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Transportation Design Parameters for a World's Fair

BRIAN S. BOCHNER and M. JANET REID

ABSTRACT

Limited information is available to assist professionals in designing transportation systems for special events. As a part of the planning effort for the 1982 World's Fair in Knoxville, data were gathered from past world's fairs. Data from the Knoxville Fair and additional data from past events were collected as a part of an UMTA-funded project to evaluate the transportation system for the 1982 World's Fair. The results of that analysis are discussed and additional information and conclusions are given. The design parameters for the transportation system for a world's fair include (a) design day attendance, (b) transportation mode split, (c) hourly distribution of the volume of inbound and outbound visitors, (d) on-site accumulation, and (e) gate distributions. These parameters can be used as a basis for the transportation system design. The transportation system serving a fair consists of (a) access routes to the fair, (b) parking supply and location, (c) facilities for loading and unloading shuttle and tour buses, (d) local transit, (e) local taxi and walk-in potential, and (f) specialized transportation modes such as ferry service or horse drawn carriages. Distributions of attendance, although variable on a day-to-day basis, follow similar patterns from fair to fair and provide a good basis for estimating design day attendance. The limited on-site accumulation data indicate a reasonable range that could be used for planning purposes. Data on hourly distribution of inbound and out-bound volumes are also limited but appear to follow similar trends, and thus could be used in estimating volumes for future fairs. Information on transportation mode split is only available for one fair and is highly dependent on local conditions. Gate distributions can be estimated from mode split but will be influenced by location of modal loadings and constrained by available capacity to accommodate transportation services at a given gate. Some guidelines are provided for use in designing a world's fair transportation system based on experience at past world's fairs.

The access, terminal, parking, and gate facilities for a special event are designed on the basis of several parameters. A special event is defined as an event that will generate significant numbers of visitors over a limited time period. Examples of special events are world's fairs, Olympic Games, and special "one time" exhibitions. Event centers such as theme parks and state fairs tend to have different design parameters than "one time" special events. These design parameters include

- Design day attendance,
- Transportation mode split,
- Hourly distribution of inbound and outbound volumes,
- On-site accumulation, and
- Gate distribution.

The statistical information provided in this paper was gathered from six world's fairs (Knoxville, San Antonio, Seattle, Spokane, Osaka, and Montreal) used to determine the appropriate design parameters. The methods for estimating each parameter are also reviewed, including the level of accuracy. Conclusions and recommendations for future design parameter estimates are provided based on the available information.

ATTENDANCE PATTERNS

Total Attendance

Although it is beyond the scope of this paper to describe how economic feasibility studies for world's fairs are performed, total attendance estimates are based on (a) the type of attraction, (b) past experience with market penetration for similar events, (c) distribution of population within the area of influence, and (d) other local factors that may affect attendance.

Transportation system planning for world's fairs accepts total attendance estimates, usually developed from economic feasibility studies, as a basic assumption. Given the total attendance and fair duration, an average day attendance can be determined. Transportation systems, however, are not typically designed for average day conditions. The 80th to 90th percentile days are generally used. The following sections briefly describe attendance patterns.

Daily Variations

Variations in attendance from day to day and month to month are substantial. Each fair appears to have followed its own general pattern, but actual attendance is not predictable on a day-to-day basis. The patterns are also not predictable from fair to fair. Figure 1 illustrates the daily pattern for the Knoxville World's Fair, as an example (1).

There was no consistency between fairs relative to the peak days either. For example, Spokane's two highest days were opening and closing day. Seattle's two highest days were the last Saturday and Sunday of the fair, and the next two highest days were non-holiday Saturdays in September and October. Opening day at Seattle was 1 percent below average. Knoxville's two highest days were Saturdays in mid-May and mid-October. Opening day in Knoxville was about 10 percent above average and the closing Saturday and Sunday were in the 15th to 20th highest day range. Low attendance days were equally inconsistent, although most have been in September.

Variations by Day of Week

Day of week variations were much more predictable. Table 1 shows such variations for world's fairs in Seattle (1962), Montreal (1967), San Antonio (1968), Osaka (1970), Spokane (1974), and Knoxville (1982)

