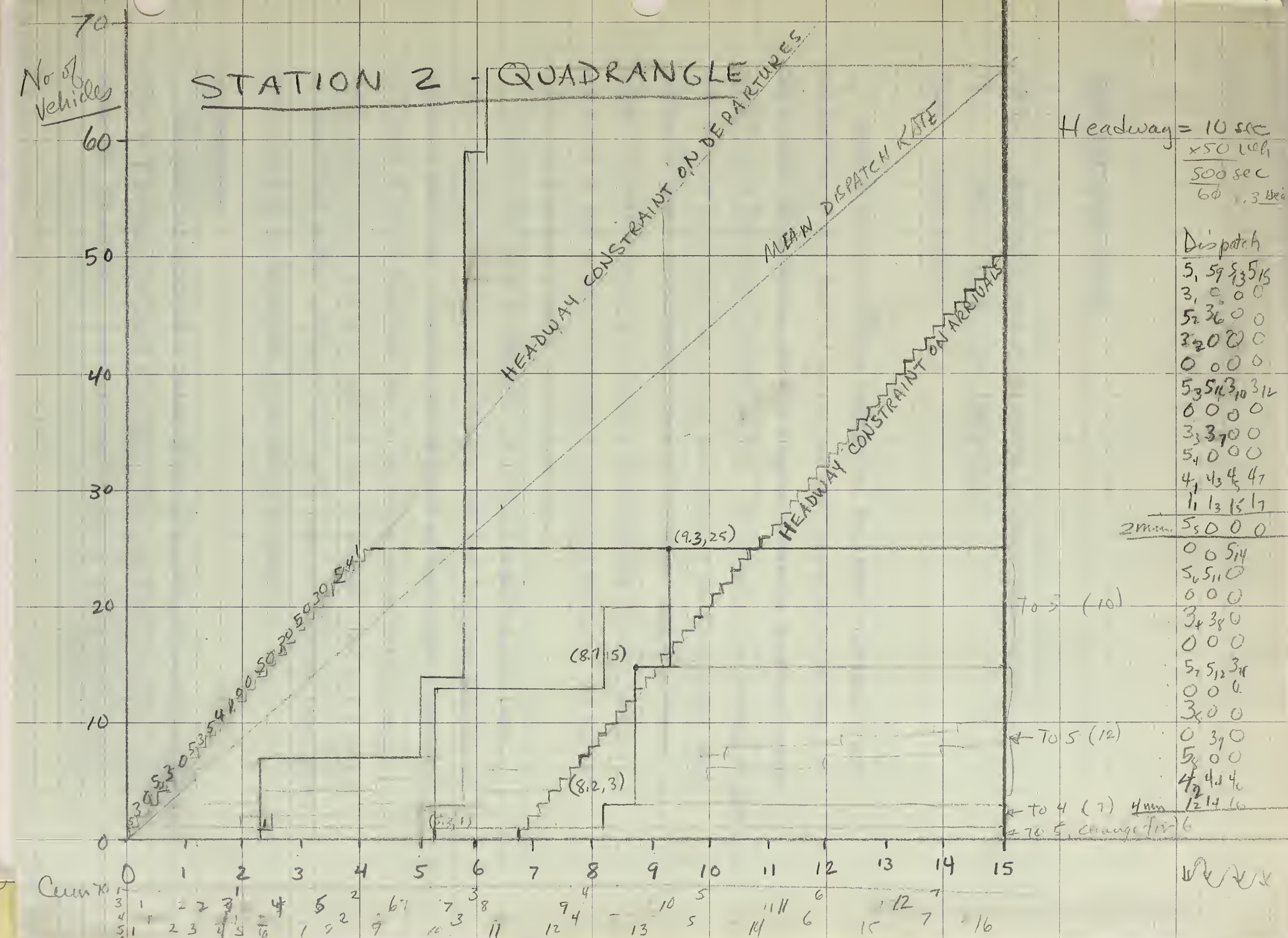

STATION 2 - QUADRANGLE
No of Vehicles
HEADWAY CONSTRAINT ON DEPARTURES
MEAN DISPATCH RATE
HEADWAY CONSTRAINT ON ARRIVALS
(9.3, 25)
(8.7, 15)
(8.2, 3)
Headway = 10 sec
x50 veh
500 sec
Dispatch
To 5 (10)
To 5 (12)
To 4 (7) 4 min
2 min

ROUGH DRAFT MEMO--8/21/70

SUBJECT: Comparative Costs of Golf-Carts for People-Mover System

TO: Robert A. Hemmes (thru Stan Price)

FROM: Henry Nejako

Based on readily available information, one cannot accurately answer the question of what level of service one could buy with $13 million (or $25 million) for Morgantown and West Virginia University assuming a system of golf-carts operating on macadam paving. The answer to the counterpart question, what it would cost to provide service equivalent to the Alden system using golf-carts, cannot be determined at this point either. A golf-cart system has certain inherent limitations which preclude its ever being equivalent in some aspects of the Alden system's performance. The use of carts on an elevated guideway is discussed below.

One can make rough estimates of the costs of acquiring golf-carts, garages, spare parts, paths (or guideways), but each cost component has to be heavily qualified. I have not yet contacted any major country club in an attempt to obtain experience data on operating and maintaining large fleets of golf-carts, but this could be done if desired. Nor have I thus far ascertained whether golf-carts can really negotiate extended steep grades such as are found in Morgantown, either uphill or downhill.

Cost Components

One could not establish a system merely by spending $13 million on acquisition of a guideway (at about $5 or $6 million) and 5,000 golf-carts (about another $5 - $8 million). One would have to provide for maintenance facili-

ties and parking space for the carts as well as the means for recharging batteries while the carts were idle. In the Morgantown proposal, the university is proposing to pick up the costs of operating the system as part of its contribution, if I understand the proposal correctly. With a golf-cart system, there would probably be a far higher component of o&m costs to keep the fleet functioning. Because of this, both acquisition costs and o&m costs are described below:

Acquisition Costs

-- Golf-carts, including batteries

-- Initial spare parts

--Parking garages with electrical outlets to permit recharging batteries

-- Maintenance facilities

-- Guideway or paved paths

-- Access control system, such as credit cards that unlock the motor switches (or permit the vehicles to be recharged) or gateways to the guideway which can be opened by coins, tokens or other means

-- Maintenance vehicles for retrieving disabled carts

-- Communications and control system (urgently needed in a system confined to a guideway; can be very simple if each user is assigned a cart for extended personal use)

Operating Costs

-- Electricity to recharge batteries

-- Personnel costs for operating and maintaining fleet and guideway (system would need mechanics, cash collectors to service fare-

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Operation Costs (cont.)

collecting gateways unless a credit card system is used, communications crew, snow and ice removal crews, painters, welders, electricians, "cowboys" to round up stray carts, laborers and office help; maintenance charges for vehicles operated by college students are likely to be significant)

-- Replacements for lost or stolen carts

-- Insurance and safety expenses (the combination of an elevated guideway and student operators would probably make this a significant item also)

-- Supplies and replacement spare parts

Cost Estimates

Carts I contacted two local suppliers of golf-carts (Cushman and E-Z Go Dealers). E-Z GO does not sell an enclosed cart, so protection from extreme weather would not be provided. Volume data were not available in either case, but quantity discounts on the order of 20 percent are probably obtainable by negotiating directly with the manufacturer. The basic ~~Cushman~~ 4-wheel, 2-passenger electric model with canopy lists for $1,280 (Cushman) or $1,310 (E-A Go). (For an enclosed cab and two doors, add $124 to the Cushman price.) A rough estimate of the price of 5,000 carts would be about $1,000 each (with canopy--$1,100 with cab), or $5 million total.

Garages The university is currently estimating $600 per space as the cost of providing parking for autos. Since golf carts are smaller and lighter, the cost should be proportionately lower ($300 - $400 per space?). But the usage characteristic envisioned means

Cost Estimates (cont.)

Garages (cont.) garages would be needed at all major activity centers, including both classroom and dormitory complexes. A rough estimate might be two locations per vehicle costing $350 each or $700 per vehicle. (This apparently does not include the cost of acquiring land or the opportunity cost of using existing land). For 5,000 vehicles, this would amount to about $3.5 million for garage space.

Maintenance Facilities Shop area, tools, fixtures, and utilities would be required. The Alden System estimate for a maintenance facility is about $850,000. It would probably be feasible to have a simpler facility to service golf-carts than would be needed for Alden vehicles, so one might reduce this estimate. Additional economy might be possible through locating the maintenance facility at one of the parking garages. An estimate of $400,000 is suggested.

Guideways The reason for proposing an elevated system in Morgantown is because there are only two steep, narrow access routes between the main campus and the two outlying campuses. It might be possible to widen these routes, adding lanes for exclusive use of golf-carts. The final report of the Morgantown feasibility study cites $250,000 per mile as the cost to widen the narrow streets. The number of miles of two-lane road between the three centers appears to be about 3 or 4. Devot-

Guideways (cont.) ing a love to exclusive use of carts would require, then, a construction investment of at least $1 million. (This assumes the city would be amenable to granting the right-of-way for such use.) If an elevated golf-cart skyway were constructed, one could use the cost-estimate for the Alden guideway as a starting point. Exit from the guideway could be either by foot (if the carts are to be garaged at stations on the guideway) or by ramps leading to the major activity centers. The guideway cost, exclusive of stations, proposed for the Alden System is $6.2 million. One might wish to retain the electrical snow-removal feautre and to keep outlets near stations for recharging stalled vehicles. But without the need for the power supply (third rail) and associated switching and safety features, the cost of an elevated guideway suitable for carts would probably be on the order of $4 -$5 million.

Access Control System Without some system of fare-collection, the system will not demonstrate anything about the economics of user demand. (One might prefer a variable pricing mechanism to obtain demand elasticity measures.) An uninformed guess at the cost of such a system is $100,00 ($200,000 for a sophisticated credit card system using existing computer facilities).

Maintenance Vehicles There are no handy ways of estimating how many tow-trucks would be needed to service a fleet of 5,000 golf-carts. Assuming driver availability to limit response to calls to pick up disabled carts, 5 to

Maintenance Vehicles (cont.) 10 tow vehicles should suffice. Tractors similar to those used at airports would probably suffice. A guess at their cost is $1,000 each.

Communications System A simple system, not involving sensing devices or closed circuit TV, could probably be installed for $5,000.

Operating Costs No basis exists for estimating these. It is suggested that URD begin to develop useful cost factors for evaluating proposed system alternatives. (A project with this purpose is included in the MITRE presentation on FY 71-72 UMTA Budget) prepared for URD.

Equivalence of Golf-Cart System and Alden System

For several reasons, most related to the lack of automation in a golf-cart system, it could never really be equivalent in service to an Alden system. Briefly, a golf-cart system would compare adversely in the following respects:

1. Individually piloted vehicles exclude those without driving skills. Pooling and hitchhiking would relieve this somewhat.

2. Empty golf-carts must remain where parked. To redeploy them would require tow vehicles and train-hitches on each golf-cart. (Assigning one cart per user is inherently inefficient.)

3. Risk of theft is greater since carts can be operated anywhere, unlike guideway-bound Alden vehicles. (This would be similar to the grocery cart problem faced by supermarkets.)

My first assignment after arriving at UMTA in August 1970.

D R A F T

PRELIMINARY ANALYSIS OF MORGANTOWN SYSTEM PERFORMANCE

Prepared by URD-23 (Systems Analysis)

November 25, 1970

D R A F T

TABLE OF CONTENTS

Page

TABLES

CHARTS

PRELIMINARY ANALYSIS OF MORGANTOWN SYSTEM PERFORMANCE

I. SUMMARY

A. Scope of Analysis

This analysis was based on minimum system configuration data, tables of current morning peak passenger demand and expected travel times between each pair of stations. Certain mathematical (and therefore theoretical) relationships were developed between headway, station capacity, station dwell time (for unloading, loading and gaining access to guideway) and vehicle capacity. Some paper-and-pencil simulation was attempted to improve understanding of the effect of multiple paths through a station and potential reutilization of vehicles once they have discharged their first peak load.

B. Factors Found Significant

Given the distance between the two stations expected to have the greatest peak trip volume (Towers and Quadrangle, approximately 8700 feet apart in the latest guideway layout) and the relatively slow speed of the vehicles (imposed by considerations of safety and power needed to negotiate steep grades), it will be possible to carry the large design load (1100 passengers in ten minutes) only by either maintaining extremely close headways or by using vehicles of capacity approaching that of a standard urban bus (or by entraining two vehicles of minibus size, or perhaps three vehicles of slightly smaller size).

Merging departing vehicles into a moving stream of automatically guided vehicles presents a difficult enough problem when all vehicles are scheduled. When vehicles are traveling over demand-actuated routes (i.e., according to a random schedule), whether this can be done safely or at all remains to be proven.

Saturating the capacity of certain links appears possible, expecially during the morning peak. According to one set of assumptions examined, there would be very little flexibility for station 5 (Towers) to dispatch vehicles to destinations other than station 2 (Quadrangle) during the early part of the peak; as a consequence, station 2 could hardly accept arriving vehicles from stations other than 5 during the latter part of the peak.

It appears that one of the challenges to consistency of operation will be posed by the need to have a hundred or more vehicles, each separately propelled and guided (albeit by commands from a central source), perform uniformly. That is, close headways cannot be maintained if one vehicle accelerates, cruises or brakes differently from the vehicles ahead of and behind it. Diagnostic procedures to detect departures from uniform operation will certainly have to be incorporated within the system.

C. Design Choices Apparently in Need of Re-Examination

The constraints of distance and attainable speed raise questions concerning the wisdom of accepting as a design goal transfer of 1100 passengers from station 5 to station 2 within 10 minutes during the first morning peak. Since the first

peak does not follow a class, early arrival so as to avoid the maximum crush is feasible for users. The fifteen-minute peak demand table provided by the university can be expected to be inadequate as a measure of the number of passengers desiring to move during that period in the future. But the reason for reducing the time available in which to serve that increased demand from 15 minutes to ten minutes is not clear. The problems this imposes on the system (whether their solution be approached by reducing headways, using larger cars or entraining cars) can be eased by continuing to plan for a 15-minute peak. The problem is somewhat eased during class-change because the system load is better balanced as well as smaller in absolute volume. But even then, it would probably be more sensible to consider 12-or 15-minute class change intervals than to strain system capability.

D. Advantages and Limitations of Present System Design

Ostensibly, selection of the Morgantown demonstration site and concept can be justified on the basis of the need to prove feasibility and acceptance of a people-mover capable of serving a congested downtown CBD (or other activity center). The Morgantown system configuration and plan of operation should demonstrate such key factors as switching, merging, automatic vehicle guidance and control, grade climbing, bad weather performance, network interactions, queuing of randomly routed vehicles and station design. Because the route configuration is strongly linear (only 6 of the 15 station-pairs are linked in such a way that one can pass from one to the other without by-passing a third station), congestion within a station that leads to queuing of arriving vehicles outside the station access ramp will hold up vehicles trying to by-pass the station. In a more typical urban setting a grid pattern would be more likely, and alternate routes would be available in case of congestion on one route. (Congestion may also occur if a vehicle breaks down on one of the heavily travelled links.)

E. Critical Analyses Still Needed

Certain analyses were beyond the scope of this preliminary investigation yet should be obtained during the feasibility study phase. Primary among these is a detailed simulation of system performance during both scheduled and demand-actuated operation. The sensitivity to system performance to variations in headway, random perturbations (such as might occur if something delays loading of a car in a busy station), vehicle malfunction on various guideway links, station capacity and configuration (including the question of whether end-of-line stations such as 1,4 and 6 should have by-passes for vehicles that are needed further on) needs exploration.

Another type of investigation that seems essential is failure mode analysis, along with considerations of types of failure that might be encountered, procedures for recovery, provision for safety and rescue (if necessary) of passengers, and length of time needed to restore acceptable service.

Not considered herein but perhaps worth pursuing is the question of whether operating economies of sufficient scale would be attained if small vehicles were intermixed with the larger basic vehicles for primary service during off-peak periods and for low-demand station-pairs during peaks. This would add one more variable to the control problem, but it is not conceptually distinct from that posed by trains (in the one case, the capacity is multiplied by a factor less than one, whereas with trains the capacity is increased by an integral multiple).

One last analysis that should be undertaken is the desirability of providing for a possible future third track on the most heavily used section of the guideway, between the Quadrangle and Engineering stations. This serves the following station-pairs: 1-3, 1-4, 1-5, 1-6, 2-3, 2-4, 2-5, and 2-6. Using the demand data provided and assuming 20-passenger vehicles, 90% full, this section will have to maintain headways of 11.5 seconds between vehicles if the entire demand is to be satisfied within the allowable 15-minute period. The third track could be reversible, perhaps with physical barriers switched twice each day, and need not actually be installed for the UMTA demonstration. But spacing the other two tracks in such a way as to permit its eventual installation might save the city and the university considerable construction costs in the future.

MORGANTOWN SYSTEM CONCEPT

The system analyzed has the following characteristics:

Six stations connected by approximately 32,000 feet of guideway.

Station 1 (County Court House)	End-of-line loop(with at least two paths)
Station 2 (Quadrangle)	Loop with station 1 plus through passage to station 3
Station 3 (Engineering)	Loop with station 2 plus through passage to link leading to either station 4 or station 5
Station 4 (Field House)	End-of-line loop(with at least two paths) linked to station 3 or station 5
Station 5 (Towers)	End-of-line loop(with at least two paths) linked to station 4 or station 3 plus a separate end-of-line loop linked with station 6; possible future conversion to through passage to station 6
Station 6 (Medical Center)	End-of-line loop linked to station 5

There is a full interchange linking stations 3,4, and 5.

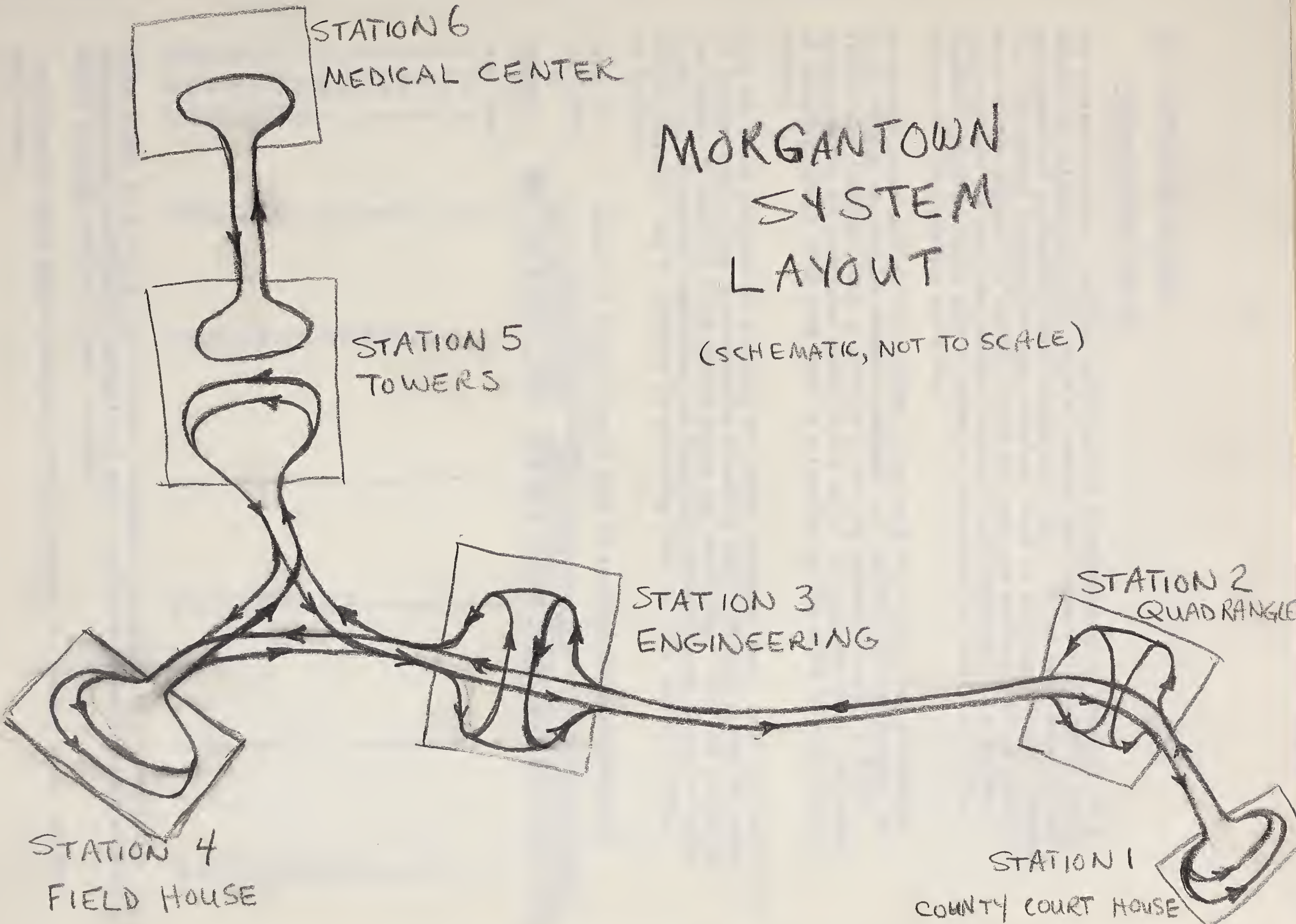
Independently propelled and guided vehicles, maximum capacity = 20 passengers. Vehicles are in individual contact, via guideway, to central control computer.

Service would be pre-scheduled during peak periods, with passengers boarding vehicles with designated destinations.

During off-peak periods, most of the vehicles would be retired to a storage facility, located in the vicinity of station 3. The remainder would provide demand-actuated service, taking passengers directly to requested destinations.

Headways on the order of a few seconds.

Station dwell-time (during which vehicle is stopped for unloading and reloading and then proceeds to an access ramp where it awaits an unoccupied block or "null" in the moving traffic) on the order of 20 seconds.


STATION 6
MEDICAL CENTER
MORGANTOWN
SYSTEM
LAYOUT
(SCHEMATIC, NOT TO SCALE)
STATION 5
TOWERS
STATION 3
ENGINEERING
STATION 2
QUADRANGLE
STATION 4
FIELD HOUSE
STATION 1
COUNTY COURT HOUSE

II. GUIDEWAY AND STATIONS

Minimum Station Capacity

The minimum number of vehicles which must be accomodated simultaneously in a station is determined by the ratio of station dwell-time (time between arrival and departure) to headway (time between arrivals). If the dwell-time is less than the headway between arriving vehicles, there is sufficient time to process each vehicle through the station before the next one arrives, and the station requires room for only one vehicle to stop in each direction. For shorter headways, however, there must be space to accomodate the vehicles arriving before the first one has moved on.

To avoid a queue outside the station, there must be at least two independent paths through the station whenever headways are shorter than dwell-time. (At little used stations, such as station 6, one may choose to accept a finite queue, provided it dissipates prior to the end of the peak period.) The number of stopping places along each path is a function of the ratio of dwell-time to headway.

With two paths through the station, very short headways (i.e., very high dwell-time to headway ratios) can be accomodated by making each path long enough to store the number of vehicles which arrive during the dwell-time. When the ratios are high (e.g., 60-second dwell-time and 6-second headways) some saving in total station capacity can be achieved by providing three or four parallel paths, as follows:

Ratio of Dwell-Time to Headway	Number of vehicles which must be accommodated simultaneously in station having:					
	Two Parallel Paths		Three Parallel Paths		Four Parallel Paths	
	Each Path	Station Total	Each Path	Station Total	Each Path	Station Total
Less than 1	1	2	1	3	1	4
1 to 2	1	2	1	3	1	4
2 to 3	2	4	1	3	1	4
3 to 4	3	6	2	6	1	4
4 to 5	4	8	2	6	2	8
5 to 6	5	10	3	9	2	8
6 to 7	6	12	3	9	2	8
7 to 8	7	14	4	12	3	12
8 to 9	8	16	4	12	3	12
9 to 10	9	18	5	15	3	12
10 to 11	10	20	5	15	4	16
11 to 12	11	22	6	18	4	16
12 to 13	12	24	6	18	4	16
13 to 14	13	26	7	21	5	20
14 to 15	14	28	7	21	5	20
15 to 16	15	30	8	24	5	20

These values hold only if an efficient assignment discipline is followed; that is, each path must be filled to capacity in turn. Any other procedure, such as alternating incoming cars, will lead to delays.

The following graph depicts required station capacity vs. headway given various dwell-times.

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

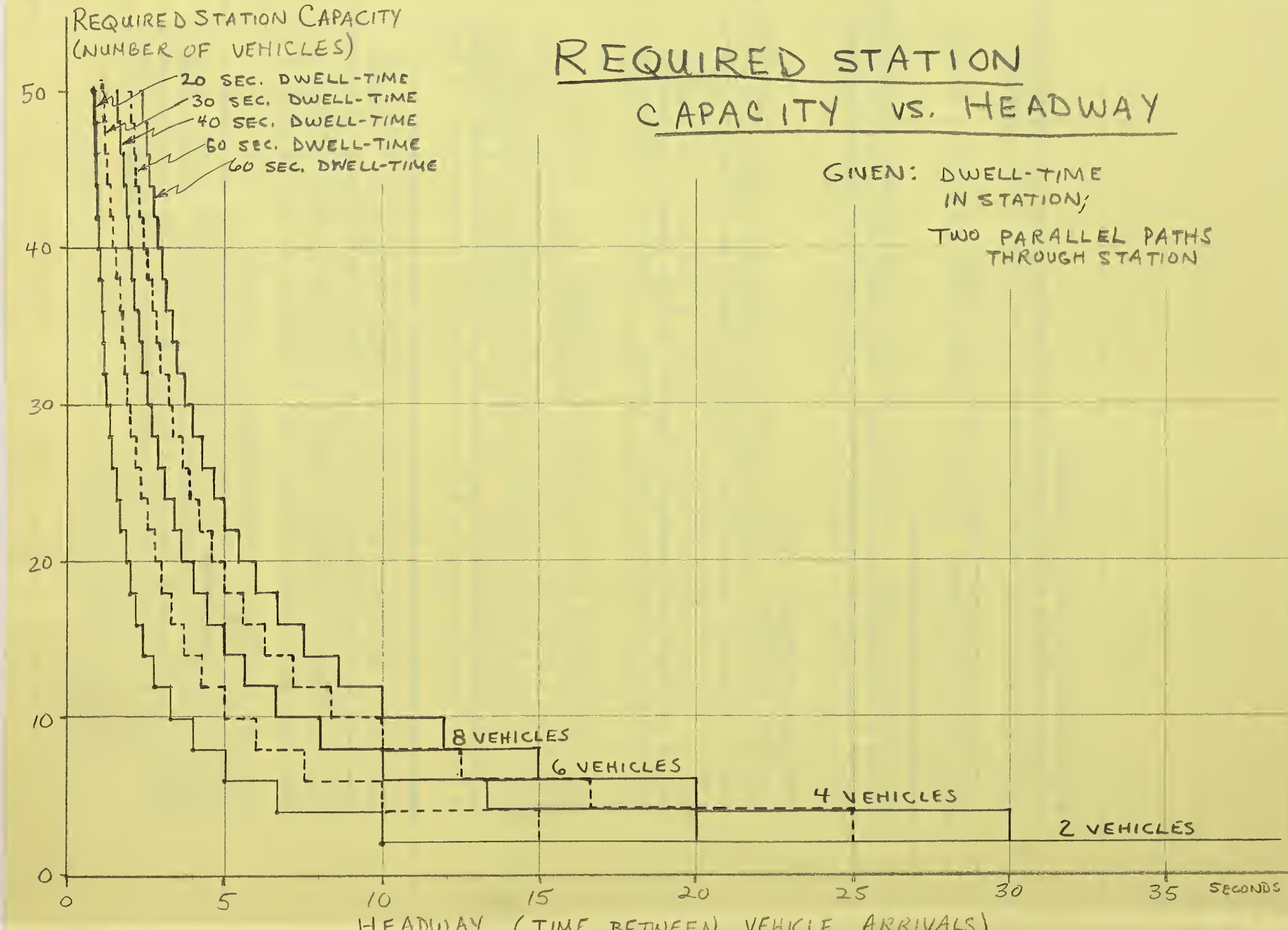
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

REQUIRED STATION CAPACITY VS. HEADWAY

GIVEN: DWELL-TIME IN STATION;
TWO PARALLEL PATHS THROUGH STATION



Station Processing Simulation

The following simulation is an illustrative example of the effect of adding parallel paths through a station on processing performance. It shows that with only one path, queuing develops outside the station. Adding a second path of sufficient length permits handling vehicles as fast as they arrive. Adding a third path does not affect processing performance, but it does reduce the total station capacity needed by 2 vehicles.

