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Dial-a-Bus for a University: Demand Response Service in a Many-to-One Environment

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ABSTRACT

The feasibility of a demand responsive bus system for Oakland University is analyzed and the recommended plan is presented. Oakland is an isolated campus, located approximately 25 miles north of Detroit, between Rochester and Pontiac, in a relatively low population density area. The University is primarily a commuter institution, with almost 100% of its 5000 commuter students traveling to the campus in personal automobiles. There is no form of public transportation serving the University, except the personal taxi. Oakland's policy is to construct parking lots to accommodate the high commuter volume. As early as 1976, the University will have to consider building parking structures to keep the lots within a reasonable walking distance from the center of campus.

This paper examines an alternative mode of transportation for Oakland. Based on an analysis of potential demand and a transportation simulation, the University should implement a four-bus system to link Oakland with the Rochester community. Each 12-passenger vehicle would be flexibly routed on demand within a quadrant of the Rochester community; the system could be operating by the beginning of the Fall term 1972.

TRANSPORTATION NEEDS AND DEMAND

Oakland's present policy is to provide parking for commuting students and staff at the rate of 2.5 students per space and 1 faculty-staff per space. The parking lots presently cost about $350 per space to construct, which is paid for by a $16 annual fee assessed to each commuter. It has been estimated that if Oakland continues its present rate of growth, it will run short of available land within a 10-min walking distance of the center of the campus by 1976. Parking structures could be built to keep parking spaces within the 10-min time constraint at an estimated cost of about $2000 per space. Since the parking lots are designed to be self-liquidating, the fee would have to be raised to $75 for each commuter, just to keep building the structures at the required rate.

There are currently about 20 acres of asphalt on Oakland's campus devoted to parking lots; there will be about 30 acres of parking lots in 1976 if those additional lots are constructed. Oakland University is located on a 1400-acre tract, formerly the Wilson estate. It would seem that 30 acres of parking is insignificant, considering the many more acres of wooded hills and fields. Furthermore, there is certainly enough space to build parking lots for just about any anticipated future demand. However, some form of transportation will have to be built to transport people from the outer lots to the central campus. Is there a better way to utilize Oakland's land resources? Would it be more desirable to build new classroom buildings near the existing campus? Are there less expensive ways to commute than by personal auto?

Regional education centers are rapidly becoming commuter institutions; students are either commuting from home or off-campus housing. There must be an attractive method of transportation to offer future students. Parking on campus is acceptable only if it continues to be cheap.

OAKLAND'S TRANSPORTATION OBJECTIVES AND POTENTIAL DEMAND - Since there is presently no way to get to and from the University other than by personal auto, development of a bus system would provide Oakland with a transportation alternative that would increase Oakland's accessibility. This alternative form of transportation would greatly increase student mobility and would also provide a means of transportation for students who are active in community service projects. It would provide transportation to students who cannot afford the luxury of an automobile, thus allowing those students to live off campus in nearby apartments. The system could also provide transportation to the nonacademic community, such as Continuing Education students and Meadowbrook Theater and Music Festival audiences.

The bus system would reduce campus congestion by sharply cutting into the demand for additional parking lots, in addition to luring commuters from their cars to small luxury buses. Enhancing Oakland's attractiveness is also quite important. By providing a cheaper alternative to commuting by personal auto, attending the University may become a realization of more students. Oakland will become physically more attractive if the bus system reduces the need for more parking. The proposed bus system could also satisfy two additional student needs. Students will be employed as bus drivers and dispatchers. Since the bus system is a cheaper alternative means of transportation, an alternative financial aid package would be available to the student.

The proposed bus system is actually only one part of an overall plan for improving transportation at Oakland. The Commuter Services office is working on implementing cooperative car pools and encouraging students to form ride pools.