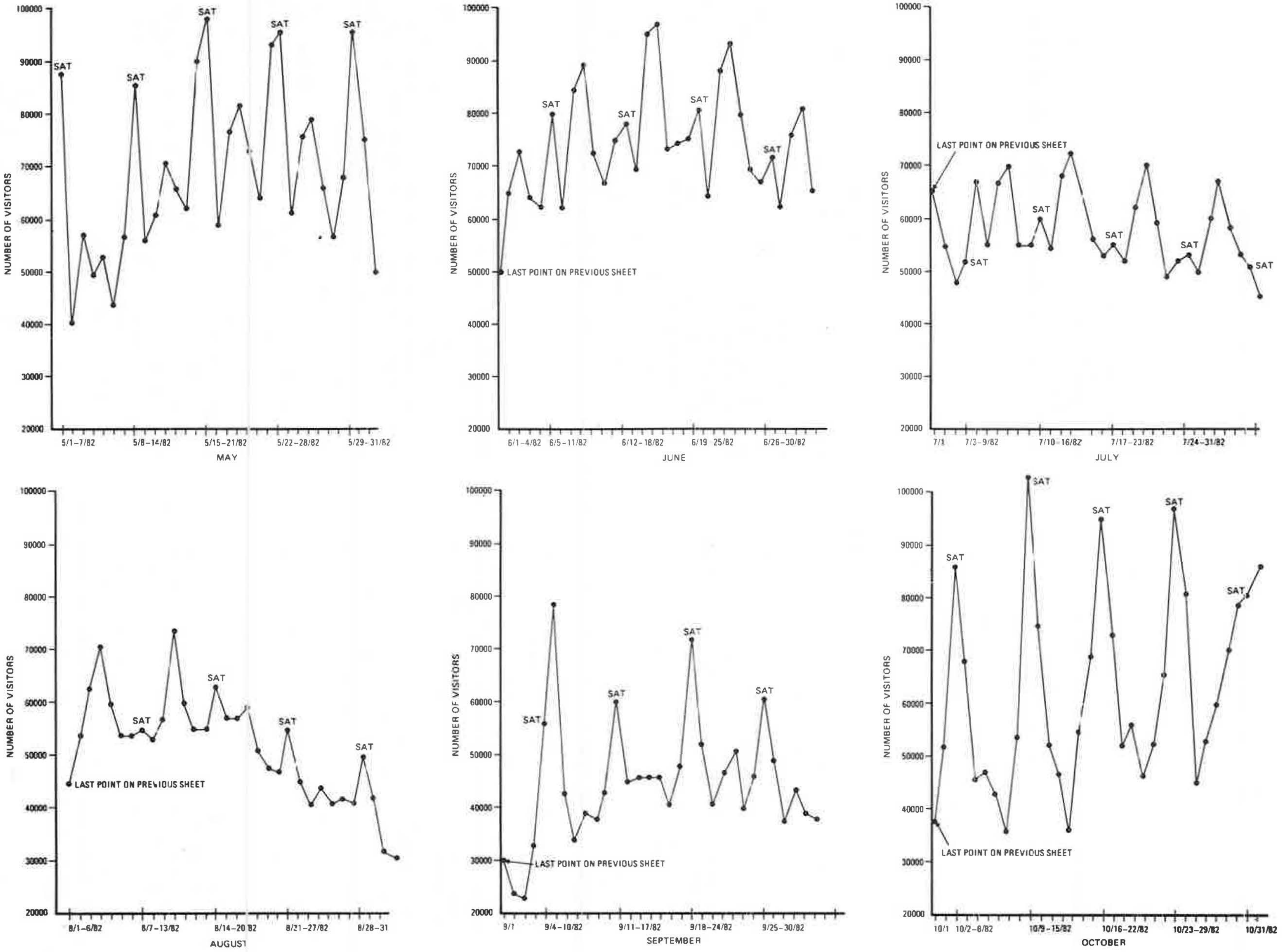

FIGURE 1 1982 World's Fair daily attendance pattern *(1)*.

TABLE 1 Variations in Attendance by Day of Week *(1)*

	Percent of Total Weekly Attendance						
Day	1962 Seattle	1967 Montreal	1968 San Antonio	1970 Osaka	1974 Spokane	1982 Knoxville	U.S. Composite
Monday	13	13	11	14	13	14	13
Tuesday	15	14	12	12	13	15	14
Wednesday	13	14	12	13	13	14	13
Thursday	12	12	11	12	12	12	12
Friday	13	13	12	14	13	14	13
Saturday	18	17	21	17	19	17	18
Sunday	16	17	20	18	17	14	17

(2-4). The Seattle, San Antonio, Spokane, and Knoxville fairs were similar in magnitude of attendance, drawing about 9.6, 6.4, 5.1, and 11.1 million visitors, respectively. The Osaka Fair drew more than 60 million visitors and its attendance patterns were generated in a different cultural setting. Montreal drew over 54 million visitors in a cultural setting similar to the United States.

The peak day of the week for the four U.S. fairs examined has been Saturday, which drew 17 to 19 percent of the weekly attendance. This averages about 25 percent above the average day. Tuesday was the peak weekday in both Seattle and Knoxville with about 15 percent of weekly attendance, which was about 5 percent above the average day. However, Spokane and San Antonio experienced flatter weekday patterns. Thursday was the low day at all four U.S. fairs, at 12 percent of average weekly attendance (about 15 percent below average day). Overall, weekdays generated about two-thirds of the weekly attendance at five of the six fairs. San Antonio's weekday attendance was well below that of other fairs. Even though Spokane experienced a flat weekday trend, it did not have total weekday attendance percentages lower than the other fairs.

Table 1 gives the composite daily distribution for the four U.S. fairs listed. With relatively minor variations, these patterns were consistent from week to week at each fair except San Antonio. Nearly all of the 10 highest attendance days at each occurred on Saturdays and Tuesdays.

Monthly Variations

Table 2 gives attendance variations by month. No two fairs have experienced strong similarities in monthly variations. However, with the exception of the Knoxville Fair, all started slowly, peaked during the summer, dipped in September, and finished stronger in October. The Knoxville Fair had May, June, and October as peak months, with its low in August; Spokane's low was also in August. A major factor contributing to the May-June peak in Knoxville was the heavy influx of tour groups, often amounting to more than 15,000 persons daily. Those numbers dropped by 50 percent or more during the summer. This was the first world's fair to market heavily to tour operators. Such a peak would not be expected for fairs if high tour volumes were not expected.

Design Day Attendance

Facilities must be designed for a certain level of activity. As has been demonstrated, specific attendance patterns are not predictable. It is customary to select a design day attendance that will adequately accommodate all but the highest attendance days.

Figure 2 shows the distributions of daily attendance for the six fairs. With the exception of the magnitude of the few peak days, all distributions are similar. In Knoxville the transportation system was designed for the 90th percentile day based on attendance distributions for Seattle and Spokane. Spokane was designed for what was expected to be the 95th percentile day. No information was available for the design days of the other fairs.

