REPORT NO. UMTA-MA-06-0049-78-7

UMTA/TSC Project Evaluation Series

The Double Deck Bus Demonstration Project

Executive Summary

Final Report
May 1978

Service and Methods Demonstration Program

U.S. DEPARTMENT OF TRANSPORTATION
Urban Mass Transportation Administration
and Transportation Systems Center

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTA-MA-06-0049-78-7		

4. Title and Subtitle	5. Report Date
The Double Deck Bus Demonstration Project, Executive Summary	May 1978
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Chester H. McCall, Jr.* and Howard Simkowitz**	1200-17-78
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
CACI, Inc. - Federal* 12011 San Vicente Boulevard Los Angeles, CA 90049	11. Contract or Grant No. DOT-TSC-1082
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
U.S. Department of Transportation Urban Mass Transportation Administration Office of Transportation Management and Demonstrations Washington, D.C. 20590	Final Report July 1974 - June 1977
	14. Sponsoring Agency Code

15. Supplementary Notes *Under Contract to: U.S. Department of Transportation**
Transportation Systems Center
Kendall Square
Cambridge, MA 02142

16. Abstract

From July 1974 through June 1977, the Double Deck Bus (DDB) Demonstration Project was conducted in New York City and in Los Angeles. The primary objective at the two sites was to assess potential increase in vehicle productivity in an express, limited busway service (L.A.) and in regular service (NYC). Double deck buses carry from 68 to 84 passengers as contrasted with conventional buses which carry from 45 to 47 passengers. Both buses call for only a single transit employee, the driver.

Bus routes in New York were characterized by congested traffic, heavy passenger loads, frequent stops, and frequent passenger turnover. A full-range of socio-economic classes was served and the routes traversed lower- to upper middle-class residential districts, major shopping centers and commercial and business areas. Only seven months of revenue service data were analyzed, due to delays in manufacturing and in satisfying United States safety and environmental requirements.

In Los Angeles two types of service were provided: during morning (CBD-bound) and evening (suburb-bound) peak periods, a park-and-ride express run utilizing approximately 15 miles of an exclusive express busway (later expanded to also permit car pools with three or more passengers); and an all-day revenue service run between the Los Angeles CBD and the suburban community of Pomona (approximately 30 miles east of the CBD). This latter route also utilized the exclusive express busway as well as the San Bernardino Freeway for much of its non-CBD run. Bus patronage was predominantly white, suburban, middle-class. Eleven months of revenue service (rather than the 24 months planned) were analyzed, due to the necessity to correct original manufacturing deficiencies in both double deck buses.

The evaluation considers passenger (and transit dependent) acceptance and perceptions of the DDB when compared with the conventional bus. Drivers and mechanics were interviewed to identify their reactions to the new bus. Statistics are presented on schedule adherence, dwell times, passenger throughput, vehicle reliability, on-board safety, repair and maintenance costs/capacity-mile and fuel and oil consumption rates. Problems encountered in introducing a non production-line vehicle into revenue service in an existing fleet are discussed.

17. Key Words	18. Distribution Statement
Double deck bus, demonstration project, evaluation, high-occupancy vehicle (HOV)	DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	52	

Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized

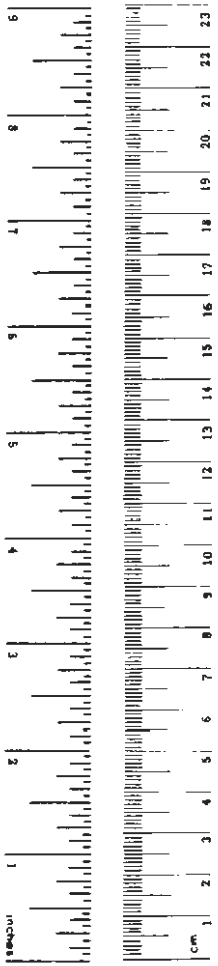
ACKNOWLEDGEMENTS

This study was sponsored by the Urban Mass Transportation Administration's Office of Service and Methods Demonstrations. Anthony Carrano and Henry Hesse at MaBSTOA, and George Wells and Frank Kirshner at the SCRTD, were extremely cooperative in providing the necessary data. Dr. William Farrell, of the University of Pittsburgh, performed the data processing for the passenger surveys. Mary Olson and Stephanie Raia of CACI assisted in data collection activities. Larry Bruno and Paul Fish at UMTA, and Howard Slavin, A. H. Studenmund, Donald Kendall, and Carla Heaton, of TSC's Evaluation Branch, gave extremely helpful suggestions.

METRIC CONVERSION FACTORS

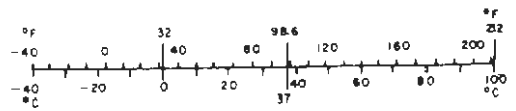
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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SUMMARY

The Double Deck Bus Demonstration Project involved the purchase and operation of contemporary double deck buses in New York City and Los Angeles. Through experience in daily revenue service, it was intended to ascertain the operational and economic feasibility of the double deck bus for several types of transit service conditions. In New York the eight British Leyland double deckers operated on two Manhattan routes characterized by congested traffic, heavy passenger loads, frequent stops, and frequent passenger turnover. In Los Angeles, the two German Neoplan buses operated between the suburbs and the central business district, providing a combination of express and collection/distribution/park-and-ride services.

The Double Deck Bus Project was hampered by problems related to the purchase of foreign vehicles which had undergone re-design to meet American requirements. The situation can be summarized as follows:

- Dealing with a foreign manufacturer resulted in project delays, poor communications (in Los Angeles), unfamiliar mechanical design, and a lack of adequate and easily accessible spare parts.

- The prototypical nature of the vehicles resulted in an unsatisfactory level of mechanical reliability and recurring maintenance problems.

- A thorough design effort should have included representatives from the transit authority's management, maintenance, and driver staffs.