COMPARISON OF ALTERNATIVE SERVICE AREAS - A system analysis has been made to measure the potential demand for the proposed bus system. Fig. 1 shows the area surrounding Oakland divided into zip code zones. The percentage of commuter students in each zone was determined. It was also postulated that the relative number of married students, apartment dwellers, and financial aid applicants in an area indicate apparent demand. Most married students can probably not afford two cars; if one half of the partnership works to support the student, or both work and study at different times, then a bus system could satisfy a transportation need for married students. Likewise, a substantial proportion of students living in nearby apartments may not need to own cars if they ride with roommates or neighbors who own cars. The percentage of financial aid applicants in an area indicates a demand for an alternative form of transportation subsidy. A common commuter expense is supporting an automobile; the maximum financial aid support per semester is currently $100 for transportation.

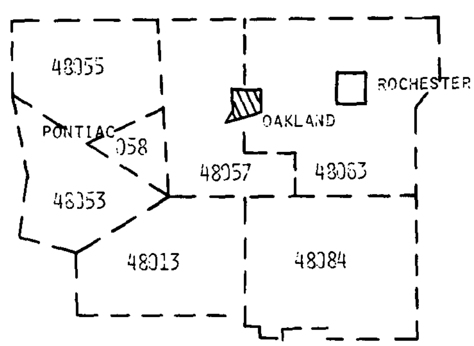

Fig. 1 - Zip code areas

Additional types of public transportation in a given area which could be coordinated with Oakland's system were considered plus factors; linking with them could improve Oakland's accessibility. The number of miles from Oakland to the center of each area is measured to indicate a relative cost in time and money. Therefore, the best choice for an area to be served would be that zip code area which maximized the relative number of

1. Commuter students.
2. Married students.
3. Apartment dwellers.
4. Financial aid applicants (commuters).
5. Community service students.
6. Other public transport.

With regard to the distance from Oakland to any given area, the best choice would be that area which minimized

1. Miles to area.
2. Cost/fixed route trip to area.
3. Time/fixed route trip to area.

The zip code areas were used because they give clearly defined areas crossing city limits; the information desired was easily accessible in that form. Table 1 shows the comparison of the selected zones and the tradeoffs that can be made.

The first choice for the initial bus-system service area is zip code area 63, since this has the high potential demand factors: commuter students, financial aid applicants, married students, and apartment dwellers. The trip length is only 1.25 miles greater than the shortest distance; the public transit factor is not significant because it would basically increase trip time to transfer from another form of transportation to the Oakland bus service. In comparison to the number of commuter students in an area, the number of community service students is very small; the major proportion of riders will likely be commuting students.

The second choice would be area 53; even though it is farther from Oakland, it has the second greatest demand factors because it is enhanced by public transit and community service projects. The highest percentage of apartment dwellers reside in areas 63 and 57, reflecting the recent growth in apartment complexes in the Rochester-Oakland area.

DEMAND RESPONSE BUS-SYSTEM SIMULATION

The demand responsive bus system has been conceived as a viable transportation alternative in a medium population density area. The service would consist of a fleet of 12 passenger vehicles; the buses would provide doorstep pickups or stops, determined by demand in the desired service area, and then take all passengers to the single destination: Oakland University. This type of service is called a many-to-one system.

Several types of many-to-one routing schemes were simulated for cost and speed comparison. The most complex type of route is shown in Fig. 2. The vehicle was permitted to make stops anywhere within zones of varying size in the city of Rochester, followed by a 5 mile line-haul trip to the University. A second method of pickup was deviation by about three blocks from the fixed line-haul route connecting Rochester and Oakland. The third route allowed the vehicle to make stops only along the fixed line-haul route.

EXPERIMENT FOR ALTERNATIVE ROUTING SCHEMES - The alternative routes described were simulated. Two types of data were recorded as a function of route type: trip time and trip distance. Pickups were generated by taking addresses from the University phone directory. Oakland University's motor pool conducted the actual experimental measurements and drove the vehicles. Each trip was defined to start at the first stop on the route and end in front of the campus library. The driver recorded the mileage at each end of the trip along with total elapsed time; 45 s were allowed for each stop. All trips were designed to pick up ten passengers.