As is readily apparent from the distribution in Figure 2, there is a break in the curve near the 90th percentile. Above that level, each percentile increase represents only 2 days but large increases in attendance. It becomes very expensive to meet the additional facility needs above the 90th percentile attendance day, particularly in view of the few times they will be needed.

Table 3 gives the peak, 90th, and 80th percentile daily attendance for the fairs as a percentage of average daily attendance. The percentage by which peak days exceeded average days varied substan-

TABLE 2 Variations in Attendance by Month *(1)*

	Percent of Total Attendance						
	Seattle	Montreal	San Antonio[(a)]	Osaka[(b)]	Spokane	Knoxville	U.S. Composite (May-Oct.)
April	—	—	10	14	--	—	NA
May	11	17	15	13	13	19	14
June	16	16	17	16	20	20	18
July	19	19	19	12	21	16	19
August	20	20	20	18	19	15	19
September	16	14	14	27	11	12	13
October	18	13	5	—	14	18	17

(a) This fair operated between April 6 and October 6.

(b) Listed by consecutive 30 day periods versus calendar months since this fair operated between March 15 and September 13.

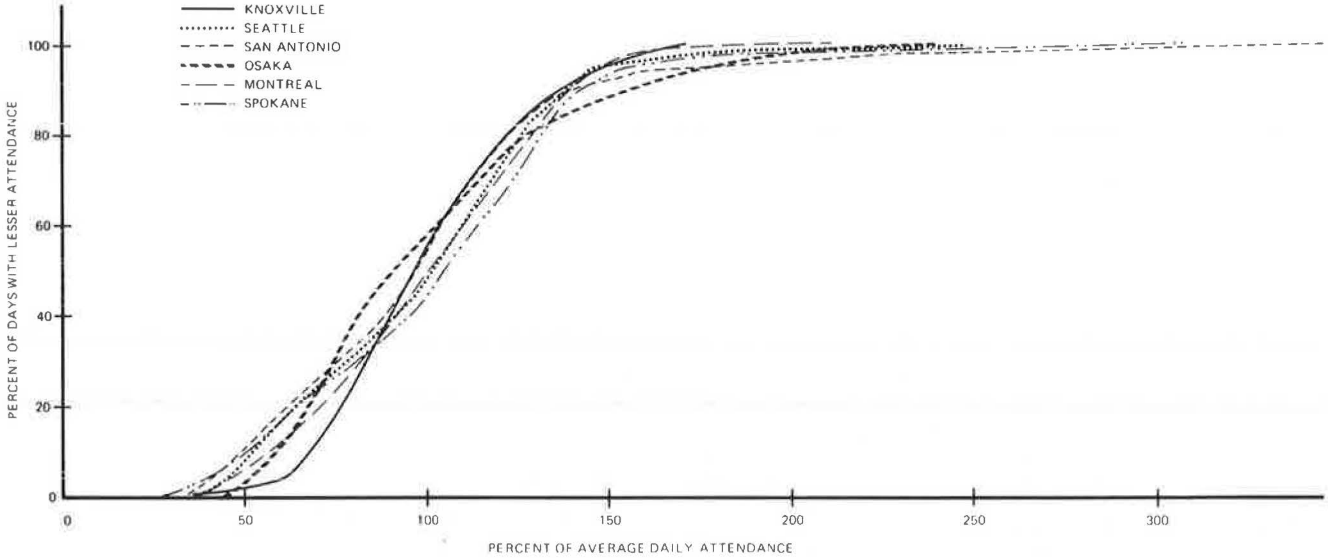

FIGURE 2 Frequency distribution of World's Fair daily attendance.

TABLE 3 Attendance Statistics

	Percent of Average Daily Attendance							
	Seattle	Montreal	San Antonio	Osaka	Spokane	Knoxville	North American Average	Recommended for Planning
Highest Days								
Day	246	208	349	239	462	170	287	—[a]
Weekday	180	175	154	196	160	160	166	160
Weekend Day	246	208	349	239	462	170	287	—
90th Percentile Days								
Day	136	139	148	165	131	138	138	138
Weekday	131	134	115	160	131	130	128	130
Weekend	146	155	225	187	164	158	170	160
80th Percentile Days								
Day	123	127	123	122	121	121	123	122
Weekday	120	122	100	120	122	116	116	120
Weekend Day	141	135	158	135	145	134	143	145

Note: Based on data acquired from unpublished World's Fair files and References *(1)*, *(2)*, *(3)*, and *(4)*.
[a] Varies according to average daily attendance.

tially. The highest attendance day at each fair was a Saturday. Peak weekdays were 60 to 80 percent above average. The relationships of the 90th and 80th percentile days to average days are consistent for Knoxville, Seattle, Spokane, and Montreal as shown in Table 3.

Because all four of the U.S. fair sites studied were in, or immediately adjacent to, downtowns, base weekday versus weekend transportation conditions represent a significant difference. In Knoxville the fair site was also flanked by the University of Tennessee, so there was even a difference between weekday conditions during regular sessions and the summer period. For that reason 80th or 90th percentile weekend and weekday attendance figures should both be used for downtown sites. Similarly, if the fair is adjacent to a seasonal land use (such as a university), attendance figures for weekends and weekdays for both in-use and not in-use seasons need to be generated.

It is advantageous and appropriate for fair transportation designers for downtown sites to use the 80th or 90th percentile weekday estimates for their design day attendance levels. It should be recognized that there will still be a number of peak days on weekends when the weekday system will not be adequate, even after allowing for capacity convertible from weekday central business district (CBD) use to weekend fair use.

