Displacement of residents (units)	Same	Same	Same	Same
c. Displacement of businesses (units)	Same	Same	Same	Same
d. Reduction of community amenities	Same	Same	Same	Same
e. Disruption to future dvlpmt.*	3	3	2	1
f. Disruption to local circulation*	3	3	2	1
g. Disruption from constr. activities	Same	Same	Same	Same
h. Savings in energy (million gal/yr.)	4.1	4.3	4.3	4.5
i. Technical risk	Same	Same	Same	Same
OBJECTIVE 4				
a. Support regional dvlpmt.	Same	Same	Same	Same
b. Support comm. dvlpmt. *	4	3	2	1
OBJECTIVE 5				
a. Reduction Air pollution (tons/yr.)	1,830	1,880	2,160	2,260
b. Noise level*	4	3	2	1
c. Visual intrusion	Same	Same	Same	Same
d. Vistas	Same	Same	Same	Same
e. Historic sites	Same	Same	Same	Same
OBJECTIVE 6				
a. Reduce accident exposure*	4	3	2	1
b. Security	Same	Same	Same	Same
OBJECTIVE 7				
a. Total annual cost** - 1985 ($ Million)	61.9	62.7	63.8	66.2
b. Total Annual Cost Per Trip ($)	0.650	0.653	0.648	0.647
c. Benefit-cost ratio***	1.11	1.09	1.13	1.13

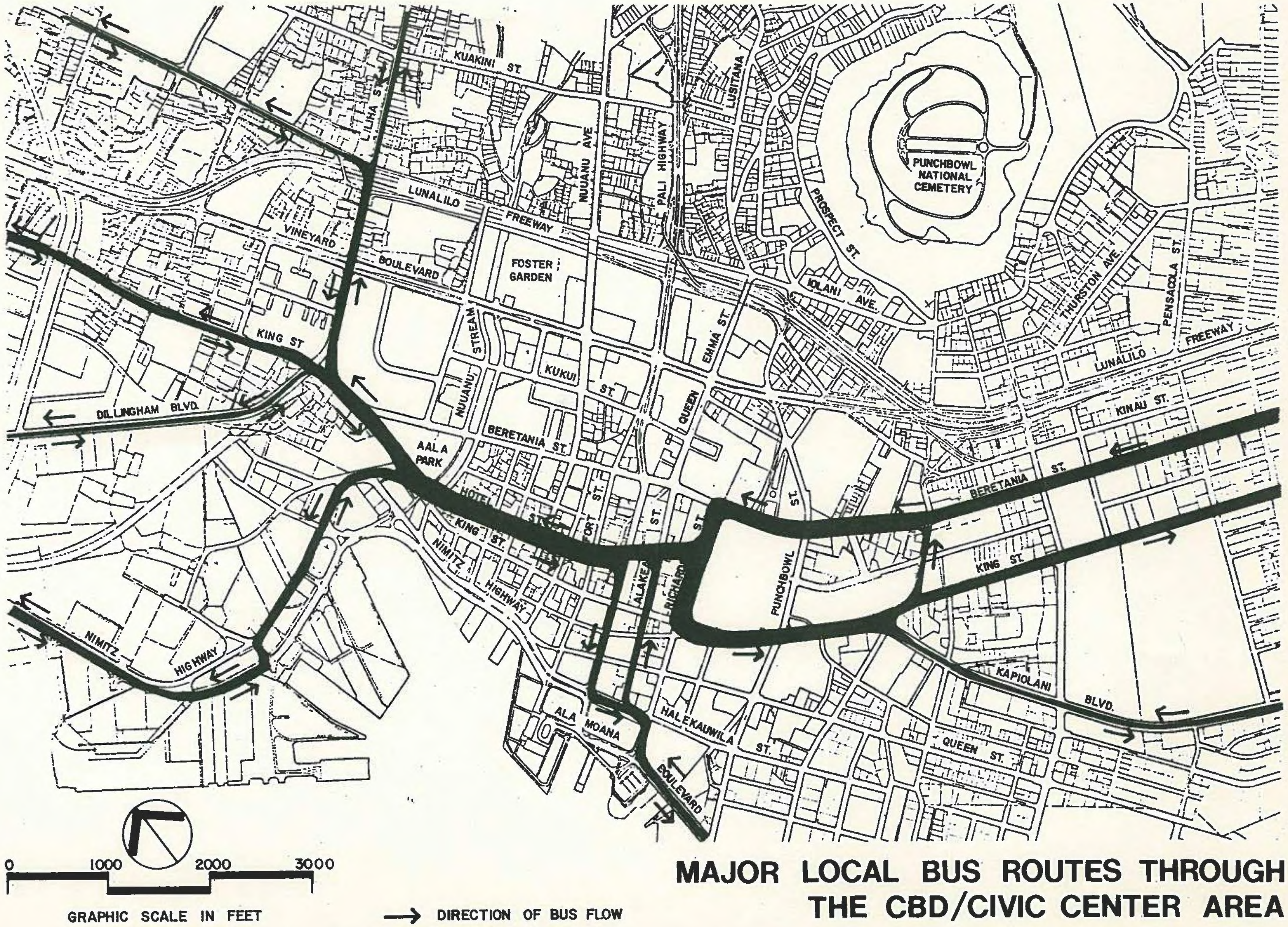
*For comparative measures, alternatives are ranked in the order of how well they met the objective.
** All costs based on constant 1975 dollars and interest rate of 7%.
***Based on constant 1975 dollars.



EXPRESS BUS ROUTES THROUGH THE CBD/CIVIC CENTER AREA

FIGURE VII-2

ITEM NO.	ITEM	NO. OF UNITS	UNIT PRICE	AMOUNT	TOTAL PRICE
6.	Each, Adjust 7" diameter sewer manholes to new road grades, including all necessary labor, material and equipment, in place complete.	2	$______ Each	$______	
7.	Each, Adjust 20" diameter Board of Water Supply manholes to new grades, including all necessary labor, material and equipment, in place complete.	253	$______ Each	$______	
8.	Each, Adjust 16" diameter Board of Water Supply manholes to new road grades, including all necessary labor, material and equipment, in place complete.	6	$______ Each	$______	
9.	Each, Adjust 14" diameter Board of Water Supply manholes to new road grades, including all necessary labor, material and equipment, in place complete.	12	$______ Each	$______	
10.	Each, Adjust 10" diameter Board of Water Supply manholes to new road grades, including all necessary labor, material and equipment, in place complete.	132	$______ Each	$______	
11.	Each, Adjust 7" diameter Board of Water Supply manholes to new road grades, including all necessary labor, material and equipment, in place complete.	17	$______ Each	$______	



MAJOR LOCAL BUS ROUTES THROUGH THE CBD/CIVIC CENTER AREA

FIGURE VII-1

Measure e. - disruption to future development and use of adjacent properties, would be affected by the alternatives relative to the location of the terminal stations. On the western end, the terminus for the 7-mile segment at Keehi Lagoon requires the acquisition of additional industrial properties to provide adequate facility to accommodate buses interfacing at this location. The 8-mile segment would also use this same station at Keehi Lagoon for interfacing buses in order to reduce the number of buses at the Airport terminus. The acquisition of additional industrial properties for terminal facilities does not significantly inhibit future development of the area but with the terminal at Halawa, these private properties would not be required. The most significant impact would occur at the eastern terminus at the University for the 7-, 8-, and 12-mile segments. The station is located near the southern boundary of the University of Hawaii campus property. The entire area is currently used for automobile parking but is master planned for an athletic field which is currently being implemented. The station structure and the guideway structure can be reasonably accommodated without seriously constraining the planned development. However, any expansion of the station site for bus facilities would seriously impact the development potential of the site. Consequently, only express buses would interface at this terminal station with local buses routed to the next station at Date Street. This requires a longer transit time for certain bus routes and also significantly impacts this particular station area.

Measure f. - disruption to local circulation is affected only by the location of the terminal station since the guideway is all grade-separated. The shorter length alternatives require the various local and express bus routes to interface in areas of greater congestion. Therefore, the longer systems are better able to meet this criteria than the shorter systems.

Measure g. - disruption by construction activities is less with the shorter system but again, when the system is extended, the disruption could be greater at a later date than if done all at one time. Therefore, the alternatives are rated as being equal for this measure.

Measure h. - savings in energy is best met by the 14-mile length, second best by the 8- and 12-mile length and lastly by the 7-mile length.

Measure i. - technical risk would naturally be the same for all alternatives.

4. Objective 4. Land Use Policies

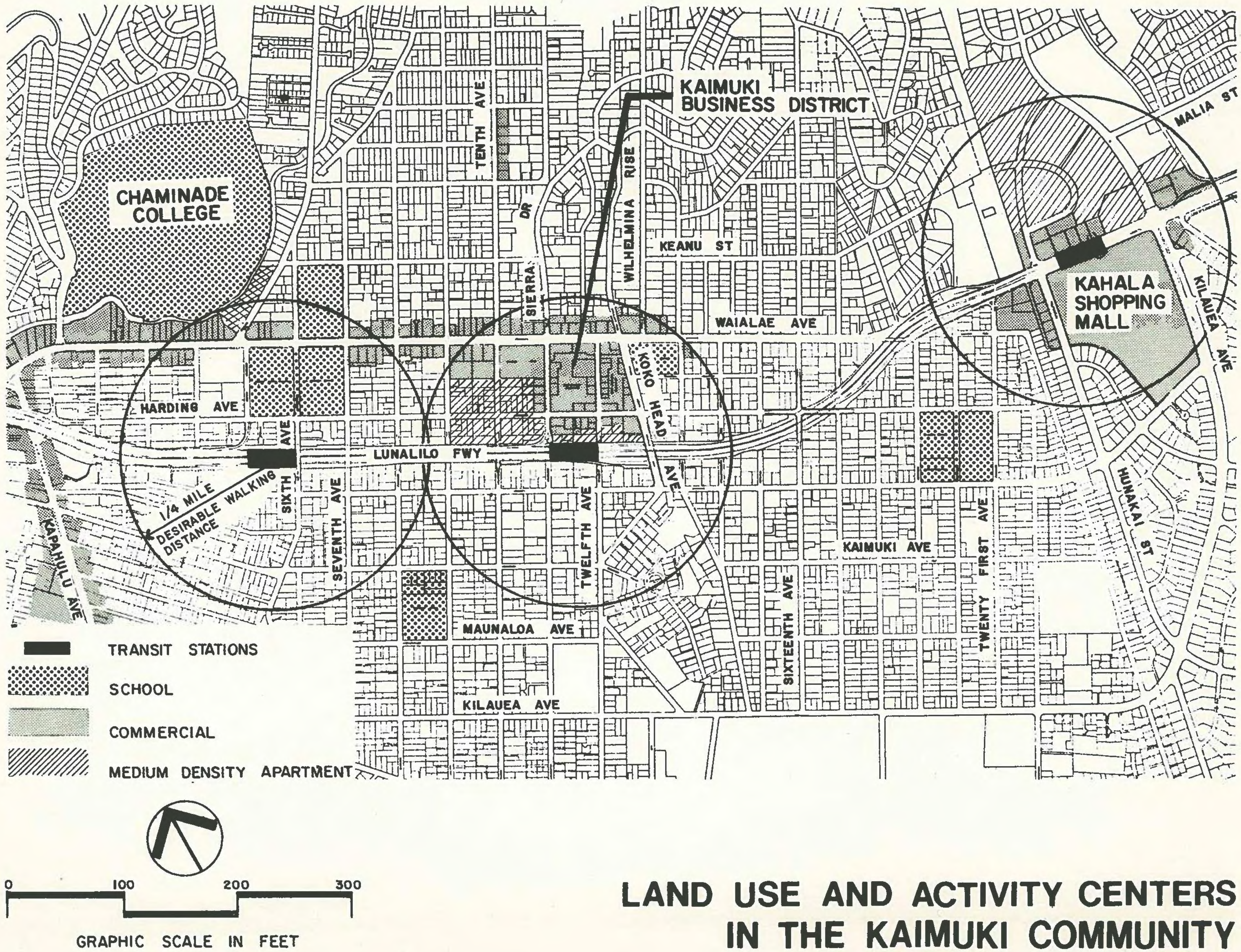
In terms of the regional development policy, it is difficult to differentiate between alternative lengths since it is the basic system type and area served that influences this measure over a long-run basis. However, the support of local community development policies is more sensitive to short term influence. The area most affected is the Kaimuki area which will be directly served by the 14-mile fixed guideway length but not by the shorter lengths.

The land use and various activity centers affected are shown in Figure VIII-2. The activities most influenced by transportation facilities are high density residential, commercial, and institutional centers. At both the Koko Head and Kahala Stations zoning permits medium density apartment development. This type of use would be reinforced by the transit stations. The 6th Avenue Station provides direct service within walking distance to a private college and high school. Relative to commercial centers, Kahala Mall is a regional shopping center which will be favorably impacted by the station. Perhaps of greater importance is the smaller Kaimuki business district which would be served by the Koko Head Station. This business district has been adversely affected by the Kahala Mall Shopping Center but it serves a vital role in providing community and neighborhood shopping opportunities to the local residents. A station located at Koko Head could aid in re-vitalizing this district which may not be realized by a shorter system.

Located on the western end of the alternative system lengths are two of the major activity centers on Oahu, namely the Honolulu International Airport and the Aloha Stadium. Providing direct service to these activity centers with the fixed guideway would be a definite support to these developments. With the short 7-mile system length neither the airport nor the stadium will be provided with direct service by the fixed guideway. The airport would be served directly with the 8-, 12-, and 14-mile system lengths and both the airport and the stadium will be directly served with the longer 12- and 14-mile systems.

5. Objective 5. Preserve Environment

Reduction in air pollution and noise level would be improved with the longer length system by replacing the more polluting and noiser buses and automobiles with the fixed guideway system. However, visual intrusion and disruption of vistas would hardly be affected by the longer length systems due to the type of areas traversed and the route location in existing freeway rights-of-way. Historic sites are not affected by the length of the system.



LAND USE AND ACTIVITY CENTERS IN THE KAIMUKI COMMUNITY

FIGURE VIII-2

6. Objective 6. Safety and Security

Greater reduction in accident exposure would be realized with a longer system since exclusive grade separated routes provide safer transportation service than those in mixed traffic. Security with the system should not be affected by the length of the system.

7. Objective 7. Provide the Most Economical System

This objective has three separate measures: a. total annual cost, b. total annual cost per trip, and c. benefit-cost ratio. This last, but most important, objective is discussed in detail in the following section.

F. ANALYSIS OF QUANTITATIVE MEASURES

1. General

The primary purpose of this economic analysis is to determine the most cost-effective guideway length for initial construction. Therefore, 1985 was selected as the basic study year for a 1-year economic analysis and also the year 1990 to permit a 5-year economic analysis as the basis for the near-term investment study.

There are several economic measures that can be used including the simple capital cost to passenger volume relationship expressed as capital cost per daily ride. This measure can then be further expanded to reflect the same relationship for different increments of added length to the basic 7-mile "core" system to determine the guideway extension which would provide the lowest marginal capital cost per daily ride. Similarly the operating and maintenance cost to passenger volume relationship can be developed and expressed as O&M cost per ride.

The above capital cost and O&M cost to passenger volume relationships can be combined to give the total capital and O&M cost to passenger volume relationship. One of the primary justifications for any capital investment is to achieve greater production efficiency as reflected by lower O&M cost which continues over the life of the facility. The capital cost is annualized and combined with the O&M cost to arrive at a total annual cost. The total annual cost to passenger volume relationship is then expressed as total annual cost per ride, for both the fixed guideway passenger volumes and total transit passenger volumes.

If greater capital investment results in attracting more transit users, there are various economic benefits which are not reflected in the previously described total annual cost per ride measure. These benefits, all quantifiable, are time savings and automobile operating and ownership savings. There are various other non-quantifiable benefits of greater transit usage as described in detail in the earlier part of this chapter. The measure which takes into account the costs and benefits of a proposed capital investment provides the only complete economic analysis of those discussed herein.

In view of the above, a detailed costs and benefits analysis was conducted to identify the system length that would provide the greatest benefits for every dollar invested. The costs and benefits analysis thus provides the only complete economic basis for measuring the cost-effectiveness of the alternative system lengths. The total annual cost analysis provides an economic cost comparison of the alternatives relative to both capital investment and annual O&M costs. It thus provides a measure of overall system efficiency in terms of total annual cost and passenger volumes attracted. The following paragraphs provide a detailed description of various economic analyses conducted to measure the cost-effectiveness of each alternative length.

2. Cost and Patronage Estimates

a. Capital Cost: Capital cost estimate for each alternative length was estimated including all facilities and equipment required to meet the projected patronage volumes. Facilities and vehicles required to meet transit demand were defined for 5-year increments between 1980 and 1995.

The capital cost estimates include costs of certain facilities and equipment for purposes of economic analysis. For example, although sufficient number of buses would be available at the time the fixed guideway system is implemented, the costs for feeder buses are included to reflect the difference in the number of buses required to support the various length guideway systems.