The station to be simulated must process at least fifty vehicles during a short peak period. The station serves a system that maintains headways of five seconds between vehicles arriving at the station. Vehicles must be dispatched from the station at least five seconds apart. Assume the station dwell-time is 36 seconds, made up of the following activities: 13 seconds unloading, 13 seconds loading, and 10 seconds moving into position on the ramp leading out of the station and accelerating onto the guideway.

We will examine the condition of the station at three points during the peak: 99 seconds after the first vehicle arrives (t=99), 60 seconds later (t=159), and 120 seconds later (t=219). Three station configurations are considered: a station with a single path and a boarding area designed to accommodate 8 vehicles; a station with two paths in parallel, each path holding 7 vehicles (total station capacity = 14 vehicles); and a station with three parallel paths each holding 4 vehicles (total station capacity = 12 vehicles).

With only one path through the station, a queue forms outside the station beginning with the arrival of the 9th vehicle. It must wait until the 8th vehicle is loaded and dispatched. Likewise, the 10th through 16th must wait for the 8th vehicle to clear the station. By the time the station is cleared (t=81), the 17th vehicle has arrived. Thus, the second group of 8 vehicles enters the station, but a vehicle remains queued outside. As time goes by, the queue of vehicles outside the station grows longer at the rate of 4 vehicles per minute. After 219 seconds, a total of 24 vehicles have been dispatched through the station.

With two parallel paths through the station, no queue develops. The only waiting occurs because one vehicle has finished loading before the preceding one has been dispatched from the guideway access ramp, but this is transitory, not cumulative, in effect. After 219 seconds, 37 vehicles have been processed through this type of station.

With three parallel paths, there is no queuing outside the station, and again 37 vehicles are processed during the first 219 seconds.

The following table summarizes performance of the three types of stations, and the accompanying figure illustrates the handling of the 44 vehicles which arrive during the first 219 seconds.

STATION PROCESSING SIMULATION:
STATION PERFORMANCE GIVEN VARIOUS NUMBERS OF PATHS THROUGH STATION

Number of independent paths through station and capacity of each path	Time (seconds) of observation (t=0 when first vehicle arrives)	Number of vehicles queued outside boarding area, waiting to unload and load	Number of Vehicles unloading	Number of vehicles loading	Number of vehicles loaded, awaiting access to guideway ramp	Number of vehicles in guideway ramp, awaiting access to guideway	Number of vehicles already departed
1 (8 veh.)	99	4	0	1	6	1	8
"	159	8	8	0	0	0	16
"	219	12	8	0	0	0	24
2 (7 veh. each)	99	0	2	3	1	1	13
"	159	0	2	3	1	1	25
"	219	0	2	3	1	1	37
3 (4 veh. each)	99	0	2	3	1	1	13
"	159	0	2	3	1	1	25
"	219	0	2	3	1	1	37

Given: 5 second headways between arriving vehicles (and between departing ones)
13 seconds to unload
13 seconds to load
10 seconds to move through ramp to guideway
(36 seconds station dwell-time)

STATION PROCESSING SIMULATION:

"Snapshots" are taken 99, 159, and 219 seconds after first vehicle (A) arrives. Vehicles arrive every 5 seconds in order ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefgh.... Vehicles spend 36 seconds inside station (dwell-time), including 13 seconds unloading, 13 seconds loading, 10 seconds on ramp awaiting access to guideway and departing.

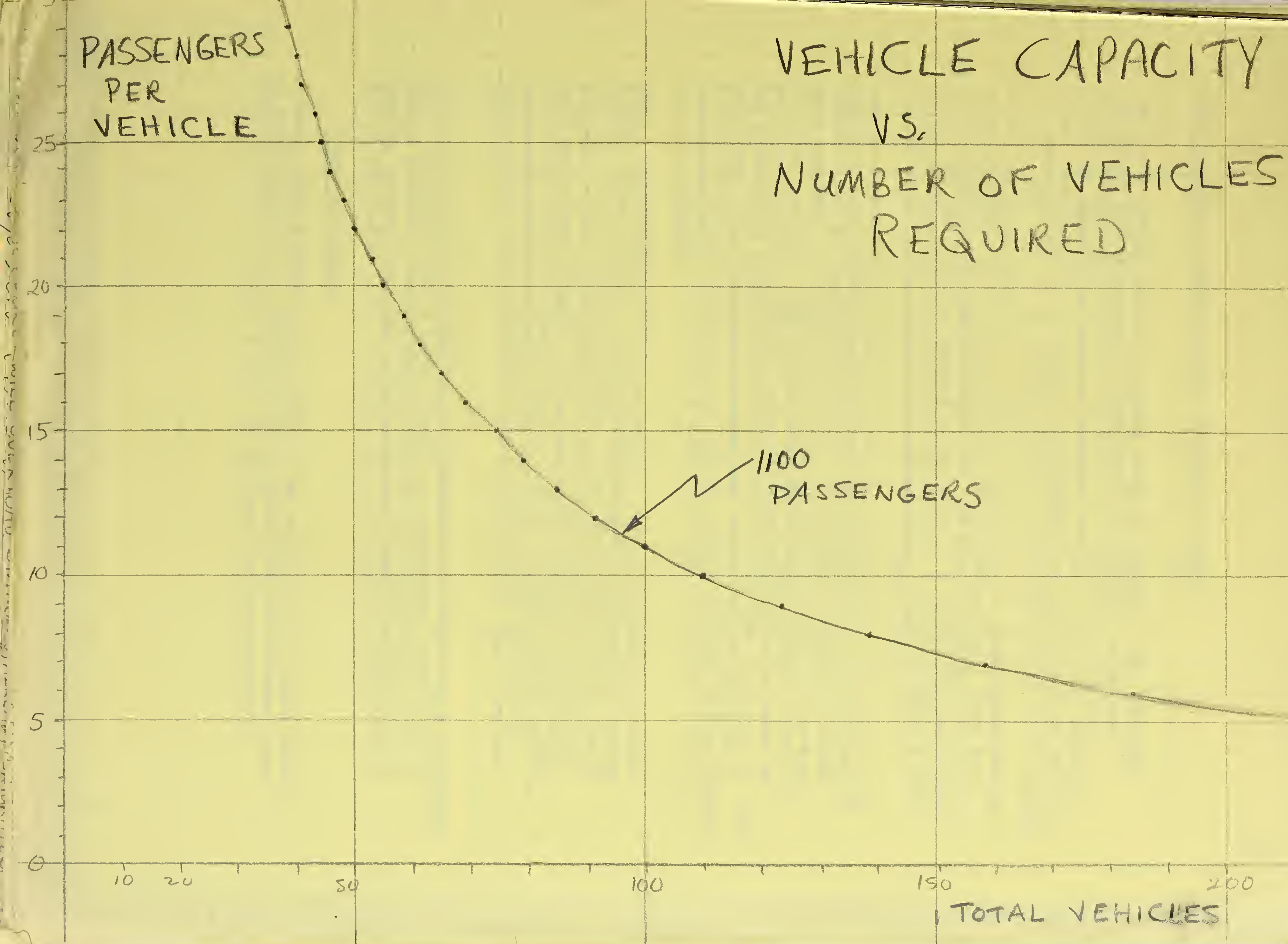
"SNAPSHOT"			STATUS OF EACH VEHICLE						
				Inside Station				Outside Station	
On Ramp	In Station	Waiting Outside Station	Departed Station (Total)	On Ramp	Waiting	Loading	Unloading	Waiting	Approaching on Guideway
One Path Through Station; 8 Positions:									
(t=99) I	JKLMNOP	QRST	ABCDEFGH (8)	I	JKLMNO	P		QRST (4)	U
(t=159)	QRSTUVWX	YZabc-def	ABCDEFGH IJKLMNOP (16)				QRSTUVWX	YZabcdef (8)	g
(t=219)	YZabcdef	ghijk-lmnopqr	ABCDEFGH IJKLMNOP QRSTUVWX (24)				YZabcdef	ghijklmnopqr (12)	s
Two Paths Through Station; 7 Positions on Each Path:									
(t=99) N	OPQRST		ABCDEFG (13) HIJKLM	N	O	PQR	ST		U
(t=159) Z	cdef / ab		ABCDEFG OPQRSTU (25) HIJKLMN VWXY	Z	a	cd b	ef		g
(t=219) l	qr / mnop		ABCDEFG OPQRSTU cdefghi (37) HIJKLMN VWXYZab jk	l	m	nop	qr		s
Three Paths Through Station; 4 positions on each path:									
(t=99) N	OPQ / RST		ABC KLM DEF (13) GHIJ	N	O	PQ R	ST		U
(t=159) Z	f / a / bcde		ABC KLM UVWX DEF NOPQ Y GHIJ RST (25)	Z	a	bcd	f e		g
(t=219) l	pqr / mno		ABCKLMUVWXfgh / DEFNOPQYZaijk/l GHIJRSTbcde (37)		m	p no	qr		s

Routing Through Stations

Proposed station configurations for stations not on the end of loops allow through traffic to bypass the stations (stations 2 and 3). This is essential if average speeds between stations 1 (or 2) and 5 are not to be degraded. For trips terminating at either station 2 or station 3, it is important that the arriving vehicles, whether or not refilled after discharging passengers, be permitted to continue either in the direction in which they originally were travelling or to make a loop turn and go back toward where they came from. (Each individual vehicle need not be offered such a choice; some continuing on and some looping back is the condition required.) Without such an option at these stations it will be difficult if not impossible to schedule more than one trip for each vehicle during the peaks. For example, suppose a vehicle travels from station 5 to station 2 and unloads; current estimates are that this will take 5.8 minutes. If that vehicle is not permitted to turn back toward station 3 (and 5), it must make a 4.6-minute round trip to station 1 before it will be ready to pick up part of the load going from station 2 to station 5. Similar problems arise if the vehicle must make a loop turn after discharging passengers (at station 3, for example).

Storage of Idle Vehicles during Off-Peak Periods

The geometry and feasible speeds of the system dictate that vehicle storage during the off-peak lull be placed somewhere near the center of gravity of anticipated peak-period trip origins. If the cars are stored near station 1 or station 4, for example, the empty vehicles will have to make long trips to preposition themselves prior to the peak. Given the high demand for vehicles at station 5 during the first morning peak, it probably will be wise to store vehicles in such a way that they feed into station 5 soon after leaving storage.


VEHICLE CAPACITY
VS.
NUMBER OF VEHICLES
REQUIRED
PASSENGERS
PER
VEHICLE
1100
PASSENGERS
TOTAL VEHICLES
25
20
15
10
5
0
10
20
50
100
150
200

III. HEADWAYS, VEHICLE CAPACITY AND SYSTEM CAPACITY

One system design objective has been cited as follows: load, transport and unload 1100 passengers in 10 minutes from station 5 to station 2 during the morning peak (7:45 to 8:00 a.m.). Referring to the graph of vehicle capacity vs. number of vehicles required to move 1100 passengers shows that 55 vehicles carrying 20 passengers each (or 62 vehicles carrying 18 passengers each or 92 vehicles carrying 12 passengers each) would be needed.

If station 2 and station 5 are 9200 feet apart and the vehicles maintain an average velocity of 17.9 miles per hour between them, it will take each vehicle 5.8 minutes to travel between them. To move 55 vehicles under such conditions would require headways on the order of 4 seconds between vehicles (allowing 20 seconds for loading and unloading). To move 92 vehicles under similar conditions would require 2.5-second headways between vehicles.

Suppose headways of less than 10 seconds were infeasible. Then the maximum number of vehicles which could make the trip under the above conditions and finish within ten minutes would be 23. If an average velocity of 24 mph were attainable, 33 vehicles could complete the trip within 10 minutes at 10-second headways. Other combinations of the feasible number of vehicles which could be moved 9200 feet, given 20-second dwell-time, are shown in the accompanying graph, which considers average velocities of 15 mph, 17.9 mph, and 24 mph. As a convenient reference, the vehicle capacity required to handle 1000 passengers is shown on the lower horizontal scale, and the headway limitations imposed by restricting station capacity to 2,4,6 or 8 vehicles are also indicated.

Again, supposing only 23 vehicles could be processed because a 10-second headway minimum existed. To move 1100 passengers in 23 vehicles requires that each vehicle carry 48 passengers. Such large vehicles would greatly increase the cost of the guideway by requiring increased width and turn radii and stronger supports. The effect would be similar to installing an elevated freeway for medium-sized city buses. During non-peak periods, the vehicles would be lightly loaded, and a far smaller proportion of large vehicles could be retired to the storage facility than of smaller vehicles.

Two possible ways of accomodating the requirement for large vehicle capacities can be considered: (1) using trains of small or medium-sized vehicles and (2) using a mixture of large vehicles, which would be retired during off-peak periods, and small vehicles, which would serve lightly used routes during peak periods and would be the primary carriers of off-peak traffic.

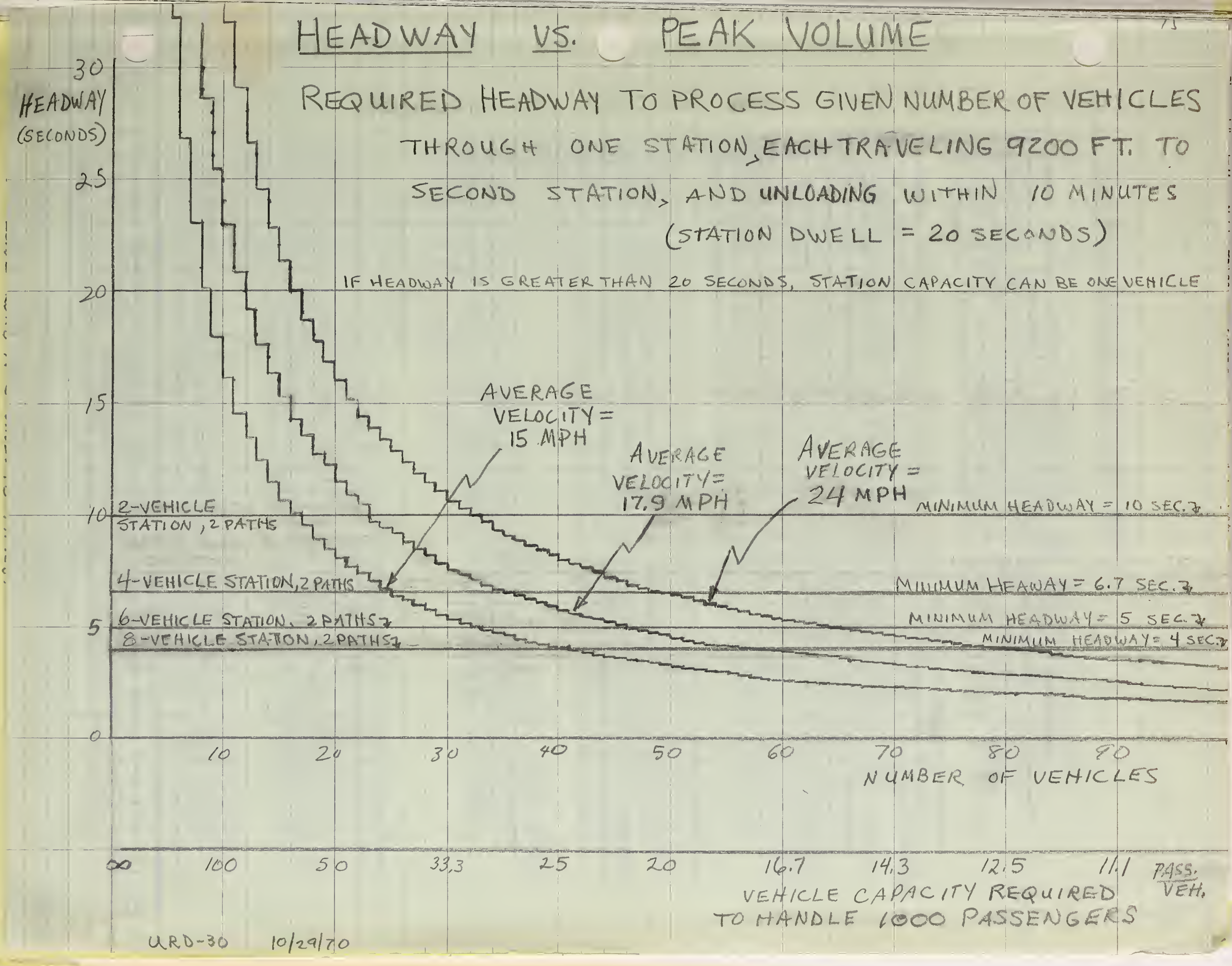
Trains of Vehicles

A train of two vehicles can be thought of as equivalent to a single vehicle of double capacity in considering how to satisfy peak period demand. One probably would not operate a train of vehicles at the same headway as

would be appropriate for the individual cars comprising it because of its increased length and the probable desire for a slightly increased safety factor for the double load being carried. But entraining two or three vehicles no doubt would permit headways significantly shorter than twice or three times the single-vehicle headways, providing an advantage that could be crucial during the morning peak.

The mechanics and dynamics of assembling trains, decoupling them, and the increased complexity this adds to the control system should be thoroughly investigated. The feasibility and desirability of entraining mixed sizes of vehicles is beyond the scope of this analysis but also deserving of study. If the propulsion systems of the entrained vehicles do not perform uniformly, one vehicle will act as a brake on the other. The implications of differences in power output in entrained vehicles should be clearly understood, as should the implications of differential braking performance (will the train decouple if the following car brakes more suddenly than the leading car?).

Questions of requiring shock-absorbent cushioning or bumpers between cars and the means for removing disabled vehicles from the guideway must also be addressed.


HEADWAY VS. PEAK VOLUME
REQUIRED HEADWAY TO PROCESS GIVEN NUMBER OF VEHICLES THROUGH ONE STATION, EACH TRAVELING 9200 FT. TO SECOND STATION, AND UNLOADING WITHIN 10 MINUTES
(STATION DWELL = 20 SECONDS)
IF HEADWAY IS GREATER THAN 20 SECONDS, STATION CAPACITY CAN BE ONE VEHICLE
HEADWAY (SECONDS)
30
25
20
15
10
5
0
AVERAGE VELOCITY = 15 MPH
AVERAGE VELOCITY = 17.9 MPH
AVERAGE VELOCITY = 24 MPH
2-VEHICLE STATION, 2 PATHS
MINIMUM HEADWAY = 10 SEC.
4-VEHICLE STATION, 2 PATHS
MINIMUM HEAWAY = 6.7 SEC.
6-VEHICLE STATION, 2 PATHS
MINIMUM HEADWAY = 5 SEC.
8-VEHICLE STATION, 2 PATHS
MINIMUM HEADWAY = 4 SEC.
10
20
30
40
50
60
70
80
90
NUMBER OF VEHICLES
∞
100
50
33.3
25
20
16.7
14.3
12.5
11.1
PASS./VEH.
VEHICLE CAPACITY REQUIRED TO HANDLE 1000 PASSENGERS
URD-30
10/29/70

IV. ROUTING AND SCHEDULING DURING PEAK PERIODS

To assure uniform, adequate service during peak periods, vehicles will be scheduled. Some means of communicating each vehicle's programmed destination to the passengers in the station will be devised, and vehicles will proceed directly to each destination, without intervening stops. After peak periods, it is planned that the bulk of the system's vehicles will proceed to storage while the remainder provide demand-actuated service.

The timing and dynamics of the change-over from scheduled to demand-actuated service, and vice-versa, warrant full elaboration. How long prior to the beginning of a peak period do empty cars leave the storage area for prepositioning at heavy-demand stations? How does the system adjust to variations in demand during the day, from day to day, and from season to season? What impact does preparation for scheduled service have on users who start trips destined for heavily used stations just before the scheduled peak period? Will they find themselves in a long queue of empty vehicles waiting to enter the station? Suppose there has been an unusually heavy demand on the system just prior to the period of scheduled service. Is the control system designed to take into account the resultant distribution of vehicles throughout the system and adjust the numbers of empties sent from storage to each station just prior to the peak?

The timing of scheduled service also deserves careful thought. There probably should be scheduled service on the fringes of the class-change peaks (e.g., beginning about 5 minutes before classes end and lasting until 5 minutes after classes begin) to accommodate those who have a class during just one of the two consecutive periods. That is, those not coming from a class would probably prefer to leave for their next class before the class-change crush, and those who do not have a second class might prefer to wait until the crush subsides before moving on.

Data provided by West Virginia University has been in two forms: hourly rates of flow between stations measured during class-change peaks and total demand during the peak period. What this ignores is the distribution of demand during the peak. Does taking into account its rise and decay times offer any insight into optimal scheduling?

Reuse of Vehicles

To conserve on the total number of vehicles which must be introduced into the system during the scheduled peak periods, the vehicles should be routed such that as many as possible make more than one trip during the peak period. Constraints on the ability to reuse vehicles during the peak periods are imposed by the distances and speeds to be traveled and by the minimum headways which must be observed both in dispatching vehicles and in admitting them to the stations.

When passenger volume between two stations is heavy, such as traffic between stations 5 and 2 during the first morning peak, vehicles from other stations bound for the heavily loaded station may be delayed because of the minimum headway requirements. This factor also affects scheduling of vehicles using the same stretch of guideway. For example, the guideway section between stations 3 and 2 must serve traffic between the following station pairs: 5-2, 5-1, 4-2, 4-1, 3-2, 3-1. The demand data provided by West Virginia University indicate that this amounts to about 985 passengers during the first morning peak.

Assuming 20-passenger vehicles, 90% full, to move that many passengers over the guideway between stations 3 and 2 would require a total of 57 vehicles. (Each vehicle loads at only one station.) Since it takes 5.0 minutes to travel from station 3 to station 2, these 57 vehicles have only ten minutes to pass or depart from station 3. During that ten-minute period, then, the minimum headway on that guideway section cannot be longer than 5.7 vehicles per minute (or 11.5 seconds between vehicles).

The interaction of travel time and traffic volume between stations may necessitate scheduling many passengers to depart during the early minutes of a peak period. In so doing, the opportunity to refill incoming vehicles may be foregone. For example, it will probably be necessary to dispatch vehicles from station 5 to stations 1 and 2 for the first few minutes of the peak. In so doing, vehicles that might have been sent from station 5 to station 4,where they could have been refilled and sent on to station 1, will arrive at station 4 too late to carry any traffic to station 1 before the end of the peak period. This means that vehicles from some other source (perhaps prepositioned) will have to be used to carry passengers from station 4 to station 1.

Using travel times and demand estimates, a table has been prepared showing the minimum frequency of dispatch of vehicles from each origin station to each destination. Travel times have been analyzed to indicate, on a second table, the earliest possible arrival of the first vehicle from any given station at its destination. A set of graphs was prepared for each station showing the overlap, if any, between the earliest possible arrival times of vehicles from other stations and the latest possible departure times that will assure passengers of arriving for class on time. Finally, an illustrative schedule was devised which handles the first morning peak demand (with some service beyond minimum demand, including service between stations for which little or no demand is anticipated during the first morning peak) with vehicles making more than one stop. The results of this schedule are that the 104 trips which must be served as a minimum are handled by 63 vehicles. Without exceeding the 15-minute time constraint of the first morning peak, these same vehicles can handle an additional 39 trips. (If it were desired to reduce power consumption and guideway use to a minimum, these extra trips could be omitted.)

A table was prepared showing the 163 trips that would be required during the first morning peak if the rule were adopted that there will be at least one departure from each station for every other station at least every 2 minutes during the first ten minutes of the peak period (i.e., at least five trips to each station).

Another table was prepared showing potential routes which reuse a vehicle during a 10-minute time constraint. For each route, the total passenger demand for all stations served is shown, both for the first morning peak and the second morning peak. Evidently there are opportunities to reuse vehicles even if peak traffic must be handled within a ten-minute constraint.

PLANNED TRAVEL TIMES AND TRAFFIC VOLUME, FIRST MORNING PEAK

(7:45 am – 8:00 am)

NUMBER OF VEHICLES, ASSUMING 20-PASSENGER VEHICLES, 90% FULL
(NUMBER OF PASSENGERS IN PARENTHESES)

FROM \ TO	1	2	3	4	5	6	TOTAL DEPARTURES
1	—	(NA) 0 2.3 min.	(40) 3 8.3 min.	(15) 1 9.5 min.	(50) 5** 9.0 min.	(35*) —(NC)	(140) 9
2	(NA) 0 2.3 min.	—	(175) 10 5.6 min.	(30) 2 6.8 min.	(200) 13** 6.3 min.	(10*) —(NC)	(415) 25
3	(NA) 0 8.3 min.	(50) 3 5.0 min.	—	(NA) 0 2.2 min.	(NA) 0 1.7 min.	(NA) 0 (NC)	(50) 3
4	(60) 4 9.5 min.	(25) 2 6.2 min.	(15) 1 2.2 min.	—	(NA) 0 2.6 min.	(NA) 0 (NC)	(100) 7
5	(50) 3 9.1 min.	(800) 45 5.8 min.	(70) 4 1.7 min	(30) 2 2.6 min.	—	(NA) 3 2.4 min.	(950) 57
6	(NC) 0	(NC) 0	(NC) 0	(NC) 0	(50) 3 2.4 min.	—	(50) 3
TOTAL ARRIVALS	(110) 7	(875) 50	(300) 18	(75) 5	(300) 21	(45) 3	(1705) 104 TOTAL TRIPS

(NA) – ASSUMED TO BE ZERO

(NC) – NOT DIRECTLY CONNECTED

* MUST GO TO STATION 5 AND TRANSFER TO STATION 6 LOOP.

** INCLUDES TRAFFIC BOUND FOR STATION 6.

NOTE: TRAVEL TIMES TAKEN FROM PAGE 52 OF WEST VA. U. PROPOSAL; INCLUDE LOAD AND UNLOAD TIMES.

PASSENGER DEMAND, SECOND PEAK, 8:55 A.M. TO 9:00 A.M. - NUMBER OF VEHICLES
(Number of Passengers in Parentheses)
(20-PASSENGER VEHICLES, 90% FULL)

FROM \ TO	1	2	3	4	5	6	Total
Station 1 (County Court House)	-- --	(6) 1	(15) 1	(7) 1	(11) 1	(5*) --	(44) 4
Station 2 (Quadrangle)	(?) 0	-- --	(150) 9	(70) 4	(196) 14	(40*) --	(456) 27
Station 3 (Engineering)	(6) 1	(130) 8	-- --	(15) 1	(10) 3	(25*) --	(186) 13
Station 4 (Field House)	(2) 1	(24) 2	(20) 2	-- --	(15) 2	(6*) --	(67) 7
Station 5 (Towers)	(10) 1	(255) 15	(20) 2	(35) 2	-- --	(30) 2	(350) 22
Station 6 (Medical Center)	(0) 0	(0) 0	(0) 0	(0) 0	(25) 2	-- --	(25) 2
Total	(18) 3	(415) 26	(205) 14	(127) 8	(257) 22	(106) 2	(1128) 75

*These passengers must travel first to station 5 and then transfer to station 6.

EARLIEST POSSIBLE ARRIVAL OF VEHICLES AT EACH STATION FOR POSSIBLE REUSE

Assumptions: 15 minutes to get last vehicle from any origin to its destination
t=0 at 7:45 a.m.
Demand table and travel times as provided by West Virginia University
20-passenger vehicles, 90% full
Minimum headway between arriving vehicles = 10 seconds = .167 min.

Station 1

From station 4, 4 vehicles, minimum travel time is 9.5 minutes; 40 sec. arriving.
From station 5, 3 vehicles, minimum travel time is 9.1 minutes; 30 sec. arriving.

Station 2

From station 3, 3 vehicles, minimum travel time is 5.0 minutes; 30 sec. arriving.
From station 5, 45 vehicles, minimum travel time is 5.8 minutes; 450 seconds = 7.5 minutes arriving.
From station 4, 2 vehicles, minimum travel time is 6.2 min.; 20 sec. arriving.

Station 3

From station 5, 4 vehicles, minimum travel time is 1.7 min.; 40 sec. arriving.
From station 4, 1 vehicle, minimum travel time is 2.2 min.; 10 sec. arriving.
From station 2, 10 vehicles, minimum travel time is 5.6 min.; 100 sec. arriving.
From station 1, 3 vehicles, minimum travel time is 8.3 min.; 30 sec. arriving.

Station 4

From station 5, 2 vehicles, minimum travel time is 2.6 min.; 20 sec. arriving.
From station 2, 2 vehicles, minimum travel time is 6.8 min.; 20 sec. arriving.
From station 1, 1 vehicle, minimum travel time is 9.5 min.; 10 sec. arriving.