CHARACTERISTICS OF ENTRY AND EXIT VOLUME

Fair entry and exit gates need to be sized to meet peak hour volumes. Entry and exit volume characteristics for the World's Fair in Knoxville were examined for the peak weekday (Tuesday) and weekend day (Saturday). Entry and exit information was available only for the Knoxville and Osaka fairs (the only fairs with outbound registering turnstiles). Figures 3 through 6 illustrate the inbound and outbound patterns for the Knoxville Fair, and the patterns for both days are similar. Entry peaks occurred between 10:00 a.m. and 11:00 a.m. when 23

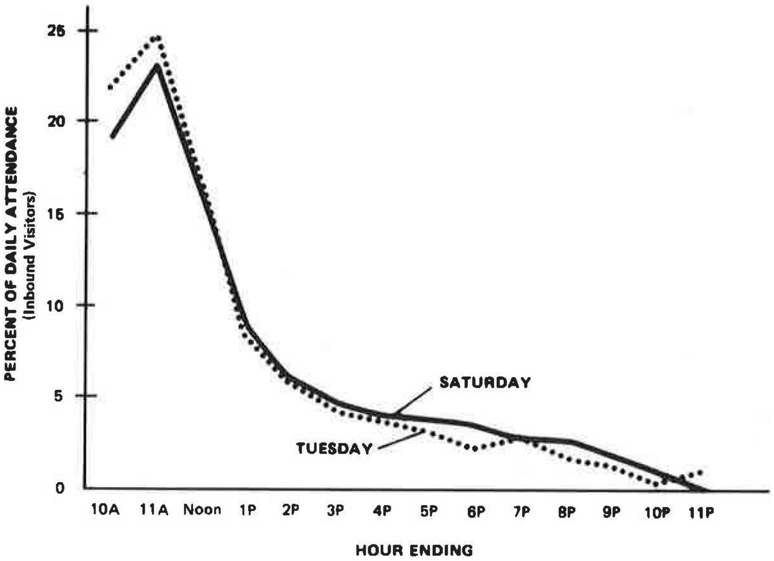

FIGURE 3 Hourly inbound visitor distributions *(1)*.

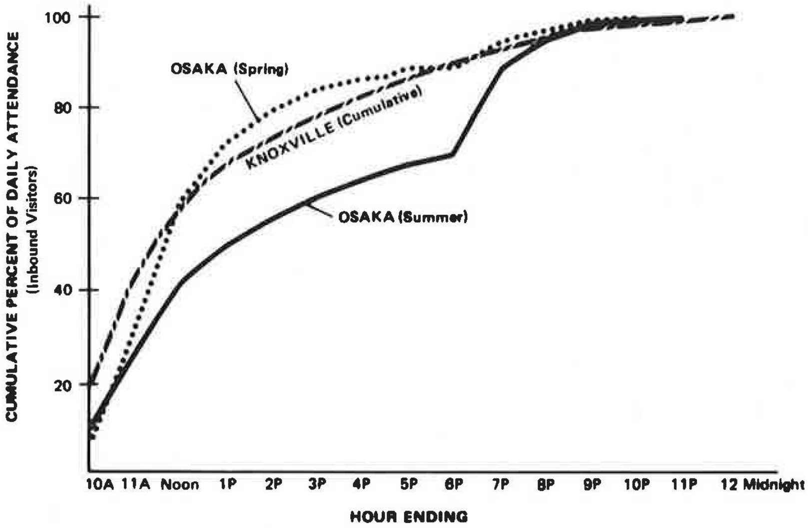

FIGURE 4 Hourly entry volume distributions *(1)*.

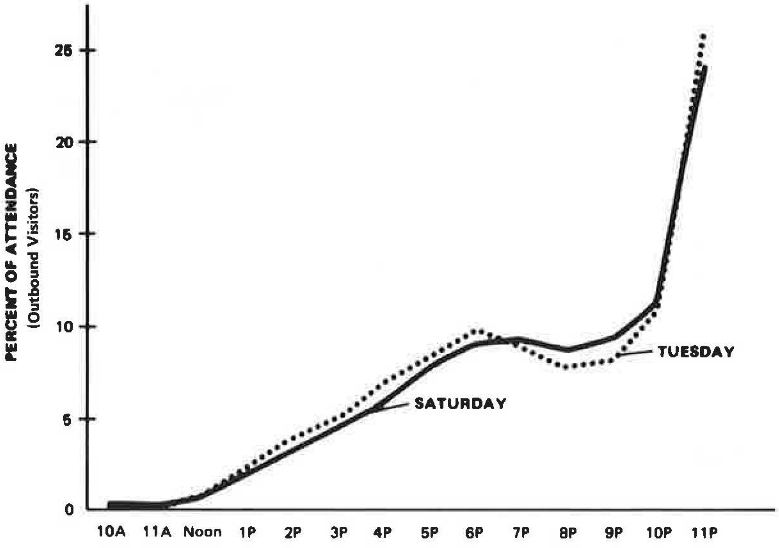

FIGURE 5 Hourly outbound visitor distributions *(1)*.