Every trip was planned ahead of time with one exception. Communication was experimented with by broadcasting simulated requests for service, using a random time sequence between requests, on a citizens' band radio, starting when the vehicle left the University. The driver was instructed to plan his trip en route, allowing for a suboptimum route. The driver was equipped with a map of zone 1, which was marked with times arranged in manhattan geometry fashion, indicating the time required to travel to Oakland. This route had a fixed time limit of 1/2 h the driver had to keep from the first stop to the trip end at Oakland.

The average measurements recorded for each route type are shown in Table 2. Fig. 3 presents 80% confidence intervals about the mean times and distances. Since the bounded flexible route parameters depended on the size of the area served, this route was simulated for three different size zones.

The average time for all the types of routes tested is too long to count on more than one round trip per hour. The fixed route could be run twice in an hour if morning and afternoon trips only picked passengers up and distributed

Table 2 - Average Measurements for Each Route Type

Route Type	Mean Trip Distance, miles	Mean Trip Time, min
Fixed	5.1	17.3
Route deviation	6.8	25.25
Bounded flexible zone 1	6.5	24.7
Bounded flexible zone 2	5.9	19.7
Bounded flexible zone 3	8.0	26.75
Bounded flexible zone 1 with communications	8.3	27.3

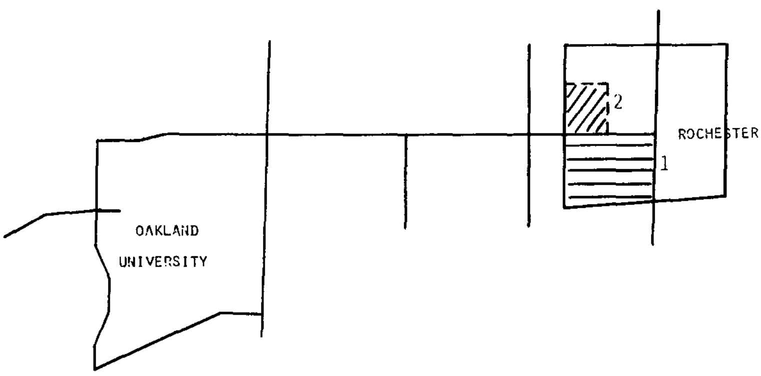

Fig. 2 - Bounded flexible route: zone 1 = 0.3 mile^2; zone 2 = 0.1 mile^2

Table 1 - Comparison of Possible Initial Service Areas

Zip Code Area	Registered Commuter Vehicles, %	Commuter Financial Aid Applicants, %	Married Students, %	Apartment Dwellers, %	Community Service Students	Public* Transit	Line-Haul Miles	Trip** Time, min	Trip† Cost
55	3	3	2	–	–	X	4.0	15.5	$3.78
57	4	2	–	2	–	–	3.75	15.0	3.56
63	7	21	4	3	–	–	5.0	17.5	4.20
84	4	2	–	1	–	–	12.0	31.5	7.80
13	1	2	1	1	–	X	8.0	23.5	5.70
53	5	15	–	–	X	X	6.0	19.5	4.77
58	1	4	1	1	X	X	4.5	16.5	3.97

*X indicates existence of factor only.
**Time figures computed from Fig. 3.
†Cost figures computed from Fig. 4 for three vehicles.

them, respectively. The bounded flexible route with communications en route is the longest, since the vehicle is permitted to backtrack. This backtracking increased trip distance an average of 1.8 miles; an area the size of zone 1 is considered to be the maximum size for a flexible route. As shown in Fig. 3, the confidence interval for trip time is too wide for a route traveling in an area as large as zone 3. It would appear that operating in a zone that large would prohibit making one round trip per hour. A flexibly routed system within a bounded area is recommended because a less comprehensive type of service does not yield more trips per hour. From the available data, a town the size of Rochester would need four vehicles to provide Oakland commuters with one round trip per hour service.

COST ANALYSIS

The costs outlined in Table 3 have been grouped according to fixed costs and variable costs, both as a function of the fleet size and number of miles driven. All capital equipment costs are spread out over 3 years. These fixed costs are inversely proportional to the number of trips made.