- The double deckers should have been treated as prototypes and undergone extensive on-site testing and re-design before the fleets were produced and accepted for revenue service.

Vehicle-related problems delayed the project and hampered the evaluation activities. Revenue service, which had been scheduled to begin April 1975 in Los Angeles and July 1975 in New York, did not begin until June 1976 and September 1976 in the respective cities. Vehicle-related problems also decreased the efficiency of the vehicles from the perspective of the transit operator:

- The major mechanical problems in New York were caused by the air conditioning and heating systems, with consequent electrical failures, and in Los Angeles by the air conditioning, brakes, and the steering bell crank.

- At both sites the double deck vehicles were out of service more than the conventional counterparts due to these mechanical difficulties. In New York the double deckers averaged 1200 miles per bus per month, while the conventionals averaged 2000 miles per bus per month. The corresponding figures in Los Angeles were 3300 and 8700 miles per bus per month. However, some of this difference in Los Angeles was due to scheduling policy.

- The New York double deckers averaged 5.5 in-service repair calls per 1000 revenue-miles, while the conventional buses averaged 2.3 calls per 1000 revenue-miles. In Los Angeles the double deckers averaged .61 in-service

repair calls per 1000 revenue-miles, while the conventional buses averaged .38 calls per 1000 revenue-miles.

- Maintenance costs in New York were unavailable. Maintenance costs for the Neoplans in Los Angeles averaged 3.8 times those for the conventional fleet: 18.26 cents per mile versus 4.84 cents per mile. This cost differential was due primarily to the inadequate braking system on the Neoplans.

Once the problems caused by the prototypical nature of the vehicles are solved, it does not appear that repair and maintenance costs and reliability will differ significantly between bus types.

There were two other vehicle-related problems:

- Due to their height, the double deck buses could not be stored or maintained at all the New York and Los Angeles facilities, and they could not be used on all routes.

- The double deckers, with their greater passenger-carrying potential, tended to fall behind schedule more often than the conventional buses. In New York the double deckers averaged three minutes late for a 60-minute run, while in Los Angeles they averaged four minutes late for a one-hour-and-30-minute run.

On the positive side of the ledger, the double deck buses had the following impacts on the transit operator:

- The unattended second level was not more susceptible to vandalism and crime in either New York or Los Angeles.

- Operating costs (fuel, oil, and drivers' salaries) were nearly identical for the two bus types (i.e., double deck versus conventional). The New York drivers received a temporary premium pay of $0.25 per hour. The premium pay was to have been discontinued in the fall of 1977, but was still in effect at the time of publication of this report.

- An analysis of dwell time per throughput passenger indicated no significant difference between bus type and between peak and mid-day service. The double deck buses processed passengers at the same rate as did the conventional buses.

- Based on schedule adherence results, several feasible scheduling options are available for the double deck bus:

  1) using only double deck buses on a route;

  2) mixing double deck and conventional buses on a route, but using the double deckers on a skip-stop basis; and

  3) using the double deck buses on express routes with a limited number of stops at either end.

- The transit operator would realize substantial savings by substituting double deck buses for conventional ones at a ratio based on seating or total capacity.

Passenger reaction to the double deck bus was overwhelmingly positive:

- Passengers preferred the double deck bus to the conventional bus.
- Passengers preferred the upper level to the lower level.
- Preference was independent of trip length.
- There were no serious problems with the use of the internal stairs. In New York there were four accidents associated with the use of the stairs, but no injuries. In Los Angeles there were no accidents associated with the use of the stairs.
- In all cases the double deck bus passengers were more positive towards their vehicle's accommodations than were the conventional bus passengers.

1. INTRODUCTION

The Urban Mass Transportation Administration (UMTA) sponsored a Double Deck Bus (DDB) Demonstration Project in Los Angeles and New York City from July 1974 through June 1977 that involved the purchase, operation, and evaluation of contemporary double deck buses. The project was funded by UMTA's Office of Service and Methods Demonstrations (SMD) and, in New York, also by the New York State Legislature. In New York the grantee was the Metropolitan Transit Authority (MTA) while the operating agency was the Manhattan and Bronx Surface Transit Operating Authority (MaBSTOA). In Los Angeles the grantee and operator was the Southern California Rapid Transit District (SCRTD).

The UMTA grant to the MTA was for $415,984 and covered the purchase of four buses plus costs associated with freight, duty, spare parts, engineering support and travel. The New York State Legislature provided the MTA with nearly $500,000 for the purchase of an additional four vehicles and associated costs and to make required safety modifications. The UMTA grant to the SCRTD was for $334,000 and covered the purchase of two buses and associated costs.

The Evaluation Branch of the Transportation Systems Center (TSC), which has primary responsibility for the evaluation of all SMD projects, conducted the evaluation with the assistance of CACI, Inc.

2. SERVICE DESCRIPTION

Two types of double deck buses were used in the demonstration. The specifications for these vehicles, as well as for the conventional buses used for comparative purposes in the evaluation, are given in Exhibit 2.1. Photographs of the vehicles appear in Exhibit 2.2 and 2.3. The Leyland vehicle is nearly seven feet shorter than both the GM and Flxible conventional buses, seats 51 percent more passengers, and has a total capacity 20 percent greater than a standard bus. Its height is 14.5 feet, four feet more than that of a conventional bus. With its wide first level aisle, it is designed for local service and high passenger turnover. The more expensive and massive Neoplan is nearly as long as a conventional bus, seats 79 percent more passengers, and has a total capacity 38 percent greater than a standard bus. The downstairs aisle is very narrow, the accommodations are plush, and the ride is smooth. The overall design lends itself to long distance express service.

In New York, eight British Leyland double deck buses replaced eight conventional buses on two bus routes characterized by congested traffic, heavy passenger loads, frequent stops, and frequent passenger turnover. These two routes ran from the northern end to the southern end of Manhattan and served a full range of activity mixes and diverse socioeconomic classes (see Exhibit 2.4).