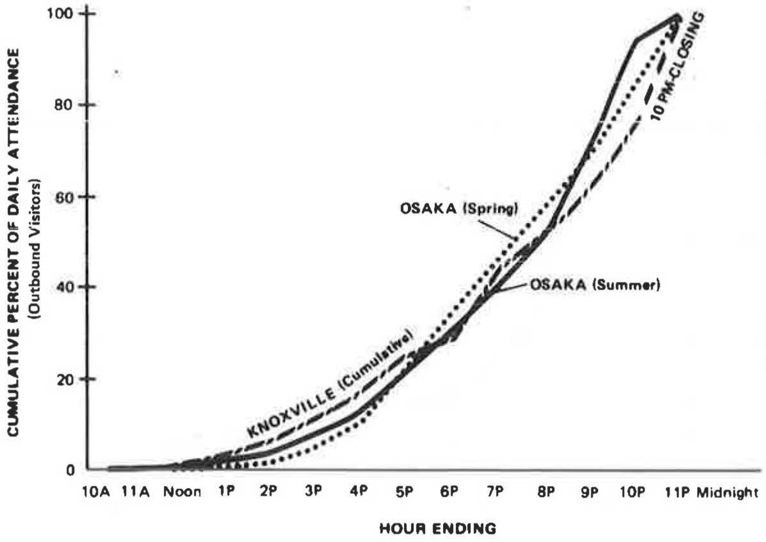

FIGURE 6 Hourly exit volume distributions *(1)*.

(Saturday) and 25 (weekday) percent of the daily attendance entered. Inbound volumes drop off rapidly after noon. Exits increased gradually starting at noon and reached a plateau of 9 to 10 percent from about 6:00 p.m. until closing at 10:00 p.m. then peaked at 24 to 26 percent during the hour following closing (10:00 p.m.). For late closings the total outbound volumes between 10:00 p.m. and 1:00 a.m. were only about 10 percent higher than the 10:00 to 11:00 p.m. hour on early closing nights. As with patterns for inbound volume, exit volumes for Tuesday and Saturday are distributed similarly.

Figures 4 and 6 show cumulative entry and exit volume distributions for Saturdays for Knoxville and Osaka. The cumulative inbound distributions for Knoxville are similar to the spring season pattern at Osaka. The summer in Osaka had an evening peak from 6:00 to 7:00 p.m.; otherwise the summer pattern is similar to Knoxville. The outbound cumulative curves are similar. Hence, these hourly patterns appear to be usable for estimating hourly volume distributions.

Two other available sources of hourly inbound and outbound distributions are data from theme parks and the State Fair of Texas. Table 4 gives these distributions and the actual hourly distributions found at the Knoxville Fair. The inbound estimates based on theme parks were not far off. However, the state fair inbound and outbound estimates were not similar. Nevertheless, all were reasonably close on the peak-hour volume in each direction. Hence, it can be concluded that the peak-hour volume magnitudes may be determined from several sources. The actual time of day when the peak will occur is not as easily determined except from world's fair data (Figures 5 and 6).

GATE SPLITS

The number of gates at recent world's fairs has varied. Gate information was available only for the Knoxville Fair and daily and peak-hour distributions for Knoxville are shown in Figure 7. As can be seen, the peak-hour and daily gate volumes were not evenly spread among the gates. Daily splits ranged between

TABLE 4 Hourly Volume Distributions for Alternate Sources, 1982

	Inbound (%)			Outbound (%)		
Hour	Theme Parks	State Fair of Texas[a]	Knoxville[b]	Theme Park	State Fair of Texas	Knoxville[b]
- 10:00 A.M.	21	0	19	0	0	0
10:00 - 11:00 A.M.	19	26	23	0	0	0
11:00 - 12:00 NOON	18	23	17	0	0	0
12:00 - 1:00 P.M.	11	17	9	0	1	2
1:00 - 2:00 P.M.	6	15	6	0	1	3
2:00 - 3:00 P.M.	4	5	5	0	2	5
3:00 - 4:00 P.M.	3	3	4	1	4	6
4:00 - 5:00 P.M.	2	2	4	45	7	8
5:00 - 6:00 P.M.	—	3	4	5	6	9
6:00 - 7:00 P.M.	—	4	3	10	5	9
7:00 - 8:00 P.M.	16	1	3	10	5	9
8:00 - 9:00 P.M.	—	1	2	20	8	9
9:00 - 10:00 P.M.	—	0	1	20	21	13
10:00 - 11:00 P.M.	—	0	1	—	23	—
11:00 - 12:00 MIDNIGHT	—	0	0	30	11	26
12:00 -	—	0	0	—	6	—

(a) Modified to meet projected average stay of eight hours over 10:00 A.M. to 12:00 Midnight operating day.
(b) Saturday.