VEHICLE COST PER TRIP - The vehicle cost per trip is calculated to estimate expected cost to the passenger. If it is assumed that the bus system will operate for two semesters for five days a week, a 10-h service day would be 1600 working hours for the system. The total yearly cost of each driver and of the dispatcher is figured on this 1600-h year. Of course, if vehicle operations are cut back during low-demand hours, this cost will be less. The vehicle cost per trip is determined by how many round trips can be made per hour and how far the trips are. The vehicle cost per trip in the following equation is plotted in Fig. 4.

$$\frac{\text{Cost}}{\text{Vehicle Trip}} = \frac{\$11.40}{(\text{K vehicles})\,(\text{n trips/h})} + \frac{\$2.80}{(\text{n trips/h})} + \$0.07\,(\text{“x” miles/trip}) \qquad (1)$$

The vehicle trip cost is not significantly affected by the

Table 3 - Fixed and Variable Costs Related to Fleet Size and Mileage

Fixed costs (inversely proportional to number of vehicles):	
Supervisor	$12,000
Dispatcher	3,200
Base citizens' band radio	80
Supplies and services	3,000
	$18,280
Fixed costs (proportional to number of vehicles):	
12-passenger van	$ 1,000
Driver	3,200
Mobile citizens' band radio	50
Insurance	200
	$ 4,450
Variable costs (proportional to mileage driven):	
Maintenance	2.0¢/mile
Gas	1.5¢/mile
	3.5¢/mile