Station 5

From station 6, 3 vehicles, minimum travel time is 2.4 min.; 30 sec. arriving. (These vehicles must return to station 6 because of loop.)
From station 2, 13 vehicles, minimum travel time is 6.3 min.; 130 sec. arriving.
From station 1, 5 vehicles, minimum travel time is 9.0 min.; 50 sec. arriving.

Station 6

From station 5, 3 vehicles, minimum travel time is 2.4 min.; 30 sec. arriving. (Note that 2 vehicles from station 2 and one vehicle from station 1 will be arriving at station 5 with transfers for station 6. The earliest these passengers can be at station 5 is 6.3 min. after t=0.)

Note: Earliest arrival times apply only to first vehicle sent from each station. If the first vehicle from station 5, for example, is sent to station 1, all other stations will receive their first arrival from station 5 at least ten seconds later than the times noted in this table. If the second vehicle from station 5 goes to station 2, then stations 3,4 and 6 will wait 20 seconds beyond the times listed, etc.

MINIMUM FREQUENCY OF DISPATCH OF VEHICLES TO VARIOUS DESTINATIONS

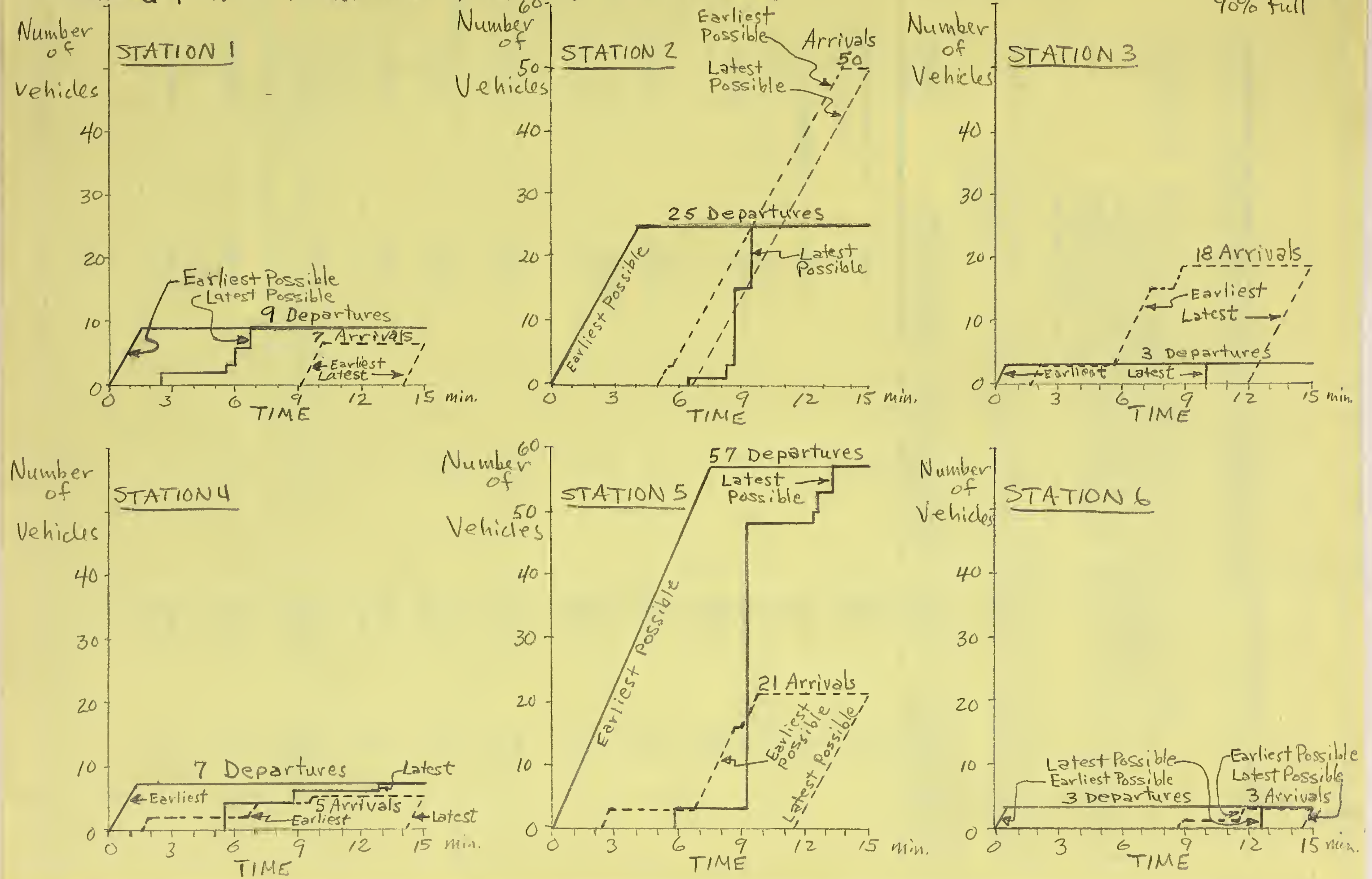
Assumptions: 15 minutes to get last vehicle from any origin to its destination
t=0 at 7:45 a.m.
Demand table as provided by West Virginia University
20-passenger vehicles, 90% full

Time Interval (min.)	Total Number of Vehicles Dispatched: Cum.	Total Number of Vehicles Dispatched: During Interval	Station of Origin	Number of vehicles dispatched for each destination station: 1	2	3	4	5	6 (via 5)	Minimum Frequency
0 - 2.6	3	3	1	-	-	-	1	-	2	Every 45 sec.
2.6-5.5	7	4		-	-	1	-	3	-	"
5.5-6.7	9	2		-	-	2	-	-	-	"
		9		-	-	3	1	3	2	
0.0-5.3	12	12	2	-	-	-	2	9	1	Every 22.6 seconds
5.3-8.7	19	7		-	-	4	-	3	-	"
8.7-9.4	25	6		-	-	6	-	-	-	"
		25		-	-	10	2	12	1	
0.0-5.0	3	3	3	-	3	-	-	-	-	Every 100 sec.
0.0-5.5	4	4	4	4	-	-	-	-	-	Every 82.5 seconds
5.5-8.8	6	2		-	2	-	-	-	-	Every 99 sec.
8.8-12.8	7	1		-	-	1	-	-	-	Every 240 seconds
		7		4	2	1	-	-	-	
0.0-5.9	30	30	5	3	27	-	-	-	-	Every 11.5 seconds
5.9-9.2	48	18		-	18	-	-	-	-	"
9.2-12.6	55	7		-	-	2	2	-	3	Every 27.3 seconds
12.6-13.3	57	2		-	-	2	-	-	-	"
		57		3	45	4	2	-	3	
0-12.6	3	3	6	-	-	-	-	3	-	Every 252 seconds

CONSTRAINTS ON NUMBERS OF VEHICLES WHICH CAN DEPART FROM OR ARRIVE AT EACH STATION DURING FIRST MORNING PEAK (t=0 at 7:45 a.m.)

KEY: - - - ARRIVALS; —— DEPARTURES

ASSUMPTIONS: 10-Sec. headways, 20-pass. Vehicles, 90% full



SCHEDULING ARRIVALS SO AS TO ENABLE VEHICLES TO MAKE MORE THAN ONE TRIP DURING FIFTEEN-MINUTE MORNING PEAK PERIOD

Assumptions: Maximum frequency of dispatch (headway) = 10 seconds
15 minutes maximum allowable time to get any vehicle from any originating station to its destination
Demand table and travel times as provided by West Virginia Univ.
20-passenger vehicles, 90 % full
t=0 at 7:45 a.m.

Notation: 3-4-5-1 means a trip beginning at station 3, unloading and refilling at station 4, unloading and refilling at station 5 and unloading at station 1

Route Layout	Time (minutes) start-to-finish	Number of vehicles following route	Station Pair	No. Trips Serving Station Pair
6-5-6-5-6-5-6	14.4	1	6-5	3
			5-6	3
......5-6-5-6	7.2*	1	5-6	2
			6-5	1
1-5-4-3	13.8	3	1-5	3
			5-4	3
			4-3	3
1-3-2	13.3	3	1-3	3
			3-2	3
1-4-5-3	13.8	1	1-4	1
			4-5	1
			5-3	1
1-5-2	14.8	2	1-5	2
			5-2	2
5-4-1	12.1	1	5-4	1
			4-1	1
2-4-2	13.0	2	2-4	2
			4-2	2
5-2-5-3	13.8	5	5-2	5
			2-5	5
			5-3	5
5-2-5-	12.1	3	5-2	3
			2-5	3
2-5-2	12.1	7	5-2	7
			2-5	7

Route Layout	Time (minutes) start-to-finish	Number of vehicles following route	Station Pair	No. of Trips Serving Station Pair
5-2-3	11.4	10	5-2	10
			2-3	10
4-1-2	11.8	3	4-1	3
			1-2	3
5-2-1	9.1	6	5-2	6
			2-1	6
3-5-2	7.5	6	3-5	6
			5-2	6
3-4-5-2	10.6	6	3-4	6
			4-5	6
			5-2	6
5-1	9.1	3	5-1	3
Total, all routes		63		143

*In order to serve demand from stations 1 and 2, this route must be scheduled such that it leaves station 5 after the first vehicles arrive at station 5 from stations 1 and 2; e.g., hold until about 7:52 a.m.

NUMBER OF TRIPS SERVING EACH STATION PAIR IF SAMPLE ROUTING IS FOLLOWED (AS COMPARED TO MINIMUM NUMBER OF TRIPS REQUIRED BY DEMAND TABLE)

KEY: A = trips provided
(B)= trips required

FROM: \ TO:	1	2	3	4	5	6	Total
1	- (-)	3 (0)	3 (3)	1 (1)	5 (5)*	0 (0)	12 (9)
2	6 (0)	- (-)	10 (10)	2 (2)	15 (13)**	0 (0)	33 (25)
3	0 (0)	3 (3)	- (-)	6 (0)	6 (0)	0 (0)	15 (3)
4	4 (4)	2 (2)	3 (1)	- (-)	7 (0)	0 (0)	16 (7)
5	3 (3)	45 (45)	6 (4)	4 (2)	- (-)	5 (3)	63 (57)
6	0 (0)	0 (0)	0 (0)	0 (0)	4 (3)	- (-)	4 (3)
Total	13 (7)	53 (50)	22 (18)	13 (5)	37 (21)	5 (3)	143 (104)

*2 transfer at 5 for 6.
**1 transfers at 5 for 6.

TOTAL SYSTEM LOAD IF RULE IS ADOPTED THAT THERE WILL BE ONE TRIP BETWEEN EACH STATION PAIR AT LEAST EVERY 2 MINUTES FOR AT LEAST FIRST 10 MINUTES OF PEAK PERIOD (5 DEPARTURES FOR EACH DESTINATION)

FROM \ TO	1	2	3	4	5	6	TOTAL DEPARTURES
1	—	0+5= 5	3+2= 5	1+4= 5	5+0 = 5	N.C.	9+11= 20
2	0+5= 5	—	10+0= 10	2+3= 5	13+0= 13	N.C.	25+8= 33
3	0+5= 5	3+2= 5	—	0+5= 5	0+5= 5	N.C.	3+17= 20
4	4+1 = 5	2+3 = 5	1+4 = 5	—	0+5 = 5	N.C.	7+13= 20
5	3+2= 5	45+0= 45	4+1= 5	2+3= 5	—	3+2= 5	57+8= 65
6	N.C.	N.C.	N.C.	N.C.	3+2= 5	—	3+2= 5
TOTAL ARRIVALS	7+13= 20	50+10= 60	18+7= 25	5+15= 20	21+12= 33	3+2= 5	104+59= 163 TRIPS

NOTES: 1. THE EXTRA 59 TRIPS SHOULD BE SCHEDULED FOR MAXIMUM VEHICLE REUSE.
2. THIS PROCEDURE WILL OVERLOAD STATION 5, ALREADY SATURATED.

SAMPLE ROUTING FOR NON-PEAK PERIODS USING SCHEDULED SERVICE BETWEEN ALL STATIONS

Route	Round Trips	Elapsed Time (min.)	Number of vehicles needed for 2-min service	Number of vehicles needed for 2.5 min service
1-2-3-4-5-4-3-2-1-2-3-4-5	1.5	37.5	7	6
5-4-3-2-1-2-3-4-5-4-3-2-1	1.5	36.9	7	5
1-3-1-3-1-3-1	3	32.6	7	6
1-4-1-4-1	2	38.0	10	8
1-5-1-5-1	2	36.4	10	8
2-4-2-4-2-4-2	3	39.0	7	6
2-5-2-5-2-5-2	3	36.3	7	6
3-5-3-5-3-5-3-5-3-5-3-5-3-5-3-5-3-5-3-5-3-5-3	11	37.4	2	2
Total Number of vehicles needed			57	47

Using Scheduled Service Instead of Demand-Actuated Service at All Times

One method of using the system which might be tested during the demonstration is that of providing only scheduled service (i.e., no demand-actuated service) at all times. This would simplify the problems of controlling merging vehicles, since their location would be (more-or-less) determinate at all times, rather than randomly distributed based on actual calls for vehicles.

A sample schedule has been worked out which serves each origin-destination pair every 2 minutes; it requires a total of 57 vehicles. If frequency of service is reduced to every 2.5 minutes, only 47 vehicles are required.

There is some possibility that this might be a more efficient way to use the vehicles. While it eliminates the "personal service" aspect of system operation (the off-peak user must wait up to 2 minutes for his vehicle and may have to share it with others wishing to travel to the same destination), it probably will result in larger loads for stations having significant off-peak demand. Based on loads actually encountered, one might later reduce the service for lightly used routes to once every 3 or 4 minutes.

Having worked out a satisfactory scheduled service for off-peak periods, one might compare the total number of passengers carried and the number of vehicles used with comparable data taken from observation of demand-actuated use of the system.

V. QUEUING

Investigation of potential queuing during demand-actuated operation is beyond the scope of this analysis. Simulation of system operation should indicate whether this is likely to be a problem. Another potential cause of queuing is random perturbations during scheduled operations. For example, if a vehicle is disabled on the guideway or delayed in departing a station, what effect might that have on total system operation, given various assumptions about the time of occurrence and length of delay?

Careful attention should probably be given to the layout of the ramps leading into the station and out of the station to build into them a bit of slack, such that delays in admitting vehicles to the station loading area will not automatically result in queues on the guideway outside the station. Similarly, if the guideway is fully loaded for several seconds, this should probably result in building up a small queue on the ramp leading to the guideway rather than hold up the loading and unloading operations.

Avoiding queuing during scheduled operation (peak periods) has been discussed above under Section II, Guideway and Stations.

VI. CONTROLS

Analysis of the control system is beyond the scope of this study, but certain aspects of the problem of controlling the system can be mentioned.

One of these is the complexity of the vehicle "signature" to be communicated to the central computer. Will this include the car's unique identity, its origin for the particular trip, its destination, the number of passengers it is carrying and its position? While the origin is probably not needed for guiding the vehicle as long as its position is known, it is important if the computer is going to tally demand for service between station pairs. (Position sensing can obviously be built into the guideway rather than the vehicle.)

If trains of vehicles of the same or different sizes are used, what effect does this have on the required performance of the control system? Suppose a mixture of trains, some made up of identical vehicles and others of vehicles of differing sizes, large vehicles and small vehicles are permitted to operate simultaneously. How greatly does this tax the control system?

VII. SAFETY, RELIABILITY AND DEPENDABILITY

Examination of all potential safety problems cannot be undertaken in this analysis, but should be a prime concern of the system engineering contractor. It appears, however, that rear-end collisions between moving vehicles and stalled ones and sideswipe collisions at the many merge junctions in the system are the most likely safety hazards. The precautions to be taken to avoid these and the procedures to be followed if they do occur should be explicitly treated in the system design documentation.

Because of the multitude of independently powered vehicles in the system, the chances of a moving vehicle's encountering a stalled one in its path seem large enough to warrant installing a special emergency brake on each vehicle. Even if the brake is seldom if ever used, its psychological value (it avoids the case where the passengers can all see a stalled vehicle in their path but are unable to avoid or soften the collision) would probably warrant the expense of incorporating it in the vehicle design.

Whether communication between the individual vehicles and the control center is to be provided requires further analysis. If communication is provided, should it be one-way or two-way? Should there be just signal devices and lighted panels or should there be voice communication? Is it best to use the guideway to transmit the signals or should there be radio communication?

VIII. ECONOMICS OF PASSENGER DEMAND FOR THE SYSTEM

One concept for collecting fares from students, who are expected to be the major users of the system, is that they will obtain passes upon payment of university fees. These passes would presumably entitle them to use the system as often as they desire. If the fee is seen as unavoidable, little information can be gained about the economic value the students place on the service provided by the system. There will be no way to vary the fare to determine whether this affects demand (i.e., whether revenue is elastic or inelastic with respect to price). Some data on this question might be collected from tallying use by those without student passes, but its adequacy as a basis for generalizing to probable behavior of passengers on a similar system installed elsewhere in revenue service may be questionable.

DEPARTMENT OF TRANSPORTATION

NEWS

URBAN MASS TRANSPORTATION ADMINISTRATION
WASHINGTON, D.C. 20590

FOR IMMEDIATE RELEASE
October 2, 1971

DOT-R-49
Phone: (202) 426-4043

Secretary of Transportation John A. Volpe today announced a grant of $616,411 to Lansing, Michigan, for the improvement of public bus transportation in that city.

"This is not a run-of-the mill assistance grant," Secretary Volpe said. "A major portion of this grant will be used to purchase six electric battery-powered, pollution-free mass transit vehicles.

"The reduction of pollutants in all transportation systems is a continuous and major activity of the Department of Transportation and we welcome Lansing's effort in helping us to meet that goal. The city's pioneering effort will be widely observed and can be expected to have an impact upon the improvement of mass transit technology," the Secretary said.

In addition to the six electric buses, the grant made today from Urban Mass Transportation Administration's funds will pay two-thirds of the cost of acquiring 15 conventional buses and land and buildings for garage and maintenance facilities.

The six electric buses will be used by Lansing to begin an innovative downtown bus distribution system. The new conventional buses will augment existing service and allow its extension into Lansing's Model Cities neighborhood.

One-third of the funding of the $924,617 project will be jointly provided by the City of Lansing, the Lansing Model Cities Agency and the State of Michigan Bureau of Transportation.

For further information contact the UMTA Office of Public Affairs (202) 426-4043 or :

Mayor Gerald W. Graves
City Hall
Lansing, Michigan 48933

####

DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
Washington, D.C. 20591

Official Business

POSTAGE AND FEES PAID
URBAN MASS TRANSPORTATION ADMINISTRATION

FIRST CLASS MAIL

U.S.MAIL

Please deliver to Henry Nejako, TRI-20, room 9407F. Thanks!

Nejako, Henry <FTA>

From: Luden, Hymie <FTA>
Sent: Wednesday, March 29, 2006 4:57 PM
Subject: Robert Hemmes -- transportation visionary

Robert Hemmes -- transportation visionary

Michael Cabanatuan

SF Chronicle

March 29, 2006

When BART rolled to a start in 1972, becoming the first computer-controlled rail transit system in the nation, it ran headlong into troubles with its computer system, train controls and braking systems.

Robert Hemmes, an engineer, academic and federal government official, helped BART work out the problems. It was among his many accomplishments during a long tenure at the Department of Transportation, where he eventually served as the assistant administrator for research, demonstration and development.

Mr. Hemmes, who was born in Los Angeles and lived in Menlo Park, died March 21 at the age of 81.

During his years at the Department of Transportation, he helped develop dial-a-ride transportation systems for the elderly and handicapped, automated "people movers" and researched air-cushioned vehicles that run on rails and high-speed rail.

He also helped promote the idea of running vehicles on natural gas, once sending a taxicab outfitted to run on natural gas to a gas station and having the attendant fill the tank with water to help give the vehicle more weight and balance -- and to see the look on the attendant's face. The stunned attendant, not aware of the natural gas tank in the trunk, obliged, then called the police.

"Bob accomplished more in four years for transportation than any previous R&D administrator, using advanced technology,'' said Carlos Villareal, a friend who worked with Mr. Hemmes at the federal transportation agency.

Mr. Hemmes' work in transportation was part of a 20-year career in federal government that also included a stint at the Bureau of Indian Affairs. It followed a career in academia, which followed studies at the California Institute of Technology and graduation from the U.S. Naval Academy. Mr. Hemmes also earned a master's degree from the Massachusetts Institute of Technology and a doctorate from Stanford University.

"He loved going to school,'' said his wife, Adelaide Gore.

His fields of interest included industrial engineering, fluid dynamics, programming, budgeting and decision-making. After graduating and before going to work for the government, Mr. Hemmes taught those subjects at a variety of universities, including George Washington and Stanford.

After leaving Washington, Mr. Hemmes settled in Menlo Park, where he was active in saving San Francisquito Creek, helping form a joint powers authority to save the urban creek. The restoration is regarded as a model for urban creek preservation. He was also active with local government and civic agencies in the Menlo Park area.

"Someone who's really, really smart and really, really funny attracts a lot of people," Adelaide Gore said. "I'm lucky I came along at the right time."

He is survived by his wife; daughters, Linda Griffith of Los Angeles and Keira Alexandra of Brooklyn, N.Y.; son, Robert Hemmes Jr. of Baltimore; and two grandchildren.

Please deliver to Henry Nejako, TRI-20, room 9407F. Thanks!

A private celebration of his life is planned. Memorial donations may be made to the San Francisquito Watershed Council, 3921 East Bayshore Road, Palo Alto, CA 94303.

ROUGH DRAFT MEMO--8/21/70

SUBJECT: Comparative Costs of Golf-Carts for People-Mover System

TO: Robert A. Hemmes (thru Stan Price)

FROM: Henry Nejako

Based on readily available information, one cannot accurately answer the question of what level of service one could buy with $13 million (or $25 million) for Morgantown and West Virginia University assuming a system of golf-carts operating on macadam paving. The answer to the counterpart question, what it would cost to provide service equivalent to the Alden system using golf-carts, cannot be determined at this point either. That golf-cart system has certain inherent limitations which preclude its ever being equivalent in some aspects of the Alden system's performance. The use of carts on an elevated guideway is discussed below.

One can make rough estimates of the costs of acquiring golf-carts, garages, spare parts, paths (or guideways), but each cost component has to be heavily qualified. I have not yet contacted any major country club in an attempt to obtain experience data on operating and maintaining large fleets of golf-carts, but this could be done if desired. Nor have I thus far ascertained whether golf-carts can really negotiate extended steep grades such as are found in Morgantown, either uphill or downhill.

SYSTEM A: ELEVATED GUIDEWAY + GOLF-CARTS

Cost Components

One could not establish a system merely by spending $13 million on acquisition of a guideway (at about $5 or $6 million) and 5,000 golf-carts (about another $5 - $8 million). One would have to provide for maintenance facili-

ties and parking space for the carts as well as the means for recharging batteries while the carts were idle. In the Morgantown proposal, the university is proposing to pick up the costs of operating the system as part of its contribution. ~~if I understand the proposal correctly.~~ With a golf-cart system, there would probably be a far higher component of ~~o&m~~ operating and maintenance costs to keep the fleet functioning. ~~Because of this, both acquisition costs and o&m costs are described below.~~ ~~The~~ Because of their ~~increased~~ significance, operating costs are included in the following tabulation of cost components.

Acquisition Costs

-- Golf-carts, including batteries

-- Initial spare parts

-- Parking garages with electrical outlets to permit recharging batteries

-- Maintenance facilities

-- Guideway ~~or paved paths~~

-- Access control system, such as credit cards that unlock the motor switches (or permit the vehicles to be recharged) or gateways to the guideway which can be opened by coins, tokens or other means

-- Maintenance vehicles for retrieving disabled carts

-- Communications and control system (urgently needed in a system confined to a guideway; can be very simple if each user is assigned a cart for extended personal use)

Operating Costs

-- Electricity to recharge batteries

-- Personnel costs for operating and maintaining fleet and guideway (system would need mechanics, cash collectors to service fare-

Operation Costs (cont.)

collecting gateways unless a credit card system is used, communications crew, snow and ice removal crews, painters, welders, electricians, "cowboys" to round up stray carts, laborers and office help. ~~maintenance charges for~~ vehicles operated by college students are likely to ~~be significant)~~

-- Replacements for lost or stolen carts

-- Insurance and safety expenses (the combination of an elevated guideway and student operators would probably make this a significant item ~~also)~~

-- Supplies and replacement spare parts

Cost Estimates

Carts I contacted two local suppliers of golf-carts (Cushman and E-Z Go ~~dealers)~~. E-Z Go does not sell an enclosed cart, so protection from extreme weather would not be provided. ~~Volume data~~ were not available in either case, but quantity discounts on the order of 20 percent are probably obtainable by negotiating directly with the manufacturer. The basic ~~Cushman~~ 4-wheel, 2-passenger electric model with canopy lists for $1,280 (Cushman) or $1,310 (E-Z Go). (For an enclosed cab and two doors, add $824 to the Cushman price.) A rough estimate of the price of 5,000 carts would be about $1,000 each (with canopy--$1,100 with cab), or $5 million total.

Garages The university is currently estimating $600 per space as the cost of providing parking for autos. Since golf carts are smaller and lighter, the cost should be proportionately lower ($300 - $400 per space?). But the usage characteristic envisioned means

Guideways (cont.)

ing a love to exclusive use of carts would require, then, a construction investment of at least $1 million. (This assumes the city would be amenable to granting the right-of-way for such use.) If an elevated golf-cart skyway were constructed, one could use the cost-estimate for the Alden guideway as a starting point. Exit from the guideway could be either by foot (if the carts are to be garaged at stations on the guideway) or by ramps leading to the major activity centers. The guideway cost, exclusive of stations, proposed for the Alden System is $6.2 million. One might wish to retain the electrical snow-removal feautre and to keep outlets near stations for recharging stalled vehicles. But without the need for the power supply (third rail) and associated switching and safety features, the cost of an elevated guideway suitable for carts would probably be on the order of $4--$5 million.

Access Control System

Without some system of fare-collection, the system will not demonstrate anything about the economics of user demand. (One might prefer a variable pricing mechanism to obtain demand elasticity measures.) An uninformed guess at the cost of such a system is $100,000 ($200,000 for a sophisticated credit card system using existing computer facilities).

Maintenance Vehicles

There are no handy ways of estimating how many tow-trucks would be needed to service a fleet of 5,000 golf-carts. Assuming driver availability to limit response to calls to pick up disabled carts, 5 to

<u>Guideways</u> (cont.)

ing a lane to exclusive use of carts would require, then, a construction investment of at least $1 million. (This assumes the city would be amenable to granting the right-of-way for such use.) If an elevated golf-cart skyway were constructed, one could use the cost-estimate for the Alden guideway as a starting point. Exit from the guideway could be either by foot (if the carts are to be garaged at stations on the guideway) or by ramps leading to the major activity centers. The guideway cost, exclusive of stations, proposed for the Alden System is $6.2 million. One might wish to retain the electrical snow-removal feature and to keep outlets at the stations for recharging stalled vehicles. But without the need for the power supply (third rail) and associated switching and safety features, the cost of an elevated guideway suitable for carts would probably be on the order of $4—$5 million.

<u>Access Control System</u>

Without some system of fare-collection, the system will not demonstrate anything about the economics of user demand. (One might prefer a variable pricing mechanism to obtain demand elasticity measures.) An uninformed guess at the cost of such a system is $150,000-$200,000 for a sophisticated credit card system using computer facilities).

<u>Maintenance Vehicles</u>

There are no handy ways of estimating how many tow-trucks would be needed to service a fleet of 5,000 golf-carts. Assuming driver availability will limit ability to pick up disabled carts, 5 to

Maintenance Vehicles (cont.) 10 tow vehicles should suffice. Tractors similar to those used at airports would probably suffice. A guess at their cost is $1,000 each, for a total of $5,000 to $10,000. (*)

Communications System A simple system, not involving sensing devices or closed circuit TV, could probably be installed for $5,000.

Operating Costs No basis exists for estimating these. It is suggested that URD begin to develop useful such cost factors for evaluating proposed new system alternatives. (A project with this purpose is included in the MITRE presentation on FY 71-72 UMTA Budget) prepared for URD.

Equivalence of Golf-Cart System and Alden System

For several reasons, most related to the lack of automation in a golf-cart system, it could never really be equivalent in service to an Alden system. Briefly, a golf-cart system would compare adversely be less effective in the following respects:

1. Individually piloted vehicles exclude those without driving skills. Persons who cannot drive would be excluded. (Cart-pooling and hitchhiking would relieve this somewhat.)

2. Empty golf-carts must remain where parked. To redeploy them would require tow vehicles, operators, and train-hitches on each golf-cart. (Assigning one cart per user is inherently inefficient.)