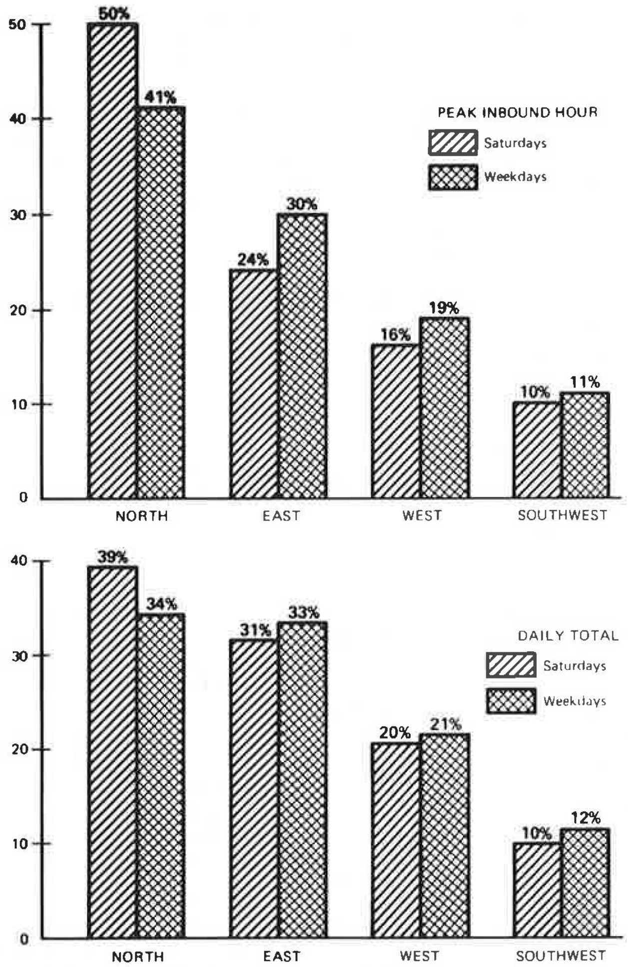

FIGURE 7 Peak hour and daily gate volumes for Knoxville *(1)*.

10 and 39 percent, whereas peak-hour splits showed an even wider spread between 10 and 50 percent of the hourly volume.

Attempts were made during early Knoxville planning stages to spread the volumes to meet capacity constraints at each gate, particularly the east gate. This was done by increasing or decreasing planned parking spaces near gates and locating bus terminals or parking areas at particular gates. Although this was a useful exercise, site and financial constraints ultimately played a bigger part in determining parking and terminal locations than the desired distribution of volume. Nevertheless, the decision to have four gates and the relative magnitude of volumes at each was planned. The procedure used was as follows:

1. Estimate volumes by primary mode of arrival (walk, drive, shuttle bus, local bus, tour bus, taxi, etc.).
2. Determine sources of walking visitors; distribute projected volume to each area; estimate numbers that will enter each gate.
3. From economic feasibility study and population (census) data, estimate distribution of arriving visitor population by approach route; determine probable parking location for each approach route, adjusting to reflect any capacity limitations on parking space; identify access gate for each lot; and estimate number to enter each gate.
4. Identify gate(s) where shuttle bus stops will be located; estimate shuttled visitors to enter those gates.
5. Identify gates near local bus stops; estimate patronage by route from distribution of fair visitors within local transit service area; estimate number to enter each gate based on the service provided by each transit route.
6. Identify gate where tour buses will unload; estimate number of visitors to enter gate.
7. Taxi and other volumes may be so low that gate distribution will not be affected. If necessary, estimate distribution of visitors by geographic location; determine approach routes and gates most likely to be used; estimate number of visitors to use each gate.
8. Sum volume (or percentages) by gate.

This procedure will yield daily gate volume splits. Peak-hour volumes must be estimated by using hourly distributions projected for visitors arriving by each mode.

At the Knoxville Fair the most severe peaking of inbound and outbound volumes was generated by tour buses, which used a terminal at the north gate. This gate operated at capacity many days starting between 9:30 and 9:45 a.m. Most buses arrived (or tried to) at about 10:00 a.m. Had not both the gate and terminal capacities constrained arrival patterns, it is possible that the peak-hour percentage at the gate would have been significantly higher. (Inbound north gate capacity was 12,000 per hour and as many as 25,000 were brought in tour buses as close to the 10:00 a.m. opening time as possible.)

ON-SITE ACCUMULATION AND DURATION OF STAY

The estimate of on-site accumulation is the basis for determining site size and quantity of facilities and parking space needs. These are based on maximum accumulation during the day. Maximum accumulation is strongly related to the average duration of stay on site. Unfortunately the average stay is dependent on many factors that are difficult to quantify. These include quality, variation, and number of attractions; entertainment; food service; rest facilities; amount of seating; protection from heat; and pricing. Because it is virtually impossible to determine the adequacy of each before the fair, assumptions about the duration of stay must be based on judgment. Figure 8 illustrates the maximum accumulation as a function of the length of stay experienced at several world's fairs.

Visitors

The average visitor duration of stay for the Knoxville Fair was 6.7 hours on Tuesdays and 6.6 hours on Saturdays. The Osaka Fair averaged 5.7 hours on Saturdays. For Montreal the average duration of stay was 5.5 hours. Spokane sponsors estimated an average duration of 7 hours. It appears that an average duration of 5.5 to 7 hours would be a reasonable estimate to use for world's fairs. Duration of stay has no planning value for the transportation system other than to help in generating an estimate of maximum accumulation (see Table 5).

On-site visitor accumulation curves for the Knoxville Fair are shown in Figure 9. Peak accumulations occurred on Tuesdays (70 percent) and Saturdays (67 percent) at 2:00 p.m. and 3:00 p.m., respectively. Osaka's Saturday peak was about 65 percent but was for a much larger attendance (64 million visitors). Montreal's peak ranged between 50 and 60 percent between 3:00 p.m. and 4:00 p.m., again for a much

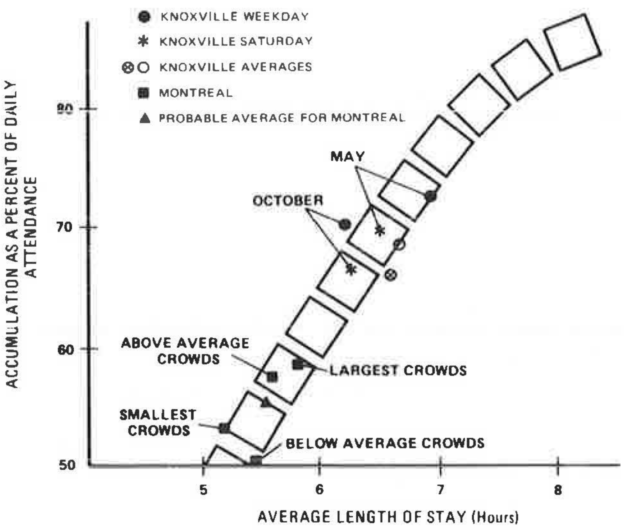

FIGURE 8 Maximum on-site accumulation as a function of average length of stay.