In Los Angeles, two German Neoplan double deck buses provided two types of service (see Exhibit 2.5): a park-and-ride express run (one round trip per day) connecting Eastland to the Los Angeles central business district (CBD) via 15 miles of the exclusive busway on the San Bernardino Freeway (one double deck bus replaced two conventional buses), and an all-day revenue service run between the Los Angeles CBD and

EXHIBIT 2.1

SELECTED DOUBLE DECK AND CONVENTIONAL BUS SPECIFICATIONS

Specification	NEW YORK		LOS ANGELES	
	British Leyland Double Deck	GM Conven-tional	Neoplan Double Deck	Flxible Conven-tional
Passenger Capacity:	81	68	98	71
Seated-Upper Level	43	-	57	-
Seated-Lower Level	25	45	27	47
Seated - Total	68	45	84	47
Standing-Lower Level[1]	13	23	14	24
Length (feet)	33.3	40	39.3	40.0
Width (feet)	8.3	8.5	8.5	8.5
Height[2] (feet)	14.5	10.4	14.0	10.0
Wheelbase (feet)	18.5	23.8	22.5	23.8
Cost Per Bus ($)[3]	99,000	80,000	150,000	72,000

[1]Estimated at 50% of lower level seated capacity.

[2]Clearances must be two inches or more above this figure due to bus bounce.

[3]Cost at time of purchase of double deck buses.

EXHIBIT 2.2

BRITISH LEYLAND DOUBLE DECK BUS USED IN NEW YORK

EXHIBIT 2.3

GERMAN NEOPLAN DOUBLE DECK BUS USED IN LOS ANGELES

EXHIBIT 2.4

NEW YORK DOUBLE DECK BUS ROUTES

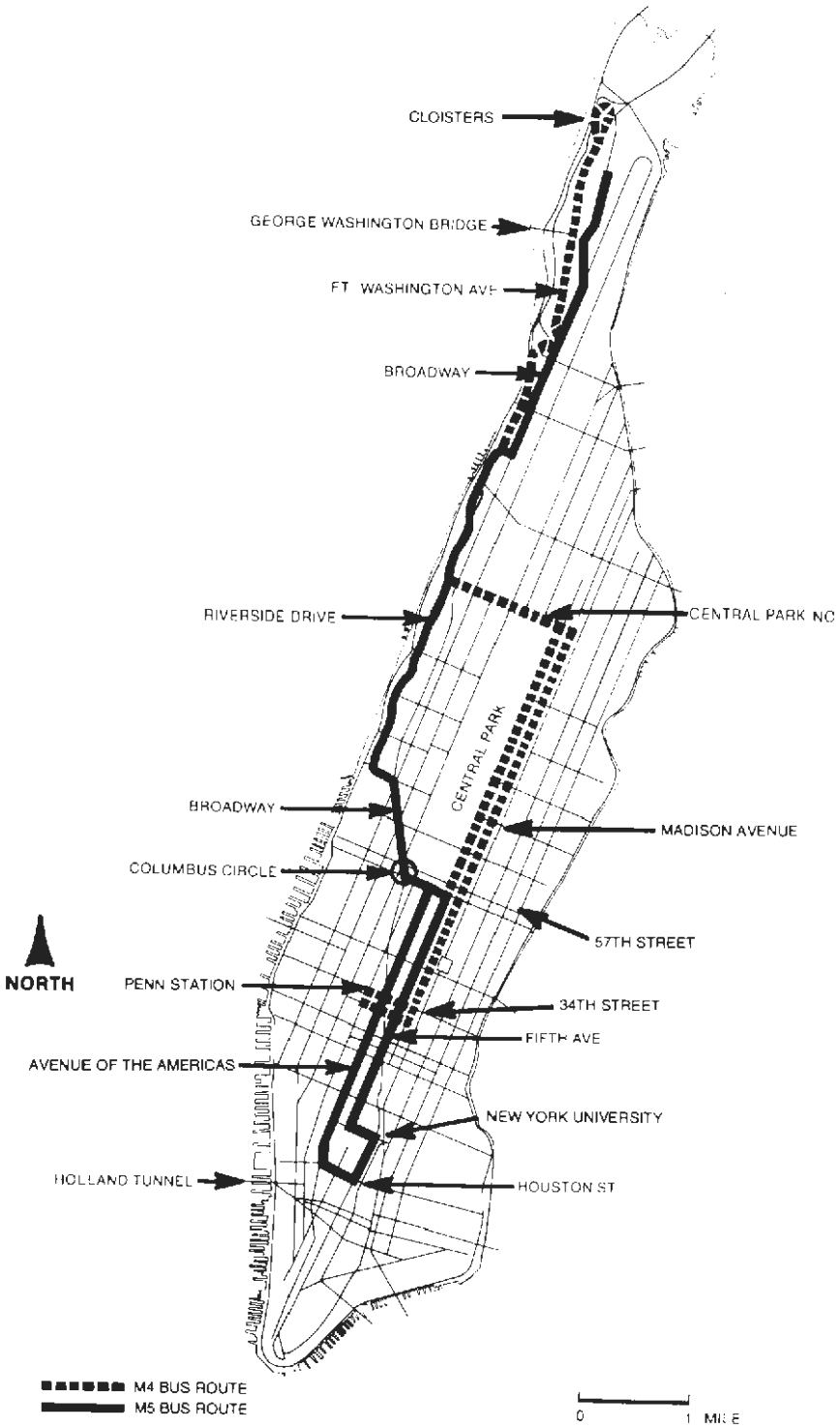
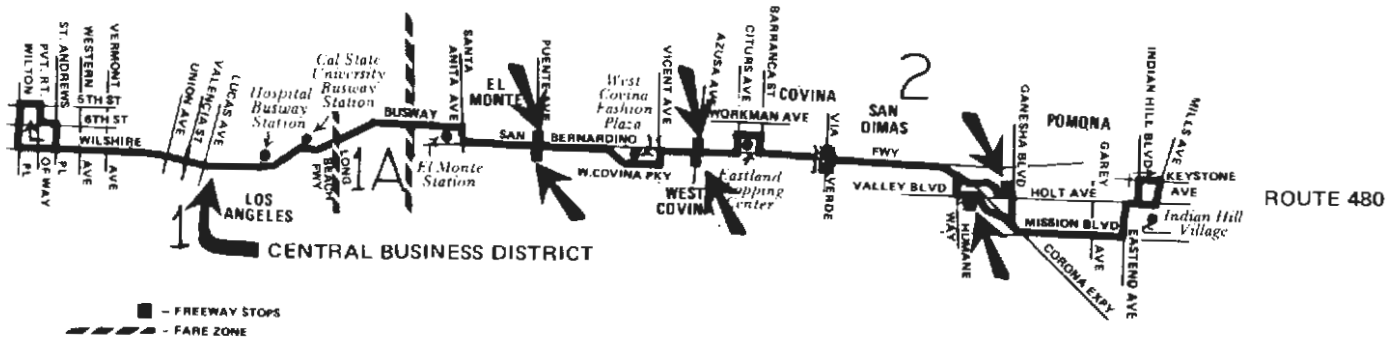
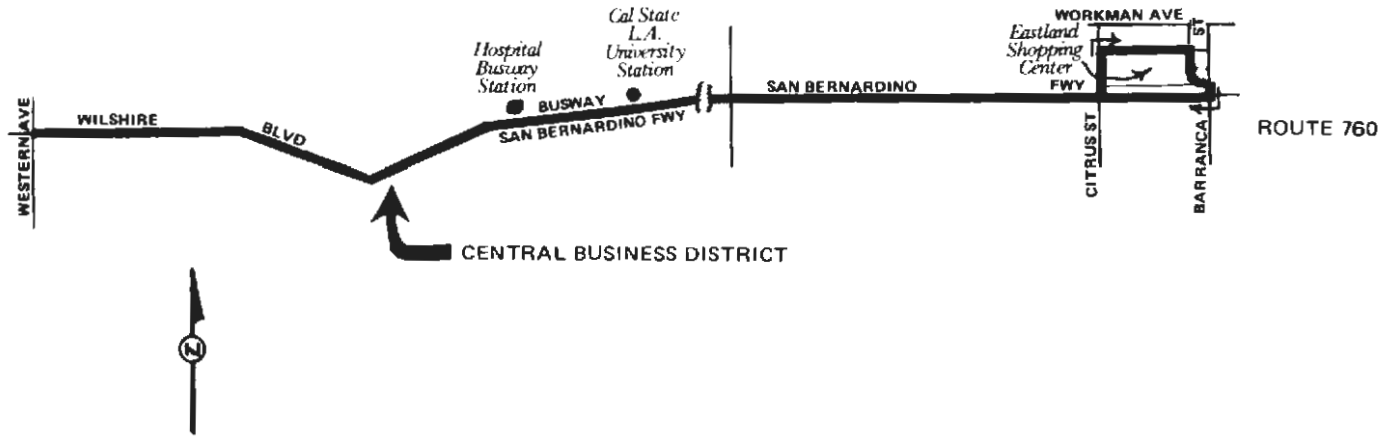