All costs are based on constant 1975 dollars and do not include the 4% State Excise Tax. Therefore, the costs used for this analysis may not necessarily match the costs developed to implement the program as shown in other documents which reflects the initial funding requirements for the program.

The estimated capital cost for each alternative length is shown in Table VIII-3. The costs are divided into three categories - structure and land, equipment and transit cars, and buses - with each reflecting different economic life of 50 years, 30 years, and 10 years, respectively.

For purposes of analyzing annual costs of each alternative length, the capital costs are annualized using 7% interest rate and the appropriate economic life as shown above. The total capital costs and annualized capital costs for 1985 and 1990 patronage volumes are shown in Table VIII-3.

b. Operating and Maintenance Cost: The operating plan for each guideway system length and its supporting feeder bus system was developed and the O&M cost estimated for 1980 and 1995 patronage volumes. The costs for the intermediate 5-year points of 1985 and 1990 were obtained by interpolation.

The O&M cost estimates reflect the 1975 wages and prices and are shown in Table VIII-3 for the alternative lengths.

TABLE VIII-3
SUMMARY OF CAPITAL AND O&M COSTS*
($ MILLION)

	1985				1990			
	7-Mi.	8-Mi.	12-Mi.	14-Mi.	7-Mi.	8-Mi.	12-Mi.	14-Mi.
CAPITAL COSTS								
Structure and Land								
Fixed Guideway Facility	180.9	187.6	208.8	229.3	-	-	-	-
Bus Maintenance Facility	-	-	-	-	4.0	4.0	4.0	-
Sub-Total	180.9	187.6	208.8	229.3	4.0	4.0	4.0	-
Equipment								
Fixed Guideway	75.7	81.7	99.5	116.8	-	-	-	-
Bus Maintenance	-	-	-	-	1.0	1.0	1.0	-
Fixed Guideway Cars	43.6	51.3	61.2	71.8	8.0	6.4	12.0	15.6
Sub-Total	119.3	133.0	160.7	188.6	9.0	7.4	13.0	15.6
Buses	31.7	30.3	26.1	23.6	9.3	8.9	7.7	7.0
Total Capital Cost	331.9	350.9	395.6	441.3	22.3	20.3	24.7	22.6
Annualized Capital Cost**	27.23	28.62	31.80	35.16	2.34	2.16	2.44	2.26
Total Annual Capital Cost	27.23	28.62	31.80	35.16	29.57	30.78	34.24	37.42
OPERATING & MAINT. COST								
Fixed Guideway O&M	9.39	9.90	11.37	12.53	10.08	10.63	12.41	13.74
Feeder Bus O&M	25.30	24.15	20.64	18.54	32.30	30.76	26.42	23.74
Total O&M Cost	34.69	34.05	32.01	31.07	42.38	41.39	38.83	37.48
TOTAL ANNUAL COST	61.92	62.67	63.81	66.23	71.95	72.17	73.07	74.90

*All Costs in constant 1975 dollars
**Based on 7% interest rate

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3. Total Capital Cost and Passenger Volume Analysis for the Fixed Guideway

The minimum 7-mile fixed guideway "core" system in 1985 is estimated to cost $332 million and attract 312,000 total daily transit riders and 193,600 daily fixed guideway riders. The longer length alternatives have incrementally higher capital costs but also attract higher patronage volumes. As one measure of cost-effectiveness, various levels of capital investment can be compared on the basis of capital cost per ride as shown in Table VIII-4. The 7-mile "core" system has the lowest unit cost, $1,714 and $1,496 for 1985 and 1990, respectively, which is as expected since it reflects higher usage of the system in the more densely developed central Honolulu area served by the shorter length system as compared to less densely developed suburban areas served by the longer length system.

Further to the above, the longer length guideways provide longer trips and hence the cost per ride would naturally be more than on shorter guideway systems. In order to compensate for this, the measure capital cost per passenger mile is used. As shown in Table VIII-4, the longer 14-mile guideway provides the lowest cost at $534 and $445 for 1985 and 1990 volumes, respectively.

In order to determine the most cost-effective incremental increase in system length over the basic 7-mile "core" system, a marginal cost-effectiveness analysis was made. As shown in Table VIII-4, the increase in system length to 14 miles was found to have the lowest marginal cost per ride of $3,218 and $2,563 for 1985 and 1990, respectively.

This particular analysis simply equates the total capital investment for facilities and equipment with long-term economic life to a daily patronage volume as estimated for 1985 and 1990. The total capital cost per ride unit of production therefore does not represent any valid measure of economic value. It only measures the unit capital cost for each ride on a daily basis for the alternative lengths and the unit capital cost for each additional ride, also on a daily basis, for each increment of guideway length added.

Although the capital cost per ride unit of production does not represent any meaningful economic value, the capital cost per passenger mile unit of production does give a comparison of cost efficiency of the systems. The longer 14-mile guideway system has the highest capital cost but also attracts the highest volume of passengers which is sufficiently higher than other alternative lengths to result in the lowest unit cost. This implies that the 14-mile guideway system is the most cost-efficient in terms of capital investment and passenger miles transported on the fixed guideway system.

TABLE VIII-4

FIXED GUIDEWAY ONLY
TOTAL AND MARGINAL CAPITAL COST ANALYSIS

	1985				1990			
	7-Mi.	8-Mi.	12-Mi.	14-Mi.	7-Mi.	8-Mi.	12-Mi.	14-Mi.
TOTAL CAPITAL COST								
Total Capital Cost (Million)*	$331.9	$350.9	$395.6	$441.3	$354.2	$371.2	$420.3	$463.9
Total Daily Patronage (Thousand)	193.6	196.1	212.2	227.6	236.7	239.7	261.7	279.5
Total Capital Cost/Ride	$1,714	$1,789	$1,864	$1,939	$1,496	$1,549	$1,606	$1,660
Average Trip Length (Mile)	2.56	2.59	3.33	3.63	2.60	2.63	3.42	3.73
Total Capital Cost/Pass. Mile	$670	$691	$560	$534	$575	$589	$470	$445
MARGINAL CAPITAL COST ANALYSIS FROM 7-MILE CORE SYSTEM								
Marginal Capital Cost (Million)	-	$19.0	$63.7	$109.4	-	$17.0	$66.1	$109.7
Marginal Daily Patronage	-	2,500	18,600	34,000	-	3,000	25,000	42,800
Marginal Capital Cost/Ride	-	$7,600	$3,425	$3,218	-	$5,667	$2,644	$2,563

*Costs based on 1975 dollars.

4. <u>Operating and Maintenance Cost Analysis for the Fixed Guideway</u>

The operating and maintenance cost reflects the length of the guideway and the passenger volume carried and hence the longer the guideway length the higher the annual O&M cost. The unit cost of production expressed as O&M cost per ride is developed for each alternative guideway length and shown in Table VIII-5. Since the trips made on the shorter guideway system has shorter average trip length, the cost per ride would obviously be less than that for a longer guideway system. However, the true measure of efficiency is on the basis of O&M cost per passenger mile which shows that the 14-mile system has the lowest cost at 5.0¢ and 4.4¢ per passenger mile for 1985 and 1990 volumes, respectively.

TABLE VIII-5

FIXED GUIDEWAY ONLY
OPERATING AND MAINTENANCE COST ANALYSIS

	1985				1990			
	7-Mi.	8-Mi.	12-Mi.	14-Mi.	7-Mi.	8-Mi.	12-Mi.	14-Mi.
Annual O&M Cost (Million)	$ 9.39	$ 9.90	$11.37	$12.53	$10.08	$10.63	$12.41	$13.74
Daily O&M Cost (Thousand)	$31.09	$32.78	$37.65	$41.49	$33.37	$35.20	$41.09	$45.49
Daily Patronage (Thousand)	193.6	196.1	212.2	227.6	236.7	239.7	261.7	279.5
O&M Cost/Ride	$0.161	$0.167	$0.177	$0.182	$0.141	$0.147	$0.157	$0.163
Average Trip Length (Mile)	2.56	2.59	3.33	3.63	2.60	2.63	3.42	3.73
O&M Cost/Passenger Mile	$0.063	$0.064	$0.053	$0.050	$0.054	$0.056	$0.046	$0.044

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5. <u>Annual Capital and O&M Cost Analysis for the Fixed Guideway</u>

The previous paragraphs analyzed the capital costs and O&M costs separately for the alternative guideway lengths. Under this analysis, the two costs are combined into a total capital and O&M cost and related to the passenger volume. The capital costs are annualized as previously described and are shown in Table VIII-6. Both the capital and O&M costs are based on constant 1975 dollars.

Similar to the previous analysis, the shorter systems have the lower unit cost of production as expressed in total annual cost per ride. However, when the difference in the trip lengths are taken into account, the 14-mile guideway system is found to be the most cost efficient with unit costs of 19¢ and 16¢ per passenger mile for 1985 and 1990 volumes, respectively.

TABLE VIII-6

FIXED GUIDEWAY ONLY
TOTAL ANNUAL COST ANALYSIS

	1985				1990			
	7-Mi.	8-Mi.	12-Mi.	14-Mi.	7-Mi.	8-Mi.	12-Mi.	14-Mi.
TOTAL ANNUAL COST*								
Total Annual Capital Cost**(Million)	$27.23	$28.62	$31.80	$35.16	$29.57	$30.78	$34.24	$37.42
Total Annual O&M Cost (Million)	$ 9.39	$ 9.90	$11.37	$12.53	$10.08	$10.63	$12.41	$13.74
Total Annual Cost (Million)	$36.62	$38.52	$43.17	$47.69	$39.65	$41.41	$46.65	$51.16
Annual Patronage (Million)	58.47	59.22	64.08	68.72	71.47	72.37	79.03	84.41
Total Annual Cost/Ride	$0.625	$0.650	$0.674	$0.694	$0.555	$0.572	$0.590	$0.606
Average Trip Length (Mile)	2.56	2.59	3.33	3.63	2.60	2.63	3.42	3.73
Total Annual Cost/Pass. Mile	$0.244	$0.251	$0.202	$0.191	$0.213	$0.217	$0.173	$0.162

*All costs in 1975 dollars.
**Annualized at 7% interest rate.

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6. Annual Capital and O&M Cost Analysis for Total Transit System

The previous paragraphs analyzed various unit costs of production for the fixed guideway element only. Since the proposed fixed guideway system is supported by an island-wide network of feeder buses, the guideway and feeder bus systems are combined and analyzed as a single integrated system. Table VIII-1 shows the number of feeder buses to support the guideway system. The longer guideway systems have fewer feeder buses since the guideway where extended replaces certain bus routes.

Table VIII-7 shows the total annual costs for each alternative length for 1985 and 1990 with all costs in constant 1975 dollars. The total annual cost per ride in 1985 ranges from a low of 64.7¢ for the 14-mile system to a high of 65.0¢ for the 7-mile ride which is an insignificant difference. However, in 1990, the 7-mile system shows a more pronounced difference with its highest cost of 61.3¢/ride. For all intents and purposes, the cost per ride can be assumed to be nearly the same for all lengths with the longer systems showing a slight advantage.

It should be pointed out that where the unit cost of production relative to cost per ride is nearly comparable for the alternative system lengths based on 100% of the capital cost plus the O&M cost, it stands to reason that the 14-mile guideway length with its lowest O&M cost would be the most cost-effective system to the local region. By making a greater capital investment for the longer 14-mile system, the annual O&M cost reduces through replacement of costly bus routes in high travel corridors with the more cost-efficient fixed guideway system. This is clearly demonstrated in the table by comparing the O&M costs in both 1985 and 1990. For example, the 14-mile length has an O&M cost which is $3.6 million and $4.9 million less than the 7-mile length in 1985 and 1990, respectively.

Once the capital investment is made, the annual repayment is fixed and not subject to increases due to inflation. However, the O&M cost is a continuing cost subject to increases due to inflation. For example, by using an escalation rate of 7% per year, the difference or savings in O&M cost now becomes $7.1 million and $13.5 million between the 7- and 14-mile lengths in 1985 and 1990, respectively. For the 5-year period between 1985 and 1990, a total O&M cost savings of over $50 million would be realized with the 14-mile length over the 7-mile length guideway system.

The above difference in escalated O&M costs reflect the lesser patronage volume for the 7-mile system. If the 7-mile system were assumed to be carrying volumes equivalent to that of the 14-mile system and assuming that the cost increases in proportion to passengers carried, then the difference increases to $11 million and $19 million between the two system lengths for 1985 and 1990, respectively, and to $75 million over the 5-year period.

In summary, this analysis indicates that all alternative lengths are equally cost-effective in 1985 and that the longer 12- and 14-mile lengths are slightly more cost-effective than the 7- and 8-mile lengths in 1990 based on the total annual cost per ride measure using constant 1975 dollars for all costs. However, it is pointed out that the on-going O&M cost will continue to increase over time due to inflation while the amount of annual repayment for the capital cost is fixed. Therefore, there would be substantial savings to the local region by implementing the 14-mile guideway length which could amount to as much as $50 million over a 5-year period.

TABLE VIII-7

TOTAL ANNUAL COST ANALYSIS

	1985				1990			
	7-Mi.	8-Mi.	12-Mi.	14-Mi.	7-Mi.	8-Mi.	12-Mi.	14-Mi.
TOTAL ANNUAL COST*								
Total Annual Capital Cost (Million)	$27.23	$28.62	$31.80	$35.16	$ 29.57	$ 30.78	$ 34.24	$ 37.42
Total Annual O&M Cost (Million)	$34.69	$34.05	$32.01	$31.07	$ 42.38	$ 41.39	$ 38.83	$ 37.48
Total Annual Cost (Million)	$61.92	$62.67	$63.81	$66.23	$ 71.95	$ 72.17	$ 73.07	$ 74.90
Annual Patronage (Million)	95.31	96.04	98.54	102.36	117.40	118.28	121.63	126.33
Total Annual Cost/Ride	$0.650	$0.653	$0.648	$0.647	$0.613	$0.610	$0.601	$0.593
TOTAL ANNUAL O&M COST (Million)								
Escalated @ 7%/Yr., Compounded	$68.24	$66.98	$62.97	$61.12	$116.93	$ 114.20	$107.13	$103.41
Difference with 7-Mile System	-	-$1.26	-$5.27	-$7.12	-	-$2.73	-$9.20	-$13.52
Total 5-Year Savings Over the 7-Mile System	-	-	-	-	-	$ 9.98	$ 37.68	$ 51.60

*All Costs in 1975 Dollars.

7. <u>Costs and Benefits Analysis for Total Transit System</u>

The previous analysis considered capital and O&M costs and patronage volumes to derive costs per ride for comparison purposes. This analysis considers those quantifiable benefits resulting from travel time savings and automobile ownership and operating cost savings. The longer the fixed guideway length, the shorter the overall transit trip time which results in greater time savings than with a shorter fixed guideway length. Also the higher volume of transit patronage with the longer length fixed guideway system results in greater automobile cost savings. The results of this analysis is shown in Table VIII-8.

Table VIII-8 contains a breakdown of the costs and benefits attributable to each of the alternative lengths evaluated over the baseline system. As seen in this table, with each additional increment of guideway length, the net annual capital cost increases but the net annual O&M cost decreases due to the greater efficiency of the fixed guideway system in transporting passengers in high volume corridors. However, the net result is that the total annual net cost increases with increased guideway length.

Although the total net annual cost increases with each additional increment of fixed guideway length, the longer guideway system is carrying more passengers. This is reflected on the benefit side of the ledger which shows total benefits increasing as the guideway length gets longer.

The following describes the incremental costs and benefits analysis for the alternative systems. First, the alternative systems are compared to the baseline system and for those alternatives with a benefit/cost ratio of greater than 1.0, they are considered to be sound economic investments. Next a comparison is made between alternative lengths to determine what length provides the best investment. The 8-mile system is first compared to the basic 7-mile "core" system and if the benefit/cost ratio is greater than 1.0, the 8-mile length is considered to be better than the 7-mile length. However, if the benefit/cost ratio is less than 1.0, then the 7-mile "core" system would be considered to be the better alternative. This process is repeated through the 14-mile alternative as tabulated in Table VIII-9.