TABLE 5 Average Duration of Stay (hours)

Fair	Tuesdays	Saturdays	Overall
Knoxville	6.7	6.6	—
Montreal	—	—	5.5
Osaka	—	5.7 (a)	—

(a)Based on very limited data.

larger attendance (54 million visitors). Generally 65 to 70 percent should cover most accumulations, and 75 percent should be a safe high estimate. The figure used will directly affect development costs; using 75 percent instead of 68 percent will increase total development costs by about 10 percent.

Employees

Few data are available on employee arrival, departure, and accumulation patterns. Records are kept by individual employers. Although employees use special turnstiles or gates, some fair visitors use the same turnstiles (complimentary ticket holders, pass holders, etc.). On-site employee accumulations for the Knoxville Fair were estimated by requesting a few large employers to "guesstimate" their peak accumulations several months before the fair opened. Because scheduling had not been started, most employers had little idea; however, the information gathered indicated that maximum accumulation might be about 80 percent of daily (not total) employment.

Actual accumulation data are available for about 1 percent of the Knoxville Fair employees. It does, however, represent a cross section of most employees. Figure 10 shows the estimated on-site accumulation pattern based on employee parking lot arrival and departure times. This curve indicates a 75 percent maximum accumulation of daily employment. It appears reasonable to expect that daily employment will be 70 to 80 percent of total employment.

MODE SPLIT

Visitors

The mode split of arriving visitors is highly dependent on the amount of tour bus, shuttle bus, and local bus service to be provided. The volume from tour buses at the Knoxville Fair was high, amounting to 18 percent of total attendance. Other fairs have had very small percentages. Despite the extensive initial use of shuttle bus service in Knoxville, the total use was low because of the wide availability of convenient parking at a cost lower than two round trip bus fares. Other fairs have had little shuttle bus activity. Local bus service has been available to all World's Fair sites.

Usable data on transportation mode split were only available for the Knoxville Fair. Data available for other fairs combine mode of access to reach the city with the mode of access to the fair itself. As shown in Table 6, mode split at the Knoxville Fair for May and June was different from the following 4 months. It also was different on the peak days of Saturdays and Tuesdays. Tour bus volumes dropped off near the end of June and remained relatively stable, as a percentage of total attendance, during the July to September period. Shuttle buses provided

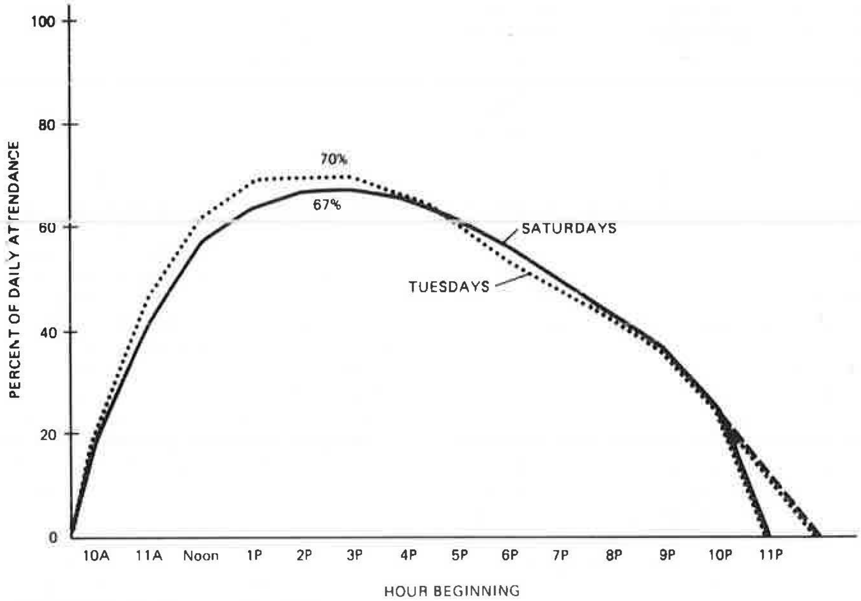

FIGURE 9 Hourly on-site visitor accumulation.

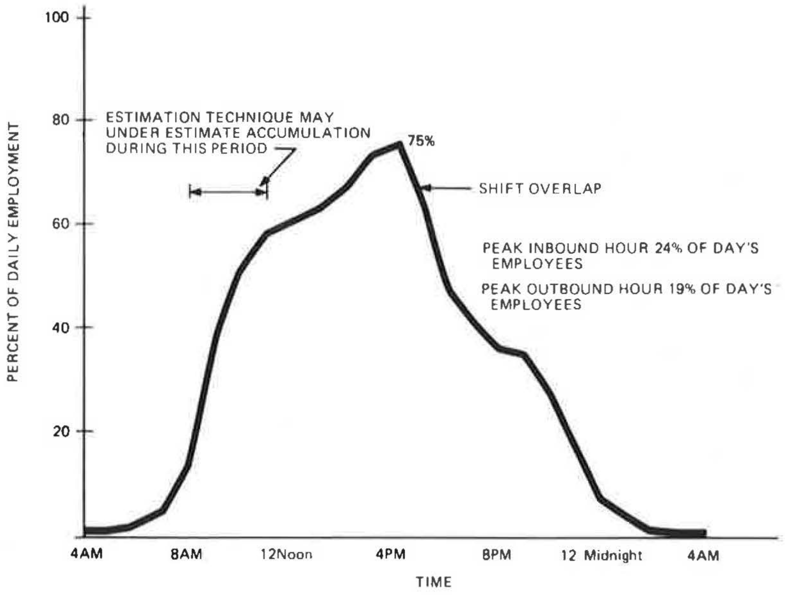

FIGURE 10 Estimated employee on-site accumulation *(1)*.