EXHIBIT 2.5

LOS ANGELES DOUBLE DECK BUS ROUTES





the suburban community of Pomona, approximately 30 miles east of the CBD, also using the San Bernardino Freeway (one double deck bus replaced one conventional bus).

At both demonstration sites, the one-way fare charged for a double deck bus ride was the same as for an identical ride on a conventional bus ($0.50 in New York and $1.00 for the park-and-ride express service and $0.90 for the Pomona/El Monte/CBD run in Los Angeles).

3. ISSUES

The purpose of the Double Deck Bus Project was to examine, through daily revenue service, the operational and economic feasibility of the double deck bus. The evaluation explored vehicle-related, transit operator-related, and user-related issues. Vehicle-related issues deal with the purchase of foreign vehicles, vehicles that have undergone major re-design. These include delivery, certification, retro-fit requirements (to meet federal and state laws, as well as American operator specifications), effects of vehicle modification on performance, availability of spare parts, and ease with which modifications to vehicles can be accomplished.

Operator-related issues address the concept of vehicle efficiency: start-up mechanical problems; costs; types of service to be provided; route modifications and other physical constraints necessary to accommodate the double deck bus; vehicle reliability; safety and vandalism; insurance and union demands; and other impacts on vehicle efficiency.

User-related issues include the acceptance of the double deck vehicle by the general public and by the elderly and handicapped, perceptions of the double deck bus accommodations and conveniences, perceptions of stairs to the second level and the unattended second level, trip characteristics of those who utilize the second level, and ease with which the handicapped and elderly could utilize the vehicles.

The remainder of this paper is organized according to the three broad issue areas. The evaluation methodology was to compare the double deck buses to conventional buses in identical revenue service. In New York the eight double deckers were compared to four standard General Motors coaches. In Los Angeles the two Neoplans were compared to two Flxibles

(see Exhibit 2.1). Data collection activities ceased at the end of May 1977.

4. VEHICLE-RELATED ISSUES

A major intent of the project was to assess the capability of the double deck bus for making available greater capacity at a cost per capacity-mile less than, or equal to, that of the conventional counterpart. However, two major vehicle-related problems complicated this assessment: (1) having to deal with a foreign manufacturer resulted in schedule delays, poor communications (in Los Angeles), unfamiliar mechanical design, and a lack of adequate and easily accessible spare parts; and (2) the prototypical nature of the vehicles resulted in an unsatisfactory level of mechanical reliability and recurring maintenance problems.