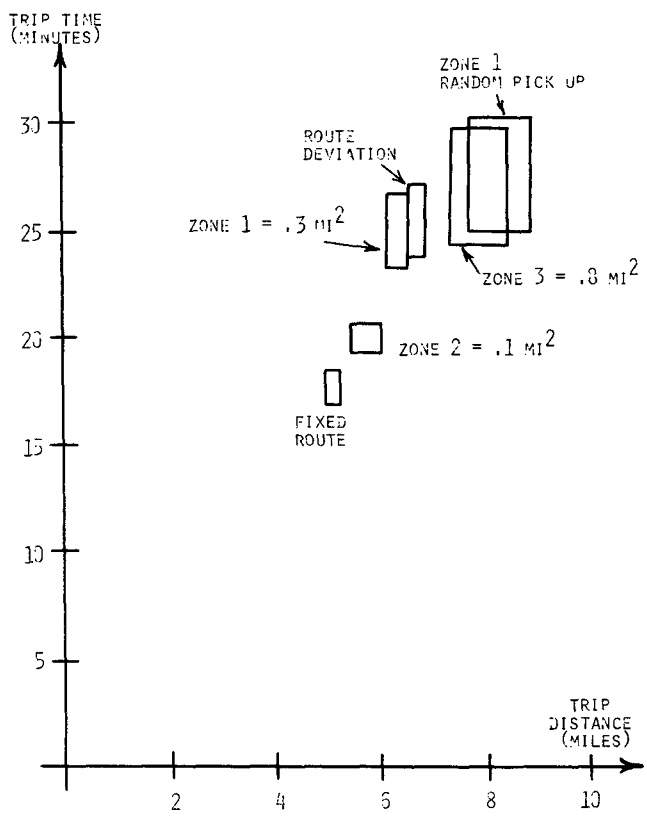

Fig. 3 - Route characteristics

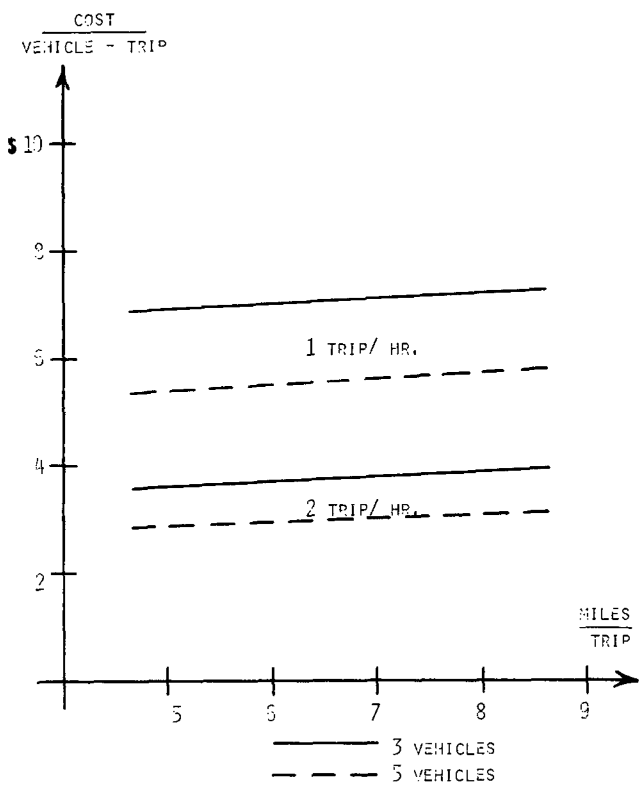

Fig. 4 - Cost per vehicle trip

mileage driven, but the cost decreases about 20% if the fleet is expanded from three to five vehicles. This is a pessimistic cost estimate, since it assumes that the system will be used as a collection or many-to-one service in the morning hours and a one-to-many service in the afternoon. If just one-half the number of passengers being collected in the morning hours could be transported from the University to the service area, the vehicle trip cost would be about 33% lower.

For the bounded flexible routes recommended, the vehicles could make only one trip per hour. If four vehicles served Rochester, the vehicle trip cost from Fig. 4 would be $6.10, but these cost curves do not include indirect labor costs. Adding Oakland University's standard indirect cost of labor, 66.81%, the vehicle cost per trip becomes $9.10 for the four vehicle system. The initial capital expenditure for this system is given in Table 4. Since the equipment costs are spread out over 3 years, this cost would be absorbed in the expected yearly cost of $58,500 for the system.

COST COMPARISON FOR THE PASSENGER - The proposed demand-responsive bus system is expected to cost about $9.10 per vehicle trip, resulting in an individual commuter fare of approximately $1.80 per round trip, if bus system fares are expected to supply all operating revenue. The daily round trip cost to an individual owning and maintaining his own car is $1.54 for a one-way trip of 6 miles to the University (1).* The cost to ride the bus system appears quite high in comparison to commuting by personal automobile; but the commuter continues to pay for his car on days he doesn't commute. The estimated two-semester cost for the commuter owning his own vehicle is about $572 for the same 6-mile trip. It would cost half as much, or $288, to use the bus system five days a week, and the investment in an automobile would be unnecessary.

Since there are no new dormitories in Oakland's current future plans, the bus system could lead the way to persuading resident students to move off campus without having to buy cars. A commuter student could share an apartment with three roomates for about $50 per month. If a $10 weekly food allowance is made, the yearly cost would be a little over $1000 for two semesters while commuting on the bus system. Room and board is currently $1050 for an Oakland resident.

Although the two-semester bus fare appears to be competitive, it is probably still too high to attract riders. A Pontiac firm ran a fixed route system between Rochester and Pontiac for one month in January 1970 (1). The one-way fare from either city to Oakland was $1.00 and hardly anyone used the bus. The Kent State University bus system, which began in 1967, found that 2.5 times as many students rode their system when they charged a quarterly fee to all students and operated without fares (1).

A round-trip fare of $1 to either Rochester or Pontiac is perhaps an acceptable fare. This would result in an $80 per semester cost, which is less than the current financial aid subsidy. Would it be attractive to have a round-trip fare of only 50¢? Of course the money to support the system would have to come from somewhere. The expected revenue for the four-vehicle system is shown along with the needed subsidy in Table 5.