The findings of the costs and benefits analysis for the selected study years are as follows:

TABLE VIII-8
SUMMARY OF COSTS AND BENEFITS ANALYSIS
($ MILLION)

	1985				1990			
	7-Mi.	8-Mi.	12-Mi.	14-Mi.	7-Mi.	8-Mi.	12-Mi.	14-Mi.
COSTS								
ANNUAL CAPITAL COST								
Alternative Systems	27.23	28.62	31.80	35.16	29.57	30.78	34.24	37.42
Baseline Bus System	4.16	4.16	4.16	4.16	4.16	4.16	4.16	4.16
Net Annual Capital Cost	23.07	24.46	27.64	31.00	25.41	26.62	30.08	33.26
ANNUAL O&M COST								
Alternative Systems	34.69	34.05	32.01	31.07	42.38	41.39	38.83	37.48
Baseline Bus System	28.71	28.71	28.71	28.71	28.71	28.71	28.71	28.71
Net Annual O&M Cost	5.98	5.34	3.30	2.36	13.67	12.68	10.12	8.77
Total Net Annual Cost	29.05	29.80	30.94	33.36	39.08	39.30	40.20	42.03
BENEFITS								
DIVERTED MOTORIST AUTO SAVINGS								
. Operating Cost	9.32	9.48	10.31	11.07	15.67	15.87	16.95	18.05
. Parking Cost	3.64	3.66	3.83	4.12	6.20	6.31	6.52	6.88
. Auto Ownership Cost	6.70	6.74	7.04	7.58	11.42	11.62	12.00	12.67
. Addit. Auto Insurance Cost	0.30	0.30	0.31	0.34	0.51	0.52	0.54	0.57
. Reduction in Fatalities	0.87	0.88	0.96	1.03	1.58	1.60	1.70	1.81
Sub-Total	20.83	21.06	22.45	24.14	35.38	35.92	37.71	39.98
TIME SAVINGS								
. Former Bus Users	11.44	11.44	12.41	12.87	13.31	13.31	14.12	14.76
. Diverted Motorists	-	-	0.13	0.62	-	-	0.37	1.21
Sub-Total	11.44	11.44	12.54	13.49	13.31	13.31	14.49	15.97
Total Annual Benefits	32.27	32.50	34.99	37.63	48.69	49.23	52.20	55.95
BENEFIT/COST RATIO	1.11	1.09	1.13	1.13	1.24	1.25	1.30	1.33

TABLE VIII-9
INCREMENTAL COSTS AND BENEFITS ANALYSIS
($ MILLION)

ALTERNATIVES COMPARED	INCREMENTAL COSTS	INCREMENTAL BENEFITS	INCREMENTAL BENEFITS/COSTS
1985:			
8-Mile Vs. 7-Mile	0.75	0.23	0.31
12-Mile Vs. 7-Mile	1.89	2.72	1.44
14-Mile Vs. 12-Mile	2.42	2.64	1.09
1990:			
8-Mile Vs. 7-Mile	0.22	0.54	2.45
12-Mile Vs. 8-Mile	0.90	2.97	3.30
14-Mile Vs. 12-Mile	1.83	3.75	2.05

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(1) When the individual alternative lengths are compared to the baseline system, they all have benefit/cost ratios greater than 1.0, with the longer 12- and 14-mile systems having the highest ratios. This means that any of the alternatives are economically justified to be implemented over the baseline, with the longer 12- and 14-mile systems found to be better investments than the shorter 7- and 8-mile systems.

(2) Under the incremental costs and benefits analysis of alternatives, the 8-mile alternative was compared to the 7-mile "core" system with the 7-mile system found to be better since the incremental benefits of the 8-mile system over the 7-mile system were not large enough to offset the higher incremental cost, thus resulting in a benefit/cost ratio of less than 1.0. When the 12-mile system was compared with the 7-mile system, the 12-mile system was found to be the better alternative, with an incremental benefit/cost ratio greater than 1.0. Finally, when the 14- and 12-mile alternatives were compared, it was found that the 14-mile alternative was the better alternative since it had an incremental benefit/cost ratio greater than 1.0. Therefore, on the basis of this incremental costs and benefits analysis, the 14-mile system was found to provide the best investment.

(3) The incremental benefits versus cost analysis conducted for the study year 1990 also confirmed the findings reached in the 1985 analysis, namely, that the 14-mile alternative was the best investment for this time period.

In summary, these analyses which consider various travel benefits accruing to the region clearly supports the 14-mile guideway length as the most cost-effective to implement as the initial construction increment.

G. SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATION

A fixed guideway transit system involves major capital investment with each additional increment of guideway length adding to the cost. To justify any incremental capital investment over the basic "core" system requires a thorough analysis of the marginal benefits to be derived. The marginal benefits of any incremental cost are the result of better quality service and greater transit usage. Better quality service results in travel time savings and greater transit usage also results in travel time savings as well as out-of-pocket travel cost savings. Together these savings result in overall economic benefits to the travelling public of the region.

The basic "core" system selected for the analysis was the 7-mile fixed guideway system from the Keehi Lagoon Park area to the University of Hawaii campus area with incremental extensions thereto for the 8-mile, 12-mile, and 14-mile length alternatives. Each incremental extension was carefully planned to achieve maximum accessibility at the terminal points as well as providing the best transit service possible to the areas traversed by the guideway. For each alternative length system, a feeder bus system was provided to efficiently support the guideway system. The following summarizes the principle findings and conclusions.

1. The baseline bus system was estimated to carry 214,300 daily passenger trips in 1980 and by 1985, it would increase to some 232,000 passenger trips. In 1985, the 7-mile "core" system together with the feeder buses is estimated to carry 315,600 passenger trips of which some 83,600 trips would be by new transit riders or diverted motorists. The 8-mile, 12-mile, and 14-mile systems are estimated to divert an additional 2,400, 10,700, and 23,350 new transit trips for an increase of 3%, 13%, and 28%, respectively, over the 7-mile system.

   The 14-mile guideway length will proportionally attract more new transit riders than the 8- or 12-mile lengths and increase new transit ridership by 28% over the 7-mile "core" system. This significant increase in ridership attributable to the extension of the guideway to 14 miles reflects the high propensity for transit usage in the affected service areas combined with the more attractive service provided by the fixed guideway than buses.

2. The 14-mile guideway length requires the highest capital investment but would provide the lowest annual operating and maintenance cost although carrying the highest volume of passengers. The resulting unit cost of production, expressed as total annual cost per ride in

constant 1975 dollars, is essentially equal to those of other alternative lengths. This highly favorable cost of production efficiency shown by the longer 14-mile system occurring as early as 1985 is further enhanced by the potential savings in O&M cost to the local region.

The lower operating and maintenance cost of the 14-mile guideway system results in substantial savings to the local region of some $50 million over the 7-mile system, $40 million over the 8-mile system, and $15 million over the 12-mile system during the 5-year period assuming a 7% escalation rate.

3. The higher passenger volume projected to be carried by the 14-mile system will result in increased economic benefits to the region. In terms of travel benefits, the transit users will enjoy both savings in travel time as well as in out-of-pocket expenses. The capital investment required for the 14-mile system, although greater than for the other lengths, would return the highest benefits for each dollar invested.

The 14-mile guideway length will provide the highest economic benefits to the region by returning $1.13 in 1985 and $1.33 in 1990 for every dollar invested. The 14-mile system was also found to be the most economically justified alternative based on an incremental benefits versus cost analysis which clearly supported the greater cost-effectiveness of the 14-mile guideway length over other alternative lengths.

4. It has been shown by the costs and benefits analysis that the longer 12- and 14-mile guideway lengths provide greater economic benefits than the shorter 7- and 8-mile guideway lengths. Although the longer lengths are both highly cost-effective, the 12-mile length with its eastern terminus located at the University campus has major access problems for both feeder buses and automobiles. It can only be developed for limited access and with considerable disruption and delay to the University's planned campus expansion program.

The placement of the eastern terminus at the University campus site would provide at best only a marginal level of access with highly disruptive consequences to the University. The termination of the guideway system at this location will result in an immediate need and justification for its extension. The deferring of this guideway extension would only add to the cost due to the loss of economies of scale, real appreciation of property value, new developments occurring in future rights-of-way, new governmental regulations, and inflation which collectively would add millions of dollars to the cost.

5. Although the justification for the 14-mile guideway length has been amply demonstrated on purely economic and financial basis, its greater overall cost-effectiveness is further justified by other equally important factors as follows:

- Provides improved service and accessibility to the all-important national defense installations at Pearl Harbor.

- Better supports national policies relative to fuel conservation and enhancement of environmental quality.

- Provides improved service and accessibility to various residential areas with high transit dependency and also to important recreation centers such as the Aloha Stadium.

- Supports local land use policy with both immediate and long-term benefits to the region by encouraging orderly growth to take place in the currently zoned urban lands and thus preserve scarce and irreplaceable agricultural lands of Oahu.

From the foregoing conclusions, it is recommended that the 14-mile length fixed guideway be implemented as the initial segment of the system. The guideway route and station locations and the type of line haul bus routes to complement the guideway system are shown in Figure VIII-3.

On the eastern end of Central Honolulu, the Kalanianaole Highway corridor will be served by an exclusive bus lane in the median of the highway. This project is currently underway as part of a highway improvement program of the State. On the western end, from Halawa to the various outlying areas of Central and Leeward Oahu, the existing H-1 and H-2 Freeways will be used as bus routes with the buses operating in mixed traffic initially and on reserved bus lanes later. To the Windward region, the three routes of the trans-Koolau corridor are the Pali Highway, Likelike Highway and the H-3 Freeway. Each of these routes would be used for express bus service either in mixed traffic or in reserved bus lanes.

The physical and operating characteristics of the recommended system including patronage estimates, capital and operation cost estimates, program schedule, and other implementation data are all described in detail in the final report of the PEEP II study. In addition, preliminary designs, plans and drawings, and design criteria and general specification documents have been developed as the final step preparatory to program implementation.

14-Mile Fixed Guideway System

RAPID TRANSIT STATIONS

1. Halawa
2. Pearl Harbor
3. Airport
4. Keehi Lagoon
5. Kalihi
6. Iwilei
7. C.B.D.
8. Civic Center
9. Ward Avenue
10. Ala Moana
11. Waikiki
12. Date Street
13. University
14. 6th. Avenue
15. Koko Head Avenue
16. Kahala

Stations
Aerial
At-Grade
Underground
Express Buses in Exclusive Bus Lane
Express Buses in Reserved Bus Lanes or Mixed Traffic

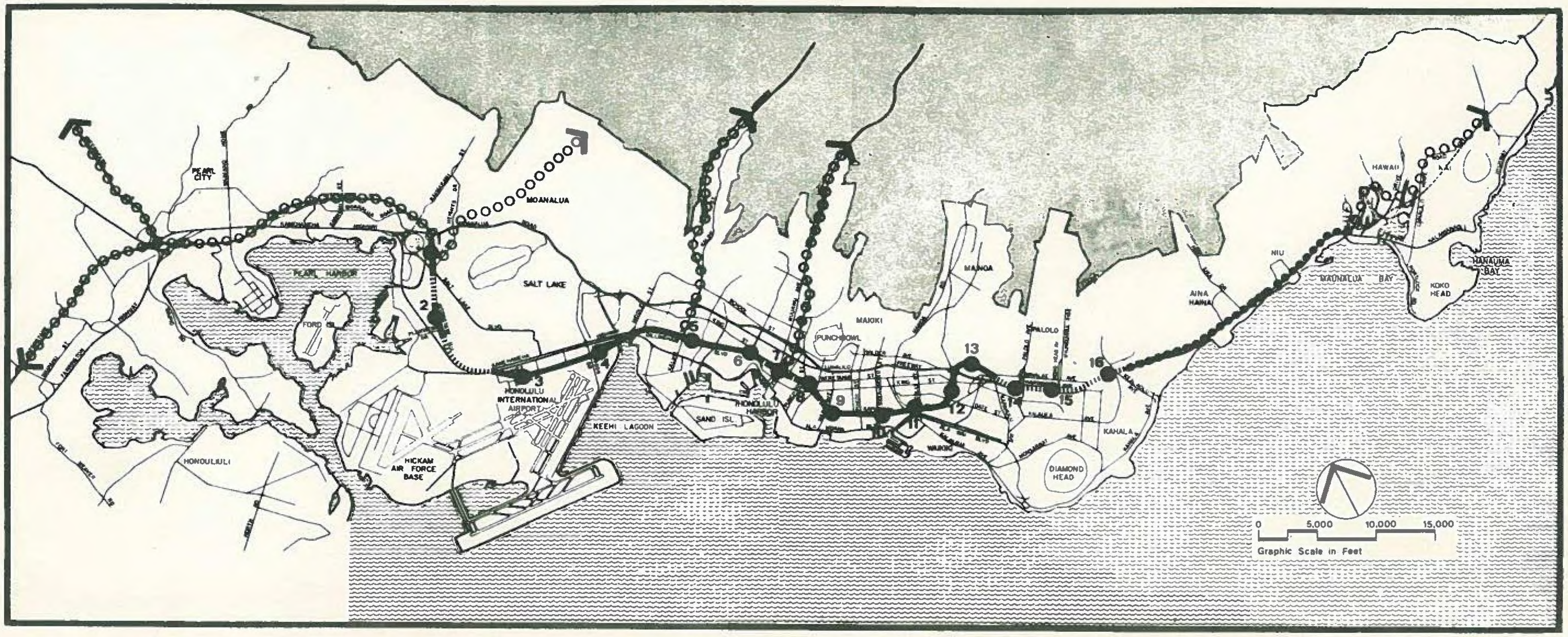

FIGURE VIII - 3

REFERENCES

REFERENCES

1. "Goals and Objectives," Honolulu Rapid Transit Project, October 1971, Daniel, Mann, Johnson, & Mendenhall

2. "Oahu General Plan," 1964, City & County of Honolulu

3. "Oahu Transportation Study," Volumes,I, II, and II, 1967, State of Hawaii and City & County of Honolulu

4. "Issues, Goals & Objectives for the Seventies and Beyond," City & County of Honolulu

5. "Proposed Objectives and Policies for the Revised General Plan," March 1974, Department of General Planning, City & County of Honolulu

6. "Population Summary for Hawaii, 1972," Statistical Report 87, January 7, 1972, Department of Planning & Economic Development, State of Hawaii

7. "State of Hawaii Growth Policies Plan: 1974-1984," General Plan Revision Program, 1974, Department of Planning & Economic Development, State of Hawaii

8. Report CTC-28, Hawaii Census Tract Committee, February 28, 1975, State of Hawaii

9. State Department of Planning & Economic Development Memo, Subject: State Economic Model Inputs, November 22, 1971

10. "Data Book, 1974" The State of Hawaii, Department of Planning & Economic Development

11. From Tables Obtained From the State Land Use Commission and Dated April 11, 1974

12. "Land Use Alternatives, Technical Report: No. 3," March 1974, Department of General Planning, City & County of Honolulu

13. OTS Land Use Model Printout dated January 7, 1972

14. "Patronage and Revenue Estimates," Honolulu Rapid Transit Project, PEEP II, November 1974, Alan M. Voorhees and Associates, Inc.

15. "TOPICS STUDY: Defining the Federal-Aid Primary Type II System and the Areawide TOPICS Plan for Honolulu," February 1971, Traffic Department, City & County of Honolulu

16. "Highway Functional Classification and Needs Study, State of Hawaii, 1970-1990," December 1971, Department of Transportation, State of Hawaii, Belt, Collings/Wilbur Smith & Associates

17. "Bus Rapid Transit Options for Densely Developed Areas," U. S. Department of Transportation, February 1975, Wilbur Smith & Associates, et al.

18. "Transportation Analysis, Technical Report No. 4," March 1974, Department of General Planning, City & County of Honolulu

19. "Highway Capacity Manual," 1965 Special Report 87, Highway Research Board

20. "Benefit-Cost Analysis" Technical Memorandum, Honolulu Rapid Transit Project, PEEP II, March 1975, Environment Capital Managers, Inc.

21. "Lunalilo Freeway (Interstate Route H-1) Traffic Surveillance and Control Study, Phase II," Draft Interim Report, September 1975, State Department of Transportation, Austin, Smith/Howard, Needles Consultants

22. "Leeward Oahu Bicycle Transportation Plan, Principle Routes," 1973 Oahu Transportation Planning Program

23. "Central Honolulu Bicycle Plan," 1974 Department of Transportation Services, City & County of Honolulu

24. "Short-Range Bus Plan for Oahu (1975-1980 Inclusive)" Interim Technical Report, February 1975, City & County of Honolulu

25. "Long Range Regional Transit Plan," Interim Report, Honolulu Rapid Transit Project, March 1972, Daniel, Mann, Johnson, & Mendenhall

26. "Route Planning Study," Honolulu Rapid Transit Project, Volumes 1, 2, & 3, March 1972, Daniel, Mann, Johnson, & Mendenhall

27. Alternative Route Evaluations conducted in PEEP II are contained in the following reports:

    a. "Feasibility Study of the H-1 Freeway Route for Fixed Guideway System," Honolulu Rapid Transit Project, PEEP II, March 1974, Daniel, Mann, Johnson, & Mendenhall

b. "Study of Alternative Alignments in the Dillingham Boulevard Corridor," Honolulu Rapid Transit Project, PEEP II, April 1974, Daniel, Mann, Johnson, & Mendenhall

c. "Study of Alternative Routes in the Moiliili/University Area," Honolulu Rapid Transit Project, PEEP II, May 1974, Daniel, Mann, Johnson, & Mendenhall

d. "Feasibility Study of the Lunalilo Freeway for Fixed Guideway System - Kapiolani Interchange to Kalanianaole Highway," Honolulu Rapid Transit Project, PEEP II, March 1974, Daniel, Mann, Johnson, & Mendenhall

28. "Honolulu Rapid Transit System," Preliminary Engineering Evaluation Program, Final Report, December 1972, Daniel, Mann, Johnson, & Mendenhall

29. "Draft Environmental Impact Statement," Volumes I, II & III, September 1972, Daniel, Mann, Johnson, & Mendenhall

30. "Evaluation of Transit Concepts and Vehicles," Honolulu Rapid Transit Project, Interim Report, December 1971, Applied Technology Laboratory

31. "Evaluation of Alternative Transportation Systems for the Pearl City - Hawaii Kai Corridor," March 1973, Alan M. Voorhees & Associates, Inc.