The Leyland buses were standard production-line vehicles with modifications made to meet federal laws and operator specifications. The major modifications were pollution control devices, safety windows, left-hand drives, and air conditioning. The performance of these modifications, uncertainty about exemptions from four federal safety standards and emissions certification, a dock strike in England, and problems between British Leyland and Trane (the American firm providing the air conditioning units) resulted in a delivery delay of approximately one year.

Each Neoplan was retro-fitted with an American drivetrain by RAAD International and two air conditioning units by Trane. The specifications for these changes were inadequate, and numerous modifications were required before the buses could be placed into service. The difficulty in dealing with a foreign manufacturer and the need for a reliable domestic representative became apparent when the steering bell crank on one of the Neoplans broke in December 1975. Twice Neoplan provided the SCRTD with faulty bell cranks. It was not until May 1976 that satisfactory bell cranks were received.

These vehicle-related problems resulted in major project delays. Revenue service had been scheduled to begin in Los Angeles in April 1975, and in New York in July 1975. In Los Angeles one double deck bus began erratic revenue service in May 1975. However, it was not until June 1976 that most of the serious mechanical problems were corrected and the two Neoplans began reliable service. In New York the double deck bus fleet did not enter revenue service until September 1976, and the buses experienced continuing mechanical difficulties. At both sites service was interrupted periodically due to unexpected failures and a lack of the appropriate replacement parts.

brakes, and air conditioning. These problems were due to the major modifications that were made to a basically sound vehicle. These problems were complicated by the difficulty in communicating with a foreign manufacturer, the lack of cooperation by the local manufacturer's liaison, the mechanics' lack of familiarity with the vehicle, and the lack of spare parts. The bell crank and air conditioning problems have since been solved, but the brakes continue to squeal and wear out considerably faster than those on the conventional buses.

Once the Neoplans began reliable revenue service in June 1976, they experienced no one predominant type of failure. During the following eleven-month period of data collection, the conventional buses averaged .38 in-service repair calls per 1000 revenue-miles. The conventional buses averaged 8,700 miles per bus per month, as contrasted with only 3,300 miles per bus per month for the double deckers. Two factors were instrumental in the low mileage generated by the double deck vehicles: the air conditioning, brake, and miscellaneous mechanical problems encountered by the double deck buses tended to keep them out of service for longer periods of time than the failures experienced by the conventional buses; and, the double deck bus on the park-and-ride route made only one round trip per day, while the corresponding conventional bus remained in service during the entire day.

Mechanics in Los Angeles indicated that the existence of three engines (two for the air conditioning) and their location made the buses difficult to service. They felt they had received sketchy training and that there were not enough double deckers in the fleet with which to become familiar.

Maintenance costs for the Neoplans averaged 3.8 times those for the conventional fleet: 18.26 cents per mile for

the double deck versus 4.84 cents per mile for the conventional. When adjusted for vehicle capacity, these figures were .19 cents per passenger-mile for the double deck bus and .07 cents for the conventional bus, or 2.7 times as great for the Neoplans. This cost differential was due primarily to the inadequate braking system on the Neoplan. The SCRTD claimed that this situation could be remedied in future models by using an electric or hydraulic retarder.

5.2 OPERATING COSTS

Operating costs included fuel, oil, and drivers' salaries. These costs were nearly identical for the two bus types. In New York the Leyland buses averaged 3.4 miles per gallon, while the GM's averaged 3.2 miles per gallon. The conventional buses required considerably more oil than the double deckers, but this was a result of the age differential between the bus types. The New York transit union demanded an increase in wages for the double deck bus drivers due to the higher capacity of the vehicles. These drivers received a premium pay of $0.25 above their average salary of $7.11 per hour, but this pay differential was to be only temporary, ending in the fall of 1977. The premium pay was still in effect at the time of publication of this report.

In Los Angeles the Neoplans averaged 3.96 miles per gallon compared to 5.40 for the Flxibles. If these mileage figures are adjusted for bus capacity, however, the double deckers out-performed the conventional buses, 383 capacity-miles per gallon to 338 capacity-miles per gallon. As in New York, the older Flxibles required more oil. Driver salaries were the same for both bus types, $7.67 per hour.

5.3 DWELL TIME AND PASSENGER THROUGHPUT

The relationship between dwell time and passenger throughput (throughput is defined as the number of passengers getting on and off the vehicle), its effect on total run time, and scheduling implications are explored in this and the following two sections.

In New York, it was hypothesized that the lower entry and exit step and wider doors on the Leyland double deckers would result in a more efficient boarding and alighting operation, but that passengers exiting from the upper level might delay the vehicle if the internal stairwell were crowded. Results from an on-board survey indicated that the double deckers were indeed easier to board than the conventional buses, and that 25 percent of the riders on the upper level found some difficulty in using the internal stairs. However, an analysis of variance of dwell time per throughput passenger indicated no significant difference between bus type and between peak and mid-day service.

For the two bus types, total run dwell time (in seconds) was compared with total run throughput. Estimated regression equations were obtained for data from both double deck bus and conventional bus runs. These equations, which were fit through the origin, were identical: $Y = 3.5X$, where Y = total run dwell time in seconds and X = total run throughput. Thus, the Leyland buses processed passengers at the same rate as did the conventional ones, indicating that the use of the stairs to the second level did not impede passenger circulation.

If the Leylands were to replace the conventional buses on a one-for-one basis, the total run dwell time would not change. However, if the double deckers were substituted at a rate less than one-for-one, they would begin to fall behind

schedule by about seven seconds per additional passenger (3.5 seconds for entry and 3.5 seconds for exit). The next section looks more closely at schedule adherence.