COST SAVINGS TO THE UNIVERSITY - Oakland's transportation policy to date has been to provide parking for all commuters at the rate of one space for every 2.5 students. The growth of the University has been estimated at 1200 students per year, necessitating the building of 2000 additional spaces by 1976. At the present cost of approximately $350 per space, the University would spend $700,000, using all the available land within 10 min of the central campus. A more conservative 5% student-body growth rate would necessitate the building of 500 parking spaces at a cost of $175,000. The proposed demand-responsive bus system could save the University a considerable proportion of this expense by diverting commuters to riding the bus system.

The proposed four-vehicle system could transport about 10 commuters per trip per bus, providing transportation for about 200 commuters daily. This would save the University about 80 parking spaces, or $28,000, in the first year of operation. Of course the bus system could transport no more commuters in future years, so the $28,000 saved would only be saved for every four vehicles in the fleet. This saving could be applied toward the equipment needed to start the system and save the bus operation almost $10,000 per year in operating expenses. The round-trip fare would be reduced to $1.50, which is even competition with commuting by personal auto.

BUS SYSTEM FINANCING AND MANAGEMENT

PARKING FEE STRUCTURE AND BUS SERVICE DEMAND - Oakland University could adjust the parking fee and create additional revenue for the bus system along with discouraging commuting by individual vehicles. Presently there is an average load of only 1.2 people per car. About 65% of all commuter students pay the $16 yearly parking fee. Although no information has been found to substantiate the

*Numbers in parentheses designate References at end of paper.

Table 4 - Capital Expenditure for Four-Vehicle System

Four 12-passenger vans	$20,000
CB radio Equipment	700
Supplies and services	3,000
Insurance	800
	$24,500

Table 5 - Four-Vehicle System Funding Requirements

Fare	Revenue	Subsidy
50¢/round trip	$16,000/year	$42,500/year
$1/round trip	$32,000/year	$26,500/year

claim, a higher percentage probably paid the $2 yearly fee in 1966 before it was raised. The University of Wisconsin has a fixed supply of parking spaces of 5500. At the previous fee of $55 per year per space, the University of Wisconsin received about 9000 applications for the 5500 available spaces; the collected revenue was approximately $300,000 yearly. The $55 fee has recently been replaced by a graduated fee ranging from $55-$180 per space, depending on the proximity of the space to the center of campus. The applications for the 5500 spaces dropped to 7000 as a result of the new fee schedule; for a mean fee of $85, the collected revenue was $467,500. So, a 55% increase in the average parking fee decreased the demand for parking over 20% and increased the parking revenue.

If Oakland were to increase its parking fee substantially, it would likely generate demand for the bus service and provide funds to finance it. Suppose the fee were doubled to $32 per year, and as a result only 60% of the commuters paid for it, as compared with the current 65%. It is assumed that the commuter population is growing at an expected growth of 5%. With this increase in parking fee, the University would realize an additional revenue of about $54,000 while increasing the demand for other transportation by about 300 students in the first year alone.

By subsidizing the system $42,900 yearly, resulting in a 50¢ round-trip fare, the parking fee would have to be increased and put in a general fund. An additional $54,000 revenue could be expected from raising the fee to $32. This would leave about $12,000 accumulating each year in a fund that could be used toward future parking and transportation needs, rather than waiting to raise the fee to meet present costs. The parking fee could be a general transportation fee, allocating funds to the bus system and other forms of transportation in addition to building parking lots.

OAKLAND'S TRANSPORTATION DEPARTMENT - Developing transportation is a prime mechanism for helping to accomplish the University's goals; hence, its multifaceted means should be coordinated. There are many small activities concerned with various aspects of Oakland's transportation problem presently within its organizational structure. For example, parking lots are constructed under the Campus Development office and car pools are organized by the Commuter Services office. Since many of these departments have other diverse and unrelated interests, it seems logical to form a task group charged with development and operation of the services directed toward Oakland's transportation needs. The transportation department would coordinate the operation of the current functions of parking lots, car pools, traffic control, and the motor pool, in addition to the proposed bus system. The parking fee could be changed to a general transportation fee to be administered by the new transportation department.

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