32. "Alternative Transit Concepts Analysis," Draft Technical Report, Honolulu Rapid Transit Project, PEEP II, July 1975, Daniel, Mann, Johnson, & Mendenhall

33. "A Study of Rubber-Tired Transit Technology," Technical Report, Honolulu Rapid Transit Project, PEEP II, December 1974, Applied Technology Laboratory

34. "Characteristics of Urban Transportation Systems," U.S. Department of Transportation, May 1974

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APPENDIX A

DESCRIPTION AND ANALYSIS OF ALTERNATIVE SYSTEMS

A. ALTERNATIVES SELECTED FOR DETAILED STUDY

The main body of this report has described the range of alternative transit modes and concepts considered for detailed study. After the initial screening, three basic concepts were selected for detailed analysis:

- A Minimum Length (7-Mile) Busway
- A Light Rail Transit (LRT) System
- A Fixed Guideway System

These alternatives were then developed for analysis and subsequent evaluation including consideration of optimum system length. Each alternative included an appropriate feeder and express bus system to produce complete comprehensive transit coverage and service. These systems are briefly described in this appendix and summary results of the system analysis presented.

B. THE BUSWAY TRANSIT CONCEPT

In PEEP I evaluations,[1/] it had been determined that a long busway comparable to the 23 mile fixed guideway concept produced both operational problems and high cost. However, the service flexibility of the basic concept and the potential for high speed and reasonable schedule reliability through the densest urban area indicated that a reduced length system may provide competitive service and cost factors. Therefore, a 7-mile busway extending from Middle Street through Central Honolulu to the University of Hawaii was selected.

At the eastern and western ends of the Busway, express service extension has been projected on existing highways using combinations of mixed traffic and reserved bus lanes. Similarly, service to Windward has been included on existing and committed highways. To provide intermediate access to the busway segment, 10 busway stations were selected where transfer to local and feeder buses could be made. In addition, direct bus access was programmed at intermediate points at Kalihi and Waikiki stations. (See Figure VI-1 in Chapter VI of this report.)

1. Busway Configuration and Operating Concept

Because of the high-volume patronage through the busway segment and resulting high volume vehicle requirements, any decision on busway configuration is directly related to and impacts operating concepts and vice versa. Therefore, it was necessary to carefully examine these features together.

Essentially, this examination considered platooned and random vehicle sequencing on a single-file busway (2-lane) and flexible operations on a busway with by-pass capabilities. Each concept was examined for headway requirement (capacity determinant), time factors, schedule reliability, system reliability, express and local operational ability, and miscellaneous through-operation capability. On the basis of this evaluation, it was concluded that the operational constraints, problems, and potential delays of the single-file concept were such that the added capital cost of the flexible concept was warranted. Table A-1 presents a summary of the evaluations.

2. System Operating Characteristics

In order to provide an acceptable balance between service flexibility and no-transfer travel, an operating plan was developed which offered both local (all station) and express (limited stop) operations on the

TABLE A-1: COMPARISON OF BUSWAY OPERATING CONCEPTS

	Single File Concept: Platoon	Single File Concept: Random	Flexible Concept
Theoretical Line Capacity (50 passengers per bus)	13,300 passengers/hour	25,000 passengers/hour Constrained at station	25,000 passengers/hour Unconstrained at station
Time Required to Start Busway Operations	Poor - buses arriving at busway must wait for its designated platoon - buses entering platoon must maneuver into designated place or slot	Good - buses arriving at busway can enter freely	Good - buses arriving at busway can enter freely
Time Required to Operate Through Stations	Fair - free to dock at designated space - must wait for front buses to leave	Poor - must wait if designated space is ahead of docked bus - must wait for front buses to leave	Good - free to dock at designated space - free to leave station unconstrained
Overall Schedule Reliability	Poor - must wait for right platoon, must maneuver into proper slot, must wait for entire platoon to move through station	Fair - unconstrained at guideway entrance but constrained at station	Good - unconstrained at guideway entrance and at station
System Reliability	Fair - buses required to by-pass disabled buses on opposite lane when clear - easier and safer with platoons	Poor - buses required to by-pass disabled buses on opposite lane when clear - difficult with random method	Good - all buses free to by-pass disabled bus at any time but at reduced speed
Express Operation	Fair - possible use of reverse lane for by-passing outlying stations by use of radio communication to control passing operation - must operate two types of platoons, local and express	Poor - possible use of reverse lane for by-passing outlying stations but difficult for safe operation due to large number of individual buses to control	Good - all stations provided with by-pass lanes
Miscellaneous Through Operations	Poor - dead-heading buses and removal of disabled buses constrained	Poor - dead-heading buses and removal of disabled buses constrained	Good - dead-heading buses and removal of disabled buses not constrained

busway.

Express operations were oriented to the longer trips with buses entering the busway at the ends (Keehi Lagoon and University Stations) and at the Kalihi Station. These buses would operate in a through-express mode with intermediate stops only at the Waikiki and CBD Stations, the largest destination stations on the busway. Local feeder buses would enter the busway at Keehi Lagoon and Waikiki Stations, stopping at all intermediate stations to provide local service. In addition, a number of "captive" buses would operate only on the busway, stopping at all stations.

This overall operational plan provided the maximum opportunity to capitalize on the higher speed capability and minimum transfer requirement of the busway concept and still offer a high level of access to non-CBD destinations. Operational features of the vehicles and busway are shown in Table A-2.

TABLE A-2

OPERATIONAL PARAMETERS - BUSWAY SYSTEM

Acceleration: 0-30 mph - 15 sec.; 30-50 mph-31 sec.
Operating Speed: 50 mph max.; 30 mph through stations (express)
Avg. Busway Speed: Express - 31 mph; local (all stations) - 23 mph
Vehicle Capacity*/: Seated - 53; Design Load - 61; Crush - 93
Avg. Dwell Time: 30 seconds

*/ Design load and crush load based on equal space per passenger for all vehicle systems to provide equivalent and uniform service standards for system comparison

3. Station Requirements

In the busway concept, station requirements are a function of the frequency (in terms of buses stopping at that station per hour) and dwell time which in turn is a function of docking time and boarding/alighting volume. These variables produce the minimum number of docking positions required for normal operations.

In addition provisions for abnormal conditions (vehicle breakdown, schedule delays, etc.) and future expansion must be included to maintain scheduling flexibility and preclude early obsolesence. To accommodate these factors, a "safety factor" of 2 was applied to the minimum number of bays required at each station and a 33%

expansion provision made to assure capacity beyond 1995. Sizing of all busway stations was based on the projected 1995 boarding and alighting forecast at each station from the mode split procedure.

4. Busway Requirements

To permit express operation, by-pass provisions must be incorporated at stations. In addition, acceleration-deceleration lanes at each end of the station will be necessary for safe operation and also to permit queuing of local buses if a delay occurs. For most of the busway lengths, the combination of acceleration-deceleration lane requirements, high busway volume and approximately 1/2 mile station spacing produce a requirement for a four-lane busway. This section extends between Waikiki and Kalihi Stations. For the balance of the busway, two-lane segments are provided between acceleration-deceleration lane merge points to reduce cost. However, sufficient shoulder width is provided to permit passing a stalled bus at reduced speed.

A radio communication system is also provided between stations, bus operator and central control to aid in traffic control on the busway. Added facility requirements for the Busway concept include provision of storage and maintenance facilities for an added 500 buses by 1995.

5. Concept Analysis

Analysis of the Busway alternative included system patronage and subsequent definition of vehicle requirements, vehicle miles, costs, benefits and other pertinent statistical data. These service and cost measures of the concept are combined with a qualitative analysis dealing with the comparative evaluation of alternatives.

a. Patronage Projections: A total of 456,250 daily passengers was forecasted for the busway system and its associated feeder systems during 1995. A summary of the patronage analysis is presented in Table A-3 showing distribution of trips between peak/daily, work/non-work, mode split, etc. Selected trip characteristics are presented in Table A-4.

b. Operational Analysis: After patronage demands were known, a detailed operating plan was prepared to match service and demand. This operational plan was the basis for estimating system requirements and performance. The various statistical measures such as bus miles, vehicle requirements etc. thus determined were

TABLE A-3
1995 PATRONAGE PROJECTIONS - BUSWAY SYSTEM

ANALYSIS CATEGORY	TOTAL DAILY	% TOTAL	P.M. PEAK HOUR	% TOTAL
1. TRANSIT PERSON TRIPS	456,250	100.0	78,790	100.0
WORK	206,640	45.3	46,050	58.4
NON-WORK	249,610	54.7	32,740	41.6
2. TRANSIT PERSON TRIPS AS:				
% TOTAL TRIPS	13.8	-	21.4	-
% TOTAL WORK TRIPS	30.7	-	42.4	-
% TOTAL NON-WORK TRIPS	9.5	-	12.6	-
3. TRANSIT TRIPS BY MODE*				
BUSWAY	288,200	-	56,270	-
BUS	554,898	-	97,780	-
4. TRANSIT USE BY AREA				
URBAN HONOLULU	329,540	72.2	56,910	72.2
WINDWARD	64,140	14.1	11,080	14.1
CENTRAL	15,410	3.4	2,660	3.4
LEEWARD	47,160	10.3	8,140	10.3

*INCLUDES INTRA-MODAL TRANSFERS

TABLE A-4
SELECTED TRIP CHARACTERISTICS - 1995
BUSWAY SYSTEM

CHARACTERISTIC	DAILY		PEAK HOUR	
	TOTAL SYSTEM	BUSWAY	TOTAL SYSTEM	BUSWAY
PASSENGER MILES	3,131,331	754,301	576,220	135,446
PASSENGER HOURS	142,361	31,467	25,785	5,911
AVERAGE TRIP TIME (MIN.)	-	-	36.3	-
AVERAGE TRIP LENGTH (MI.)	6.86	2.62	7.31	2.41
AVERAGE TRIP SPEED (MPH)	-	-	12.1	-

subsequently used to establish operating costs and appropriate capital costs. They are used in the main body of this report in comparative evaluation of alternatives. Selected operating characteristics are presented in Table A-5.

TABLE A-5: SELECTED OPERATING STATISTICS - 1995
BUSWAY SYSTEM

Statistic	Total System	Busway Local	Busway Express	Feeder Bus Local	Feeder Bus Express
Vehicle Hours (Daily)	7,838	729	616	3,594	2,899
Vehicle Miles (Daily)	151,716	14,651	15,657	43,126	78,282
Vehicles in Peak Hour					
Service	847	81	82	291	393
Spares	84	8	8	29	39
Passengers/Vehicle Mile	3.01	-	-	-	-

c. Capital and Operating Costs: Capital and operating cost estimates were developed in late 1974-early 1975, using prices to reflect 1975 costs as shown in Table A-6.* Included in the capital cost are all vehicles required in 1995 including the feeder buses. In addition to the busway facility cost, including rights-of-way, the reversible at-grade bus lane in Kalanianaole Highway is also included. Operating costs include all labor and expenses necessary to maintain and operate the system for the 1995 patronage volume.

*Subsequent to the development of operating costs shown in the table, a new labor agreement was reached in mid-1975 which increased labor rates and fringe benefits substantially over the estimated amounts. The net result of this new wage agreement was an increase in the estimated operating cost by approximately 15%.

TABLE A-6

ESTIMATED COSTS - 1995 BUSWAY SYSTEM
($ THOUSANDS)

Total Capital Costs

Item	Cost
1. Busway Facilities	
Way Structures	$ 95,850
Stations	88,862
Communications	1,000
Yards & Shops	5,000
Subtotal	$187,712
Contingency (10%)	18,771
Admin & Engrg (13%)	26,843
Total	$233,326
2. ROW & Relocation	$ 83,380
Contingency (10%)	8,338
Admin. (3%)	2,752
Total	$ 94,470
3. Buses	$ 60,515
4. Kalanianaole Hwy	$ 26,100
5. Grand Total	$414,411

Annual Operating Costs

Item	Cost
1. Busway Facilities	
Way Structures	$ 986
Station Oper.	846
G&A	78
Station Power	490
Subtotal	$ 2,400
Contingency (10%)	240
Total	$ 2,640
2. Transportation	$40,073
3. Grand Total	$42,713

C. THE LIGHT RAIL TRANSIT CONCEPT

Light Rail Transit (LRT) is in reality a modern version of the PCC rail transit vehicle and is receiving serious consideration for application in several cities. Initial applications will be in San Francisco and Boston to replace existing PCC rail cars. Its development was the result of the combined efforts of those cities and UMTA to develop a standard vehicle system with expanded operational flexibility. Overhead power pick-up permits operation in non-exclusive rights-of-way as well as on aerial structure or in subway. Articulation permits short turning radius allowing operation on the surface of city streets. The vehicle may be operated as a single unit or coupled into trains (current designs permit 4-car maximum). Propulsion and control systems are relatively simple state-of-the-art versions of time proven concepts. These features offer extensive application potential and have sparked wide interest in the system.

1. Honolulu Application

In applying the LRT concept to Honolulu, a basic 28 mile system was developed to take full advantage of the inherent operational features. As with all alternatives, the same basic alignment was used for the grade separated segment through the heavily urbanized area of Central Honolulu. In addition, selected feeder bus routes were replaced with LRT. In order to complete comparative testing, variations on the basic system using 7, 14, and 23 mile alignments were also developed. This family of alternatives is briefly described below. (See Figure VI-2 in Chapter VI of this report.)

The basic 28-mile system is comprised of 14 miles of exclusive, grade separated right-of-way, 9 miles of exclusive, non-grade separated right-of-way, and 5 miles of route in city streets with mixed traffic operation. The shorter segment lengths tested are:

- a 23-mile length from Pearl City to Hawaii Kai which eliminates the 5 miles of city street operation of the 28-mile system.

- a 14-mile length from Halawa to Kahala which eliminates the 9 miles of exclusive, non-grade separated right-of-way of the 23-mile system.

- a 7-mile length from Keehi Lagoon to the University which is the minimum length system.

2. System Operating Characteristics

System operation was developed for each alternative LRT system which made maximum use of the inherent features of the concept. In the basic system, selected heavy bus routes were replaced with LRT to the extent operationally feasible within headway and capacity limitations in the primary corridor. As the system was scaled in length, the overall operating characteristics more and more closely paralleled the fixed guideway alternative. In essence, the 14-mile and 7-mile systems are identical in both concepts.

In all LRT alternatives, the compatibility to make in-service consist changes was used to balance system capacity to forecasted passenger demand by dropping or adding cars at appropriate points rather than turning back whole trains. This ability was also used to interject branch line service in the basic LRT alternative. This approach produces constant headways over the entire length of the system.

Table A-7 presents the basic vehicle and system operating parameters used in analyzing the LRT systems.[2/]

3. Guideway Requirements

Guideways for the LRT concept included (depending on sub-alternative): Aerial structure; Subway; At-grade exclusive R.O.W.; At-grade mixed traffic.

Aerial structure was based on the use of precast, prestressed concrete girders supported on single reinforced concrete columns with appropriate noise barriers at the outside edges. Trolley wire support uses a "T" support at the center of the 23' wide guideway. Subway structure was based on a double-box constructed by cut and cover methods. Piston effect of trains traveling through the subway sections was assumed to provide ventilation with emergency exhaust fans installed in vent shafts. Exclusive at-grade segments were based on conventional tie and ballast construction in a minimum 24' foot ROW with traffic barriers at the outer edge. Mixed traffic segments were based on tie and ballast construction with flush concrete paving to allow mixed traffic operations. Trolley wires were assumed supported from curbside poles.

4. Station Requirements

Four basic station types were projected, again depending on sub-alternative: aerial; subway; exclusive at-grade; street at-grade. All grade-

TABLE A-7

VEHICLE AND SYSTEM CHARACTERISTICS
LRT ALTERNATIVES

Vehicle

Dimensions:	71' long; 8'-10" wide; 11'-6" high; 69,000 pounds (empty)
Capacity* :	68 seated; 100 design load; 154 crush load
Training:	Min. train - 1 car; Max. train - 8 cars**
Performance:	Max. Speed - 55 MPH; Acceleration -2.8 MPHPS Braking - 3.5 MPHPS (Service), 6.0 MPHPS (Emergency)

System

Avg. Speed:	Pearl City - Halawa:	28.2 mph
	Halawa - Kahala:	22.5 mph
	Kahala - Kuliouou:	26.6 mph
	Mixed Traffic on Street:	12.0 mph
	Avg. Dwell Time:	20 seconds
	Acceleration:	3.0 MPHPS***
	Deceleration:	2.6 MPHPS***
	Max. Train in Mixed Traffic:	2 cars
	Frequency:	Peak: 2 min; Base: 4 min; Night: 4 min.