In Los Angeles, as in New York, an analysis of variance of dwell time per throughput passenger indicated no significant difference between bus type and between peak and midday service. Estimated regression equations (again forcing the fit through the origin) were Y = 4.0X for the conventional bus and Y = 3.7X for the double deck bus. Since the two slopes were found not to be significantly different from each other, a pooled estimate of 3.9 was obtained. Therefore, on the average, each additional passenger increased run time by about 7.8 seconds. The implications of this are the same as for New York.

5.4 SCHEDULE ADHERENCE

Schedule adherence was compared for the two bus types to ascertain whether the double deckers, with their greater passenger-carrying potential, tended to fall behind schedule more often than the conventional buses. In New York a sample of 67 double deck bus runs and 69 conventional bus runs averaged respectively three minutes late and .3 minutes early for a scheduled run of 60 minutes. The double deck bus tended to fall behind schedule more frequently than the conventional bus (42 percent versus 33 percent). Schedule adherence improved for the double deck bus during its period of revenue service.

Dispatchers in New York generally felt that the double deck bus tended to fall behind schedule more often than the conventional bus, particularly during peak periods and in the more congested downtown areas. They attributed this to higher passenger patronage resulting in longer dwell times at stops.

In Los Angeles the results were similar. The double deck buses were behind schedule more often than the conventional ones (80 percent versus 47 percent). The double deck buses averaged 4.0 minutes late, while the conventional buses arrived .3 minutes early for a schedule run of one hour and 30 minutes. The double deck bus drivers felt that their vehicles tended to arrive late, but that their performance had been improving over time.

The differences in schedule adherence at both sites were found not to be statistically significant at the .05 level. However, this lack of significance was probably due to the large variability of the data and the relatively small sample sizes. It was felt by the evaluators that a difference did, in fact, exist. This was further substantiated by observations made by drivers, dispatchers, and other operating personnel, although these individuals seem to have overstated the actual delays.

5.5 SCHEDULING IMPLICATIONS

Since the double deck buses process passengers at the same rate as conventional buses, they tend to fall behind schedule as their loadings increase. Thus, if one schedule is to be maintained per route, mixed-fleet operations are not feasible. However, there are several plausible scheduling options available: (1) using only double deck buses on a route; (2) mixing double deck and conventional buses on a route, but using the double deckers on a skip-stop basis; and (3) using the double deck buses on express routes with a limited number of stops at either end.

In Option 1 it is assumed that the double deckers are substituted at a rate less than one-for-one, and the schedule time is increased to compensate for the additional passenger throughput per run. This option is suitable on routes where

the patronage is sufficient to justify the increased capacity and where headways are small enough so the substitution of fewer vehicles does not have a noticeable effect on wait time. If the buses are to provide local service, the Leyland, with its wide first-level aisle, offers the preferred design.

In Option 2 the skip-stop double deck buses should be able to realize travel times equivalent to or less than the conventional buses that are providing local service. However, if passengers traveling between points served by the double deckers take the first bus that comes along, even though it is a conventional bus making all intermediate stops, the level of service on the conventional buses would deteriorate.

Option 3 minimizes the schedule adherence problem since most passengers would get on and off during the layover portion of the run. The extreme situation would be a park-and-ride/express service with only one stop in the CBD.

5.6 SAFETY AND ACCIDENTS

In New York there were nine reported passenger-related accidents on the eight double deck vehicles, and only one passenger-related accident on the four conventional vehicles. Four of the nine double deck passenger-related accidents were associated with use of the stairs to the upper level. In two cases passengers fell down the stairs, and in two cases passengers reported an injured leg as a consequence of climbing the stairs. However, all the accidents were minor, and no claims were filed against MaBSTOA. There was only one accident related to the size of the double deck bus: a driver did not follow a route modification that was required due to bus height, and the bus struck the bottom of an overpass, putting it out of service for six weeks. There were no injuries to passengers as a consequence of this accident.

In Los Angeles there were two passenger-related accidents reported on the conventional buses, and only one on the double deckers. This accident was not associated with the internal stairs. There were no injuries in all three cases. This low accident rate can be attributed, in part, to the lack of passenger movement throughout the vehicles due to the limited-stop nature of the runs.

5.7 VANDALISM AND CRIME

Contrary to what had been expected before the demonstration on the given routes, the unattended second level was not more susceptible to vandalism and crime in either New York or Los Angeles. However, drivers reported that the conventional bus was the easier of the two in controlling on-board activity. The Leylands were equipped with a periscope so that the drivers could observe activities on the second level.

5.8 GARAGING, ROUTE AVAILABILITY, AND MANEUVERABILITY

Due to their height, the double deck buses could not be stored or maintained at all the New York and Los Angeles facilities. In New York the double deckers were housed at a garage different from that used by other buses on the same routes, causing crew scheduling and union problems. In Los Angeles routes were selected that were near usable maintenance facilities.

The dynamic height of the vehicles, the physical height plus approximately two inches to allow for spring action, had to be considered when determining acceptable routing. This height precluded the selection of a number of routes. In both locations trees had to be trimmed and lights raised, and one New York route had to be re-directed around a low overpass at the George Washington Bridge. Drivers at both sites

felt that the height of the buses required that care be taken to avoid obstructions.

Drivers in New York tended to react more favorably to the ease of operation of the double deck bus. In Los Angeles the drivers felt that the Neoplan had less power, but was easier to handle, primarily because of the power steering, and that it rode better than the Flxible. They also felt that it outranked the conventional bus in the areas of steering efforts (it has power steering), tracking, cornering stability, maneuverability, and noise level.

5.9 FINANCIAL IMPLICATIONS OF DOUBLE DECK BUS SUBSTITUTION

The preceeding analysis has failed to uncover any significant differences in vehicle efficiency between the two bus types as long as the mechanical problems of the double deck buses are solved. It has been pointed out that for certain scheduling options the double deck buses could be substituted for conventional buses at a rate less than one-for-one. This section explores financial implications of such a substitution.