3. Risk of theft is greater since carts can be operated anywhere, unlike guideway-bound Alden vehicles. (This would be similar to the grocery-cart loss problem faced by supermarkets.)

(*) (insert) These tow vehicles might also be used to move trains of carts from one location to another to redistribute carts when the demand and supply become unbalanced.

Maintenance Vehicles (cont.) 10 tow vehicles should suffice. Tractors similar to those used at airports ~~would probably suffice~~ might be used. A guess at their cost is $1,000 each, for a total of $5,000 to $10,000. (*)

Communications System A simple system, not involving sensing devices or closed circuit TV, could probably be installed for $5,000.

Operating Costs No basis exists for estimating these. It is suggested that URD begin to develop ~~sound~~ such cost factors for evaluating proposed new system alternatives. ~~(A project with this purpose is included in the URTA presentation on FY 1975 UMTA Budget Request for FY 1975.)~~

Equivalence of Golf-Cart System and Alden System

For several reasons, most related to the lack of automation in a golf-cart system, it could never really be equivalent in service to an Alden system. Briefly, a golf-cart system would ~~compare unfavorably~~ be less effective in the following respects:

1. ~~Individually piloted vehicles exclude those without driving skills.~~ Persons who cannot drive would be excluded. (Cart-pooling and hitchhiking would relieve this somewhat.)

2. Empty golf-carts must remain where parked. To redeploy them would require tow vehicles, operators, and train-hitches on each golf-cart. (Assigning one cart per user is inherently inefficient.)

3. Risk of theft is greater since carts can be operated anywhere, unlike guideway-bound Alden vehicles. (This would be similar to the grocery-cart loss problem faced by supermarkets.)

(*) (insert) These tow vehicles might also be used to move trains of carts from one location to another to redistribute the carts when supply becomes depleted near a lab.

4. Risk of accidents and golf-cart jams is far greater because student drivers (vs. unpiloted Alden cabs). (Casual stops to greet friends can tie up the guideway or path.

5. Performance capability of golf-carts is not available, but it is doubtful that they could negotiate Morgantown's hills in anything like the ten minutes allowed between classes (walking would probably be faster). They may be more suitable at dispersed sites on level ground.

6. Performance of golf-carts in severe winter weather is also not known. In addition, the environmental controls proposed for the Alden cab offer far more comfort to the passenger than would be available from a golf-cart.

7. Campus land-use policies would probably prohibit further garage construction. Service to the Morgantown CBD would require a garage there also. (If no guideway is used, it is likely that local residents would drive the carts home at night, whether or not this were legal.)

<u>Summary</u> One could perhaps establish a system of golf-carts, garages and guideways serving Morgantown and the university at an outlay of about $2,500 per cart as an initial investment. This would buy about 5,000 carts. For twice the outlay, one could probably get 15,000 carts, since guideway costs would not increase proportionately. But reliable, all-weather, demand-actuated, swift, automatic operation, would be sacrificed, along with convenience and comfort.

STEPS REMAINING IN ANSWERING GOLF-CART QUESTION	TARGET COMPLETION DATE
1. Summarize analysis and information available to date.	Wednesday,30Sep(draft
2. Attempt to obtain maintenance and operation costs from local jobber who supplies carts to Congressional Country Club (and others)	Tuesday, 6Oct70
3. Refer to Electric Vehicle News, vol.2, number 4 of which (September 1970) has just been circulating in URD. Indicates a wide variety of operational vehicles. Published by The Electric Vehicle Council, 750 Third Avenue, New York, N.Y. 10017. (Individual membership: $50 per year; group sponsorship:$1,000/yr)	N/A
4. Refer to University of Michigan 2-day state-of-the-art course, October 29-30, entitled "Electric Propulsion for Automobiles."	N/A
5. Draft report and recommendations (presently, it appears this should be a New Systems concern when innovation is proposed, and a capital grants concern if existing vehicles are to be used. Tying in some sort of central dispatching or leasing system (a la Minicar) could be demonstration)	15 Oct 70

AD SELLS ELECTRIC FORK LIFTS

Attached is an unusual ad published in September in the San Francisco Daily Commercial News, Electrical West, and U. S. News & World Report. Sponsored by Pacific Gas and Electric Co, the ad will be run again in November and December. It dramatizes in an effective way the advantages of electric vehicles.

OFF-THE-SHELF ELECTRIC VEHICLES

-American Mobile Products Corp, Lansing, Michigan, has available a battery operated personnel carrier that is capable of speeds up to 15 mph. The company suggests this capability would enable security guards to patrol three to four times the area normally covered by walking. The quiet vehicles can run up to two full shifts or 50 miles between charges. Removable battery trays are available for continuous operation.

-Cushman Motors has a "Four-Wheel Executive" that can also range up to 50 miles per charge. It has a 36-volt d c traction motor, a steel body riding on a steel frame and a speed range to 8 mph or 11 mph with factory modification. Standard equipment includes an integral battery charger, sealed-beam lights, and front and rear shock absorbers. Four persons may ride when the car is fitted with an optional rear-facing seat rather than cargo compartment.

-Westinghouse Electric Corp manufactures an instant starting mini fire truck that comes with chemical and water extinguishers, hoses, fog and pressure nozzles, wire cutters, lights, and safety equipment. It holds one fireman and measures $77\frac{1}{2}$ in long, 33 in wide and 58 in high.

-Westinghouse Electric Corp has also gone into production of an all-electric pickup truck powered by six six-volt lead acid batteries. The three wheel vehicle carries two passengers and a cargo weighing up to 500 pounds. It can travel up to 12 miles per hour around factories and warehouses.

NEWS BRIEFS

-Business Week, October 24, 1970, reports that Minicars, Inc of Goleta, California, a pioneer in electric hybrids, is now working on a hybrid power plant that would cut battery size and use a flywheel to carry much of the load.

-Curtis Instruments, Inc has available a new illustrated bulletin on the company's Elapsed Time Indicators. The bulletin covers the various models manufactured, detailed descriptions, and suggested applications for each. For a copy of the catalog, write to Dept CA, Curtis Instruments, Inc. 200 Kisco Avenue, Mount Kisco, NY 10549.

-At the Institute of Electrical and Electronics Engineers' Northeast Electronics Research and Engineering Meeting, November 4, 5 and 6 in Boston, one of the outstanding features was a Technical Film Theater. The film "The Electric Car" produced by Electric Utilities Television, Madison, Wisconsin, was shown 10 times in a 300 seat theater. The film was shown to demonstrate the feasibility of the electric car as a means of personal transportation. It describes

Sep 70 Westinghouse ENGINEER p. 158

Battery-Powered Vehicles Find More Applications

Widespread use of battery-powered electric vehicles in place of vehicles powered by internal-combustion engines could go far in reducing air pollution, but they will not be generally competitive in other performance characteristics until better batteries are devised. In the meanwhile, however, some users are taking advantage of battery-powered vehicles' pollution-free operation by applying them in areas where they *are* competitive. Examples of such areas are indoors, as in manufacturing plants and warehouses, and congested city areas.

Changeover from gasoline- to electric-powered tugs by Alfred M. Lewis, Inc., a California-based food distributor, provided much less noise and much cleaner air in the warehouses, increased the productivity of order fillers, and reduced maintenance costs by about 75 percent. Each tug pulls up to 5000 pounds (four to six four-wheel carts). Average battery life under normal operating conditions is from 18 to 24 months. When not in use, tugs are plugged into 50-ampere chargers for 8 to 10 hours; after charging, they can operate up to 12 hours. The tugs were made by the Westinghouse Electric Vehicle Department.

Warehouse operation with the gasoline tugs required 16 to 20 man-hours a day for maintenance; now maintenance takes only five man-hours a day. The tugs are serviced by two employes, who check for proper water level in the batteries and perform additional maintenance, such as brake adjustment, as needed.

A new product of the Electric Vehicle Department is an electric passenger bus designed to carry up to 18 passengers. Typical uses include transportation within industrial complexes, shopping centers, college campuses, and other activity centers where people otherwise would have to walk long distances and where fume-free operation is especially advantageous. One of the first applications was by a manufacturing company in the Los Angeles area to carry employes, visitors, and customers around the office and production facilities. The bus is capable of operating for eight hours straight, making more than 500 stops and starts. Typical speeds are 6½ miles an hour loaded and 9 empty.

The bus is 14 feet long, 5½ feet wide, and 7½ feet high. Power for the four-horsepower dc series-wound motor is provided by 12 six-volt batteries; two other batteries power accessories. The six doors for entrance to and exit from the side-facing seats are removable for warm-weather use. Total weight is 3000 pounds, of which 1000 pounds is battery weight.

Electric bus carries up to 18 passengers. Intended for use in high-density areas, such as shopping centers or industrial complexes, the electric vehicle produces no air pollution and practically no noise. Twelve 6-volt batteries power a 4-horsepower motor and enable the vehicle to operate for eight hours.

AEC Assigns Liquid-Metal Breeder Reactor Responsibilities

The U. S. Atomic Energy Commission has awarded a five-year contract to WADCO Corporation to manage its liquid-metal fast breeder reactor development and technology programs at the Pacific Northwest Laboratory, Hanford, Washington. (WADCO is a wholly owned subsidiary of Westinghouse Electric Corporation.) The programs include design, construction, and operation of the Fast Flux Test Facility, which will be used for testing fuels and other materials under fast-reactor conditions.

Another program is operation of a new High Temperature Sodium Facility scheduled for completion in 1972. That facility will be used for engineering development in support of the liquid-metal fast breeder reactor concept, especially studies of the effects of high-temperature sodium on reactor components and structural materials.

Materials Test Loop Completes 10,000-Hour Run

An important milestone was reached when one of the Westinghouse Advanced Reactors Division's materials test loops completed a 10,000-hour run with flowing sodium under simulated liquid metal fast breeder reactor (LMFBR) conditions.

In fact, ten test runs have been completed to date and represent an accumulated operational time of over 40,000 hours. The most recent test, which lasted 10,000 hours, showed that the corrosion rates are acceptably low, even at elevated temperatures of 1325 degrees F, provided the oxide impurity level is kept low.

The testing program on the materials test loops for the LMFBR program is approximately 70 percent complete. Additional test runs are underway to complete the planned test matrix.

Many of the developmental facilities at the Westinghouse Waltz Mill Site near Pittsburgh, Pennsylvania, were built to help solve problems like:

How fast will Type 316 stainless steel piping corrode when liquid sodium is circulated through it at a flow rate of 20 feet per second, at a temperature of 1325 degrees F?

How much carbon is transferred from one section of piping to another section at different temperatures?

What effects does hot sodium liquid have on valves, pumps, tanks, and loops?

How is a system designed to handle and compensate for all of the expected temperatures, pressures, and other ma-

Elevated Guideway

$13 M system

	$5 M	Guideway
	.4 M	maintenance
	.6 M	all other investment except garages
Sub-total	6.0 M	~~Leaving~~
Leaving	$ ~~7~~ 7.0 M	available for carts and garages
	5.0 M	for carts - (5000 @ $1,000)
	2.0 M	for garages 4 @ $500,000

$25 M System

	$5 M	Guideway
	.6 M	maintenance
	.8 M	all other inv. except garages
Subtotal	$7.4 M	
leaves	17.6 M	avail for carts + garages
	5.0 M	for garages
	12.6 M	for carts (12,600 carts)

In $25 M system, might wish to widen guideway ~~and allow~~ to 4 lanes in certain sections, raising throughput (and price), and reducing amount available for carts.

Jack Downing, Congressional Country Club Bethesda

1. How many carts?

	3 wheel	4 wheel
electric		
gasoline		
~~three~~ total		

2. How much storage space is allocated and what kind?

range ~~travel~~ is about 10 miles at top speed, about 30% less ~~(7 miles)~~ on steep grades. F

SEP 197

Subject: Large Golf-Cart Fleet Operation

I met briefly with Mr. Jack Downing of the club manager's office of Congressional Country Club, Potomac, Maryland.

The club leases a fleet of about 72 2-passenger Cushman golf-carts from a jobber (Mr. Ray Briscuso, 524-4911) who also rents to other clubs. Mr. Downing also manages his own club, ~~and spoke partly from this~~ where ~~he owns~~ the fleet is owned.

Some of his observations:

- electric carts are far easier to maintain than gasoline-powered ones

- they are simple to operate, having only two gear settings, forward (which automatically shifts to "low" when under ~~load~~ strain) and reverse.

- They operate all day (72 holes of about 7200 yards per 18 holes - the carts run parallel to the fairways ~~but cross~~ but the manner in which they are used makes it difficult to gauge how far the carts travel). Mr. Downing's recollection was that ~~their~~ its one-way range ~~travel~~ is about 10 miles at top speed, about 30% less ~~(7 miles)~~ on steep grades. F

Storage space

3 story barn –
fleet size – 71 – 72
1 maint. cart –
1-8 pass cart

could probably park
about 9 in a std 2-car garage

Electric carts

Range (yds? 36 holes?)

72-holes | 7200 yds/18 holes

10 miles at top speed

Procedure for recharging
(overnight?)

How often recharged?

When are batteries replaced?

What is approximate cost for electricity to charge carts?

What components break down?

wheels/tires?
Steering?
Suspension?

How are repairs handled?
Sent out to:

____
____

In House.

~~If in-house - how m~~

If repaired in house what ~~proportion~~ ratio of fleet is in maintenance typically? $\frac{\text{out of svc}}{\text{Total}}$ =

How do you get disabled carts back to clubhouse?

What is annual repair bill for fleet?

Can they be entrained?

Any "surprise" costs of O&M that uninitiated wouldn't expect?

How long do they last?
(how old
when scrapped?)
Are they turned in to mfr as "trade-ins?"

typically good condition ~3 years

Performance

Speed - level ground
uphill

Braking.

Canopies, cabs, sidecurtains

What is roughest weather
in which used?

3-wheel vs 4 wheel
cart capabilities,
handling.

Can most males
drive one w/o instruction?
females?

Control

Are any lost to theft?

Do they have ignition locks?

Insurance

Any way to estimate ~~add~~ insurance premium?

Ray Briscuso
Off 524-4911

- The carts have no difficulty negotiating a ~~[illegible]~~ 12° grade on the back nine.

- They are recharged overnight.

- They are housed in a three-story barn of modest size (about the size of a suburban split-level home).

- He used to count ~~on them~~ on a new cart lasting for ~~the~~ three seasons ~~before~~ beginning to ~~[illegible]~~ require ~~extensive~~ maintenance.

- ~~Only rarely [illegible]~~

- Only rarely need to drive the one used for ~~maintenance~~ ~~full ma~~

- Members allowed to drive carts except when there has been heavy rain or when there is snow on ground.

For further information, call Ray Briscusi, golf-cart jobber (leaser). 524-4911.

8/21/70

Henry, (On Morgantown Question)

As discussed, a one page executive summary stating the basic costs for the basic systems envisioned ("Elevated Guideway", "On-Grade Reserved Lane", "Use Existing Roadways") with resulting number of carts for each funding level (13 million & 25 million). Perhaps a reference to the body of the discussion with each to describe conditions expected with resulting numbers of carts. There seems to be a wide cost and performance variation depending on operation of system conceived, i.e., whether each student keeps his cart with him as he goes through the day, or whether ~~a~~ pools of carts are established at various places around campus, from which students draw at random, or whether student (paid) drivers cart riders, or deadhead carts from pooling area to pooling area throughout the day to keep a balanced supply. Discussion of main attributes and deficiencies of each would be illuminating.

If country club could be contacted for rough O&M costs plus grade-climbing performance - that would strengthen your present discussion.

Finally a capsule summary (on Exec. Sum. page) perhaps of why you ~~s~~ conclude that the golf cart system could now satisfy requirements as well as Aldon — with, again, back up material in main body of paper.

Stan Powe

To Complete Morgantown Analysis

1. Summary presentation.

2. Two factual inquiries:
   a. Performance on long, steep grades
   b. Maintenance experience.

3. Add congestion factor, entraining considerations to discussion.

4. Add at-grade + use of existing street system to discussion.

HEMMES SUGGESTS TALK, VISIT TO CONGRESSIONAL

SYSTEM A: ELEVATED GUIDEWAY + GOLF CARTS

	5000 carts	,000 carts
GUIDEWAY	4.0 M	7.0
GOLF-CARTS (5,000)	5.0	.
MAINTENANCE FAC. + VEH.	.4	.6
GARAGES	3.5	5.5 ~~5.6~~
~~ACCESS CONTROL~~	~~.1~~	~~.1~~
~~MAINT. VEHICLES~~	~~.01~~	~~.1~~
~~COMMUNICATIONS~~	~~.005~~	~~.01~~

~~4.0~~
~~5.0~~
~~3.4~~
~~3.~~

25
19
18

7/10

	5,000 carts		12,000 carts
GUIDEWAY	4.0	5.0	~~6.0~~ 5.0
GOLF-CARTS	5.0	12.0	12.0
GARAGES	3.5	7.2	~~8.4~~ 7.2
MAINT. FACILITY + VEHICLES	0.5	0.8	0.8
	13.0	25.0	~~23.8~~ ~~25.5~~ ~~26.2~~

B AT-GRADE

EXCL. CART LANE	1.0	~~1.0~~	~~1.0~~	~~1.0~~	2.0
GOLF-CARTS	7.5	~~10.0~~	~~7.4~~	~~7.5~~	15.0
GARAGES	4.0	~~[illegible]~~	~~4.0~~	~~4.0~~	7.0
MAINT. FACILITY + VEHICLES	0.5	~~[illegible]~~	~~0.6~~	~~0.5~~	1.0
	13.0		~~12.6~~	~~13.0~~	25.0

C. EXISTING STREETS

CARTS	8.0	
GARAGES	4.4	
MAINT FAC + VEH	0.6	
	13.0	25.0

NEW SYSTEMS

27 AUG 70

FRANZ GIMMLER
~~JOHN~~ CROSSAN
HEMMES

PHASE I	300k
II	3 – 10 M
III	10 – 20 M
IV	10 – 25 B

Questions -

1. How many?
2. Electric or gasoline?
3. (If gasoline skip to Q. 7)
4. What is range without recharge (18 holes?) (approx yds)
5. How often is each recharged?
6. How many spare batteries?
7. How maintained (sent out?)
8. Annual repair bill?
9. Speed on level ground? Uphill?
10. Braking system?
11. 3 vs 4 wheel carts
12. What is worst weather (cold, rain) in which used?
13. Do they have side curtains for winter
14. What is electricity cost for charging, if separable from other charges?
15. Storage facilities - size, cost
16. Aspects of cart maintenance
    - tires
    - paint
    - canvas
    - gears etc - internal parts

Key Questions

1. Storage
2. Maintenance costs.
3. Performance, endurance, range
4. Operating costs

N

20 AUG 1970

Ways in which golf-cartsystem would not actually match Alden system performance.

1. Need for drivers
   - need skill as pilot for GC
   - GC's can't circulate empty to reposition themselves for additional users

2. Need for parking, including overnight recharge facility
   - they are smaller than autos so they could be more densely stored

3. Attrition risk

4. General policing problem - student-operated vehicles

5. Congestion in guideway

in Morgantown

1. Grades too steep a. Climb too slow
   b. Braking on down-hill trips

2. Weather too severe

3. Access roads limited (could put carts on guideway?)

4. No room for additional parking (build facilities?)

guideway costs

Alden figures:

Structure $300 /ft

electrical distr 20 /ft. (lighting + snow removal only)

Control components — $5 /ft (some sensors + switches to indicate loading + jams)

$325 /ft

30,000 ft

$ 9,750,000

---

per WHL proposal:

6.162 guideways

1.008 stations

~~.852 maint facility~~

$7.170 — with heavy electrification, controls

less (?) ~~ex (6.670)~~ ~~$6.500~~ - reduced electrification, controls

1 9 AUG 1970

How well could Morgantown satisfy its
Source? → intra campus transportation needs
call mfr? country club → using electric golf carts
running on macadam paths

Morgantown costs will be less than DC costs – but ≈ DC contractor est.
get Morgantown contractor est? sq yd? cu yd?

— Maintenance assumptions < carts / paths

- Network assumptions -
- Capacity of carts (1 - 2 ?)

What would it cost to satisfy them
As well as the proposed Alden system?

Weather – plowing?

WVU	Alden
30,000 ft.	45,000 ft.
90 veh	200 veh

Acquisition Costs

Cart costs — ~ $1,000 without cab
Batteries cost — $150
Spares cost — ??
Maintenance facilities cost — $850K (p 39 of WVU proposal)
Parking costs — $600/space for full-size spaces
(assume $300/space)
Guideway costs — $6.0 million (incl. "stations" & electrification)
Control system costs — (?) — $950K in Alden proposal
Tow vehicle ~~costs~~ — (2?)
or should train-hitches be installed in each car, raising price?

Operating costs ~~[illegible]~~

Electricity —
car maintenance — $200,000/yr. ~~$200 [illegible]~~ ($2,871/veh for Alden)
"cowboys" — 10 @ 8K = $80,000/yr
guideway maintenance,
replacement of stolen or wrecked cars $70,000/yr,
access control

~~$500,000~~ 5,000
2,500) 12,500,000

500
2.5) 12 | 500

19 AUG 1970

15000 students today
6200 faculty + staff
3 campuses 1½ mi apart

2000 live in Towers
UNIV now operates 16 buses
5 peaks/day 50,000 trips/wk
10,000 private vehicles in reg use
parking problems
Terrain is so steep as to prevent
bicycling (or walking ?) between classes

Street widening (p 39) $250,000/lane/mi
Parking space " $600/Space
(3,000 spaces)

Only 2 routes between campuses:
(1) Monongahela Blvd 4 lane, steep grades
funnels into Beechurst ave, 2 lanes
(2) Univ Ave, very narrow 2-lane, steep

1

August 19, 1970

2 pass-canopy	
1060	
180	
70	
1,280	

Remo-Cushman talked w. Fred Draeger

passengers –

all-weather? –

batteries –

4-wheel – electric – $1,490 + $150 batteries, $70 canopy

– ~~gas~~

seats 2

1060 basic
150 battery
102 cab
92 doors
$1,404 unit list price

2 passenger exec – $1,060 + 150 + ~~70~~ $42 battery

Cab $102
Seat $50
doors $46

20% off for

~~person~~

1300
260
1,040

~~4-wheel gasoline –~~

4-wheel electric with options

gasoline model ~~1875~~ $1,900

4-pass canopy

4-pass – elect – canopy –

3-wheel, 2 seats 1,355 + 150

4-wheel, 2 seats 1,375 + 1

2-passenger w cab $1,060 + 102 + 46 + 150

$1,358
$1,270
$1,088

1,060 + 150 + 42

Cost of Golf-cart people-movers.

Total cost =
acquisition of cart
+ " of batteries
+ " " spares
+ " " garages
+ " " guideway + installation
+ " " (command?) control, (comm?)
+ " " tow vehicles for disabled carts

+ electricity to charge batteries
+ maintenance personnel
+ golf-cart "cowboys" to round up idle carts + transfer to needy location (link in trains?)
+ guideway maintenance (+ snow removal)
+ attrition replacement (cf. supermarket buggies)
+ operating costs for user-access control system ($n buys ~~credit~~ key for month, semester, year?) (or credit-card system?)
+ added insurance costs (high premium rates?)
safety

Note - univ to furnish all ~~staff (labor)~~ manpower to operate + maintain system.

1 9 AUG 1970

Golf Carts

Bag Boy - (retail) Angelo's Repair 966-0157

Cushman - Remo-Cushman 424-5566

E-Z Go Golf Car - Stevens+Kendall 948-5117

Pargo - Royce Dist. 345-5123

Westcoaster - Ace Equipment 927-6223

Paving

A B Veirs, Rockville — 762-2778
American Asphalt, Occoquan — 546-3810
Standard Paving, Rockville - 881-5544
Finley Asphalt Chantilly - 471-4400
E E Lyons Consts, Vienna - 759-2171
Alaska Paving, Newington, Va 780-7800
5000 / 200 / 3500000 Asphalt Contractors, Inc. Beltsville - 776-6330
Corson + Gruman, Wash FE 3-3046
Curtin + Johnson, NE 832-3800

E-Z Go - 2 passenger - $1,250 + $60 top -
3-wheels

Cost Factor	Potential Sources	Remarks

CM's Golf Car Buying Guide for 1971

So why show club managers instead of golf cars on the first page of a golf car buying guide?

What you see on the preceding page isn't just another group of club managers. They are the epitome of the new breed, the type of manager who is answering the challenge of more responsibility by learning about club life outside, as well as inside, the clubhouse.

The managers pictured were the participants in CMAA's first outdoor recreation administration workshop the past summer at Houston. It is indeed significant that CLUB MANAGEMENT has news of that historic workshop (page 33) in this section about golf cars. The managers at Houston, and those attending other outdoor recreation administration sessions this year, where golf operations are studied, are living proof that club directors and officers expect managers to know more about overall club operations.

CLUB MANAGEMENT is happy to cooperate by supplementing the manager's knowledge of golf cars. Some of the information in this section deals with the "nuts and bolts" of golf car purchasing, merchandising and maintenance. Other material discusses the old and reliable and the new and exciting in golf car models for 1971.

Leading golf car manufacturers, at the request of CLUB MANAGEMENT, provided details about their models, including prices. (Remember, the prices quoted are f.o.b the factory.)

AMERICAN CONTINENTAL, INC., Box G, Industrial Park, Willmar, Minn. 56201.

ACG: Gas, $1,086, three-wheeler, 660 pounds, 90 inches long, 47.5 inches wide, tiller steering (wheel optional), fiberglass body.

ACE: Electric, $1,086, three-wheeler, 900 pounds with batteries, 90 inches long, 47.5 inches wide, tiller steering (wheel optional), fiberglass body.

Both cars have double coil springs and shock absorbers. Gas car has eight-horsepower engine and heavy duty transaxle.

CLUB CAR, INC., P. O. Box 897, Augusta, Ga. 30903

Caroche: Electric, $1,266.75, four-wheeler, 840 pounds with batteries, 93 inches long, 45.5 inches wide, wheel steering, fiberglass body.

Company is dropping its three-wheel Club Car in 1971 because of excellent acceptance of Caroche. Model has hydraulic wheel brakes plus a mechanical braking system on rear wheels.

COLUMBIA CAR CORP., P. O. Box 5544, Charlotte, N. C. 28205.

Pargo 800: Electric, $1,345*, three-wheeler, 490 pounds without batteries, 89 inches long, 42.5 inches wide, tiller steering, reinforced fiberglass body.

Pargo 801 (one passenger): Electric, $850*, three-wheeler, 253 pounds without batteries, 67 inches long, 30 inches wide, tiller steering, reinforced fiberglass body.

Pargo 803: Electric, $1,395*, three-wheeler, 490 pounds without batteries, 89 inches long, 42.5 inches wide, wheel steering, reinforced fiberglass body.

Pargo 804: Electric, $1,495*, four-wheeler, 760 pounds without batteries, 97 inches long, 42.5 inches wide, wheel steering, reinforced fiberglass body.

All 1971 models equipped with automatic electric cut-out switch which eliminates possibility of passenger operating car while driver is not in vehicle.

*Prices established August 1, 1969.

CUSHMAN MOTORS, 900 N. 21st St., Lincoln, Neb. 68501.

Town & Fairway: Electric ($1,835) or gas ($1,920), four-wheeler, 824 pounds for electric (without batteries) and 945 pounds for gas, 108.75 inches long and 48 inches wide, wheel steering, terneplate steel body.

GC-400 Electric: $1,565 without batteries, four-wheeler, 742 pounds without batteries, 102 inches long, 47 inches wide, wheel steering, terneplate steel body.

GC-400 Gas: $1,725 without battery, four-wheeler, 863 pounds without battery, 102 inches long, 47 inches wide, wheel steering, terneplate steel body.

GC-300 Electric: $1,425 without batteries, three-wheeler, 700 pounds without batteries, 102 inches long, 47 inches wide, wheel steering, terneplate steel body.

GC-300 Gas: $1,580 without battery, three-wheeler, 774 pounds without battery, 102 inches long, 47 inches wide, wheel steering, terneplate steel body.

Trophy (pictured): Electric, $1,350 without batteries, four-wheeler, 625 pounds without batteries, 91.75 inches long, 43 inches wide, wheel steering, terneplate steel body.

Champion: Electric, $1,098 without batteries, three-wheeler, 510 pounds without batteries,

87.5 inches long, 39.5 inches wide, wheel steering, welded steel body.

Scotsman: Gas, $785 without battery, three-wheeler, 420 pounds with battery, 78.25 inches long, 40.25 inches wide, tiller steering, welded steel body.

Trophy is a new model for 1971. Its features include individual bucket seats. A gas gauge on gasoline models and positive timer control for battery charger are new innovations on 1971 Gran Cushmans.

ELECTRIC CARRIER CORP., D207 Petroleum Center, San Antonio, Tex. 78209.