*Design load and crush load capacities established to provide equal space per passenger on all vehicle concepts

**Assumes present limit of 4-cars/train can be increased to satisfy projected demand

***Acceleration/deceleration rates set equal to fixed guideway concept for equivalent passenger comfort separated and exclusive right-of-way stations were projected to include fare collection equipment, ticket machines, money changers, etc. at the station concourse. All vertical in-station movements were provided by stairs, escalators and elevators. Platform length and location (center or side) was dictated at each station according to maximum train length to be accommodated and physical features of the station and ROW at specific locations. For in-street stops, curbed passenger islands were contemplated. Nominal illumination was assumed at each passenger island for night operations.

5. Train Control and Communication

The LRT system is based on manual operation with a conventional block signal system with wayside control and cab signals to provide train protection. In addition, radio communication between train, stations and central control was assumed.

6. Concept Analysis

Analysis of the overall LRT concept alternatives included patronage, operational requirements (vehicles, vehicle miles, etc.) costs, benefits and other quantitative statistical indicators. In addition, qualitative analyses were conducted as contained in the main body of this report.

a. Patronage: Mode split analysis was conducted on the basic 28-mile LRT alternative and manual adjustments were made in that output to produce 23-mile system forecasts based on system variations. The 14-mile and 7-mile systems used patronage forecasts from the fixed guideway analysis because the system performance of the two concepts (LRT and fixed guideway) were identical for these two common system lengths.

In the manual adjustment to the 28-mile system, it was concluded that removal of the two surface LRT routes in Hawaii Kai would produce a loss of approximately 2,000 daily riders. However, an offsetting gain was determined for the Waikiki area. The lower patronage with the LRT spur into Waikiki was a result of the replacement of the feeder buses in Waikiki with the LRT which eliminated the direct service between the University and Waikiki areas via the proposed University Avenue bridge across the Ala Wai Canal. Other trip interchanges were determined to be essentially equivalent under each alternative. Therefore from a system standpoint, overall patronage and travel characteristics were judged generally equal between the 28 and 23 mile systems as tested. Table A-8 presents a summary of the patronage forecasts by LRT alternatives with selected trip characteristics shown in Table A-9.

b. Operational Analysis: Using the projected patronage and specific link and station volumes, other system parameters and operating statistics were determined for use in estimating capital and operating costs. Table A-10 presents selected operating statistics for the various LRT alternatives examined.

c. Capital and Operating Costs: Table A-11 shows the total estimated capital and operating costs developed in late 1974-early 1975, using prices to reflect 1975 prices.* Included in the capital cost are all vehicles required in 1995 including the feeder buses. Capital costs include all construction, rights-of-way, and relocation costs associated with system development. Operating costs include all labor and expenses necessary to maintain and operate the system for 1995 patronage volumes.

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*Subsequent to the development of operating costs shown in the table, a new labor agreement was reached in mid-1975 which increased labor rates and fringe benefits substantially over the estimated amounts. The net result of this wage agreement was an increase in the estimated operating cost by approximately 15%.

TABLE A-8
1995 PATRONAGE PROJECTIONS - LRT ALTERNATIVES

Analysis Category	28 Mile/23 Mile Total Daily	% Total	PM Peak Hour	% Total	14 Mile Total Daily	% Total	PM Peak Hour	% Total	7 Mile Total Daily	% Total	PM Peak Hour	% Total
1. Transit Person Trips	474,520	100.0	82,210	100.0	473,300	100.0	81,860	100.0	459,300	100.0	79,380	100.0
Work	217,710	45.9	48,430	58.9	215,300	45.5	47,910	58.5	208,800	45.5	46,520	58.6
Non-Work	256,810	54.1	33,780	41.1	258,000	54.5	33,950	41.5	250,500	54.5	32,860	41.4
2. Transit Trips As:												
% Total Trips	14.4	-	22.3	-	14.3	-	22.2	-	13.9	-	21.6	-
% Work Trips	32.3	-	44.6	-	32.0	-	44.2	-	31.0	-	42.8	-
% Non-Work Trips	9.8	-	13.0	-	9.8	-	13.1	-	9.5	-	12.7	-
3. Transit Trips On:												
Guideway*	358,750	75.6	65,420	79.6	306,900	64.8	56,000	68.4	277,300	60.4	50,110	63.1
Bus	398,060	-	69,469	-	527,600	-	92,800	-	561,470	-	99,190	-
4. Transit Use by Area												
Urban Honolulu	342,730	72.2	59,380	72.2	341,850	72.2	59,120	72.2	331,740	72.2	57,330	72.2
Windward	66,710	14.1	11,560	14.1	66,530	14.1	11,510	14.1	64,560	14.1	11,160	14.1
Central	16,030	3.4	2,780	3.4	15,990	3.4	2,780	3.4	15,520	3.4	2,700	3.4
Leeward	49,050	10.3	8,490	10.3	48,930	10.3	8,450	10.3	47,480	10.3	8,190	10.3

*Trips using guideway system for all or part of total trip distance. In 23/28 Mile system, statistic is for 28 mile system and reflects trips using branch lines rather than feeder and local buses. Bus passengers include intra-mode transfers.

TABLE A-9
SELECTED TRIP CHARACTERISTICS - 1995
LRT ALTERNATIVES

Statistic	28 Mile/23 Mile				14 Mile				7 Mile			
	Daily		PM Peak Hour		Daily		PM Peak Hour		Daily		PM Peak Hour	
	System	Guideway*	System	Guideway*	System	Guideway	System	Guideway	System	Guideway	System	Guideway
Passenger Miles ($x10^6$)	3.22	1.76	.59	.33	3.23	1.18	.59	.21	3.10	.73	.57	.13
Passenger Hours ($x10^4$)	13.16	6.48	2.40	1.23	13.43	3.86	2.44	.69	13.60	2.53	2.47	.46
Avg. Trip Time (Min.)	-	10.8	32.4	11.2	-	7.5	33.7	7.4	-	5.5	35.2	5.5
Avg. Trip Length (Mi.)	6.79	4.90	7.22	5.09	6.82	3.84	7.26	3.76	6.74	2.63	7.19	2.64
Avg. Speed (MPH)	-	27.2	13.4	27.2	-	30.5	12.9	30.6	-	28.8	12.3	28.7

*Includes branch lines on street but excludes feeder bus portion of linked trips. (28 Mile system shown)

TABLE A-10

SELECTED OPERATING STATISTICS - 1995
LRT ALTERNATIVES

System Alternative	Daily Vehicle Miles	Vehicles In Peak Hour Service	Spares	Passengers Per Vehicle Mile
1. 28-Mile System				
Total System	151,160	776	77	3.14
Guideway	79,515	373	37	4.52
Local Buses	25,920	182	18	-
Express Buses	45,725	221	22	-
2. 23-Mile System				
Total System	151,440	729	73	3.13
Guideway	75,530	295	30	4.68
Local Buses	30,680	216	21	-
Express Buses	45,230	218	22	-
3. 14-Mile System				
Total System	140,100	707	71	3.38
Guideway	45,840	180	18	6.70
Local Buses	31,080	210	21	-
Express Buses	63,180	317	32	-
4. 7-Mile System				
Total System	148,185	803	80	3.10
Guideway	23,580	99	10	11.76
Local Buses	45,645	308	31	-
Express Buses	78,960	396	39	-

TABLE A-11

ESTIMATED COSTS - 1995 LRT ALTERNATIVES
($ THOUSANDS)

TOTAL CAPITAL COSTS	28-Mile	23-Mile	14-Mile	7-Mile
LRT Facilities and Equipment				
Way & Structure	146,457	138,267	109,492	83,243
Stations	85,429	85,429	74,443	53,804
Power & Control	49,618	46,080	35,687	21,454
Yards & Shops	13,194	13,194	11,716	10,925
Subtotal	295,198	282,970	231,338	169,426
10% Contingency	29,520	28,297	23,134	16,943
13% Admin & Engrg	42,212	40,465	33,081	24,228
TOTAL	366,950	351,732	287,553	210,597
ROW and Relocation	59,980	59,980	51,020	47,410
10% Contingency	5,998	5,998	5,102	4,741
3% Admin	1,967	1,967	1,684	1,575
	67,945	67,945	57,806	53,716
Transit Vehicles	215,250	169,575	103,950	57,225
10% Contingency	21,525	16,958	10,395	5,723
5% Admin & Engrg	11,839	9,327	5,717	3,147
	248,614	195,860	120,062	66,095
Buses	28,800	31,000	37,700	50,300
	712,289	646,537	503,121	380,708
Kalanianaole Highway Busway	-	-	26,100	26,100
GRAND TOTAL	712,289	646,537	529,321	406,808

ANNUAL OPERATING COSTS	28-Mile	23-Mile	14-Mile	7-Mile
Way & Structure	2,863	2,493	1,788	1,362
Vehicle	3,005	2,416	1,547	967
Transportation	4,381	3,647	2,690	2,021
G&A	4,193	3,793	2,873	2,400
	14,442	12,349	8,898	6,750
Power	5,640	5,390	3,400	1,900
	20,082	17,739	12,298	8,650
10% Contingency	2,008	1,774	1,230	865
	22,090	19,513	13,528	9,515
Feeder Bus	19,390	20,800	24,900	33,840
GRAND TOTAL	41,480	40,313	38,428	43,355

D. THE FIXED GUIDEWAY TRANSIT CONCEPT

Fixed guideway transit is defined as a grade separated exclusive right-of-way system with trained vehicles operating in a normal transit mode; i.e. all trains stop at each station. The basic concept and requirements of this transit concept are well established with long histories of experience. Each application, however, incorporates current state-of-the-art improvements and is tailored to the specific demands of its service area.

1. Honolulu Application

Fixed guideway transit was analyzed as early as 1966 under OTS.[3/] Detailed planning of a similar system was completed in 1972. These studies provided extensive data and community factors on which to base system selection and location in Honolulu.

In essence, a potential for a basic 23-mile system was identified through a specific corridor and routes. Identified demand also indicated that a medium capacity system in the range of 25-30,000 passengers per hour was most appropriate. The particular vehicle system used in this study is a medium sized, rubber tired, light weight vehicle having these features.[4/] As in the busway and LRT alternatives, identical alignments have been used through Central Honolulu. As in the LRT alternative, various lengths of guideway have been considered to determine the most appropriate system length. Lengths of 23, 14, and 7 miles have been analyzed. The family of fixed guideway alternatives is briefly described below. (See Figure VI-3 in Chapter VI of this report.)

The basic 23-mile system is totally grade separated in exclusive rights-of-way and includes 6.3 miles at-grade in freeway rights-of-way between Pearl City and the Pearl Harbor Interchange and between the Kapiolani Interchange and Kahala, 1.7 miles of subway through the downtown area with the remaining 15.2 miles in aerial configuration. This system contains 21 stations. Shorter segment lengths are:

- a 14 mile system extending from Halawa to Kahala which eliminates the 5± mile aerial segment from Kahala to Hawaii Kai and the 4± mile at-grade segment from Halawa to Pearl City. This system contains 15 stations.

- a 7-mile system extending from Keehi Lagoon to the University which is a minimum length system containing 10 stations.

2. System Operating Characteristics

Various operational concepts were evaluated to identify the optimal service in terms of travel time, local and longer trip movements, and system efficiency.[5/] Station by-pass features to permit express or skip-stop operation were compared to conventional transit mode (all-station) operation.

From this evaluation, it was found that with system headways in the two-minute range, any time saving for express passengers was offset by time loss for shorter trip requirements. In addition, the relatively small express time saving could not justify the large increase in capital cost and community impact produced by the four-track system. Therefore, a conventional transit mode operating plan was adopted.

Similarly, branch lines were found to produce serious operating and capacity restraints and that the high cost could not be justified. Therefore, a single line route was adopted.

An operating plan was developed which provided through routing of all trains between terminals with no intermediate turnbacks. This will permit sizing trains to accommodate outlying passenger volume demands with seated loads and retain vehicle load factors in peak-load sections comparable to those provided in other concepts.

Table A-12 presents the basic vehicle and system operating parameters used in analyzing the fixed guideway system.

3. Guideway Requirements

Basic guideway configurations include aerial, at-grade and subway structures. Aerial structure was based on precast, pre-stressed concrete girders supported on single reinforced concrete columns with appropriate noise barriers at the outer edge of the 23' wide guideway. At-grade structure was designed as a double "T" section of precast concrete supported on conventional spread footings. Barrier walls at each side of the right-of-way topped with chain link fencing prevents auto-incursion and other access. Subway structure was based on a double box section constructed by cut and cover methods.

TABLE A-12

VEHICLE AND SYSTEM CHARACTERISTICS
FIXED GUIDEWAY ALTERNATIVES

VEHICLE

Dimensions: Length - 45'-0" (A-Car), 41'-8" (B-Car)

Width - 9'-2", Height - 11'-0", Empty Weight - 32,000 lbs. (A-Car), 29,000 lbs. (B-Car)

Capacity* : Seated - 36; Design - 72; Crush - 110

Training: Min. Train - 2 A-Cars; Max. Train - 2 A-Cars & 8 B-Cars

Performance: Max. Speed - 50 mph; Acceleration - 3 MPHPS; Braking - 2.6 MPHPS (Service)

SYSTEM

Avg. Speed (Terminal to Terminal): 23 mile - 32.7 MPH;
14 mile - 30.5 MPH;
7 mile - 28.7 MPH

Avg. Dwell Time - 20 seconds

Frequency - Peak: 2 min; Base: 4 min; Night: 4 min.

*Design load and crush load capacities established to provide equal space per passenger on all vehicle concepts.

4. Station Requirements

Each station was designed and sited in relation to traffic patterns, physical character of the area and to provide for bus and auto access for transfer of passengers. Auto parking was included at the Pearl City (750) and Hawaii Kai Stations (400) in the 23-mile system and stadium parking facilities were assumed available for transit users at the Halawa Station in the 23 and 14 mile systems. No parking was provided for the 7-mile system.

All stations were designed to accommodate the maximum 10-car trains. Stairs, escalators and elevators were included at each station to accommodate vertical movements in the stations and to permit use by handicapped persons.

5. Support Systems

Vehicles, stations, yard and shops area, and central control were interconnected with voice communication systems including telephone, radio and public address systems. Closed circuit television was assumed to monitor station activities outside the station agent's normal field of view. Automatic fare collection systems were included at all stations and control entry to the system. Train control systems provide for fully automatic train protection and train operation with provision for ultimate addition of train supervision to produce complete fully automated operation. Yards and shops to accommodate the 1995 system requirements would be located adjacent to Keehi Lagoon.