A comparison of the capital cost differential (resulting from the substitution of double deck for conventional buses), to the present value of potential savings in driver salaries, was made using the following assumptions: today's purchase prices for conventional, Leyland, and Neoplan buses are $100,000, $125,000, and $215,000 respectively; driver salaries plus benefits are between $23,000 (New York) and $30,000 (Los Angeles) per year and are increasing at an annual rate of eight percent; the discount rate is nine percent; the lifetime of a bus is between twelve and 15 years; and, the double deck buses are substituted at a rate less than one-for-one, depending on the bus type and whether total capacity (Leyland: five for six; Neoplan: five for seven), or just

seating capacity (Leyland: two for three; Neoplan: four for seven), is used to define the substitution rate.

The results are presented in Exhibit 5.3, and indicate that under all assumptions the transit operator would realize a substantial savings by substituting double deck buses for conventional ones. The double deck buses appear most favorable when the substitution ratio is based solely on seating capacity as it should be for long distance trips. The analysis probably understates the cost savings since fuel, repair, and maintenance costs have not been included, and these tend to increase less than proportionately with capacity. Only one driver salary has been assumed to be saved for each unit decrease in fleet size, when, in fact, this number is probably closer to one and a half since the buses could be used for a spread of twelve to 14 hours. Finally, the estimate for the Leyland's standing capacity is probably low since its aisle is wide relative to the number of lower level seats.

Exhibit 5.4 gives the payback period, the number of years the double decks would have to remain in revenue service to justify their additional capital costs, for each set of assumptions. The payback periods range from zero to nine years.

EXHIBIT 5.3

PRESENT VALUE OF SAVINGS FOR DOUBLE DECK BUS SUBSTITUTION[1]

DRIVER SALARY AND BENEFITS	BUS LIFE	LEYLAND ($125,000)		NEOPLAN ($215,000)	
		Substitution Rate	Present Value of Savings per DDB ($000)	Substitution Rate	Present Value of Savings Per DDB ($000)
$23,000	12 years	2 for 3	151	4 for 7	148
		5 for 6	45	5 for 7	25
	15 years	2 for 3	180	4 for 7	193
		5 for 6	57	5 for 7	49
$30,000	12 years	2 for 3	189	4 for 7	206
		5 for 6	61	5 for 7	56
	15 years	2 for 3	226	4 for 7	263
		5 for 6	76	5 for 7	87

[1]Costs include driver salary and benefits and purchase price of the vehicles. The conventional bus was assumed to cost $100,000.

EXHIBIT 5.4

PAYBACK PERIOD[1]

DRIVER SALARY AND BENEFITS	LEYLAND ($125,000)		NEOPLAN ($215,000)	
	Substitution Rate	Payback Period (Years)	Substitution Rate	Payback Period (Years)
$23,000	2 for 3	0	4 for 7	3
	5 for 6	2	5 for 7	9
$30,000	2 for 3	0	4 for 7	2
	5 for 6	1	5 for 7	7

[1]Costs include driver salary and benefits and purchase price of the vehicles. The conventional bus was assumed to cost $100,000.

6. PASSENGER-RELATED ISSUES

Two passenger surveys were conducted in New York, the first in October 1976, and the second in May 1977. Passengers on both double deck and conventional buses were surveyed. Overall preference for and choice of bus type were analyzed with respect to passenger demographics and trip characteristics, ratings of double deck and conventional bus accommodations were compared, and elderly and handicapped passenger responses were analyzed to see how they rated the accommodations of each bus type and to assess their overall preference.

In Los Angeles a survey of double deck bus riders was performed in June 1976. Passenger preferences for bus type were compared with a number of passenger and trip characteristics. Passengers were asked to rate various bus accommodations.

6.1 PREFERENCE

Exhibit 6.1 summarizes the response of New York double deck bus riders to the question, "Which type of bus do you like best?" For all categories double deck bus passengers preferred the double deckers. More transit-dependent passengers on the double deckers preferred this vehicle than not. A considerably higher proportion of passengers on the upper level preferred the double deck bus as compared with those riding on the lower level. All of these results were statistically significant at the .05 level.

Both dispatchers and drivers in New York felt that the passengers preferred the double deck bus over the conventional one and that the upper level was preferred over the lower level, with the exception of the elderly and handicapped,

EXHIBIT 6.1

RESPONSE TO QUESTION: "WHICH TYPE OF BUS DO YOU LIKE BEST?"

NEW YORK DOUBLE DECK BUS PASSENGERS

Preference	All Passengers	Transit Dependent	Regular Riders	Made Special Plans	Double Deck Bus	
					Lower Level	Upper Level
Conventional	13.8%	20.9%	15.0%	6.8%	21.3%	5.7%
Double Deck	57.6	43.5	57.7	80.5	42.9	72.8
Don't Know	6.4	7.6	5.7	3.2	7.3	5.4
No Preference	22.3	27.9	21.6	9.6	28.5	16.1

who seemed to prefer the lower level. This is substantiated by the fact that 71 percent of the handicapped and elderly surveyed in October rode on the lower level as against 49 percent of all passengers.

In Los Angeles, 52 percent of the double deck bus riders surveyed preferred the double deck bus, while eleven percent preferred the conventional bus. Preference for the vehicle was significantly stronger for those riding on the upper level: upstairs 67 percent preferred the double deck, while nine percent preferred the conventional; downstairs the corresponding figures were 38 percent and 13 percent, with 49 percent indicating no preference. These results are summarized in Exhibit 6.2.

EXHIBIT 6.2

LOS ANGELES DOUBLE DECK BUS PASSENGER RESPONSES TO:
"WHICH TYPE OF BUS DO YOU LIKE BEST?"