Electric Caddy Model 300: $1,375 with batteries and charger, three-wheeler, 900 pounds with batteries, 90.5 inches long, 46 inches wide, wheel steering (tiller optional), steel body.

Electric Caddy Model 304: $1,495 with batteries and charger, four-wheeler, 900 pounds with batteries, 90.5 inches long, 46 inches wide, wheel steering (tiller optional), steel body.

Models have complete coil spring and shock absorber suspension; also direct-drive transmission which company representatives say delivers battery life up to three years and more in fleet service.

E-Z-GO CAR DIV., TEXTRON, INC., P. O. Box 388, Augusta, Ga. 30903.

X-440 S: Electric, $1,485, three-wheeler, 560 pounds without batteries, 90 inches long, 47 inches wide, wheel steering, steel body.

X-444 (pictured): Electric, $1,625, four-wheeler, 590 pounds without batteries, 96.75 inches long, 47 inches wide, wheel steering, steel body.

Company also has gasoline models GX-440 (three-wheeler) and GX-444 (four-wheeler). Cars have wrap-around rubber bumpers and full suspension with four shock absorbers. Steel body panels can be replaced. Single solenoid electrical system and direct drive.

LAHER SPRING & ELECTRIC CAR CORP., 2615 Magnolia St., Oakland, Calif. 94607.

MG-470 (pictured): Electric, $1,675, four-wheeler, weight not given, 99.5 inches long, 44 inches wide, wheel steering, fiberglass body.

MP-370: Electric, $1,525, three-wheeler, weight not given, 99.5 inches long, 44 inches wide, wheel steering, fiberglass body.

FM-270: Electric, $1,395, three-wheeler, weight not given, 99 inches long, 44 inches wide, wheel steering, fiberglass body.

Company's 1971 models include new cowling and deck design, suspension, frame and chassis, automatic "hill holder" and extended operating range.

TAYLOR-DUNN, 2114 W. Ball Rd., Anaheim, Calif. 92804.

Tee Bird GT 348: Electric, $1,465, four-wheeler, 1,065 pounds with batteries and charger, 88 inches long, 45.5 inches wide, wheel steering, steel body.

VIKING CORP., 1626 Werwinski St., South Bend, Ind. 46628.

Viking I: Electric, price not given, three-wheeler, 783 pounds with batteries, 98 inches long, 48 inches wide, wheel steering, reinforced fiberglass body.

Baron: Electric, price not given, three-wheeler, 823 pounds with batteries, 88 inches long, 46 inches wide, wheel steering, 14 gauge steel body.

The Baron is a new model. Its front cowl has an "on top" storage tray for beverages and balls and a lower compartment for sweaters and hand bags.

WESTINGHOUSE ELECTRIC CORP., Gateway Center, Pittsburgh, Pa. 15222.

437: Electric, price not given, three-wheeler, 965 pounds with batteries, 91.25 inches long, 47.5 inches wide, wheel steering, steel body.

This is a new model, featuring an axle system with an integral drive unit with no chains or belts, wrap-around tubular bumper and adjustable individual seats.

Replacing the Old Fleet

There is a direct correlation between the attractiveness of a golf car fleet and the extent of its use, officials of Cushman Motors, Lincoln, Nebraska, believe.

So, those officials say, because newer cars are more likely to be used, a club could be hurting itself by trying to extend the use of an older fleet.

Based upon experience in both leasing and selling, Cushman recommends a replacement cycle of three to four years. Although local conditions such as climate and weather may cause a variance in the extent of golf car use, the point of diminishing returns is generally reached in the third or fourth year, company officials say. Most lease contracts by Cushman stipulate a fleet replacement in three or four years.

Personal preference and satisfaction of club members are the paramount factors in replacing a fleet on a staggered basis. It must be pointed out, however, that if there are some new cars and some two or three years old, the golfer will choose the newer car and may turn away with damaged pride if he is offered an older model.

It is particularly important to

consider replacing an entire fleet, company officials say, when a model, style or construction change has been made. It will be less significant if the new car looks the same as the old. The same rules apply if the club switches from gas cars to electric, or vice versa, or changes from one make to another.

If club executives determine that they should replace only a portion of their fleet at a time, however, say one-third, there are certain procedures which can help eliminate the problems:

•1) Rent all cars at random, without giving a make or model preference to any individual.

•2) Establish different rates for different brands or models. The cost of vehicles continues to increase, so club executives will be faced with increasing their rental rates sometime, anyway. Establish a new rate for the newer cars and offer the older models at the former rate.

•3) Purchase part of a new fleet and retain some of the old cars for peak days. It is not economical to have a new fleet of 50 cars when 10 of them might make only two or three rounds a week. The answer is to have a new fleet of 40 cars and keep 10 old ones for busy days. ■ ■

Golf Car Maintenance Chart

(Courtesy of the E-Z-Go Car Division of Textron, Inc., Augusta, Georgia.)

	DAILY	WEEKLY	MONTHLY	SEMI-ANNUAL	ANNUALLY
BATTERIES			• WIPE DIRT AND FOREIGN MATTER FROM TOPS OF BATTERIES. • CLEAN TERMINALS. • REPLACE DEFECTIVE BATTERY CAPS. • WASH BATTERIES (USE BAKING SODA).		
A. CHECK	X				
B. CLEAN		X			
C. ADD WATER		X			
TIRES			• EXAMINE DAILY FOR CUTS AND EXCESSIVE WEAR. • CHECK PRESSURE WEEKLY.		
A. PRESSURE		X			
B. CONDITION	X				
BRAKES		• CHECK BRAKES (AND ADJUST IF NECESSARY) ON A DAILY BASIS, BEFORE CAR IS USED.			
A. CHECK	X				
B. ADJUSTMENT		X	• DO NOT USE WITH FAULTY BRAKES		
CHARGER AND CHARGER PLUG.		• TIGHTEN WIRES AT CHARGER PLUG, & ON CHARGER • KEEP RECEPTACLE FREE OF DIRT & FOREIGN MATTER			
ACCELERATOR SWITCH		• DO NOT OIL OR GREASE CONTACTS.			
A. CONTACTS		• CHECK CONDITION		X	
B. LEAD CONNECTIONS		• CHECK TIGHTNESS		X	
FOR & REV SWITCH		• USE LIGHT LUBRICATION ON CONTACTS.			
A. CONTACTS	• CHECK CONDITION			X	
B. LEAD CONNECTIONS	• CHECK TIGHTNESS			X	
FRONT WHEEL BEARINGS		• USE A GOOD GRADE CUP GREASE FOR REPACKING			
A. REPACK					X
B. ADJUSTMENT			X	• SEE SERVICE SECTION	
STEERING ASSEMBLY		• BE SURE PINCH BOLTS ON ENDS OF TIE ROD ARE TIGHT			
A. CHECK			X	• USE S.A.E. 140 WT. IN STEERING BOX.	
B. LUBRICATE LINKAGE				X	
C. TILLER			X	• TIGHTEN SET SCREWS	
D. STEERING COLUMN			X	• SEE SERVICE SECTION	
FORK BEARINGS	• USE A GOOD GRADE CUP GREASE FOR REPACKING				X
FRONT WHEEL ALIGNMENT			X	SEE SERVICE SECTION FOR ALIGNMENT PROCEEDURE	
ACCELERATOR & HILL BRAKE LINKAGE		• MAKE SURE LINKAGE RODS ARE NOT BENT OR BINDING ON FRAME.			
A. CHECK		X	• USE LIGHT LUBRICATION OIL ON MOVING PARTS.		
B. LUBRICATE			X		
RESISTOR BOARD					
A. COILS			X	• CHECK CONDITION	
B. LEAD CONNECTIONS			X	• CHECK TIGHTNESS	
CHECK SEATS FOR BROKEN SPRINGS	X	• LOOK FOR HOLES IN SEAT COVER.			
DIFFERENTIAL LUBRICANT		S.A.E. 50 WT.			
A. CHECK				X	

ANNUAL – TO INCLUDE DAILY, WEEKLY, MONTHLY, AND SEMI-ANNUAL ITEMS.

New Car Spoils Members

Although the decision of whether to replace a fleet of golf cars all at once or in stages is left up to the needs of its club customers, the Laher Spring & Electric Car Corporation, Oakland, California, believes (as does Cushman) there is a higher financial outlay in gradual replacement.

A company official pointed out that when a club replaces cars gradually, invariably the club ends up completing the replacement much faster than planned. It's not because of accelerated wear on the old cars, but because of human preference for the newer ones. Everyone wants to drive a *new* golf car.

Filling Needs and Wants

How many golf cars does your club need?

Think this one out carefully before answering.

One car for every 20 golfing members is a popular formula. One manufacturer says, however, that a private club should have 50 to 75 cars for each 18 holes. His point: Having too few cars can be just as bad as having too many.

It all depends on each club's circumstances. Number of members who golf regularly and rounds played each week, for example; and whether the cars are more for club profit or member convenience.

Determining Car 'Life'

What are the determining factors in the life expectancy of a golf car?

An official of the Laher Spring & Electric Car Corporation, Oakland, California, listed the following:

Care given by users and maintenance personnel; prestige and "lasting" style and equipment on the car; type of course (hilly, rough) and mileage covered during a round of golf; number of rounds used annually.

Setting Rental Fee For Golf Car Fleet

Unless there are unusual circumstances, the rates for golf car rental should be set so that your club may expect a gross income of at least $1,100 to $1,200 a year for each car. The club should net 50 per cent a year on each car.

These are recommendations by officials of the E-Z-Go Car Division of Textron, Inc., Augusta, Georgia. Other suggestions:

- Full depreciation should be set up for a three-year period. For example, the annual depreciation on a car costing $1,200 would be $400.
- The club should be able to hire a full-time maintenance man for $6,000 to $7,000 a year. Say it's $6,600 for easy figuring, or $132 a year per car for a fleet of 50. The figure would vary, depending on the number of cars, but it's a workable average.
- Parts might run as high as $20 a year per car after the first year.
- Insurance, a necessity, costs $15 and more a year per car.
- Using a $15,000 shed as an average, storage expenses could be amortized over a 25-year period at $600 a year ($15,000 divided by 25). If there were 50 cars, this expense would be $12 a year for each vehicle.
- If the average car went 140 rounds a year at $8 a round, the gross income would be $1,120 and the net profit $560.

Maintenance Training

Before a club leases or buys golf cars, it should make arrangements for the club employees who will be maintaining those cars to learn the maintenance procedures. Any reputable dealer or manufacturer's representative can provide such help.

Proper winter storage of golf cars is the first step to spring profits. To be sure your club takes that first step, see the storage tips in the October issue of CLUB MANAGEMENT.

Here is the way one club predicted its profit on a golf car, based on anticipated income and expenses using the car seven years:

	1st Year	2nd	3rd	4th	5th	6th	7th
Income	$1,150	$1,150	$1,150	$1,150	$1,150	$1,150	$1,150
Depreciation	($400)	($400)	($400)				
Interest	($80)	($80)	($80)				
Parts	—0—	($20)	($20)	($30)	($40)	($40)	($40)
Batteries	—0—	($100)	($100)	($100)	($100)	($100)	($100)
Tires	—0—	—0—	($10)	($10)	($10)	($10)	($10)
Maintenance Man	($132)	($132)	($132)	($132)	($132)	($132)	($132)
Insurance	($20)	($20)	($20)	($20)	($20)	($20)	($20)
Electric	($30)	($30)	($30)	($30)	($30)	($30)	($30)
Building Depreciation	($30)	($30)	($30)	($30)	($30)	($30)	($30)
Extra Maintenance	—0—	—0—	—0—	—0—	($100)		
	$458	**$338**	**$328**	**$798**	**$688**	**$788**	**$788**

Trade value: $200.
Average $627 net profit per year per car or 52.2 per cent.

CMAA's Outdoor Recreation Workshop

By W. R. "RED" STEGER, CCM
River Oaks Country Club, Houston

Admittedly, it was a struggle to attract the number of club managers desired to CMAA's first outdoor recreation administration workshop in July at Houston. About 20 managers participated.

Now that the subject matter has been presented, however, other outdoor recreation administration workshops this year are no doubt attracting many more as word of the fine education reaches others.

Paul Alexander, educational director of the Golf Course Superintendents Association, and Quinton A. Johnson, greens superintendent at Brookhaven Country Club, Dallas, discussed golf course administration and organization, agronomy problems, golf course equipment, water systems, golf course budgeting and a "profile of the superintendent."

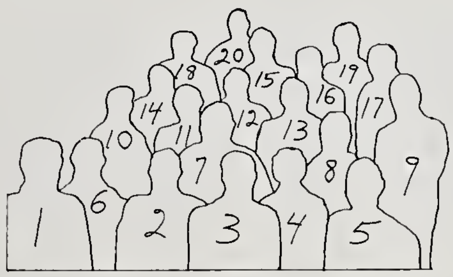
John M. Franklin, administrative assistant of the Professional Golfers' Association of America, and Max Elbin, honorary president of the PGA and pro at Burning Tree Country Club, Bethesda, Maryland, covered the subjects of the golf pro and his staff, what a pro looks for when accepting a club job and what the club should expect from the golf pro.

Vaughn E. Border, director of marketing for Cushman Motors, Lincoln, Nebraska, reviewed golf car operations. He presented the know-how for all phases of modern buggy operation.

Prof. John Scherlacher of West Virginia University covered tennis, swimming and other outdoor sports operations featured at many clubs.

W. R. "Red" Steger, River Oaks Country Club, Houston, was the CMAA representative at the workshop.

The association's second outdoor recreation administration workshop was conducted at Ithaca, New York, in August. Other sessions will be October 12-15 at Chicago and November 16-19 at Portland, Oregon. ■■



Those pictured on page 29:

(1) Kirby McLain; (2) George DeMayo; (3) W. D. Rogers, Shreveport (La.) C.C.; (4) Betty Moore, Fairwood C.C., Baton Rouge, La.; (5) Edward F. Rafferty, Annandale G.C., Pasadena, Calif.; (6) William Edwards, Texarkana (Ark.) C.C.; (7) William Douglass, Mid Pacific C.C., Kailua, Hawaii; (8) Hans Kohler, Forest Club, Houston; (9) W. C. Myers, Commissioned Officers' Club, Naval Amphibious Base, Coronado, Calif.; (10) W. R. "Red" Steger, River Oaks C.C., Houston; (11) Hubert Conrad, Baton Rouge (La.) C.C.; (12) John Williams, Augusta (Ga.) C.C.; (13) Jack Maness, Park Manor C.C., Monroe, La.; (14) Herschel Nead, Abilene (Tex.) C.C.; (15) Quinton Johnson and (16) Paul Alexander, workshop speakers; (17) Jim Holub; (18) Donald Stone, Lake Charles (La.) C.C.; (19) Conrad Schmidt, Houston; and (20) Pat Ginther, El Dorado G.C., Humble, Tex.

UNITED STATES GOVERNMENT

Memorandum

DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION

DATE:

In reply refer to:

SUBJECT: 4/1 Meeting with JPL Morgantown Project Team

FROM : S. Price, Systems Analysis Branch

TO : Robert A. Hemmes

Attendees:	L. Divone	JPL
	H. McComber	JPL
	D. Smith	JPL
	J. Winn	URD-24
	S. Price	URD-3

The primary purpose of this meeting was to assess JPL's status and methodology in systems analysis of the Morgantown project.

Summary of Impressions:

. JPL is attempting to accomplish several major tasks in parallel - because of constricted project timing - which would best be accomplished in series.

. Nearly entirely lacking is a preliminary overall system-wide analysis of expected operation.

. It is believed that the combinatorial problems (of vehicle assignment and operation to meet the time-varying passenger demand schedule) will be severe, in itself - and will be compounded by the requirements for varying vehicle speeds (due to terrain) and accommodation of the two system operating modes ("scheduled" and "demand actuated") and the necessary transition between these modes.

Conclusion:

There is a danger in the present method that the separately-developed subsystems may not provide an effective total system.

Recommendation:

More emphasis be placed on the systems integration aspect of the project, beginning with a more comprehensive systems analysis of total system operation. A system-wide simulation accounting for each vehicle during a 24-hour day would provide such a preliminary analysis.

Specific Topics Addressed Included:

. The overall approach that is being taken toward System Integration. So far this approach has been an iterative process of separate sub-system (e.g. vehicle, guideway, station, command and control) analysis or preliminary design, followed by a Design Committee meeting during which the probable overall effect of putting the parts together is assessed, followed by further individual subsystem design, and continuing through the cycle.

. Review of the present basic system capacity requirements (as specified in "Requirements and Constraints Document). These are: 1100 people from Towers to Beechurst in 20 minutes; the 6 minute vehicle travel time between these points; and the demand schedules at the separate stations.

. Under system integration, Lou Divone, the analytical work to be carried by Hal McComber consists of: "deterministic analysis", which is an analytical model developed by System Control Inc., a subcontractor, which models a system simplified from the actual Morgantown system to an extent that the real utility of the model is not clear, and to "Simulations Type 1 and Type 2." Type 1, running now, is a GPSS model very much simplified of a 2 station system, with fairly restrictive design assumption regarding vehicle use. Type 2, to be developed by June, will be more complex and is to be capable of examining alternative operational strategies.

. They have received a 24 hour period, 5 minute increment, demand schedule for each station, from WVA. They presently think that noon may be the peak period - rather than 7 - 8 AM.

. Alden and WVU, defined the "X people in Y minutes" constraint differently in previous documentation.

. The latest design, "Design B", turned out to be too costly, therefore design B′ is postured upon a 6 passenger vehicle.

. There are presently about 7 men full time in the Systems Integration area.

Separate trade-off studies to date have included heated vs. enclosed guideway, electrical vs. hot water heating, steel vs. concrete guideway, enclosed vs. open stations, route selection (4 iterations so far), and combined towers and engineering stations.

. Mr. Divone is presently using the requirements and constraints document as a basic design guide. Discussion developed that this document may have inconsistencies in the several major system determinants. A new and updated R&C document is to be provided by April 30th.

. In addressing separate design items Mr. Divone has placed highest priority on those specifications which are deemed to have disasterous effects if incorrect, for example e.g. not enough clearance for vehicles based on wind requirements.

. System Analysis work to date:

In general a comprehensive systematic approach to the entire problem apparently does not presently exist. For example, the whole concept of a "system control algorithm" apparently has not really been addressed yet; no detailed analysis has been accomplished regarding a synchronous vs. asynchronous system - or in particular what the definitions of those terms amount to as applied to the Morgantown system. JPL present thinking, it was stated, is to attempt to develop a synchronous system. Little has been done so far in addressing the peak vs. off-peak differences in system operating modes, or the transition required between them.

. Whether AC or DC power to be used is not decided upon yet.

. The effect of the power company and perhaps the insurance company may have impact on the system design.

. System safety, which appears to be a complicated subject in itself, although the impact of stopping distance on headways has been addressed, but the overall impact on system design has not yet been determined.

This could reflect heavily on system design, and system cost. For example, if a lock to guideway is required on each vehicle.

A concept for setting safety levels was brought to JPL's attention. This concept is based on the measure, "fatalities, or injuries, per exposure hour." Work by Chauncey Starr at UCLA. ("Social Benefit Versus Technological Risk", Science, Vol. 165, No. 3899 pp. 1232 - 1238, September 19, 1967.

. An example of the effect of lack of an overall system control algorithm might be the inability to specify the in-guideway vehicle sensor spacing requirements prior to guideway design specifications.

. Few alternative station designs apparently have been considered. Presently it looks, for example at Beechurst, as if acceleration will be required around a curve using the present station design.

. Present JPL thinking is not to train vehicles during the "schedule" mode.

. The university has agreed to stagger classes to accommodate the relaxed (20 minute period rather than 10) system requirements.

The impact of staggered hours on the separate station demand schedules, and the impact of those altered demand schedules on total system operation apparently has not yet been addressed. Little analysis has been accomplished to date on the requirements, if any, for "slack track" i.e. buffer guideway for dynamic vehicle storage during normal system operation in order to accommodate demand ebbs and flows.

. A potentially difficult problem is the mechanism to get the system started again in the case of a complete power outage.

. At 300 feet headways it appears that 80% of the guideway might be in use to any given time (assuming 100 cars).

Maintenance Cost Analysis

. JPL has gathered data on similar systems to address this, but apparently no analysis yet based on expected vehicle use.

. JPL's statement at conclusion of meeting was that their most pressing needs are:

1. A scheduling algorithm.
2. Design of system failure mode.

Brief review of the analytical activities carried out by Harry Cottrell in the command and control area showed that he has analyzed the promising propulsion system, the promising wayside power distribution systems, and vehicle size, shapes, steering, lock-on, and vehicle power and braking requirements.

CONSTRAINTS ON ARRIVAL AND DEPARTURES AFFECTING POSSIBLE REUSE OF VEHICLES DURING PEAK PERIODS

To conserve on the total number of vehicles which must be introduced into the system, service during the scheduled peak periods should be routed such that each vehicle makes more than one trip, if possible. Constraints on the ability to reuse vehicles during the peak period are imposed by the distances to be traveled on both the first and second trips (if two-trip time is longer than 15 minutes during the 7:45 to 8:00 peak, some students will arrive late for class), and by minimum headways.

When passenger volume between two stations is heavy, such as morning peak traffic from station 5 to station 2, vehicles from other stations bound for the heavily loaded destination station may be delayed because of the required minimum headways. This factor also affects scheduling of vehicles using the same stretch of guideway. For example, the guideway section between stations 3 and 2 must serve traffic between the following station pairs: 5-2, 5-1, 4-2, 4-1, 3-2 and 3-1; the demand data provided by West Virginia University indicate that this currently amounts to about 985 passengers during the 7:45 to 8:00 a.m. peak. Assuming 20-passenger vehicles, 90% full, this requires a total of 57 vehicles to traverse this section of guideway; because it takes 5.0 minutes to get from station 3 to station 2, these 57 vehicles have only ten minutes to pass or depart from station 3, implying that the minimum headway on that guideway segment during the first morning peak cannot be longer than 5.7 vehicles per minute (or 11.5 seconds between vehicles).

The interaction of travel time and traffic volume between stations may necessitate scheduling such a large proportion of vehicles departing during the early part of the peak period for the high-volume destinations that opportunities for potential reuse of cars may be lost. For example, support the first 48 vehicles from station 5 all leave for either stations 1 or 2. Departures for stations 4 and 3 would then be delayed by 6 minutes (assuming 10-second headways). The earliest vehicles arriving at station 4 from station 5 would be on hand and ready for reloading would then be t=8.6 minutes (6 minutes plus the 2.6-minute travel time). They would be on time to carry loads from station 4 to either station 2 or station 3, but they would be too late to carry any of the load from station 4 to station 1 (the last car must depart station 4 for station 1 not later than t=5.5 minutes).

Travel time and demand data have been used to prepare a table of minimum frequency of dispatch of vehicles from each station toward each destination. Travel times have been analyzed to indicate, on a second table, earliest possible arrival of the first vehicle from any given station at its destination. Finally, an illustrative schedule is presented which handles the demand (providing some service beyond minimum demand, including service between stations for which little or no demand is anticipated during the first morning peak) with moderate reuse of vehicles during the first morning peak.

H G F E D C B A
88 71

OK →

	P	O	N	M	L	K	J	I
Arr	75	70		60		50		40
Entered Stat	75	71	71	71	71	71	71	71
Unloaded	88	86	86	86	86	86	86	86
loaded	101	99	99	99	99	99	99	99
left	149	139		129		119	114	109
Stat at t=99	Loading	Q	Q	Q	Q	Q	Q	Ramp Q

F' − 4

	X	W	V	U	T	S	R	Q
ent − 149								149
unloaded	Q	Q	Q					162
loaded								175
left	220	215	210	205	200	195	190	185

10 vehicles

Outside = 8
inside = 3

t = 150

Q
R
S
T
U
V
W
X

G admitted at t=149

Y
Z
A'
B'
C'
D'

6 held

E'
155 F'

arrive t=159 admitted at t=220

G
1:1

Y 100
5
W 10
X 15
Y 20
Z 25
A' 30
B' 35
C' 40
D' 45
E' 150
F' 55
59 60 sec
G' 60
H' 5
I' 70
J' K' 70
L' 5
M' 90
N' 5
O' 200
P' 5
Q' 209

at t=149
A' − U
into station

149 − 159
D'C'E'F' arr
were there

t = 209

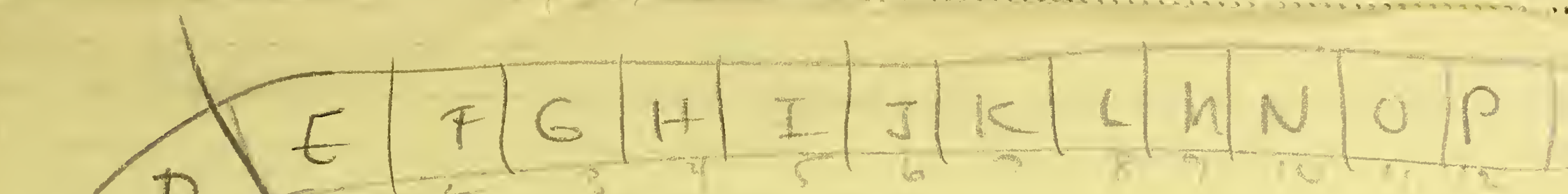
(from W Va U proposal, p. 52)

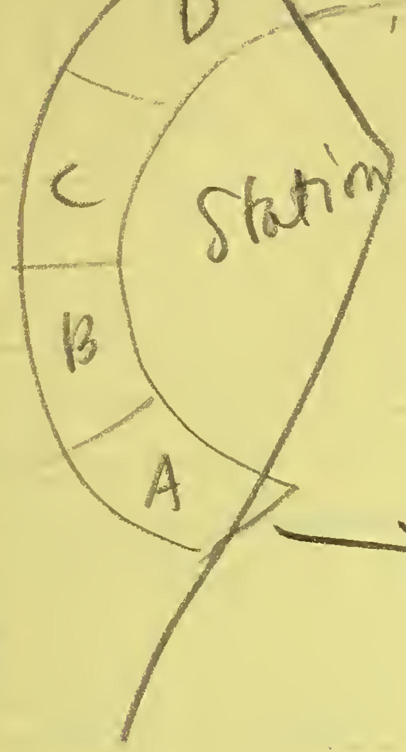
From \ To	1 Walnut Street	2 Quadrangle	3 Engineering	4 Field House	5 Towers	6 Medical
Walnut Street 1	X	2.3	8.3*	9.5*	9.0 *	12.4 *
Quadrangle 2	2.3	X	5.6	6.8	6.3	9.7
Engineering 3	8.3	5.0	X	2.2.	1.7	5.1
Field House 4	9.5	6.2	2.2	X	2.6	6.0
Towers 5	9.1	5.8	1.7	2.6	X	2.4
Medical 6	11.9	8.6	4.5	5.4	2.4	X

AC to AC

Total Trip Time
(Station-to-station, including both loading and unloading)
Figure 14

* These total trip times from station 1 are probably in error because as given it is faster to travel from station 1 to station 2 and transfer to a vehicle bound for these destinations.