6. Concept Analysis

Analysis of the fixed guideway alternatives included patronage and operational analysis and projections of cost and operating statistics for use in subsequent system evaluations.

a. Patronage: Patronage projections were made through application of the computer models to each alternative length fixed guideway system and its accompanying feeder and express bus system. Projected 1995 patronage is shown for each sub-alternative in Table A-13 and selected travel characteristics presented in Table A-14.

b. Operational Analysis: Using the patronage estimates, a detailed operating plan was prepared for each sub-alternative and analyzed

TABLE A-13: 1995 PATRONAGE PROJECTIONS - FIXED GUIDEWAY ALTERNATIVES

ANALYSIS CATEGORY	7-MILE				14-MILE				23-MILE			
	TOTAL DAILY	% TOTAL	P.M.PK. HOUR	% TOTAL	TOTAL DAILY	% TOTAL	P.M.PK. HOUR	% TOTAL	TOTAL DAILY	% TOTAL	P.M.PK. HOUR	% TOTAL
1. TRANSIT PERSON TRIPS	459,300	100.0	79,380	100.0	473,300	100.0	81,860	100.0	490,000	100.0	84,920	100.0
WORK	208,800	45.5	46,520	58.6	215,300	45.5	47,910	58.5	224,500	45.8	49,890	58.7
NON-WORK	250,500	54.5	32,860	41.4	258,000	54.5	33,950	41.5	265,500	54.2	35,030	41.3
2. TRANSIT PERSON TRIPS AS:												
% TOTAL TRIPS	13.9	-	21.6	-	14.3	-	22.2	-	14.8	-	23.1	-
% TOTAL WORK TRIPS	31.0	-	42.8	-	32.0	-	44.2	-	33.3	-	46.0	-
% TOTAL NON-WORK TRIPS	9.5	-	12.7	-	9.8	-	13.1	-	10.1	-	13.5	-
3. TRANSIT TRIPS BY MODE												
GUIDEWAY	277,300	60.4	50,110	63.1	306,900	64.8	56,000	68.4	332,600	67.9	60,800	71.6
BUS *	561,470	-	99,190	-	527,600	-	92,800	-	568,800	-	103,700	-
4. TRANSIT USE BY AREA												
URBAN HONOLULU	331,740	72.2	57,330	72.2	341,850	72.2	59,120	72.2	353,920	72.2	61,340	72.2
WINDWARD	64,560	14.1	11,160	14.1	66,530	14.1	11,510	14.1	68,880	14.1	11,940	14.1
CENTRAL	15,520	3.4	2,700	3.4	15,990	3.4	2,780	3.4	16,550	3.4	2,870	3.4
LEEWARD	47,480	10.3	8,190	10.3	48,930	10.3	8,450	10.3	50,650	10.3	8,770	10.3

*INCLUDES INTRA-MODAL TRANSFERS

TABLE A-14: SELECTED TRIP CHARACTERISTICS - 1995 FIXED GUIDEWAY ALTERNATIVES

CHARACTERISTIC	7-MILE FIXED GUIDEWAY				14-MILE FIXED GUIDEWAY				23-MILE FIXED GUIDEWAY			
	DAILY		P.M. PK. HOUR		DAILY		P.M. PK. HOUR		DAILY		P.M. PK. HOUR	
	TOTAL SYSTEM	GUIDE-WAY	TOTAL SYSTEM	GUIDE-WAY	TOTAL SYSTEM	GUIDE-WAY	TOTAL SYSTEM	GUIDE-WAY	TOTAL SYSTEM	GUIDE-WAY	TOTAL SYSTEM	GUIDE-WAY
PASSENGER MILES	3,095,084	728,842	570,600	132,281	3,228,410	1,178,140	594,450	210,591	3,458,125	1,747,793	637,107	324,422
PASSENGER HOURS	136,043	25,310	24,670	4,610	134,326	38,570	24,400	6,871	137,510	53,390	25,044	9,815
AVERAGE TRIP TIME (MIN.)	-	5.5	35.2	5.5	-	7.5	33.7	7.4	-	9.6	31.6	9.7
AVERAGE TRIP LENGTH (MI.)	6.74	2.63	7.19	2.64	6.82	3.84	7.26	3.76	7.06	5.25	7.50	5.34
AVERAGE TRIP SPEED (MPH)	-	28.8	12.3	28.7	-	30.5	12.9	30.6	-	32.7	14.2	33.0

TABLE A-15: SELECTED OPERATING STATISTICS - 1995 FIXED GUIDEWAY ALTERNATIVES

STATISTIC	7-MILE FIXED GUIDEWAY				14-MILE FIXED GUIDEWAY				23-MILE FIXED GUIDEWAY			
	TOTAL SYSTEM	GUIDE-WAY	FEEDER BUS LOCAL	FEEDER BUS EXPRESS	TOTAL SYSTEM	GUIDE-WAY	FEEDER BUS LOCAL	FEEDER BUS EXPRESS	TOTAL SYSTEM	GUIDE-WAY	FEEDER BUS LOCAL	FEEDER BUS EXPRESS
VEHICLE MILES (DAILY)	158,940	34,335	45,645	78,960	158,485	64,225	31,080	63,180	189,885	111,495	31,680	46,710
VEHICLES IN PEAK HOUR												
SERVICE	850	146	308	396	767	240	210	317	831	383	223	225
SPARES	85	15	31	39	77	24	21	32	83	38	22	23
PASSENGERS/VEHICLE MILE	2.89	8.08	-	-	2.99	4.78	-	-	2.58	2.98	-	-

for vehicle requirements, vehicle miles and other operating statistics necessary to determine costs and for subsequent system evaluation. Selected operating statistics are presented in Table A-15.

c. Capital and operating costs: Table A-16 presents the estimated capital and operating costs developed in late 1974-early 1975, using prices to reflect 1975 costs as shown.* Included in the capital cost are all vehicles required in 1995 including the feeder buses. For the 7 and 14 mile systems, costs for the exclusive, single lane reversible busway in Kalanianaole Highway between Hawaii Kai and Kahala is included as part of the feeder bus system. Operating costs include all labor and expenses necessary to maintain and operate the system for 1995 patronage volumes.

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*Subsequent to the development of operating costs shown in the table, a new labor agreement was reached in mid-1975 which increased labor rates and fringe benefits substantially over the estimated amounts. The net result of this new wage agreement was an increase in the estimated operating cost by approximately 15%.

TABLE A-16
ESTIMATED COSTS - 1995 FIXED GUIDEWAY ALTERNATIVES
($ THOUSANDS)

	SYSTEM LENGTH		
	7-MILE	14-MILE	23-MILE
TOTAL CAPITAL COSTS			
F.G. FACILITIES & EQUIP.			
WAY STRUCT. & GUIDERAILS	$ 79,696	$112,235	$157,051
STATIONS	47,489	65,996	84,194
POWER & CONTROL	24,130	39,976	52,951
YARD & SHOPS	11,935	13,546	14,807
VEHICLES	52,800	86,600	137,800
SUBTOTAL	$216,050	$318,353	$446,803
CONTINGENCY (10%)	21,605	31,835	44,680
ADMIN & ENGRG. (13%)	30,895	45,524	63,892
TOTAL	$268,550	$395,712	$555,375
F.G. ROW & RELOCATION			
ROW & RELOCATION	$ 47,410	$ 51,020	$ 53,380
CONTINGENCY (10%)	4,741	5,102	5,338
ADMIN. (3%)	1,565	1,684	1,762
TOTAL	$ 53,716	$ 57,806	$ 60,480
FEEDER BUS SYSTEM			
KAL. HWY. IMPROVEMENTS	$ 26,100	$ 26,100	-
BUSES	50,310	37,700	$ 32,045
TOTAL	$ 76,410	$ 63,800	$ 32,045
GRAND TOTAL	$398,676	$517,318	$647,900

	F.G. SYSTEM LENGTH		
	7-MILE	14-MILE	23-MILE
ANNUAL OPERATING COSTS			
FIXED GUIDEWAY SYSTEM			
WAY & STRUCTURE	$ 1,458	$ 1,891	$ 2,643
VEHICLE	950	1,474	2,369
TRANSPORTATION	2,021	2,690	3,467
GENL. & ADMIN.	2,400	2,873	3,793
POWER	1,766	3,031	4,965
SUBTOTAL	$ 8,595	$11,959	$17,237
CONTINGENCY (10%)	859	1,196	1,724
TOTAL	$ 9,454	$13,155	$18,961
FEEDER BUS SYSTEM	$33,840	$24,900	$21,900
GRAND TOTAL	$43,294	$38,055	$40,861

REFERENCES

1. "Draft Environmental Impact Statement," Volume III, Honolulu Rapid Transit Project, September 1972, Daniel, Mann, Johnson, & Mendenhall

2. "Standard Light Rail Vehicle Specification," Technical Section, October 1972, Massachusetts Bay Transportation Authority and San Francisco Municipal Railway

3. "Oahu Transportation Study," Volumes I, II, and III 1967, State of Hawaii and City & County of Honolulu

4. "Study of Rubber-Tired Transit Technology," Honolulu Rapid Transit Project, PEEP II, December 1974, Daniel, Mann, Johnson, & Mendenhall

5. "Study of Fixed Guideway Operational Concepts," Technical Report, July 1974, Daniel, Mann, Johnson, & Mendenhall

APPENDIX B

THE LIGHT RAIL TRANSIT CONCEPT

APPENDIX B

THE LIGHT RAIL TRANSIT CONCEPT

A. GENERAL

The Light Rail Transit (LRT) has its gensis in the President's Conference Committee (PCC) vehicle developed in the early 1930's. It is the result of a joint development program by the U. S. Department of Transportation and the Cities of San Francisco and Boston, both of which still operate PCC cars in transit service.

Basic objectives of the LRT program include development of a vehicle technology incorporating proven components and applicable to medium volume demands between conventional bus operations and full scale rapid transit such as the Bay Area Rapid Transit (BART) system. Another objective was the flexibility to operate on non-exclusive rights-of-way such as city streets and also offer trained operation on exclusive rights-of-way. These attributes of the LRT offer increased application potential for the system.

1. System Applications

Initial application for this system will be in San Francisco and Boston. In San Francisco, existing street rail operation on 5 lines using PCC cars is to be up-graded to accept the new LRT vehicles. In several instances, the rail bed is being completely rebuilt together with street improvements including passenger loading islands, new street illumination, traffic signal modifications, new trolley poles and underground distribution.

The new system in San Francisco also utilizes the operational flexibility offered by this concept. The service plan will entail street operation in mixed traffic as well as subway operation in Market Street. It will also involve both in-service consist changes at branches and merging of branches to produce a minimum headway of 2 minutes and maximum of 4 minutes. Because several of the improvement projects have already received bids and the fact that the San Francisco system employs the full range of flexibility offered by the LRT concept, much of the basic data used to develop the LRT alternative in Honolulu has been derived from data on that system.

In addition to San Francisco and Boston, several other cities or regions including Dayton, Ohio, Austin, Texas, and Portland, Oregon are or have been analyzing the system for potential application. In addition, several cities including Cleveland (Shaker Heights), Philadelphia, Newark, and Pittsburgh have lines with light rail characteristics but using out-moded equipment. In Europe, light rail applications are common.

2. Positive and Negative Features

As in any general purpose system designed to cover a broad range of applications, some compromises are inherent in the design. As a result, some features incorporated to provide flexibility may be redundant or introduce some negative features for specific application. Some of the more important features of the vehicle system are described below.

Feature	Positive	Negative
Articulation	Vital for on street operation of car with this length; permits short radius curves in street rights-of-way.	Redundant for most grade separated applications although short radius permits alignment flexibility in tight rights-of-way.
Pantograph power pick-up	Essential for street operation in non-exclusive ROW to prevent contat with power rail.	Requires added overhead structure in exclusive at-grade ROW and in aerial configuration. Some adverse aesthetic impact.
Narrow width	Important for street operation.	Reduces aisle width and limits seat width in exclusive ROW application.
All cars double-ended	Permits single car operation.	Produces some redundancy in trained operation and precludes use of "A" & "B" cars to reduce control system costs, also precludes walk-through of trained vehicles.

Feature	Positive	Negative
Trainability	Permits flexibility in routing and capacity.	Currently 4-car maximum train limits capacity in grade separated or exclusive ROW. (Modest redesign may expand capability).

In general, none of the necessary compromises in this vehicle system produce significant negative aspects. Also, modest redesign of selected vehicle components can permit tailoring the vehicle to more specific applications within the basic system concept. In fact, although the 71 foot articulated car will constitute the initial order, the manufacturer's literature proposes a "family" of light rail vehicles including both articulated and non-articulated concepts. This will expand the ability to tailor a more or less standardized vehicle concept to specific application.

3. Application to Honolulu

While this "family" of vehicles may ultimately be produced, the current articulated vehicle has been used in the alternative system evaluation for Honolulu since it offers a distinctly different operating concept. Other alternatives focused on an all-bus with busway system with variations in operating approach and a fixed guideway system supported by bus feeders. Introduction of the LRT concept permits combining both apporaches where appropriate by taking advantage of the LRT ability to operate both in mixed traffic and as a rapid transit fixed guideway system.

However, some features of the current vehicle were not retained as limiting elements. For example, the current 4-car limit in train consist would have severely limited capacity at comparable quality of service with respect to the other alternatives tested or else required multiple lines in the primary corridor. Therefore, it was assumed that modest redesign of limiting elements would permit expansion to longer trains. Other limitations and assumptions relative to a Honolulu application of LRT will be discussed in subsequent sections as appropriate.

B. OPERATING CHARACTERISTICS

1. System Capacity

Two factors make up system capacity; vehicle capacity (and train capacity) and headways. With respect to vehicle capacity, published literature on the LRT system indicates the following capacities for the present articulated vehicle (MUNI configuration).

Seated Load	68
Normal Load	100 (147% load factor)
Crush Load	219 (322% load factor)

These data would imply that under maximum conditions the LRT would have a capacity at 2 minute headways in excess of 6000 passengers per hour for a single car and over 24,000 per hour for a 4 car train. However, some added examination of these values for reasonableness should be made.

For this evaluation, floor areas available for standees were first tabulated for both "normal" and "crush" conditions. It was assumed that under normal conditions, door passageways would not be occupied by standees. All these spaces were, however, included in crush-load floor areas.

Floor areas and computations for space available to standees at rated capacities are summarized below:

NORMAL LOAD FLOOR AREA	AREA PER STANDING PASSENGER	CRUSH LOAD FLOOR AREA	AREA PER STANDING PASSENGER
173.42 sq. ft.	5.42 sq. ft.	234.99 sq. ft.	1.56 sq. ft.

As can be seen from the space per standee values, the rated normal load represents a reasonable value. However, the rated "crush" load represents an "always room for one more" philosophy and should not be considered for a high quality system.

For purposes of this analysis, and to provide an equal quality service, per passenger space allocation equal to those used in other system concepts will be used. The table below presents the resulting vehicle capacities based on total floor area of the car including space occupied by seats since variations in seat arrangement can materially influence vehicle capacity.

VEHICLE CAPACITIES

Load Condition	Fixed Guideway Sq. Feet/ Passenger*	Fixed Guideway Capacity	LRT Sq. Feet/ Passenger*	LRT Capacity
Seated	9.14	36	6.75	68
Normal (Design)	4.57	72	4.57	100
Crush	2.99	110	2.99	154

*Total effective floor area for fixed guideway vehicle = 329 sq. ft. and for LRT = 459 sq. ft. Passenger capacity for LRT calculated by dividing total effective floor area by sq. ft. /passenger equivalent to fixed guideway allowances.

As can be seen from the above table, the normal load determined from the fixed guideway vehicle is equivalent to that stated in the LRT literature, however, the crush load is a more realistic value. In any event, the normal load capacity should be used for design purposes since basing system capacity on crush conditions is not consistent with improved quality of transit operation.

2. Headways

Safe operating headways are determined by several variables including maximum dwell time, stopping distance, etc. In the case of the LRT system with block signal and speed control coupled with manual operation and cab signals, headways in the 90 to 120 second range should be acceptable at the projected operating speeds. However, where in-service consist changes and/or surface operations are contemplated, another area of uncertainty must be considered.

In the case of San Francisco Municipal Railway (MUNI) where 5 branch lines will be merged into the Market Street subway, changes in train consist are projected to occur at two points in the branches where headways are four minutes. The resulting two branches are then projected to merge at the entrance to the subway to produce two minute headways but train consist will remain the same. This proposed operational plan is still under analysis and information on which to assure workability has not yet been released. Some problem areas are, however, apparent.

One area of uncertainty results from the on-street operations where traffic problems could delay the arrival of a car intended to be added to a train. This could have serious consequences on down-stream scheduled headway maintenance and also produce back-up on up-stream trains at close hadways. Therefore, the number of branch lines should be kept to a minimum in order to permit the coupling operation without seriously impairing desired headways.

With respect to surface operation in mixed traffic, headways of two minutes or less should pose no problems because of the low speeds involved. For operation at-grade in exclusive rights-of-way in street or highway medians however, another factor must be considered. This method of operation is anticipated in both Kalanianaole and Kamehameha Highways to minimize capital cost by taking full advantage of LRT flexibility.

In these instances, operating speeds in the range of 35-40 miles per hour are contemplated to make the system reasonably comparable with the posted automobile speed. Both of these highways involve several at-grade intersections where heavy cross or turning traffic movements are required. In these conditions, care must be taken to assure that these traffic movements can be accomplished within the operating headways of the transit system.

To determine the limiting factors in these conditions, a time/space analysis was conducted. The analysis was based on a 35 mph maximum operating speed and diagrams prepared for both 90 and 120 second headways. From this parametric study, it was apparent that the traffic signal cycle at each intersection must coincide or be a multiple of the train headway.

It was also clear that the time available for crossing traffic is a function of the composite headways of trains operating in both directions. At a location where opposing trains are exactly staggered, for example, the effective headway would be 1/2 the train headway. With 2 minute headways, this would produce an effective headway of 60 seconds. Allowing reasonable clearance times and safety margins, headways in this range will definitely limit cross traffic capacity.

Based on this analysis, it appears that a 120 second headway is a reasonable minimum for the Kalanianaole Highway section. Any headway less than 120 seconds would severely hamper the flow of traffic either crossing or turning left unto the highway. To insure safe operation, all traffic signals are assumed to be interlocked with train detection and that crossing semaphores and flashing lights will be installed at track-side in addition to standard traffic signals at each intersection.

On this basis, 2 minutes has been set as a minimum safe headway throughout the system. This also assumes that the change in train consist at branch lines can be made in that time. It also does not permit merges except by train consist changes since 60 second headways would produce a serious speed reduction on the grade separated sections and could also produce unstable operations with minor vairation in dwell time.

3. Limitations of Train Length in Mixed Traffic Operation

Because of the necessity for access to street frontage for at least drop-off and pick-up if not curb parking, it will be necessary to operate the LRT cars in the center lanes under on-street operation. Early street car operations often did not provide passenger islands for loading and unloading operations. However, this method of operations, particularly in Honolulu with narrow streets and high passenger volumes, produces an unsafe condition and any new system should provide load/unload islands for passenger safety.