PREFERENCE	ALL PASSENGERS (Percent)	LOWER LEVEL (Percent)	UPPER LEVEL (Percent)
Conventional	11	13	9
Double Deck	52	38	67
No Preference	37	49	24

6.2 TRIP CHARACTERISTICS

In New York conventional bus passengers tended to ride buses slightly more frequently than double deck bus riders, and 20 percent of the double deck bus riders said they had made special plans to ride the bus. There was no significant difference between the distribution of trip purpose for the double deck and conventional bus passengers. While it had been hypothesized that persons making short trips would not choose to go upstairs on the double deckers, the distribution of trip lengths was not significantly different for double deck and conventional bus riders, nor was it significantly different for those riding on the upper and lower levels of the double deckers.

Comparisons were made between conventional and double deck bus ridership with respect to preference when classified by trip frequency, trip purpose, age, and disability. With respect to trip frequency and trip purpose, there was no significant difference between the distribution of preferences for conventional bus riders. This was also true for double deck bus riders. With respect to age, double deck bus riders under 65 exhibited a stronger preference for the double deck bus than did those 65 and older, while conventional riders 65 and over exhibited a stronger preference for the conventional bus than did those under 65. There was no significant difference within bus type with respect to preferences by those who do and those who do not possess a physical disability.

In Los Angeles there was a significant difference in response to the question about which bus type the passenger preferred based on age. Of those under 65, 54 percent preferred the double deck bus and 12 percent preferred the conventional bus. Of those 65 or older, both figures were less: 32 percent preferred the double deck bus, while five

percent preferred the conventional bus. More than half of the elderly had no preference.

6.3 ACCOMMODATIONS

In New York, passenger responses to questions concerning accommodations indicated that, in all cases, the double deck bus passengers were more positive towards their vehicle than were the conventional bus passengers. The following areas elicited a statistically significant difference in response: ease of boarding (the Leyland bus had lower steps and wider doors than the conventional bus); comfort of seats (Leyland seats were padded); use of grab rails; internal environment (the Leyland buses had debilitating problems with the air conditioning and heating systems, but both surveys were performed on days with moderate temperatures); and noise level (much of this difference can be attributed to the passengers on the upper level who felt that the double deck bus was quieter than the conventional bus, 71.8 percent versus 41.9 percent). The following responses were not significantly different, but were more positive towards the double deckers: walking through the bus; comfort of the ride (although it was obvious that the spring suspension on the Leylands gave a more bumpy ride on New York's ill-repaired streets than the air suspension on the conventionals); and interior lighting.

Seventy-five percent of the double deck passengers on the upper level found that the stairs were easy to use. However, regardless of the difficulties in maneuvering through the stairwell, double deck bus riders still preferred the double deck bus. Only 23 percent of riders on the lower level stated they were there because the upper level was crowded or hard to reach. By contrast 65 percent of those riding on the upper level said they were there because they preferred it. The major negative comment about the double

deck bus was associated with the stairwell, with many of the comments highlighting the narrowness and steepness of the steps.

6.4 HANDICAPPED AND ELDERLY

Handicapped and elderly passengers in New York were analyzed separately in the October 1976 survey. Forty-four percent of these transit dependents riding the double deck bus indicated a preference for that bus type, while only 17 percent preferred the conventional bus. Among double deck bus riders, no significant difference in bus preference was noted when considering trip frequency, level on which riding, or trip length. With respect to the trip characteristics of frequency, length, and purpose, there were no significant differences between double deck and conventional bus riders. For all questions concerning accommodations, the handicapped and elderly on the double deck bus gave a more positive rating than did those on the conventional bus.

7. SUMMARY AND CONCLUSIONS

The double deck bus evaluation was originally scheduled to include two years of revenue service. However, this was considerably shortened due to construction and delivery delays and the poor mechanical reliability resulting from the prototypical nature of the vehicles. In New York the vehicles were still considered to be in their "burn-in" phase at the end of the evaluation period in May 1977, while in Los Angeles, the vehicles appeared to be providing reliable service, even though problems with the braking system had not been completely solved. While the resulting data base turned out to be smaller than had originally been planned, a number of statements can be made about the double deck bus and its place in the American bus fleet.

Passengers preferred the double deck to the conventional bus and preferred the upper to the lower level, regardless of trip length. Passengers also preferred the accommodations of the double deck buses to the conventional ones. There were no serious problems with the use of the internal stairs nor with crime and vandalism on the second level.

From the transit operator's viewpoint, there were two major problem areas: the prototypical nature of the vehicles resulted in a lack of mechanical reliability and recurring maintenance problems; and having to deal with a foreign manufacturer resulted in schedule delays, poor communications (in Los Angeles), unfamiliar mechanical design, and a lack of adequate and easily accessible spare parts.

If these problems had not existed, it appears that the double deck buses would have performed as well as the conventional counterparts. Since they processed passengers at the same rate as conventional buses, the double deckers

tended to fall behind schedule as their loads increased, by about seven to eight seconds per additonal passenger. Three plausible scheduling options were proposed to deal with this problem: using only double deck buses on a route and re-defining the schedule; mixing double deck and conventional buses on a route, but using the double deckers on a skip-stop basis; and using the double deck buses on express routes with a limited number of stops at either end. Large savings in driver salaries could be realized if double deck buses were to be substituted for conventional buses at a rate less than one-for-one.

It has become obvious from this demonstration that foreign production line vehicles cannot undergo major modifications necessary to meet American requirements and still perform satisfactorily without a thorough design effort including representatives from the transit authority's management, maintenance, and driver staffs. Both the Leyland and the Neoplan vehicles should have been treated as prototypes and undergone extensive on-site testing and re-design before they were produced as standard production line vehicles and accepted for revenue service. This procedure is recommended for all future purchases of double deck vehicles.

In summary, the evaluation results argue for the incorporation of the double decker into American bus fleets from both an economic and level-of-service point of view. Experience with the demonstration vehicles has aided manufacturers and transit operators in the development of vehicle specifications appropriate for the American market.

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