Assumptions

1. Start at t = 0 with 4 empty V's at A, B, C, D.
2. Arrival each 5 sec
3. 5 seconds to shuffle, load
4. 30 seconds to unload

5. 1 ... queue

t	Activity	No Vehicles launched	Queue length
0	begin loading	0	Φ
5	continue "	0	1
10	" "	0	2
15	launch	4	3
Shuffle → 20	file 5 6 7 8 into place	4	4−4 = 0
25	unloading	4	1
30	unloading	4	2
35	begin loading	4	3
40	cont. "	4	4
45	" "	4	5
50	launch	8	6
Shuffle 55	9, 10, 11, 12 arrive	8	7−4 = 3
60			

35-second cycles, 4 launches per cycle, queue grows by 3 veh/cycle

t	Activity	No Vehicles launched	Queue length
Shuffle 90	13, 14, 15, 16 arrive	12	3+7−4 =
" 125	17, 18, 19, 20 "	16	9
" 160	21, 22, 23, 24 "	20	12
" 195	28	24	15
230	32	28	18
265	36	32	21
300	40	36	24
335	44		27
370	48		30
405	52		33
440	56		36
475	60	56	39
510	64	60	41
545	68	64	44

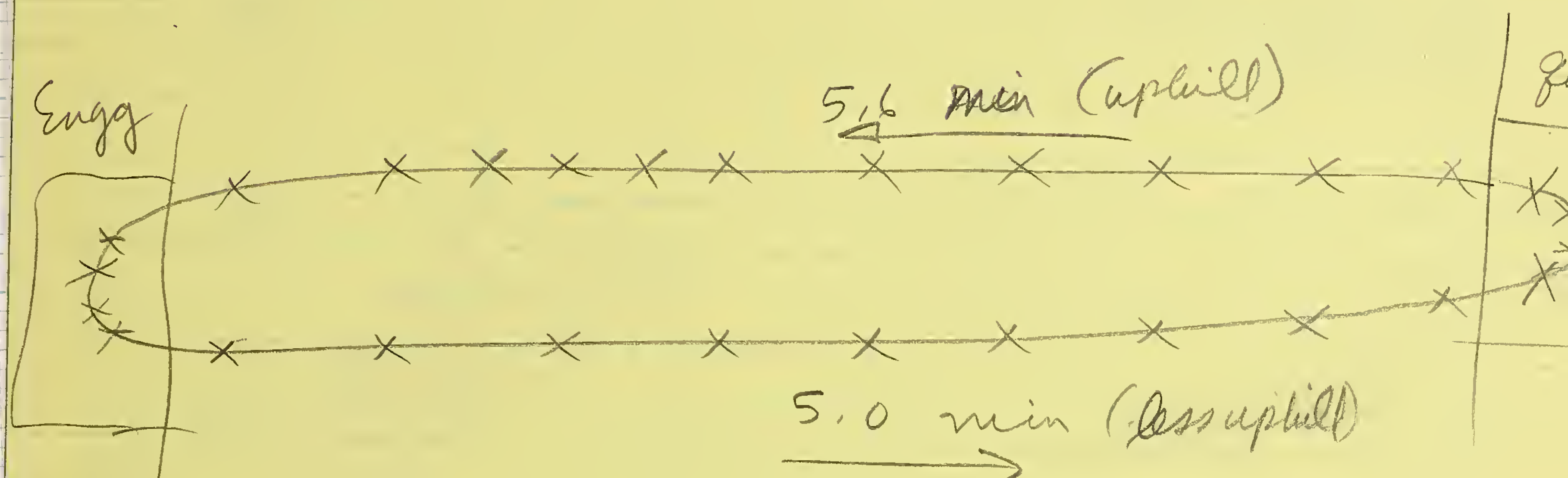
68 launches
× 12
136
680
816 persons launched

only half will arrive by end of 600 sec if 300 sec needed for trip

35
15
105
350
455

30 = 44
22.5 = 33
15 = 22

4.5 second headway = 100 ft. at 15 mi/hr = 2
167 ft at 25 mi/hr = 3



4 cars in station

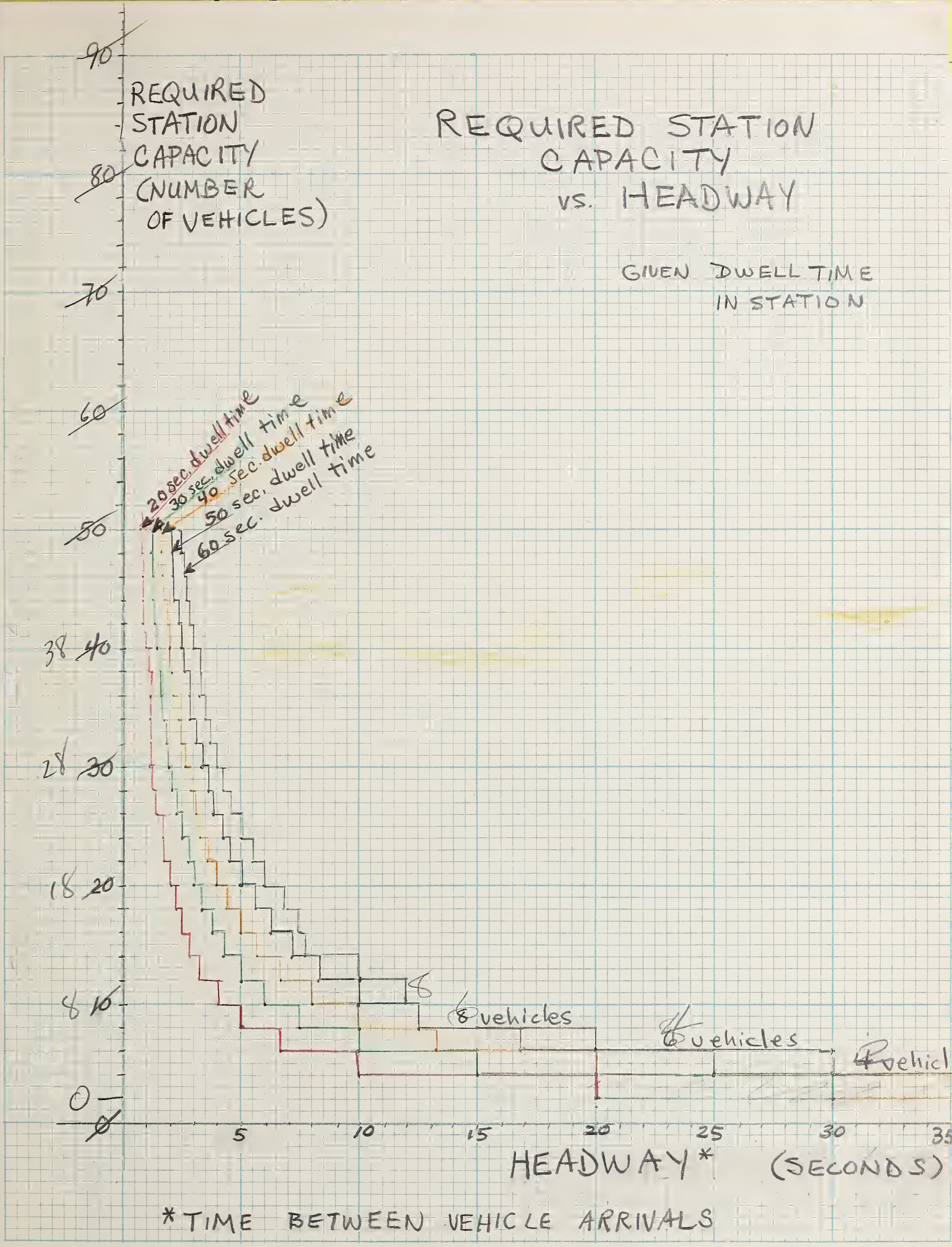
Question - would there be queuing outside engg stati

90 cars
−8 spurs

82 avail. for synchronous operation
12

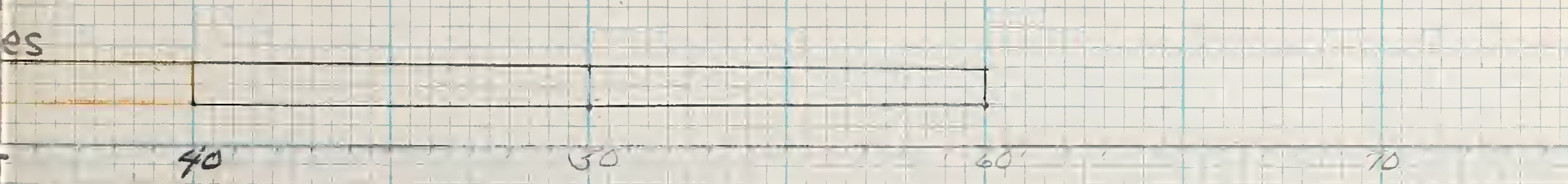
820
164

984 pass. at one time

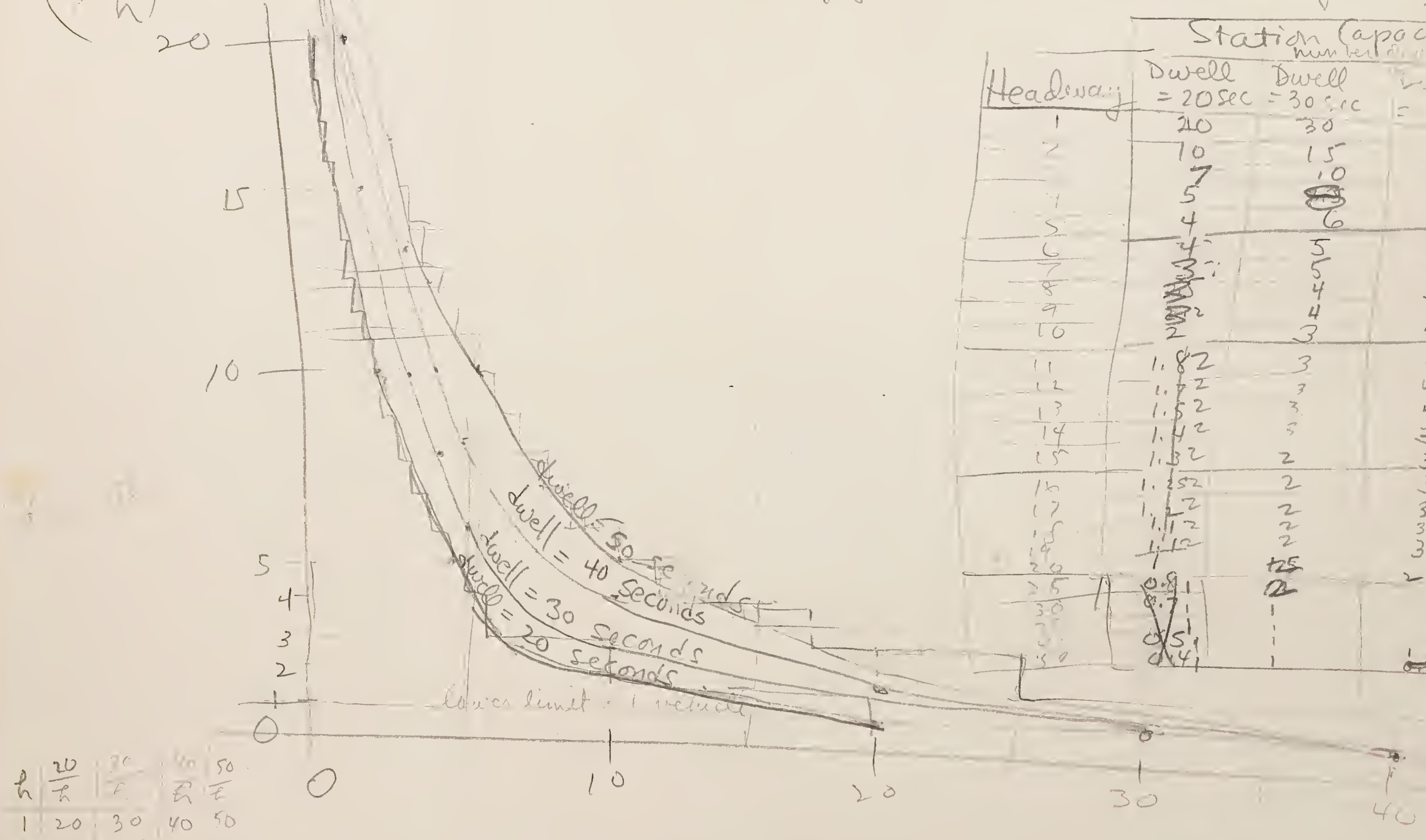


BEE 10x10

BEE 10x10

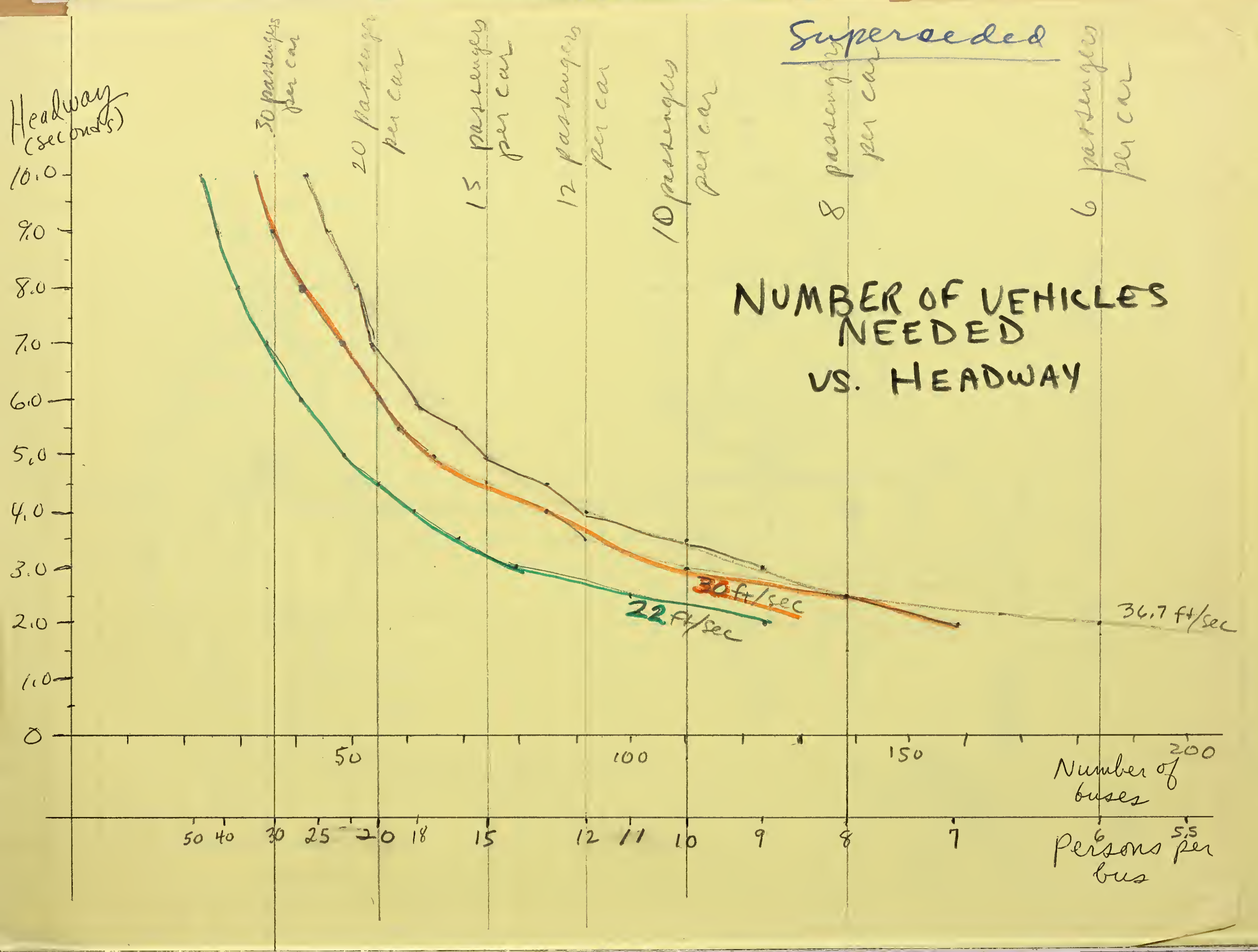

es
40
50
60
70

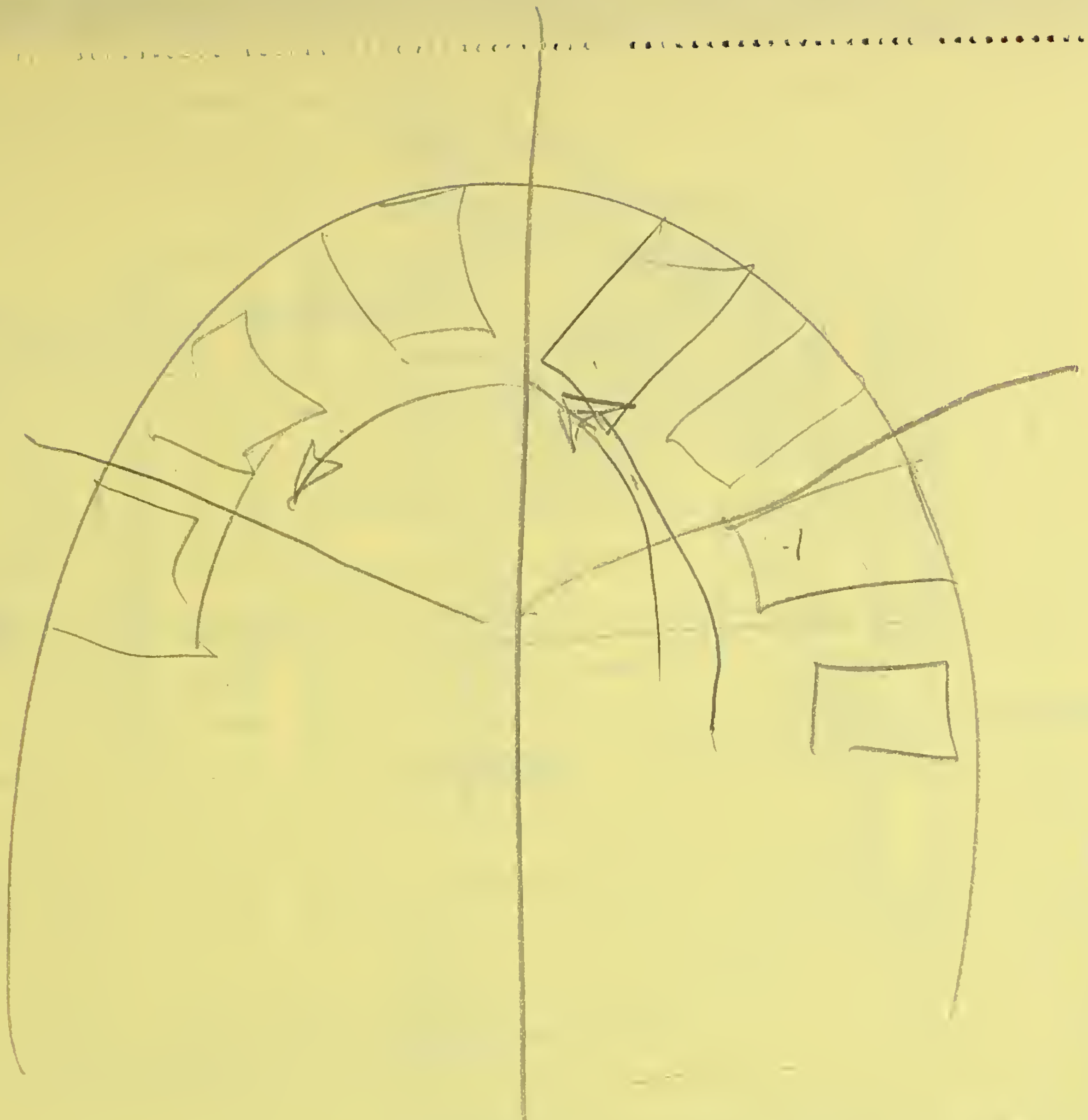
Required station capacities vs. headway for ~~various~~ given dwell-times

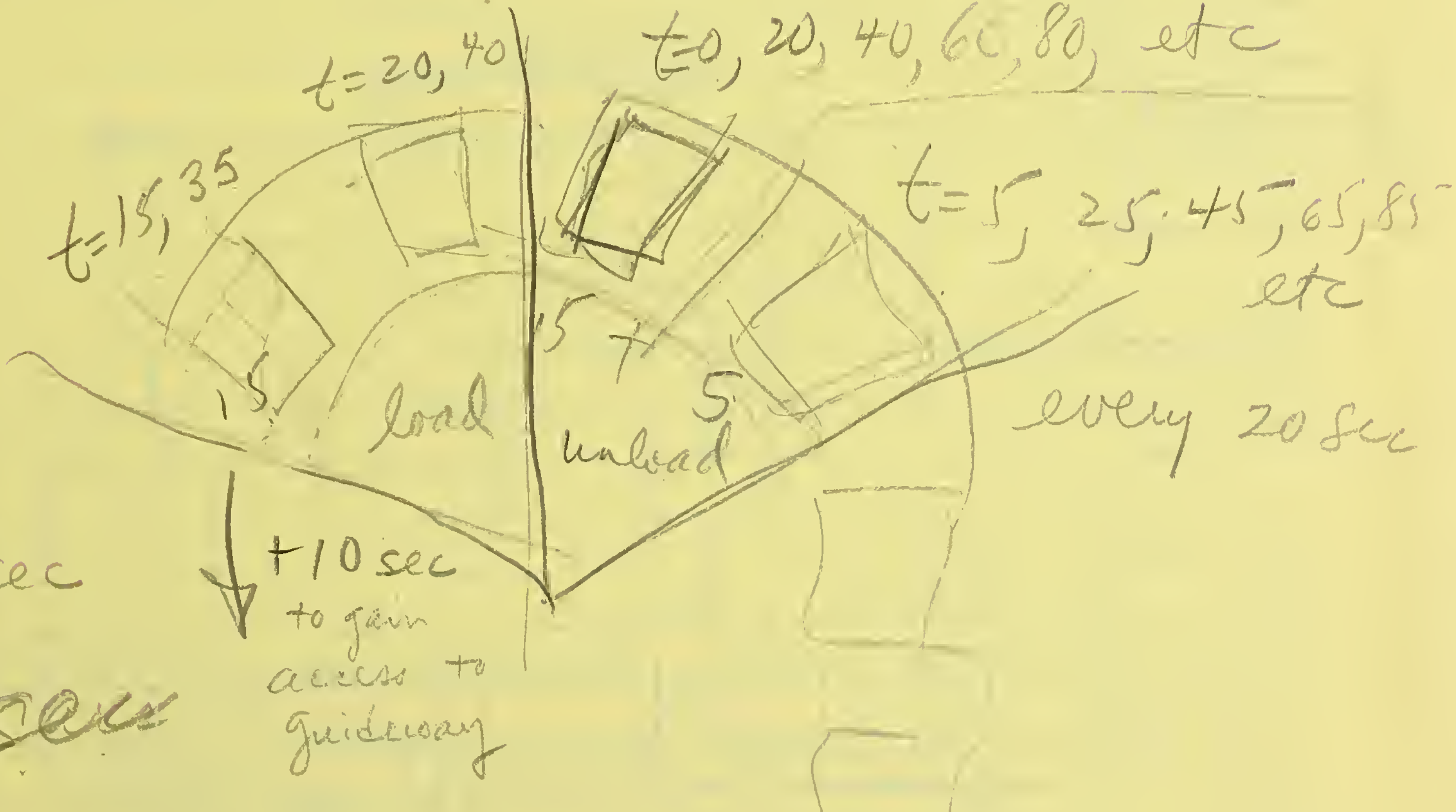


	Station Capacity Required (number of vehicles)			
Headway	Dwell = 20 sec	Dwell = 30 sec	Dwell = 40 sec	Dwell = 50 sec
1	20	30	40	50
2	10	15	20	25
3	7	10	14.3	17.5
4	5	8	10	13.5
5	4	6	8	10
6	4	5	7.7	9.3
7	3	5	6	8
8	3	4	5	7
9	2	4	5	6
10	2	3	4	5
11	1.8 2	3	4	5
12	1.7 2	3	4	5
13	1.5 2	3	4	4
14	1.4 2	3	3	4
15	1.3 2	2	3	4
16	1.25 2	2	3	4
17	1.2 2	2	3	3
18	1.1 2	2	3	3
19	1.1 2		3	3
20	1	1.25 / 2	2	3
25	0.8 1	1	2	2
30	0.7 1	1	2	2
35	0.5 1	1	2	2
40	0.4 1	1	1	1

h	20/h	30/h	40/h	50/h
1	20	30	40	50
2	10	15	20	25
3	6.7	10	13⅓	16⅔
4	5	7½	10	12½
5	4	6	8	10
10	2	3	4	5
20	1	1½	2	2½
30	[illegible]	1	1⅓	1⅔


Superseded
NUMBER OF VEHICLES NEEDED VS. HEADWAY
Headway (seconds)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0
30 passengers per car
20 passengers per car
15 passengers per car
12 passengers per car
10 passengers per car
8 passengers per car
6 passengers per car
22 ft/sec
30 ft/sec
36.7 ft/sec
50
100
150
200
Number of buses
50 40 30 25 20 18 15 12 11 10 9 8 7 6 5.5
Persons per bus

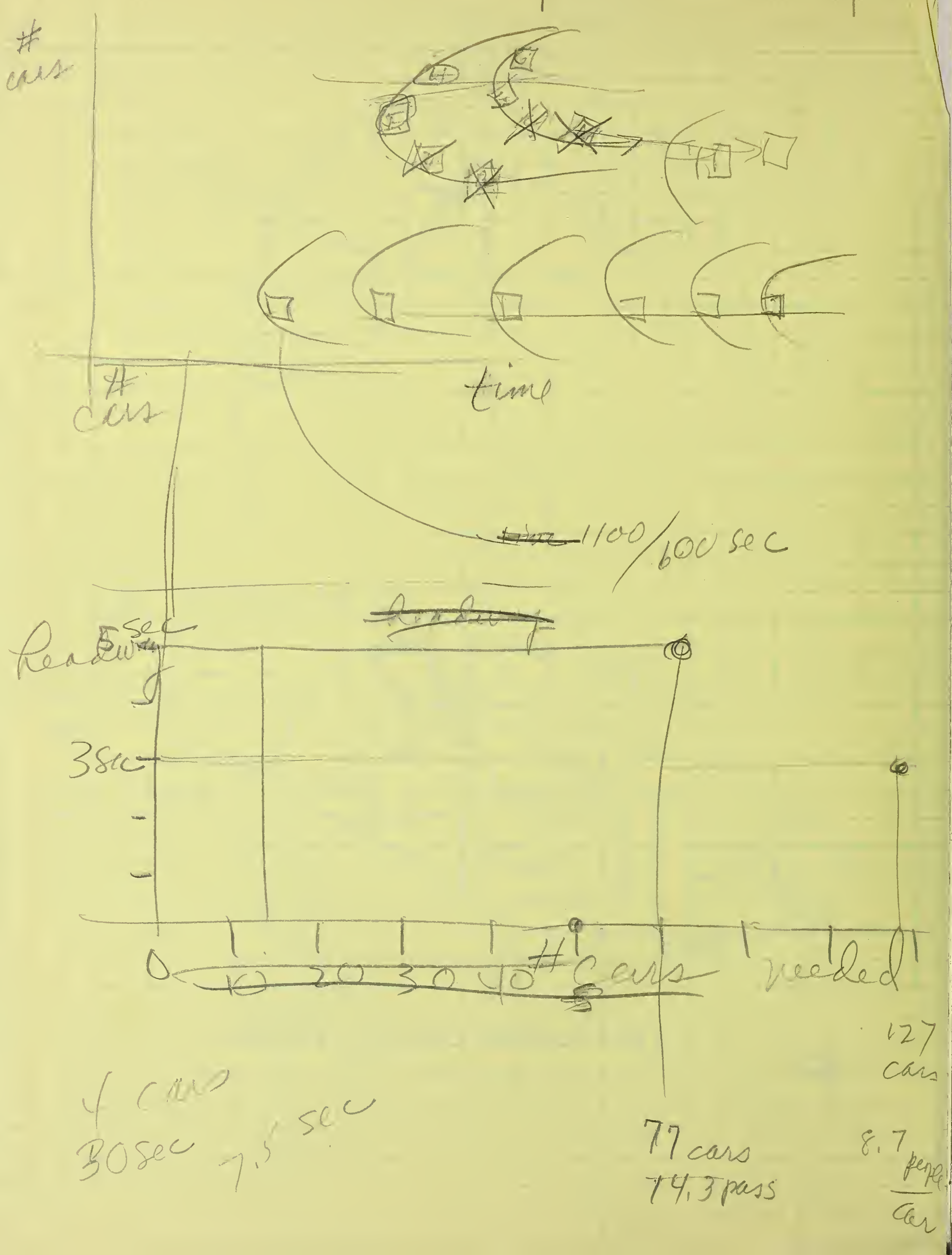




2 cars / 35 sec

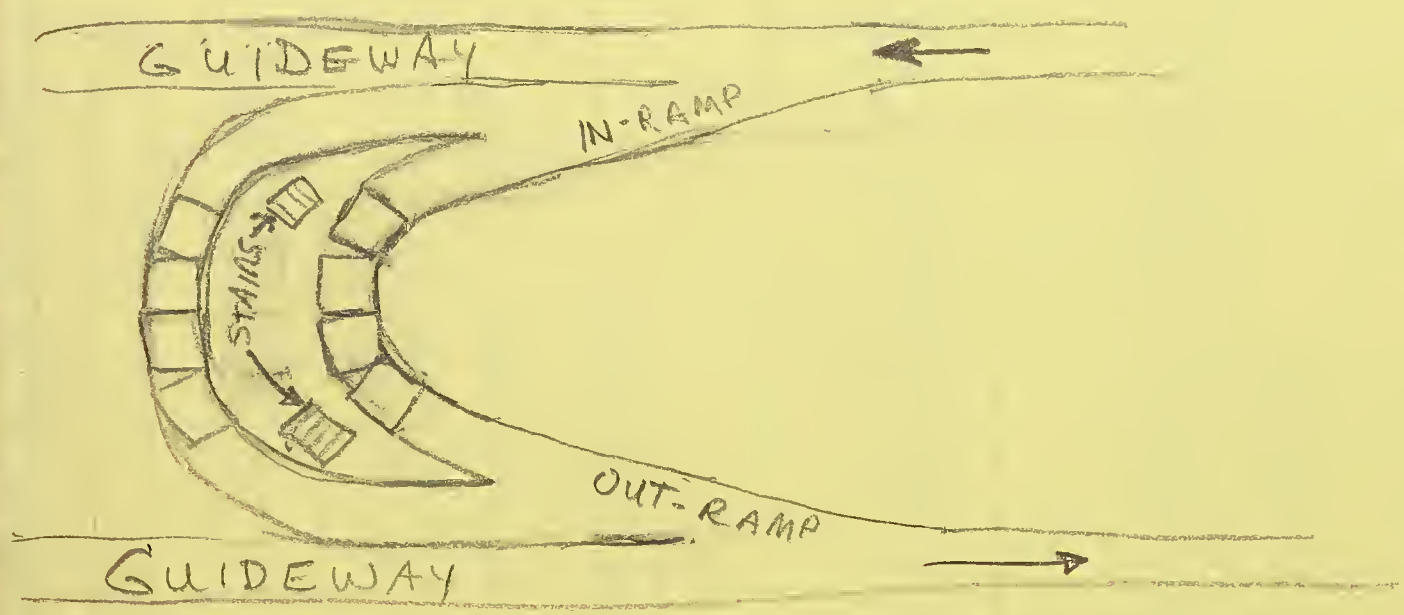
1 car / 15 sec

Total station dwell = 40 sec.



cars
time
cars
1100/600 sec
Readway
5 sec
3 sec
0 10 20 30 40 # cars needed
127 cars
4 cars
30sec
7.5 sec
77 cars
74.3 pass
8.7 people/car

STATION CONFIGURATION FOR FOUR-VEHICLE TRAINS



h_t = headway between trains

d_s = dwell-time in station, including in-ramp and out-ramp

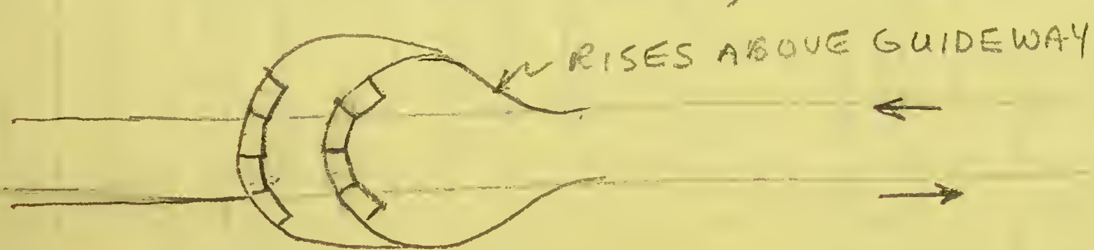
This will service 4-vehicle trains without queuing provided $h_t > \frac{d_s}{2}$.