This requirement, combined with vehicle length, will produce a limitation on train length under on-street operation. The LRT is approximately 71 feet long with three doors per side. Thus, a loading platform must be approximately 60 feet for a single car operation and 120-140 feet for two car operation. Recognizing that many block faces in Waikiki and urban Honolulu are in the range of only 200 feet, this clearly dictates a maximum train length of 2 cars and even that length will produce some limiting of driveway access to parking lots, business establishments and residential locations if passenger loading islands are provided.

C. NETWORK DESIGN

1. Primary Corridor

The definition of a test network employing LRT in Honolulu requires some initial evaluation of the potential service areas. Chapters III and V of this report describes the basis for selection of the primary service corridor and routes for the City.

While the dominant primary corridor is readily apparent, it is also apparent that some important secondary corridors cannot be directly linked because of location or physical constraints. For example, the length of Waikiki and its location at the edge of the corridor are such that direct service is difficult without missing several other important service areas. At the same time, the intensity of development as both an origin and destination point result in a heavy travel demand.

Similarly, the growing residential development around Salt Lake, north of the airport, is somewhat isolated by topography and adjacent land uses. The number of residential units in this area and the limited ingress/egress points produce a fairly concentrated traffic condition at those points.

Another secondary corridor reflects the off-line location of the military complexes associated with Pearl Harbor and Hickam Field. This corridor may be defined by the "Y" formed by Nimitz Highway and Kamehameha Highway just west of the airport.

Other smaller corridors are produced by the fingers of development extending northerly into the mountains along the entire length of the corridor. However, with the exception of Manoa and Nuuanu Valleys, these corridors are very short with steep grades and very narrow streets.

Other important or major secondary corridors are of a more regional nature. These include access to the Windward district via Pali and Likelike Highways, the Central district via H-2 and the developments toward Ewa Beach and beyond in the Leeward district. These are discussed in their regional context in earlier sections of this report.

2. Route and Network Configurations

In defining the test ntework and route configurations for the LRT alternative, a major effort has been made to maximize the flexibility opportunities inherent in the concept to extend direct service to secondary corridors through use of the at-grade potential and in-service charge in train consist. At the same time, care was exercised to assure that the final network was reasonably cost-effective so as not to bias the evaluation. These trade-offs imply an optimizing process in network development.

3. Branch Lines

Due to higher capital investments required for the LRT system, peak hour volumes in excess of 5,000 passengers should exist in corridors for LRT application. On this basis, any corridor with patronage projections in excess of 5,000 passengers per hour were considered candidates for LRT replacement for buses. It should be pointed out that this analysis does not consider other non-economic values such as noise, air quality, aesthetics, etc., which may have added value in selecting one mode over another.

To gain insight into probable cost effective LRT branches, patronage estimates from fixed guideway and busway networks were used and compared to the demand volume criteria. On this basis, extension of the basic corridor from Kahala to Hawaii Kai and from Halawa to Pearl City combined with a branch to serve the Waikiki area appeared justifiable.

A second criterion was operability. As indicated earlier, a 2 minute headway had been established as a minimum. It was also shown that multiple branches from a single line could introduce increasing uncertainty and hence should be avoided.

4. System Network

Comparisons of projected maximum link volumes on the busway and fixed guideway systems clearly indicated that the current limit in train length to a 4 car maximum could not accommodate the Honolulu demand. Therefore, it was assumed that a redesign could be accomplished to permit longer trains. Unless this assumption was made, it would have required parallel service routes or crush loading, neither of which would provide comparable conditions with competing alternatives.

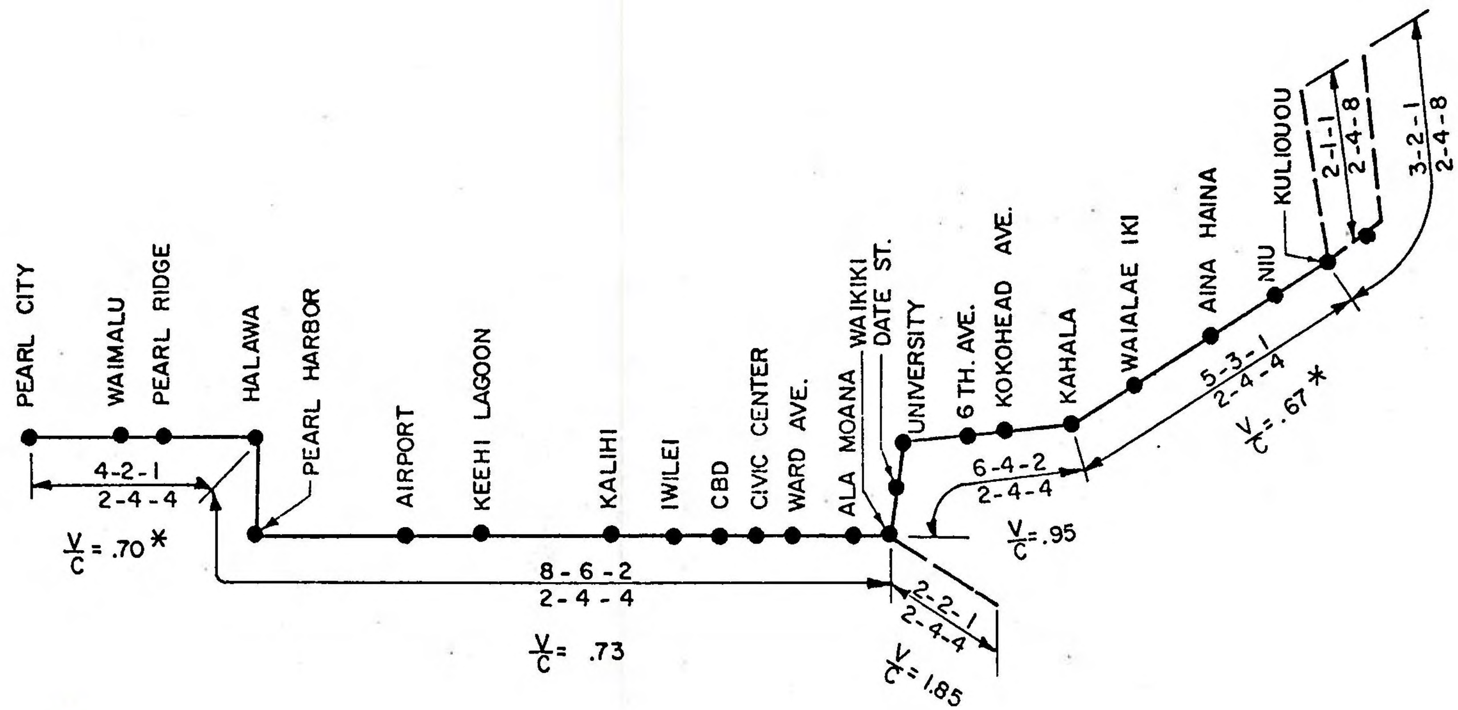
With respect to vertical alignment, a cursory examination of the central urban area volumes clearly shows a requirement for full grade separation. The capacity constraint imposed by two car trains coupled with severe speed limitation imposed by on-street operation indicate that this is an unacceptable configuration in the denser areas of Honolulu. For example, in San Francisco, present rail operations using P.C.C. cars in surface operation average less than 10 mph for end to end travel with one line averaging less than 8 mph. In Honolulu, an average speed comparable to that of a bus could be expected or about 11 to 12 miles per hour. A speed this low is likely to produce a significant patronage reduction and the added cost for the LRT wouldbe of questionable value.

The resulting 28-mile LRT network is shown in Figure B-1. The segment between Halawa and Kahala stations is projected to be on grade separated right-of-way with the segment through the CBD in subway. The Waikiki branch is projected to be surface operation in mixed traffic as are the legs into Hawaii Kai. The portions in Kamehameha Highway and Kalanianaole Highway are projected to be surface operation in exclusive rights-of-way. On these exclusive right-of-way segments, traffic signal interlocks, vehicle detection and crossing signals are assumed at each side of the right-of-way to preclude incursion into the transit lanes.

The network includes 24 stations in the exclusive right-of-way section between Pearl City and Hawaii Kai. Branch lines in Waikiki and Hawaii Kai are projected to use passenger loading islands spaced at approximately 800 feet. Station dwell time was set at 20 seconds.

As in any trunkline system, a comprehensive bus feeder system is required. The system for the LRT network is essentially the same as that used in the 23 mile fixed guideway network except that buses have been eliminated in Waikiki and Hawaii Kai due to the surface operation of the LRT.

Service characteristics for the 28-mile LRT network are summarized in the table below.



LEGEND

●	Station name.
8 - 6 - 2 / 2 - 4 - 4	No. cars/train – Peak, Base, Night / Frequency – Peak, Base, Night
V/C	Peak hour volume/Capacity ratio at maximum link in segment at design load (100 pass/car)
*	V/C ratio of 0.68 represents full seated load.

SERVICE LEVELS BY TIME OF DAY

FIGURE B - 1

LRT NETWORK SERVICE CHARACTERISTICS

Characteristic	Peak	Base	Night
Frequency (All Lines)	2 Min.	4 Min.	4 Min. *
Train Length**	2 to 8 Cars	1 to 6 Cars	1 to 2 Cars
Schedule Speed (Mph)	On-street-12	Same	Same
	Exclusive-29	Same	Same
Max. Speed (Mph)	50	50	50
Scheduled Load/Car	100	68	68

* Night frequency on Hawaii Kai branches becomes 8 minutes by alternating service on each leg with one-car train.

** Assumes cars are added or dropped from trains to serve branches and at turn-backs. Minimum shown indicates minimum no. of cars on any leg. At-grade street operation may require higher loading due to two-car limit on train length. On exclusive sections, projected demand at scheduled load determines train length.

5. Operations Analysis

Based on the projected patronage and specifically the link volumes in the LRT alignments at the specified headways, other system requirements such as numbers of vehicle per train and turnback points may be determined. From these data, various operating statistics such as peak vehicle requirement, miles of vehicle operation, passengers per vehicle mile, vehicle utilization, etc. can be estimated. These data are essential in estimating capital and operating costs and also as measures of system efficiency. Some selected statistics on the 28-mile LRT system is tabulated below.

	Total System	Guide-Way	Bus Local	Bus Express
Vehicle Miles (Daily)	151,160	79,515	25,920	45,724
Veh. in Peak Hr. Service	776	373	182	221
Spares	77	37	18	22
Passengers/Vehicle Mile	3.14	4.52	-	-

Vehicle capacity has been used to determine the total vehicle requirements shown above based on the link volume on the guideway system and route volume for the bus routes. The link volumes for the LRT route has been translated into train requirements at specified headways as shown in the diagram on the following page. Also shown are volume-capacity ratios for the maximum link in each segment.

As in all other alternatives, system capacity has been set to reasonably match demand to produce a maximum system efficiency. In this case, the maximum link volume in the Ala Moana to Ward Avenue link of the guideway system would normally become the determining factor. However, because of the almost comparable volume in the Date to Waikiki link, a six car train is required to meet the design standards. This produces an eight car train after the Waikiki junction which in turn reduces the volume/capacity ratio (v/c) at the maximum link to 0.73 or only slightly above a seated load v/c of 0.68. At the same time, the in-street configuration of the Waikiki Branch produces a significant overload because of the two-car train limitation of in-street operation.

The Waikiki branch will also result in a very high transfer volume at the Waikiki station since passengers to and from the easterly direction must transfer at this station. Thus, while the branch line demonstrates a very high utilization, it also introduces an operational complexity both from the standpoint of the change in train consist and limited ability to accurately match volume/capacity measures, either side of the Waikiki station. It is clear however, that the resulting system produces a high quality service aside from the Waikiki line.

APPENDIX C

BENEFIT/COST ANALYSIS

APPENDIX C

BENEFIT/COST ANALYSIS

The traditional benefit/cost method of evaluating public investments was used as one of the measures for evaluating alternatives with varying system attractiveness. The approach taken for comparison of alternatives was to consider only those direct travel benefits which reflects patronage volumes. Since capital costs are incurred early in the project life and benefits usually increase downstream, it is necessary to assume some time frame and bring both costs and benefits to present value. In keeping with other aspects of this study, a 30-year period of operations has been used for this purpose. In determining present worth, various discount rates have been used to reflect the sensitivity of the ratio to varying economic situations. Discount rates of 4%, 7%, and 10% are applied to both costs and benefits equally.

A baseline all-bus system, or "null" alternative, was used as the basis of measuring the benefits which would accrue to the region with the implementation of the various alternatives studied. This baseline system was assumed to have a total fleet of 450 buses carrying 214,300 transit riders daily. It would have an operating plan similar to that which is in operations today. For this benefit/cost analysis, the baseline system was assumed to be constant over the entire 30-year period.

1. Capital and Operating Costs

A 30-year period, 1980 to 2010, is assumed with 1995 selected as the "study year" with costs, along with benefits, scaled forward or backward in time from this base year. The operations and maintenance costs for the alternative systems were developed for the year 1995 and then extrapolated over the 30-year period in the same manner as that used to obtain the total economic benefits. This procedure is explained in the following section.

The capital cost estimates for each alternative system and length are contained in Appendix A of this report. Also shown are the operating and maintenance costs for each alternative. All costs reflect the 1975 dollar value and are based on the 1995 patronage volumes. Salvage values of the fixed facilities and equipment after the 30-year period was also considered in the analysis.

Both the capital cost and operations and maintenance cost required to operate the baseline system over the 30-year period was then deducted from the total cost of each alternative system. This net cost was then used in developing the benefit/cost ratio.

2. Benefits

The total economic benefits which will accrue to the Honolulu region by the implementation of each of the alternative transit systems tested, during the 30-year analysis period, is based on the annual benefits during the year 1995. Using 1995 as a reference point, it was estimated that initial patronage would be approximately 55 percent for both peak hour and total patronage. It was further assumed that patronage would grow arithmetically from 1980 to 1995 and the mid-point would represent an average for the first 15 years. Further, it was estimated that patronage would increase by 22-1/2 percent by 2010. Again assuming an arithmetic growth the midpoint of these trends represent an average for the second half of the 30-year analysis period.

In the analysis of benefits only quantifiable transportation benefits were considered and these were in terms of:

- Time savings to both transit users and non-users.
- Vehicle operating, insurance, parking, and ownership savings to the diverted motorists.
- Reduction in fatalities.

a. Time Savings

The time savings accruing to the transit user and the continuing motorist was valued on the basis of a 1969 study[1/] presented to the 49th Highway Research Board Conference in 1970. This study concluded that the value of travel time saved for commuting motorists is established as a function of the motorist's income level and amount of time saved. The study found the value of time connected with work trips to be $2.82 per person per hour, in 1968 prices which was adjusted to $4.24 to represent 1975 prices. The adjustment was based on the average growth rate of wages in Hawaii.[2/]

The value of commercial vehicles time was valued at $5.75 per hour (1965 dollars) based on a 1967 study by Texas Transportation Institute.[3/] This value of time was then adjusted to $11.00 per hour to represent 1975 dollars. This adjustment was also based on the average growth rate of wages in Hawaii, but from 1965.

b. Operating Savings

The vehicle miles avoided by the diverted motorist will result in auto operating cost savings to the former auto user. Vehicle operating cost avoided accruing to the transit user included gas, oil, maintenance and tires. A 1972 report by the U.S. Department of Transportation, Federal Highway Administration,[4/] determined the per mile cost of gas and oil at 2.8 cents and maintenance, accessories, parts and tires at 2.3 cents per mile. Based on these unit costs the total per mile cost of operating and maintaining the automobile would be 6.8 cents in 1975 dollars. This adjustment is based on the change in the consumer price index, transportation sector,[5/] between 1972 and 1975.

c. Parking Savings

The commuter driving his automobile to work must, in most cases, pay for parking. Therefore, those diverted motorists will avoid this out-of-pocket expense. The average parking cost for all day parking in 1975 dollars was 88.2 cents per day or $221 per year.

d. Ownership Savings

Many households will realize the savings obtained by the elimination of the need for a second or third car, or in some cases the first car, as a result of the use of the transit system. Those individuals who eliminate ownership of an automobile, eliminate the annual insurance premium and depreciation. The average annual cost of insurance for basic coverage of a new automobile in 1975 dollars was $299.70. The average depreciation of a new automobile in terms of 1975 dollars was $513.90.

e. Insurance Savings

In addition to the actual cost of operating the vehicle, the commuters who forego the use of their automobile for work trips will save on their automobile insurance premiums and parking cost. Current practice in the automobile insurance industry calls for a minimum surcharge of 15 percent if the automobile is used for work commute trips. In 1975 this represented a $36.32 markup on a basic insurance policy.

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f. Reduction in Fatalities

The fatality rate on transit is much lower than that of automobiles and will result in a saving of lives. The value of a human life cannot be objectively measured, however, we can measure the lost income attributable to a fatality. The reduction in fatalities represents a savings of this lost income. This lost income was based on the average annual wage earned on Oahu and discounted over 35 years at 3 percent totalying $205,000 per life saved.

The quantifying of these various categories of benefits are shown in Table A. Table B summarizes the various input data necessary to develop the quantified benefits for the various alternative transit systems.