Delays:

If one train is delayed y seconds, queuing may occur. If headways are maintained by halting oncoming trains, first train and all subsequent trains will be late by y seconds.

If delay is small relative to headway (and following train keeps advancing during delay) only train experiencing delay will be the first one,

OR, MORE LIKELY,



UNITED STATES GOVERNMENT

Memorandum

DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION

DATE: October 15, 1970

In reply refer to:

SUBJECT: Outline: Initial Analysis of Morgantown System Performance

FROM : Henry A. Nejako, Jr. *Henry A. Nejako Jr*

TO : Jim Winn

This is a tentative outline of what I expect to incorporate in our analysis of the Morgantown system. Please review and discuss with us so that we can limit the study to elements you feel would be useful.

I. Summary

A. Factors found to be most significant in determining system performance
B. Design choices apparently in need of re-examination
C. Advantages and limitations of system as presently conceived

II. Present system concept (WVaU proposal)

A. Guideway and stations
B. Vehicles
C. Controls
D. Scheduling and routing
E. Desired system capability (transport 1100 persons in ten-minute peak)

III. Detailed analysis

A. Guideway and stations

1. Headway vs. dwell-time in station
2. Station capacity related to headway and dwell time
3. U-turns vs. through-station routing → Q, E, T will have both.
~~4. Boarding ramps just outside stations for peak periods~~
5. Loops with efficient transfer as alternative
6. Storage of idle vehicles during off-peak periods

B. Vehicles

1. Vehicle capacity vs. expected loads and feasible headways and speeds
2. One-sided access to vehicle and effect on station design
3. Trains of vehicles at peak periods
4. Mixed sizes of vehicles vs. training vs. "optimal" size vehicle

C. Controls

1. If trains are used
2. When can demand-actuated use be tolerated?

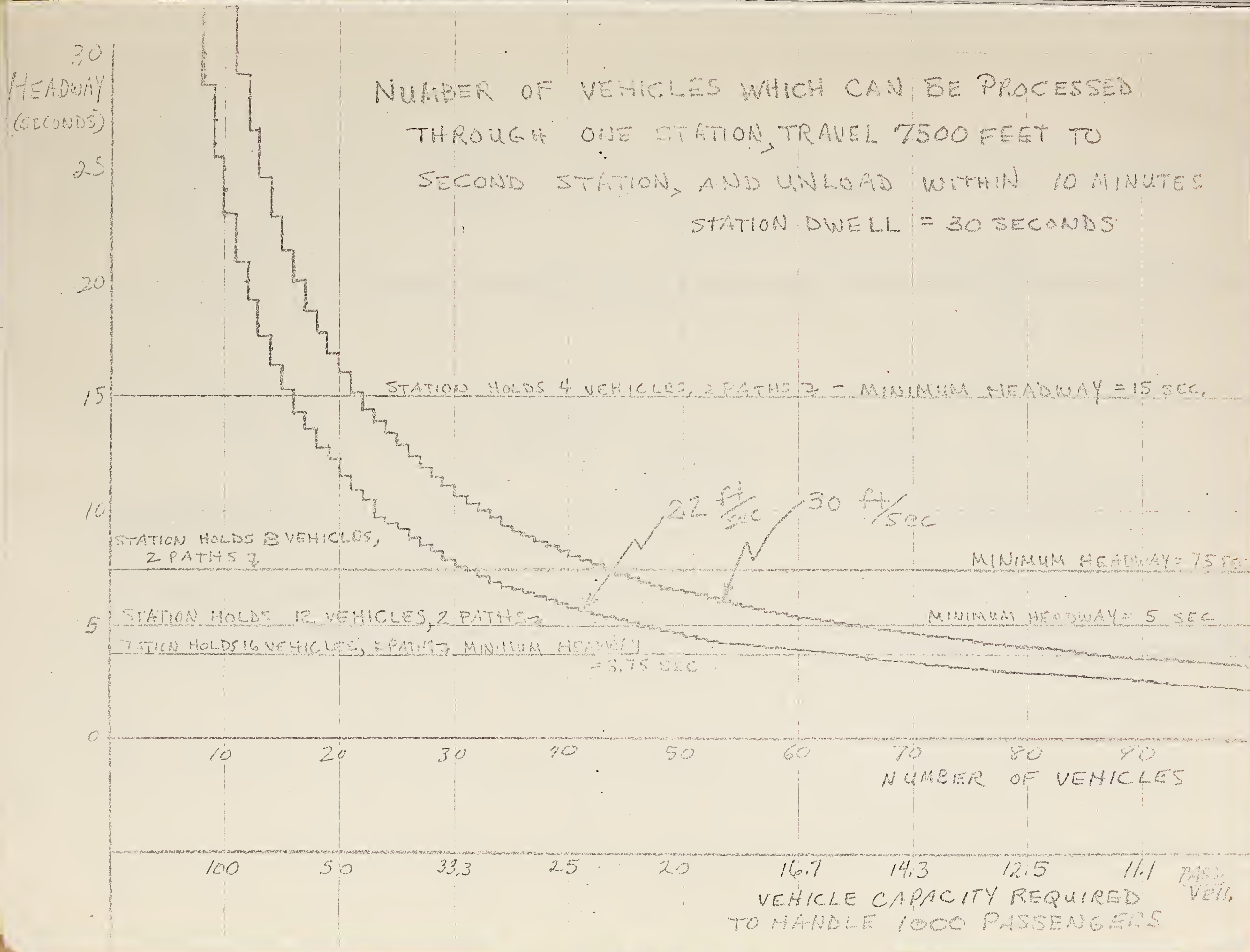
VEHICLE CAPACITY REQUIRED TO HANDLE 1000 PASSENGERS

MODELING

3. Queuing during non-scheduled (demand-actuated) use
4. Individual vehicle "signature" enabling control center to schedule vehicles for peaks

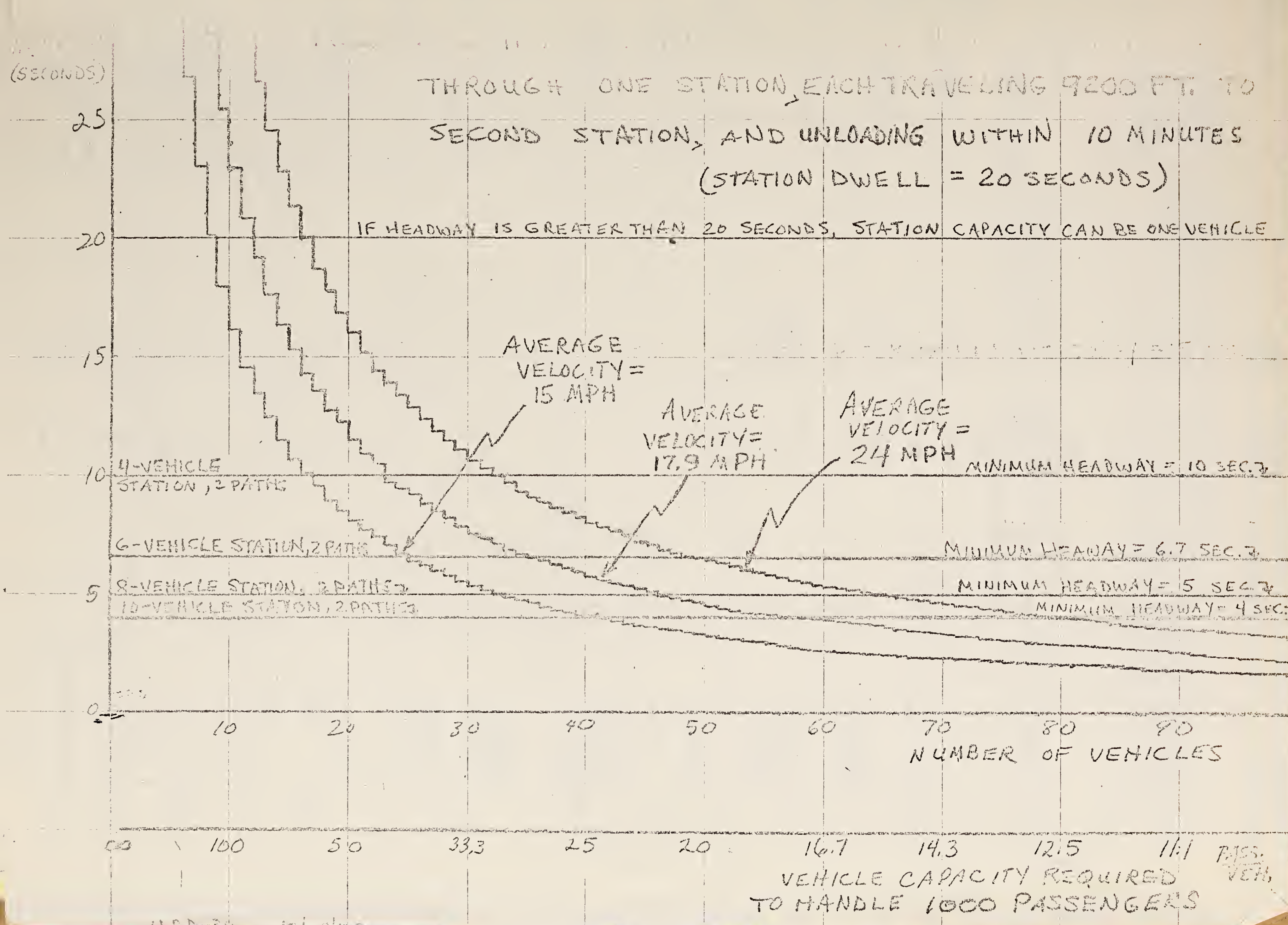
D. Scheduling and routing

1. Capacity of 90 vehicles to move 1100 persons within 10 minutes
2. Headway vs. total number of vehicles needed to move given load (1000 persons) over longest, slowest leg in 10 minutes (also 500 persons)
3. Headway limitations imposed by dwell-time and station capacity
4. Load-carrying implications of using trains of vehicles
5. Expected capability of vehicles to make more than one trip within time limits of class-change (10 minutes)
6. Marshalling empty vehicles prior to each peak such that all stations are adequately serviced
7. Need to operate scheduled service prior to and after class change
8. Determinate (programmed) destinations vs. random user choice and impact on efficiency of vehicle utilization
9. Queuing
   a. Designing for no queuing outside stations
   b. Permissible queuing on guideway and in stations
   c. Queuing impact of random perturbations (stalled car, delay in loading)
   d. Impact of random perturbations on schedule adherence (Can some slack be designed into system or is efficiency penalty too great?)
10. Dynamics of change-overs from scheduled to demand-actuated service (and vice versa)



MORGANTOWN MODELLING

THINGS TO DO



MORGANTOWN MODELING

THINGS TO DO

D = ~~9200~~ D 9200 _ 4101 sec - 450 / 439 / 161

THINGS TO DO

MORGANTOWN

"Snapshots" are taken 99, 159 and 219 seconds after first vehicle (A) arrives. Vehicles arrive every 5 seconds in order ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijkl.... Vehicles spend 36 seconds inside station (dwell-time), including 13 seconds unloading, 13 seconds loading, 10 seconds in guideway ramp awaiting null, and departing.

"SNAPSHOT" STATION Ramp	Outside Station: Approaching on Guideway	Outside Station: Queued	Inside Station: Unloading	Inside Station: Loading	Inside Station: Queued	On Ramp	Departed (Total)
One Path:							
t=99 TSRQ PONMLKJ I →	U	TSRQ (4)		P	ONMLKJ	I	HGFEDCBA (8)
t=159 fedcbaZY XWVUTSRQ →	g	fedcbaZY (8)	XWVUTSRQ				HGFEDCBA (16) PONMLKJI
t=219 nmlkjihg opqr fedcbaZY →	s	rqponmlkjihg (12)	fedcbaZY				HGFEDCBA (24) PONMLKJI XWVUTSRQ
Two Paths:							
t=99 → TSRQ / PO N	U	—	TS	RQ P	~~P~~O	N	HGFEDCBA MLKJI (13)
t=159 → fedcba Z	g	—	fe	dcb	a	Z	XVWUTSRQ HGFEDCBA Y PONMLKJI (25)
t=219 → nm / rqpo l →	s	—	rq	n po	m	l	kjihg XVWVUTSR HGFEDCBA fedcbaZY PONMLKJI (37)
Three paths:							
t=99 → QPO / TSR N →	U	—	TS	QP R	O	N	MLK CBA FED JIHG (13)
t=159 → f / a / edcb Z →	g	—	f e	dcb	a	Z	XWVU MLK CBA Y QPON FED (25) TSR JIHG
t=219 → rqp / l / onm →	s	—	rq	p on	m	l	hgf XWVU MLK CBA kji aZY QPON FED (37) edcb TSR JIHG

If 8700 ft between 2 + 5, speeds become

$\frac{9200}{8700} =$

14.2
16.9
22.9

mph

$\frac{8700 \text{ ft}}{x \frac{\text{ft}}{\text{sec}}}$

$t = \frac{9200}{32} = \frac{8700}{x}$

$x = \frac{87}{92} 32 = 20.8$

600 sec

$-((n-1)h + u+l) = \frac{d}{v}$

$\frac{20.8 \text{ ftps}}{22 \text{ fps}}$ 15 mph

9200

419 sec

14.2 mph

439
20

30 ft/sec

250 sec travel
30 sec dwell

26.2 fps
24.8 fps

or 260 sec travel
20 sec dwell

$\frac{d}{v} = \frac{9200}{341} = \frac{8700}{x}$

$x = \frac{87}{92} \cdot 27 =$

16.9 mph

$h = 3.5$ sec

$n = 92$ veh

$(n-1)h = 319$

$u+l = 20$

339

$\frac{d}{v} = 261$

320
20
340

$\frac{d}{v} = 260$

$\frac{9200}{260 \text{ sec}}$

$\frac{8700}{v} = 260$

$v = \frac{8700}{260} \frac{\text{ft}}{\text{sec}} = 33.5 \frac{\text{ft}}{\text{sec}}$

$\frac{33.5}{22} = \frac{x}{15}$

$x = 22.9$ mph

$D = 9200$ $\quad \frac{D}{v} = \frac{9200}{22} = 418.2$ sec $\quad$ $600 - 439 = 161$

$v = 15$ mph $= 22$ ft/sec

$d = 20$ sec $\quad$ 1st car is available for loading at $t = 0$.

$\frac{D}{v} + d$	h	n	$(n-1)h$	$t_{total} = \frac{D}{v} + d + (n-1)h$
438.2→439	1.0	162	161	439 + 161 = 600
	1.5	108	107	600
	2.0	81	160	599
	2.5	65	160	599
	3.0	54	159	598
	3.5	47	161	600
	4.0	41	160	599
	4.5	36	158	597
	5.0	33	160	599
	5.5	30	160	599
	6.0	27	156	595
	7.	24	161	600
	8	21	160	599
	9	18	153	592
	10	17	160	599
	11	15	154	593
	12	14	156	595
	13	13	156	595
	14	12	154	593
	15	11	150	589
	16	11	160	599
	17	10	153	592
	18	9	144	583
	19	9	152	591
	20	9	160	599
	21	8	147	586
	22	8	154	593
	23	8	161	600
	24	7	144	583
	25	7	150	589
	26	7	156	595
	27	6	135	574
	28	6	140	579
	29	6	145	584
	30	6	150	589
	35	4	135	574
	40	5	160	599

X	$\frac{161}{X}$
33	4.88
34	4.73
35	4.60
36	4.47
37	4.35
38	4.24
39	4.13
40	4.02
41	3.93
42	3.83
43	3.75
44	3.66
45	3.58
46	3.50
47	3.43
48	3.36
49	3.29
50	3.22
55	2.93
60	2.68
65	2.48
70	2.30
75	2.15
80	2.01
85	1.90
90	1.79
95	1.70
100	1.61
125	1.29
150	1.07
161	1.00

X	$\frac{161}{X}$
1	161
1.5	107+
2.0	$80\frac{1}{2}$
2.5	64.4
3.0	$53\frac{2}{3}$
3.5	46
4.0	$40\frac{1}{4}$
4.5	35.8
5.0	$32\frac{1}{5}$
5.5	29.3
6.0	$26\frac{5}{6}$
7.0	23
8	$20\frac{1}{8}$
9	$17\frac{8}{9}$
10	16.1
11	14.6
12	13.4
13	12.4
14	11.5
15	10.7
16	$10\frac{1}{16}$
17	9.48
18	8.95
19	8.48
20	8.05
21	7.67
22	7.32
23	7.00
24	6.72
25	6.44
26	6.19
27	5.97
28	5.75
29	5.56
30	5.37
31	5.19
32	5.03

THINGS TO DO

MORGANTOWN

$\overline{229}$ Sec

7500 371 Sec

371 = 30 + 341

20 + 351

280 = 250 + 30

260 + 20

Headway Needed to Process GIVEN NUMBER of VEHICLES

Number of Vehicles which can load at one Station, Travel 7500 feet to a second station and Unload within a ten-minute period

total processing time = $\frac{D}{v} + d + (n-1)h$

where $D = 7500$ ft

v = velocity in ft/sec

d = station dwell-time

n = total vehicles processed

h = headway in seconds

For $v = 15$ mph = 22 ft/sec, $\frac{D}{v} = 341$ seconds

Let $d = 30$ seconds. Then $\frac{D}{v} + d = 371$ seconds

$\frac{D}{v} + d$	h	n	$(n-1)h$	$t = \frac{D}{v} + d + (n-1)h$	n such that $t \to 600$ sec
371	1.0	2	1	372	
		8	7	378	600 − 371 = 229
		230	229	600	229
371	1.5	154	230	602	
		153	228	601	153
		152	227	599	
371	2.0	114	228	599	114
371	2.5	92	228	599	92
371	3.0	77	228	599	77
	3.5	66	228	599	66
	4.0	58	228	599	58
	4.5	51	225	596	51
	5.0	46	225	596	46
	5.5	42	226	597	42
	6.0	39	228	599	39
	7.0	33	224	595	33
	8.0	29	224	595	29
	9.0	26	225	596	26
	10.0	23	220	591	23
	11.0	21	220	591	21
	12.0	20	228	599	20
	13.0	18	221	592	18
	14.0	17	224	595	17
	15.0	16	225	596	16
	16.0	15	224	595	15
	17.0	14	221	592	14

$V = 15$ mph $= 22 \frac{ft}{sec}$ $D = 7500$ ft $\frac{D}{v} = 341$ sec

$d = 30$ sec $\frac{D}{v} + d = 371$ seconds

$\frac{D}{v} + d$	h	n	$(n-1)h$	$t = \frac{D}{v} + d + (n-1)h$	n such that $t \to 600$
371	18.0	13	216	587	13
	19.0	13	228	599	13
	20.0	12	220	591	12
	21.0	11	210	581	11
	22.0	11	220	591	11
	23.0	10	207	578	10
	24.0	10	216	587	10
	25.0	10	225	596	10
	30.0	8	210	581	8
	35.0	7	210	581	7
	40.0	6	200	571	6
	45.0	6	225	596	6
	50.0	5	200	571	5
	55.0	5	220	591	5
	60.0	4	180	551	4

$V = 30 \frac{ft}{sec} = 20.45$ mph $\frac{7500}{v} = 250$ sec $\frac{D}{v} + d = 280$ sec

$\frac{D}{v} + d$	h	n	$(n-1)h$	t	n such that $t \to 600$
280	1.0	321	320	600	321
	1.5	214	320	600	214
	2.0	161	320	600	161
	2.5	129	320	600	129
	3.0	107	318	598	107
	3.5	92	319	599	92
	4.0	81	320	600	81
	4.5	72	320	600	72
	5.0	65	320	600	65
	5.5	59	319	599	59
	6.0	54	318	598	54
	7	46	315	595	46
	8	41	320	600	41
	9	36	315	595	36
	10	33	320	600	33
	11	30	319	599	30
	12	27	312	592	27
	13	25	312	592	25
	14	23	308	588	23
	15	22	315	595	22
	16	21	320	600	21
	17	19	306	586	19

THINGS TO DO

MORGANTOWN

$v = 30$ ft/sec $D/v = 250$ sec $d = 30$ sec $\frac{D}{v} + d = 280$ sec

$\frac{D}{v} + d$	h	n	$(n-1)h$	$\frac{D}{v} + d + (n-1)h$
280	18	18	306	586
	19	17	304	584
	20	17	320	600
	21	16	315	595
	22	15	308	588
	23	14	299	579
	24	14	312	592
	25	13	300	580
	30	11	300	580
	35	10	315	595
	40	9	320	600
	45	8	315	595
	50	7	300	580
	55	6	275	555
	60	6	300	580
280	26	13	312	592
	27	12	297	577
	28	12	308	588
	29	12	319	599
371	26	9	208	579
	27	9	216	587
	28	9	224	595
	29	8	203	574

8) 229 = 28 5/8
16
69
64

10 − 11
8 − 9

9) 229 = 25.4 (22.9)
18
49
45
40

11) 229 = 20.8
22

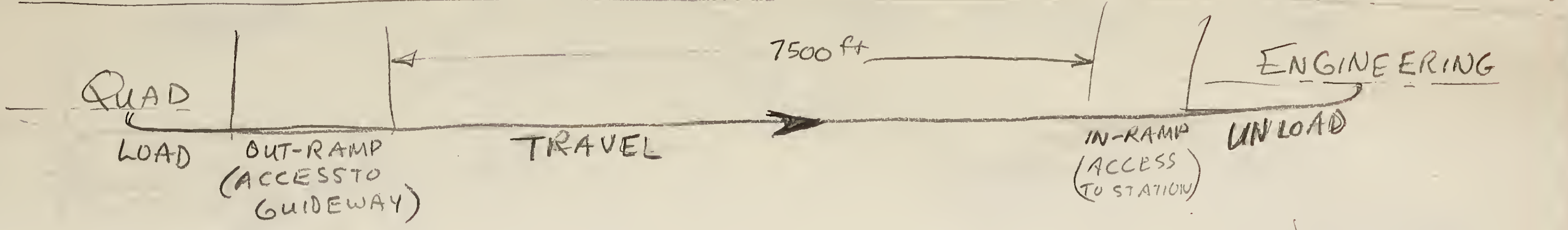
7) 229

THINGS TO DO

MORGANTOWN MODELLING

TRANSFER TIME QUAD →

DERIVATION OF CLASS-CHANGE TRANSFER TIME, QUAD → ENGINEERING



1st vehicle		nth vehicle
LOAD = 15 sec	=	LOAD
OUT-RAMP = 10 sec	=	OUT-RAMP
TRAVEL = $\frac{7500 \text{ ft}}{v \text{ ft/sec}}$	=	TRAVEL
IN-RAMP = negligible (no queuing)	=	IN-RAMP
UNLOAD = 15 sec	=	UNLOAD (LAUNCH OCCURS $(n-1)h$ SECONDS LATER)

2nd vehicle

SAME VALUES, EXCEPT THAT LAUNCH OCCURS h SECONDS LATER.