3. Benefit/Cost Evaluation

Varying discount rates (4%, 7%, and 10%) were used to determine the present worth of the annualized total benefits accrued by the use of each alternative transit system by the populace of the City and County of Honolulu over a 30-year period. The total present worth of benefits and costs for each of the alternative systems for the various discount rates, is tabulated in Table C.

TABLE A

DESCRIPTION, METHOD OF QUANTIFICATION AND VALUE OF BENEFITS

Name and Description of Benefits	Annual Formula	Fixed Guideway 7-Mile	Fixed Guideway 14-Mile	Fixed Guideway 23-Mile	Busway 7-Mile	Light Rail Transit 7-Mile	Light Rail Transit 14-Mile	Light Rail Transit 23-Mile	Light Rail Transit 28-Mile	TSM -
		Annual Value for Year 1995 (In Millions 1975 $)								
Time Savings Benefits to Peak-Period Diverted Motorists	$B_1=(U_{apw}-U_{bpw})CF_p\cdot\frac{T_m}{60}\cdot A_w\cdot V_t$	0	1.90	4.96	0	0	1.90	3.75	3.62	0
Time Savings Benefits to Peak-Period Former Bus Users	$B_2=U_{bpw}\cdot CF_p\cdot\frac{T_b}{60}\cdot A_w\cdot V_t$	15.09	16.21	18.16	14.72	15.09	16.21	16.95	16.95	8.10
Time Savings Benefits to Peak-Period Motorists Remaining on Roadway	$B_3=(W_p-U_{apw})CF_p\cdot\frac{T_c}{60}\cdot A_w\cdot V_t$	25.40	26.20	27.23	25.28	25.40	26.20	26.52	26.52	0
Time Savings Benefits to Peak-Period Commercial Vehicle Travel	$B_4=0.093\cdot\frac{B_3}{V_t}\cdot V_{tc}$	6.13	6.32	6.57	6.10	6.13	6.32	6.40	6.40	0
Automobile Operating Cost Savings Benefits for Diverted Motorists	$B_5=\left[\frac{(U_{ad}\cdot L_{ad})-(U_{bd}\cdot L_{bd})}{O_d}\right]A_{eq}\cdot V_o$	22.43	23.88	26.40	22.81	22.43	23.88	23.66	23.86	12.30
Parking Cost Savings Benefits Due to Reduction in Automobiles Used for Work Trips	$B_6=\frac{(U_{adw}-U_{bdw})}{O_p}\cdot 0.5\cdot V_p$	9.04	9.55	10.28	8.87	9.04	9.55	9.74	9.74	4.73
Additional Vehicle Savings Benefits Due to Reduction in Vehicle Ownership	$B_7=\frac{B_6}{V_p}\cdot 0.5\cdot V_a$	16.64	17.58	18.92	16.33	16.64	17.58	17.93	17.93	8.71
Additional Insurance Savings Benefits	$B_8=\left(\frac{B_6}{V_p}-\frac{B_7}{V_a}\right)\cdot V_i$	.0.74	0.78	0.84	0.73	0.74	0.78	0.80	0.80	0.39
Reduction in Fatalities Benefits	$B_9=\left[(M_{dw}\cdot A_w\cdot\frac{E_w}{100})+(M_{dn}\cdot A_{eq}\cdot\frac{E_n}{100})\right]V_f$	2.09	2.22	2.46	2.12	2.09	2.22	2.20	2.22	1.14
Total Annual Quantified Benefits		97.56	104.64	115.82	96.96	97.56	104.64	107.95	108.04	35.37

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TABLE B

INPUT DATA

SYMBOL	DESCRIPTION	UNIT	Fixed Guideway 7-Mile	Fixed Guideway 14-Mile	Fixed Guideway 23-Mile	Busway 7-Mile	Light Rail Transit 7-Mile	Light Rail Transit 14-Mile	Light Rail Transit 23-Mile	Light Rail Transit 28-Mile	TSM -
A_w	Working days per year	Days	250	250	250	250	250	250	250	250	250
A_{eq}	Equivalent average weekdays per year	Days	300	300	300	300	300	300	300	300	300
CF_p	Peak period ridership conversion factor from peak hour	Number	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
O_d	Average daily vehicle occupancy	Persons/Auto	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87
O_p	Average peak hour vehicle occupancy	Persons/Auto	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
U_{bd}	Daily transit ridership on base system	Person Trips	214,300	214,300	214,300	214,300	214,300	214,300	214,300	214,300	214,300
U_{bdw}	Daily transit work trips on base system	Person Trips	94,300	94,300	94,300	94,300	94,300	94,300	94,300	94,300	94,300
U_{bpw}	Peak hour transit work trips on base system	Person Trips	20,280	20,280	20,280	20,280	20,280	20,280	20,280	20,280	20,280
U_{ad}	Daily transit ridership on alternative systems (1995)	Person Trips	459,300	473,300	490,000	456,250	459,300	473,300	474,520	474,520	367,300
U_{adw}	Daily transit work trips on alternative systems (1995)	Person Trips	208,800	215,300	224,500	206,640	208,800	215,300	217,710	217,710	154,200
U_{apw}	Peak Hour transit work trips on alternative systems (1995)	Person Trips	46,460	47,910	49,890	46,050	46,460	47,910	48,430	48,430	33,200
W_p	Total work trips made during peak hour on all modes (1995)	Person Trips	108,580	108,580	108,580	108,580	108,580	108,580	108,580	108,580	108,580
L_{bd}	Daily average transit trip length on base system	Miles	4.85	4.85	4.85	4.85	4.85	4.85	4.85	4.85	4.85
L_{ad}	Daily average transit trip length on alternative system (1995)	Miles	6.74	6.82	7.06	6.86	6.74	6.82	6.76	6.80	5.90
T_m	Unit time saved during peak hour work trips by diverted motorists	Minutes/person/day	0	3.0	7.3	0	0	3.0	5.8	5.6	0
T_b	Unit time saved during peak hour work trips by former bus users	Minutes/person/day	32.4	34.8	39.0	31.6	32.4	34.8	36.4	36.4	17.4
T_c	Unit time saved during peak hour work trips by motorists remaining on roadway	Minutes/person/day	17.8	18.8	20.2	17.6	17.8	18.8	19.2	19.2	0
M_{dw}	Daily vehicle miles avoided for work trips by diverted motorists (1995)	Vehicle miles (million)	0.905	0.963	1.065	0.920	0.905	0.963	0.954	0.962	0.495
M_{dn}	Daily vehicle miles avoided for non-work trips by diverted motorists (1995)	Vehicle miles (million)	1.152	1.226	1.355	1.171	1.152	1.226	1.214	1.225	0.632
V_t	Value of commuters' time (1975 $)	Dollars/hour	4.24	4.24	4.24	4.24	4.24	4.24	4.24	4.24	4.24
V_{tc}	Value of commercial trip time (1975 $)	Dollars/hour	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
V_o	Value of vehicle operating cost (1975 $)	Dollars/vehicle mile	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068	0.068
V_i	Value of insurance savings (1975 $)	Dollars/vehicle	36.32	36.32	36.32	36.32	36.32	36.32	36.32	36.32	36.32
V_p	Value of average parking cost (1975 $)	Dollars/year	221.00	221.00	221.00	221.00	221.00	221.00	221.00	221.00	221.00
V_a	Value of vehicle ownership savings (1975 $)	Dollars/vehicle	813.60	813.60	813.60	813.60	813.60	813.60	813.60	813.60	813.60
V_e	Present value of wages earned per employee life saved (1975 $)	Dollars/Life	205,000	205,000	205,000	205,000	205,000	205,000	205,000	205,000	205,000
E_w	Employees' lives saved per 100 million vehicle miles avoided (work-trips) by diverted motorists	Number	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21
E_n	Employees lives saved per 100 million vehicle miles avoided (non-work trips) by diverted motorists	Number	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

TABLE C

SUMMARY OF BENEFIT/COST ANALYSIS*
($ MILLION)

ALTERNATIVE SYSTEMS	DISCOUNT RATES 4%	7%	10%
FIXED GUIDEWAY ALTERNATIVE:			
- 7-Mile System			
Benefits	1516.18	1051.31	776.48
Cost	655.12	552.11	491.26
B/C Ratio	2.31	1.90	1.58
- 14-Mile System			
Benefits	1626.21	1127.60	832.83
Cost	658.35	592.16	552.15
B/C Ratio	2.47	1.90	1.51
- 23-Mile System			
Benefits	1799.96	1248.08	921.81
Cost	820.89	744.86	697.70
B/C Ratio	2.19	1.68	1.32
BUSWAY ALTERNATIVE:			
- 7-Mile System			
Benefits	1506.86	1044.84	771.70
Cost	673.22	574.25	515.83
B/C Ratio	2.24	1.82	1.50
LIGHT RAIL TRANSIT ALTERNATIVE:			
- 7-Mile System			
Benefits	1516.18	1051.31	776.48
Cost	665.54	562.78	501.86
B/C Ratio	2.28	1.87	1.55
- 14-Mile System			
Benefits	1626.21	1127.60	832.83
Cost	678.87	609.59	567.58
B/C Ratio	2.40	1.85	1.47
- 23-Mile System			
Benefits	1677.65	1163.27	859.17
Cost	814.58	739.08	691.91
B/C Ratio	2.06	1.57	1.24
- 28-Mile System			
Benefits	1679.05	1164.24	859.89
Cost	895.70	812.71	760.54
B/C Ratio	1.87	1.43	1.13
TSM ALTERNATIVE:			
- All-Bus System			
Benefits	549.68	381.15	281.51
Cost	425.78	289.48	211.07
B/C Ratio	1.29	1.32	1.33

*Total benefits and costs calculated over a 30-year period, discounted at the indicated rates and expressed in constant 1975 dollars.

REFERENCES

1. "The Value of Time for Commuting Motorists as a Function of Their Income Level and Amount of Time Saved," by Thomas C. Thomas and Gordon I. Thompson, Stanford Research Institute, Highway Research Record, Number 314.

2. "Employment and Payrolls in Hawaii, 1969-1975" by the Research and Statistics Office, Dept. of Labor and Industrial Relations, State of Hawaii.

3. "Values of Time Savings of Commercial Vehicles," by William G. Adkins, Allen W. Ward, and William F. McFarland, Texas Transportation Institute, published in National Cooperative Highway Research Program Report #33, by the Highway Research Board, 1967.

4. "Cost of Operating An Automobile," U.S. Department of Transportation, Federal Highway Administration, April 1972.

5. Monthly Labor Review, U.S. Department of Labor, Bureau of Labor Statistics.

APPENDIX D

ADJUSTMENT TO PATRONAGE VOLUMES

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APPENDIX D

ADJUSTMENT TO PATRONAGE VOLUMES

For purposes of evaluating alternative lengths of the fixed guideway system, further review of the patronage forecasts was made to determine if the previous forecasts appropriately reflected the differences in the guideway lengths. Since the forecasts were made with the objective of obtaining conservative results for use in economic and financial analyses, regardless of which guideway length would be finally selected, the following areas in the forecast process were identified for potential adjustments in the patronage.

1. Special Trips

The trip generation model used does not include special trips such as University trips, tourist trips, etc. The University trips were specially developed and included in the final patronage forecasts. Tourist trips, however, were not included in the original O-D survey and hence were not included in the patronage forecast. The following identifies those special trips not accounted for in the forecasts.

- Visitor Trips

  The average daily visitor population is some 40,000 on Oahu of which many uses public transit to visit various attractions. The USS Arizona Memorial has over 1 million visitors each year. A modest growth to 1.25 million visitors in 1985 would amount to 2.5 million annual trips or some 7,000 daily trips. A conservative 15% diversion to transit with the 12- and 14-mile guideway systems would amount to approximately 1,000 additional daily rides.

- Airport-Waikiki Trips

  Another important special trips are those made by air passengers between Waikiki and the Airport. It is estimated that this movement would exceed 15,000 daily trips by 1985 and a convenient, economical service could divert 15% of the trips to transit or over 2,000 daily trips by providing service to the Airport which the 8-, 12-, and 14-mile systems will do but not the 7-mile system.

- Aloha Stadium Trips

  This new 50,000 seat stadium has approximately 7,000 parking spaces which cannot meet demand even at less than full capacity attendance. At the recent Hula Bowl game with 40,000 in attendance, some 4,000 trips were made on special stadium buses provided by the City with additional patrons using the regular transit service in the area. Assuming a 50% increase with direct fixed guideway service to the stadium, 6,000 trips per event would be attracted. With continuing increase in stadium use combined with a lower fare than the 75¢ currently charged and the knowledge of an established scheduled service for all events, a capture of more than an average of 1,000 daily trips can be expected with the 12- and 14-mile systems.

2. Refinement of Traffic Analysis Zones for Walk Trips to Transit Stations

A review of the basic traffic zones used in the allocation of trips to the transit network revealed that the zones are in many cases too large to properly reflect the potential number of walk-in trips to the guideway stations. The area within one-quarter mile walking distance of a guideway station would be provided with superior service by the short headway or waiting time between the guideway trains and therefore would be highly attractive to many travellers. An average of 2,500 residents are located within a quarter mile walk distance at the 3 additional stations provided by the 14-mile guideway system which would generate a total of 23,000 daily trips. An increase of 4% transit diversion due to the convenience of direct walk-in to the station would generate an additional 1,000 daily trips.

3. Effects of Future Station Area Developments

It may be assumed that developments around station impact area (1/4 mile walking distance) would accelerate with high density residential and commercial structures once the fixed guideway system is formally adopted. With the land use policy emphasizing greater containment of future growth in existing urbanized areas, the redevelopment taking place is toward higher density developments. This potential increased density near stations is not reflected in the patronage forecasts, again because of the established large traffic zones used in the forecasts. A modest redevelopment of as little as 10 acres of land into higher density apartments represented by 2 or 3 large structures would increase population by at least 2,000 at each of the 3 stations. This would generate an additional 20,000 daily trips and assuming an increase in transit diversion by 4% would be another 1,000 daily rides.

4. Induced Trips

Induced trips as used herein are those trips not previously made but would be made with the introduction of the new fixed guideway system. In the trip generation model used for transit patronage forecasting, induced trips are not included in the model and hence are not reflected in the patronage volumes.

Although the urbanized areas of Oahu are reasonably well served by the existing bus system, there are many areas and various trip purposes that are not conveniently served by existing service. In addition, the streets and highways serving primary east-west travel corridor which contains all of the major activity centers of the island are heavily congested and accessibility to these centers are difficult. By making these activity centers more readily accessible by the fixed guideway, it can be assumed that this would induce many new trips not currently made.

Since the longer fixed guideway lengths provide direct access to more activity centers, it stands to reason that they would attract more induced riders. Similarly, the longer guideway lengths provide higher level of service to residential areas which should also result in more induced riders. Accordingly, it was conservatively estimated that the 7- and 8-mile guideway systems would attract 2%, the 12-mile guideway system 3%, and the 14-mile system 5% more riders which are induced riders.

5. Refinement of Bus Access Time to Terminal Station

The patronage forecasts obtained from the modal split analysis indicated a relatively small difference in the patronage volumes between the various fixed guideway lengths. In order to determine the reasonableness of the forecasts, a detailed review of the process, including the input data, was conducted.

It was found that approximately 45% of the trips made on the guideway originates at the two terminal stations. A detailed review of the assumptions made in determining trip time for the various feeder routes indicated that the assumed average bus speeds were generally good but a more detailed check of the interface facilities at these two stations was made. It was generally found that some additional time should be added on to the trip time to properly reflect the relatively difficult access to these stations. It was determined that the added trip time to the various bus routes would reduce daily patronage by some 1,500 daily trips.

6. Refinement of Transfer Time Penalty

Another area in the modal split model is the penalty assigned for the transfer or waiting time of 2-1/2 times the actual time. Where trips are short and one or more transfers are required due to the shortness of the fixed guideway system, the question then is how valid is the 2-1/2 times penalty assigned for waiting time.

In 1985, the fixed guideway systems are carrying 200,000 daily trips of which approximately 75,000 trips are transfers from feeder buses at the 2 terminal stations. A modest reduction of up to 1% of these transfer trips at the terminals resulted in reducing the 1985 volume by 750, 650 and 400 daily trips for the 7-, 8-, and 12-mile lengths, respectively.

In summary, these adjustments were made on a very conservative basis so as not to bias any one length over the others. There are other potential adjustments which would tend to increase the differences between alternative lengths by a greater margin than those shown. One major area is in the forecasted population and the land use distribution used as the basis for trip productions and attractions which could be adjusted for the following:

- Population - used 924,000 in 1995 and now projected to be 970,000 by the State DPED, or about 5% greater growth.
- Population Distribution - Recent action of State Land Use Commission limiting relcassification of agricultural land to urban use implying greater containment of future growth in existing urbanized areas.
- Hotel Rooms in Waikiki - Assumed maximum of 27,000 rooms in 1995 while the land use designation would permit over 40,000 rooms.

The net result of any adjustments that would have an overall effect of increasing patronage would tend to make the difference in the volume greater between the alternatives. Again, to take a conservative approach, some of these potential adjustments were not included.