3rd vehicle

LAUNCH OCCURS $2h$ SECONDS LATER

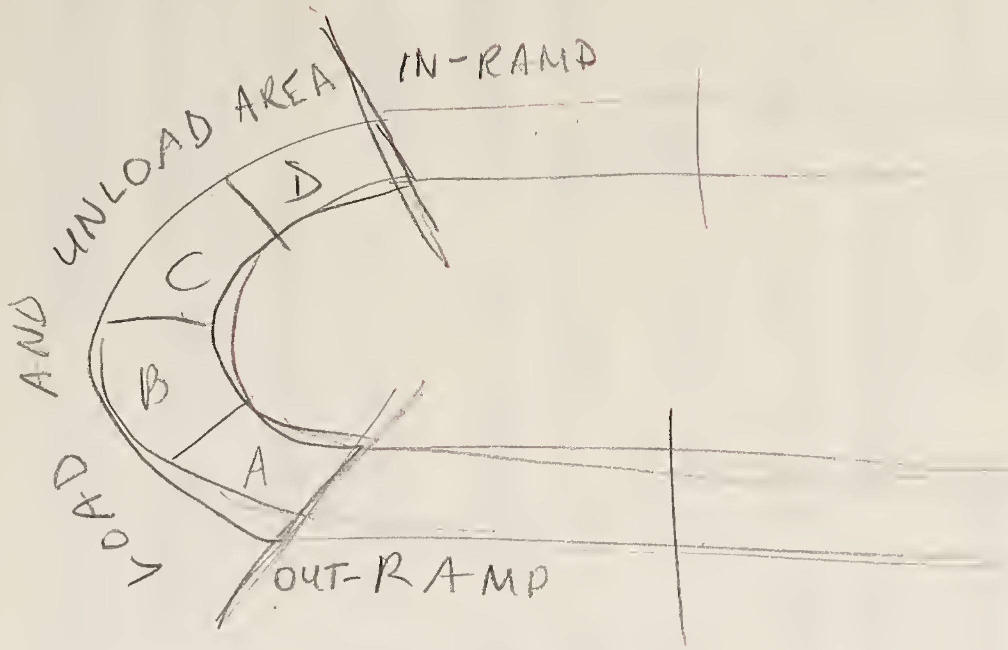
time	Activity
0	LOAD 1st vehicle
15	MOVE TO OFF RAMP
25	LAUNCH 1st vehicle
$25+h$	LAUNCH 2nd vehicle
$25+2h$	LAUNCH 3rd vehicle
⋮	⋮
$25+(n-1)h$	LAUNCH nth vehicle
$25+(n-1)h+\frac{7500}{v}$	nth vehicle arrives at IN-RAMP
$25+(n-1)h+\frac{7500}{v}+15$	nth vehicle unloaded
$= 40+(n-1)h+\frac{7500}{v}$	Total transfer time for n vehicles

NOTE: If p = capacity of each vehicle, total passengers carried (max.) $= np$

MORGANTOWN MODELLING

THINGS TO DO

TRAIN OF m vehicles, loaded, launched, unloaded simultaneously



1st TRAIN

LOAD = 15 SEC

OUT-RAMP = 10 SEC

TRAVEL = $\frac{7500}{v}$

IN-RAMP = NEGLIGIBLE (NO QUEUEING)

UNLOAD = 15 SEC

(ALL TIMES WOULD PROBABLY INCREASE SLIGHTLY FOR LONGER TRAINS, EXCEPT TRAVEL TIME)

2ND TRAIN

SAME TIME NEEDED, BUT LAUNCH OCCURS h_t SECONDS LATER

n^{th} TRAIN

LAUNCH OCCURS $(n-1)\, h_t$ SECONDS LATER

FOUR-CAR TRAINS

(ASSUMING NO QUEUEING AT DESTINATION'S IN-RAMP)

t	ACTIVITY
0	LOAD 1st TRAIN
15	MOVE TO OUT-RAMP
25	LAUNCH 1ST VEHICLE
$25 + \frac{7500\,ft}{v}$	REACH IN-RAMP AT DESTINATION
$25+\frac{7500}{v}+15$	UNLOADING COMPLETE FOR 1ST TRAIN
⋮	⋮
$25+(n-1)h_t$	LAUNCH n^{th} TRAIN
$25+(n-1)h_t + \frac{7500}{v}$	n^{th} TRAIN REACHES DESTINATION'S IN-RAMP
$25+(n-1)h_t + \frac{7500}{v}+15$	n^{th} TRAIN UNLOADED, CLASS-CHANGE TRANSFER COMPLETE

NOTE: If p = passengers per vehicle, total load (max.) = $m\,n\,p$

THINGS TO DO

MORGANTOWN MODELING

STORAGE OF VEHICLES

SINCE A LARGE NUMBER OF EMPTY VEHICLES IS NEEDED AT QUADRANGE FOR THE PEAK PERIOD, THEY SHOULD BE DISPATCHED FROM STORAGE SO AS TO ARRIVE AT QUADRANGLE EXACTLY AS NEEDED. IF STORAGE IS LOCATED CLOSE TO QUADRANGLE, IT WILL BE POSSIBLE TO ADJUST TO UNFORESEEN DELAYS AT QUADRANGLE BY WITHHOLDING VEHICLES WHICH WOULD OTHERWISE BEGIN TO QUEUE OUTSIDE THE QUADRANGLE STATION. IF THE STORAGE IS LOCATED TOO FAR AWAY, THE DECISION TO LAUNCH AN EMPTY VEHICLE TO QUADRANGLE MUST BE MADE TOO FAR IN ADVANCE OF THE VEHICLE'S ARRIVAL TO PERMIT ADJUSTMENTS. ALSO, IF THE STORAGE IS LOCATED BETWEEN ENGINEERING AND QUAD., ADJUSTMENTS COULD BE MADE FOR VEHICLES DESTINED FOR QUAD. WHICH WERE LAUNCHED FROM ENGINEERING JUST BEFORE CLASS-CHANGE (THESE ARE THE ONLY OCCUPIED VEHICLES WHICH CAN BE UNLOADED AND RELOADED AT QUAD DURING CLASS-CHANGE)

MORGANTOWN SYSTEM CONCEPT

Guideway and Stations

6 stations connected by 32,100 feet of guideway

- Morgantown CBD (C) - end-of-line loop
- Quadrangle (Q) - loop plus through passage
- Engineering (E) - loop plus through passage
- Field House (F) - end-of-line loop
- Towers (T) - loop plus through passage
- Medical Center (M) - end-of-line loop

All stations except M have 50-ft platforms and will hold 4 cars, combining load and unload operations

Station M is on spur (C was proposed for spur but UMTA has decided it should be integral part of system)

Full interchange between E and T stations connecting each to F.

Double-track synchronous operation; third-rail power distribution

Vehicles

Each vehicle holds 12 seated passengers (no standees)

Vehicles operate independently (no trains) and are self-~~powered~~ propelled by electric motors

Initial complement of 90 vehicles to handle approximately 1100 persons during ten-minute class-change peak

Controls

Vehicles are in individual contact with central control computer

Vehicles follow electronic null around guideway, adjusting speeds as needed

Communications system built into guideway(and vehicle contact to third rail?)

Scheduling and Routing

Scheduled (fixed destination for each car) service during class-change peaks, demand-actuated service during off-peak periods

Storage of idle cars during off-peak periods in car-barn

Two speeds forward: 25 mph for straightaway and 15 mph for turns and grades.

4.5-second headways between cars (capable of being reduced to 2.45 seconds later)

40-second station dwell (15 sec unload,15 sec load, 5.4 sec transfer to launch position and 4.5 seconds to accelerate to 15 mph)

CONSECUTIVE TRIPS BETWEEN STATIONS - ELAPSED TIME

Stations: 1: County Court House — 4: Coliseum
2: Quadrangle — 5: Towers
3: Evansdale Engineering — 6: Medical Center

First Trip Origin	First Trip Destination	First Trip Time (min.)	Second Trip Destination	Second Trip Time (min.)	Combined Trip Time (min.)	Remarks	Leg-by-leg Demand
1	1	---	1	---	---		
			2	2.3	2.3		
			3	8.3	8.3		
			4	9.5	9.5		
			5	9.0	9.0		
			6	12.4*	12.4*		
	2	2.3	1	2.3	4.6	Feasible	0 – 0
			2	---	2.3		—
			3	5.6	7.9	Feasible	0 – 10
			4	6.8	9.1	Feasible	0 – 2
			5	6.3	8.6	Feasible	0 – 13
			6	9.7	12.0*		—
	3	8.3	1	8.3	16.6*		3 – 0
			2	5.0	13.3*		3 – 3
			3	---	8.3		—
			4	2.2	10.5*		3 – 0
			5	1.7	10.0*		3 – 0
			6	5.1	13.4*		—
	4	9.5	1	9.5	17.0*		1 – 4
			2	6.2	15.7*		1 – 2
			3	2.2	11.7*		1 – 1
			4	---	9.5		—
			5	2.6	12.1*		1 – 0
			6	6.0	15.5*		—
	5	9.0	1	9.1	18.1*		5 – 3
			2	5.8	14.8*		5 – 45
			3	1.7	10.7*		5 – 4
			4	2.6	11.6*		5 – 2
			5	---	9.0		—
			6	2.4	11.4*		—
	6	12.4*	1	11.9*	24.3*		X
			2	8.6	21.0*		
			3	4.5	16.9*		
			4	5.4	17.8*		
			5	2.4	14.8*		
			6	---	12.4*		

*Trip cannot be completed within ten-minute time constraint.

First Trip Origin	First Trip Destin- ation	First Trip Time (min.)	Second Trip Destin- ation	Second Trip Time (min.)	Combined Trip Time (min.)	Remarks
2	1	2.3	1	---	2.3	
			2	2.3	4.6	Feasible
			3	8.3	10.6*	
			4	9.5	11.7*	
			5	9.0	11.3*	
			6	12.4	14.7*	
	2	---	1	2.3	2.3	
			2	---	---	
			3	5.6	5.6	
			4	6.8	6.8	
			5	6.3	6.3	
			6	9.7	9.7	
	3	5.6	1	8.3	13.9*	
			2	5.0	10.6*	
			3	---	5.6	
			4	2.2	7.8	Feasible
			5	1.7	7.3	Feasible
			6	5.1	10.7*	
	4	6.8	1	9.5	16.3*	
			2	6.2	13.0*	
			3	2.2	9.0	Feasible
			4	---	6.8	
			5	2.6	9.4	Feasible
			6	6.0	12.8*	
	5	6.3	1	9.1	15.4*	
			2	5.8	12.1*	
			3	1.7	8.0	Feasible
			4	2.6	8.9	Feasible
			5	---	6.3	
			6	2.4	8.7	Feasible
	6	9.7	1	11.9*	21.6*	
			2	8.6	18.3*	
			3	4.5	14.2*	
			4	5.4	15.1*	
			5	2.4	12.1*	
			6	---	9.7	

First Trip Origin	First Trip Destination	First Trip Time (min)	Second Trip Destination	Second Trip Time (min)	Combined Trip Time (min)	Remarks
3	1	8.3	1	---	8.3	
			2	2.3	10.6*	
			3	8.3	16.6*	
			4	9.5	17.8*	
			5	9.0	17.3*	
			6	12.4*	20.7*	
	2	5.0	1	2.3	7.3	Feasible
			2	---	5.0	
			3	5.6	10.6*	
			4	6.8	11.8*	
			5	6.3	11.3*	
			6	9.7	14.7*	
	3	---	1	8.3	8.3	
			2	5.0	5.0	
			3	---	----	
			4	2.2	2.2	
			5	1.7	1.7	
			6	5.1	5.1	
	4	2.2	1	9.5	11.7	
			2	6.2	8.4	Feasible
			3	2.2	4.4	Feasible
			4	---	2.2	
			5	2.6	4.8	Feasible
			6	6.0	8.2	Feasible
	5	1.7	1	9.1	10.8*	
			2	5.8	7.5	Feasible
			3	1.7	3.4	Feasible
			4	2.6	4.3	Feasible
			5	---	1.7	
			6	2.4	4.1	Feasible
	6	5.1	1	11.9*	16.0*	
			2	8.6	13.7*	
			3	4.5	9.6	Feasible
			4	5.4	10.5*	
			5	2.4	7.5	Feasible
			6	---	5.1	

First Trip Origin	First Trip Destination	First Trip Time (min)	Second Trip Destination	Second Trip Time (min)	Combined Trip Time (min)	Remarks
4	1	9.5	1	---	9.5	
			2	2.3	11.8*	
			3	8.3	17.8*	
			4	9.5	19.0*	
			5	9.0	18.5*	
			6	12.4*	21.9*	
	2	6.2	1	2.3	8.5	Feasible
			2	---	6.2	
			3	5.6	11.8*	
			4	6.8	13.0*	
			5	6.3	12.5*	
			6	9.7	15.9*	
	3	2.2	1	8.3	10.5*	
			2	5.0	7.2	Feasible
			3	---	2.2	
			4	2.2	4.4	Feasible
			5	1.7	3.9	Feasible
			6	5.1	7.3	Feasible
	4	---	1	9.5	9.5	
			2	6.2	6.2	
			3	2.2	2.2	
			4	---	---	
			5	2.6	2.6	
			6	6.0	6.0	
	5	2.6	1	9.1	11.7*	
			2	5.8	8.4	Feasible
			3	1.7	4.3	Feasible
			4	2.6	5.2	Feasible
			5	---	2.6	
			6	2.4	5.0	Feasible
	6	6.0	1	11.9*	17.9*	
			2	8.6	14.6*	
			3	4.5	10.5*	
			4	5.4	11.4*	
			5	2.4	8.4	Feasible
			6	---	6.0	

[illegible]

First Trip Origin	First Trip Destination	First Trip Time (min)	Second Trip Destination	Second Trip Time (min)	Combined Trip Time (min)	Remarks
5	1	9.1	1	---	9.1	
			2	2.3	11.4*	
			3	8.3	17.4*	
			4	9.5	18.6*	
			5	9.0	18.1*	
			6	12.4	21.5*	
	2	5.8	1	2.3	9.1	Feasible
			2	---	5.8	
			3	5.6	11.4*	
			4	6.8	12.6*	
			5	6.3	12.1*	
			6	9.7	15.5*	
	3	1.7	1	8.3	10.0	Feasible
			2	5.0	6.7	Feasible
			3	---	1.7	
			4	2.2	3.9	Feasible
			5	1.7	3.4	Feasible
			6	5.1	6.8	Feasible
	4	2.6	1	9.5	12.1*	
			2	6.2	8.8	Feasible
			3	2.2	4.8	Feasible
			4	---	2.6	
			5	2.6	5.2	Feasible
			6	6.0	8.6	Feasible
	5	---	1	9.1	9.1	
			2	5.8	5.8	
			3	1.7	1.7	
			4	2.6	2.6	
			5	---	---	
			6	2.4	2.4	
	6	2.4	1	11.9*	14.3*	
			2	8.6	11.0*	
			3	4.5	6.9	Feasible
			4	5.4	7.8	Feasible
			5	2.4	4.8	Feasible
			6	---	2.4	

First Trip Origin	First Trip Destin-ation	First Trip Time (min)	Second Trip Destin-ation	Second Trip Time (min)	Combined Trip Time (min)	Remarks
6	1	11.9*	1	---	11.9*	
			2	2.3	14.2*	
			3	8.3	20.2*	
			4	9.5	21.4*	
			5	9.0	20.9*	
			6	12.4*	24.3*	
	2	8.6	1	2.3	10.9*	
			2	---	8.6	
			3	5.6	14.4*	
			4	6.8	15.4*	
			5	6.3	15.1*	
			6	9.7	18.3*	
	3	4.5	1	8.3	12.8*	
			2	5.0	9.5	Feasible
			3	---	4.5	
			4	2.2	6.7	Feasible
			5	1.7	6.2	Feasible
			6	5.1	9.6	Feasible
	4	5.4	1	9.5	14.9*	
			2	6.2	11.6*	
			3	2.2	7.6	Feasible
			4	---	5.4	
			5	2.6	8.0	Feasible
			6	6.0	11.4*	
	5	2.4	1	9.1	11.5*	
			2	5.8	8.2	Feasible
			3	1.7	4.1	Feasible
			4	2.6	5.0	Feasible
			5	---	2.4	
			6	2.4	4.8	Feasible
	6	---	1	11.9*	11.9*	
			2	8.6	8.6	
			3	4.5	4.5	
			4	5.4	5.4	
			5	2.4	2.4	
			6	---	---	

from W Va U proposal

From \ To	Walnut Street	Quadrangle	Engineering	Field House	Towers	Medical
Walnut Street		2.3	8.3	9.5	9.0	12.4
Quadrangle	2.3		5.6	6.8	6.3	9.7
Engineering	8.3	5.0		2.2.	1.7	5.1
Field House	9.5	6.2	2.2		2.6	6.0
Towers	9.1	5.8	1.7	2.6		2.4
Medical	11.9	8.6	4.5	5.4	2.4	

AC to AC

Total Trip Time

Figure 14

Station-to-station, including loading and unloading

Morgantown:
Factors to be analysed as suggested by DMJM statement of experience:

Relation between rates of flow and safety of operation
"merge and exit movements for small car systems,
stopping distance relative to safety and comfort of the passenger
checkout methods for entering vehicles (i.e., onto guideway) to assure uniformity of operating characteristics; Relation between the performance parameters of acceleration, braking, maximum speed and route configuration and station intervals need to be developed.
Operating methods and line configurations in relation to schedule speeds should be evaluated for public acceptance

MTBF analysis
time to restore normal operation after failure

noise
track and rail designs
propulsion systems

Don't overlook
arrivals of vehicles

e.g. Quad must be e
devoted to Towers
for final 4 min

Factors
(per Kaiser)
- unit capacity
- speed
- headway
- schedule
- operating method
- guidance + control
- wayside requirements
- air pollution
- all-weather capability
- dependability
- safety
- operating costs

Factors
(per Kaiser)

- unit capacity
- speed
- headway
- schedule
- operating method
- guidance + control
- wayside requirements
- air pollution
- all-weather capability
- dependability
- safety
- operating costs

Morgantown:
Factors to be analysed as suggested by DMJM statement of experience:

Relation between rates of flow and safety of operation
"merge and exit movements for small car systems,
stopping distance relative to safety and comfort of the passenger
checkout methods for entering vehicles (i.e., onto guideway) to assure uniformity of operating characteristics; Relation between the performance parameters of acceleration, braking, maximum speed and route configuration and station intervals need to be developed.
Operating methods and line configurations in relation to schedule speeds should be evaluated for public acceptance

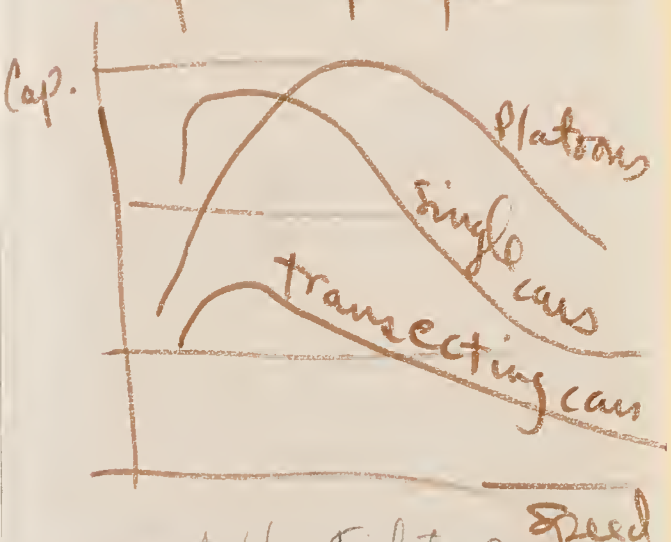
MTBF analysis
time to restore normal operation after failure

noise
track and rail designs
propulsion systems

Don't overlook
arrivals of vehicles

e.g. Quad must be entirely
devoted to Towers Traffic
for final 4 minutes of cycle?

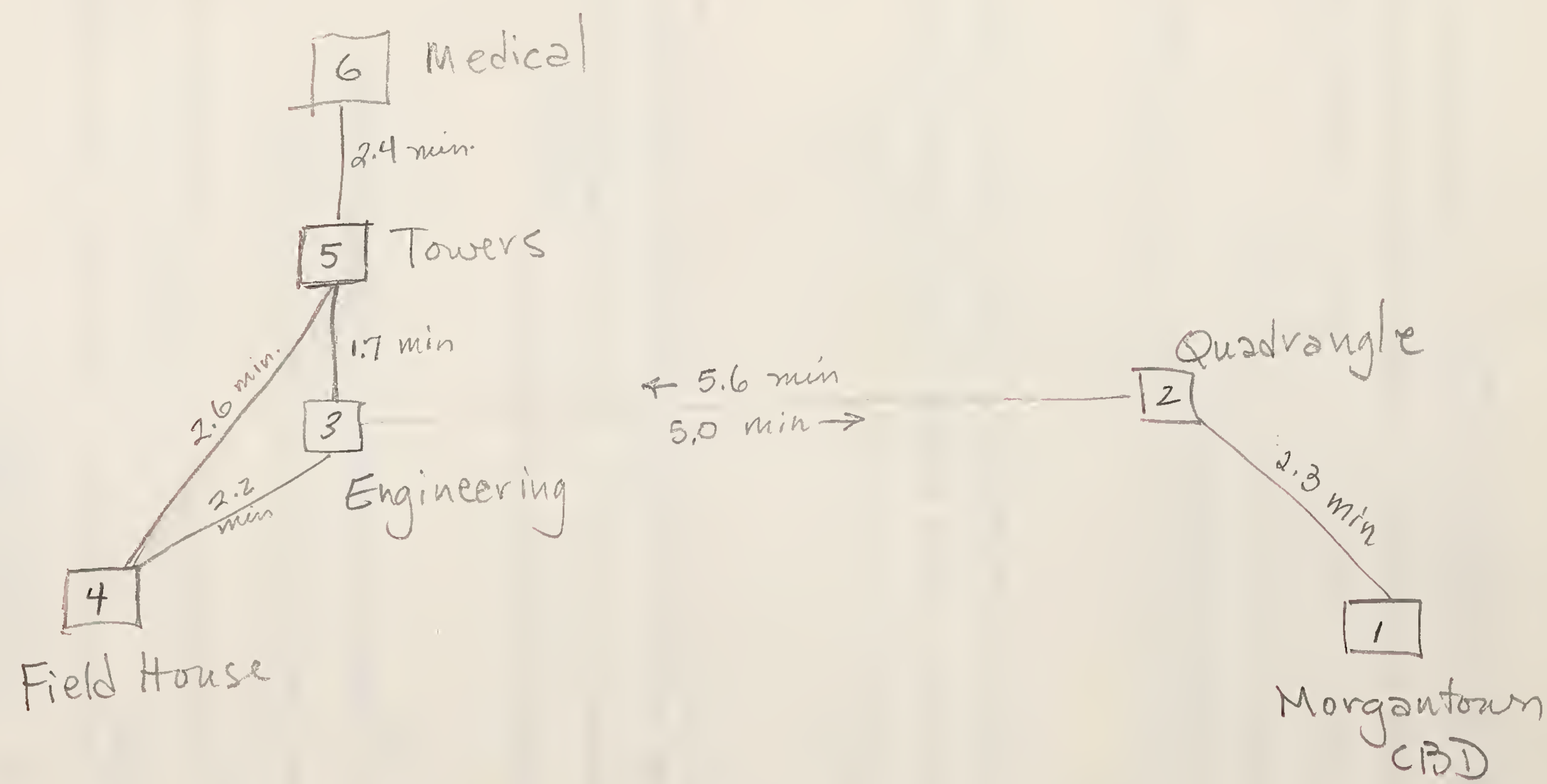
Effect of station-departure merging on system performance.



Suggested by Fichter paper HRR 251 ([illegible])

"Snapshots" are taken 99, 159 and 219 seconds after first vehicle (A) arrives. Vehicles arrive every 5 seconds in order ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijkl..... Vehicles spend 36 seconds inside station (dwell-time), including 13 seconds unloading, 13 seconds loading, 10 seconds in guideway ramp awaiting null and departing.

"SNAPSHOT" STATION Ramp	Outside Station Approaching on Guideway	Outside Station Queued	Inside Station Unloading	Inside Station Loading	Inside Station Queued	On Ramp	Departed (Total)
One Path:							
t=99 TSRQ → PONMLKJ I →	U	TSRQ (4)		P	ONMLKJ	I	HGFEDCBA (8)
t=159 fedcbaZY XWVUTSRQ →	g	fedcbaZY (8)	XWVUTSRQ				HGFEDCBA PONMLKJI (16)
t=219 nmlkjihg opqr → fedcbaZY →	s	rqponmlkjihg (12)	fedcbaZY				HGFEDCBA PONMLKJI XWVUTSRQ (24)
Two Paths:							
t=99 TSRQ PO N	U	—	TS	RQ P	~~P~~O	N	HGFEDCBA MLKJI (13)
t=159 fedcba Z	g	—	fe	dcb	a	Z	XVWUTSRQ HGFEDCBA Y PONMLKJI (25)
t=219 nm rqpo l →	s	—	rq	n po	m	l	kjihg XVWVUTSR HGFEDCBA fedcbaZY PONMLKJI (37)
Three paths:							
t=99 QPO N → TSR	U	—	TS	QP R	O	N	MLK CBA FED (13) JIHG
t=159 f a Z → edcb	g	—	f e	dcb	a	Z	XWVU MLK CBA Y QPON FED (25) TSR JIHG
t=219 rqp l → onm	s	—	rq	p on	m	l	hgf XWVU MLK CBA kji aZY QPON FED (37) edcb TSR JIHG



STATION LAYOUT AND TRAVEL TIMES *

* FROM PAGE 52 OF WEST VIRGINIA UNIVERSITY PROPOSAL; INCLUDE LOADING AND UNLOADING

MORGANTOWN SYSTEM CONCEPT

Guideway and Stations

6 stations connected by 32,100 feet of guideway

- Morgantown CBD (C) - end-of-line loop
- Quadrangle (Q) - loop plus through passage
- Engineering (E) - loop plus through passage
- Field House (F) - end-of-line loop
- Towers (T) - loop plus through passage
- Medical Center (M) - end-of-line loop

All stations except M have 50-ft platforms and will hold 4 cars, combining load and unload operations

Station M is on spur (C was proposed for spur but UMTA has decided it should be integral part of system)

Full interchange between E and T stations connecting each to F.

Double-track synchronous operation; third-rail power distribution

Vehicles

Each vehicle holds ~~12~~ ? seated passengers ~~(no standees)~~

Vehicles operate independently (no trains) and are self-~~powered~~ propelled by electric motors

Initial complement of ~~90~~ ? vehicles to handle approximately 1100 persons during ten-minute class-change peak between Towers and Quadrangle.

Controls

Vehicles are in individual contact with central control computer

Vehicles follow electronic null around guideway, adjusting speeds as needed

Communications system built into guideway(and vehicle contact to third rail?)

Scheduling and Routing

Scheduled (fixed destination for each car) service during class-change peaks, demand-actuated service during off-peak periods

Storage of idle cars during off-peak periods in car-barn

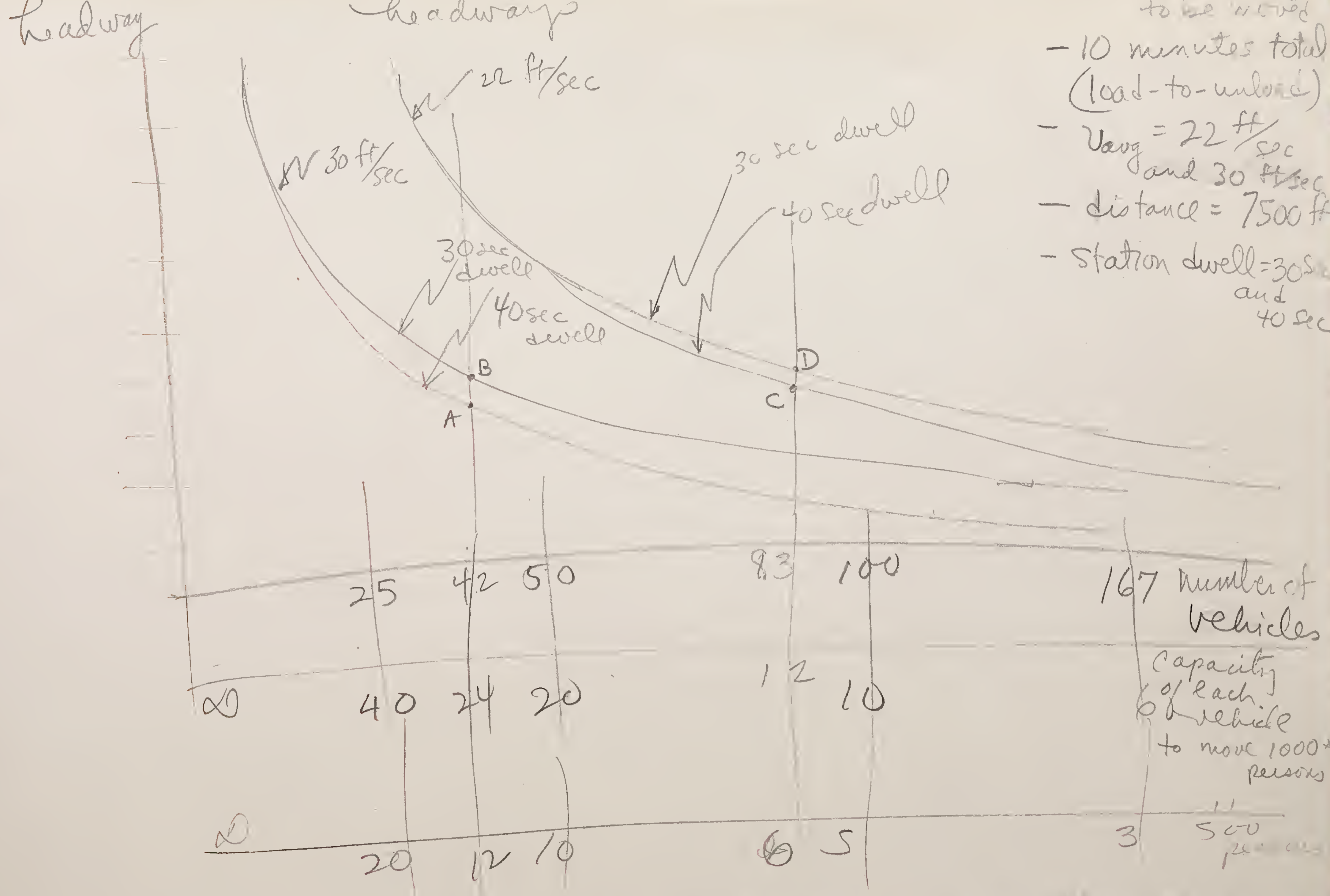
Two speeds forward: 25 mph for straightaway and 15 mph for turns and grades.

4.5-second headways between cars (capable of being reduced to 2.45 seconds later)

40-second station dwell (15 sec unload, 15 sec load, 5.4 sec transfer to launch position and 4.5 seconds to accelerate to 15 mph)

Number of vehicles Required to move 1000 persons in 10 minutes at various headways

Given: - 1000 passengers to be moved
- 10 minutes total (load-to-unload)
- V_{avg} = 22 ft/sec and 30 ft/sec
- distance = 7500 ft
- Station dwell = 30 sec and 40 sec



To find number of cars needed to transport 20__ persons, [illegible]

THINGS TO DO

MORGANTOWN MODELLING