TABLE 6 Estimated 1982 World's Fair Visitor Transportation Mode Split (percent)

	May-June		July-October		
Mode	Tuesday	Saturday	Tuesday	Saturday	Total
Personal Vehicle	59	53	66	66	64
Tour Bus	19	30	17	21	18
Shuttle Bus[a]	11	5	6	2	7
Local Scheduled Fixed Route Bus	2	3	2	2	2
Taxi, Limousine, etc.	1	1	1	1	1
Walk	8	8	8	8	8
	100	100	100	100	100

[a] Excludes shuttle buses from remote (½ to 1½ miles) official World's Fair parking lots.

an extremely high level of service during the first days of the fair. Service quickly decreased with lower levels of demand and leveled off by midsummer. The use of local buses was lower than originally expected but was relatively stable, as were the taxi and walking modes of access.

It should be noted that the figures in Table 6 are estimates. Complete surveys necessary to make an accurate determination of transportation mode split were not conducted. However, daily counts of tour buses, selected counts of shuttle bus passengers, and changes in local bus use provided a basis for estimating use of those modes. Estimates of the numbers of walk-ins were based on variations in gate volumes under varying conditions. The taxi and limousine estimate is a guess based on observations of taxi operations and limited interviews with taxi companies. The remainder was attributed to personal vehicles; this was substantiated by a lot occupancy count in May. The estimates in Table 6 are consistent with the results of visitor interviews, which were compiled in a way that is not directly usable for transportation purposes.

On the basis of past experience, it is not probable that the May-June percentage of tour bus riders will be much higher at future world's fairs. The management of the Knoxville Fair aggressively pursued tour group business, and hired an experienced marketing staff who were highly regarded by tour operators. It is possible that the combination of shuttle and local bus percentages can be exceeded in the future. More crowded parking or traffic conditions, more local bus service to visitor lodging locations, and more effective and efficient (and less competitive) shuttle service could increase the local and shuttle bus share. Taxi and limousine access will be limited under most circumstances. Walk-ins will depend on the amount of lodgings within walking distance. Parking prices (generally $4 to $10 in Knoxville) do not appear to have deterred many people from driving because their other choices, except for local buses, would have been more costly and no more convenient.

CONCLUSIONS

The attendance and gate volume information presented in this paper provide a reliable basis for estimating transportation system design parameters for future world's fairs. On-site accumulation data are limited because of the absence of registering turnstiles at most previous world's fairs (world's fair managers have trusted their abilities to judge on-site accumulations for scheduling labor and entertainment instead of counting). Theme parks and state fairs appear to have somewhat different attendance patterns.

Gate volume splits can be estimated based on transportation mode splits; however, the estimates will be affected by available modal loading locations and directions of approach and constrained by the capacity to accommodate transportation services at a given gate. However, daily or monthly variations of mode split may well change gate splits (and percent of daily volume during peak hours). If adequate capacity cannot be provided at a given gate, it is desirable to shift some facilities for serving transportation vehicles to another gate where sufficient capacity can be developed.

Finally, the design of the site and the transportation system should be based on the 80th or 90th percentile of one day's estimated attendance (the number chosen depends on financial and physical capabilities), not on peak day of week percentage or peak month percentage as is commonly done in economic feasibility studies; this will provide more credible results.

Although the information contained in this paper is the most comprehensive to date, it represents only a small portion of what could have been available had arrangements been made to make appropriate counts and selected surveys. This effort should be included as part of future world's fair management activities, perhaps being encouraged by the U.S. Departments of Transportation or Commerce.

ACKNOWLEDGMENT

This paper is based on findings developed by the authors as part of an evaluation of transportation provided for the 1982 World's Fair (2,5). This work was conducted as part of a joint effort funded by the Urban Mass Transportation Administration. Participants in this evaluation effort were, in alphabetical order, Barton-Aschman Associates, Inc., the Knoxville International Energy Exposition, Inc., Knoxville-Knox County Metropolitan Planning Commission (project coordinators), and K-Trans. The authors wish to express their gratitude to each of these organizations and their participating staffs. Particular thanks are due to them for their assistance to future world's fair sponsors, transportation providers, and host cities in preparing for future transportation needs.

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The Transport Versus Land Use Dilemma

STEPHEN POTTER

ABSTRACT

The transport sector seems remarkably inflexible to changes in fuel prices and energy measures. The suggestion is made that the long-term land use and social effects of cheap motorized travel has produced a land use and transport system that is dangerously inflexible to changing needs and that planning and transport investment methods tend to unnecessarily heighten such problems. The degree of land use conflict between alternative modes of travel is examined in a case study of the British new towns. These have been built to a wide variety of land use and transport designs, some specifically intended to reduce the degree of transport conflict. The nature of this paper is necessarily strategic and general. It seeks to identify the key factors involved and broad social and planning principles rather than specific details. The case study of the British new towns suggests that it is possible to provide urban structures that are capable of accommodating wide variations in travel patterns and energy availability. Yet, 10 years after the 1973-1974 energy crisis there seems to be little political interest to take such ideas seriously. It was concluded that equitable and energy-efficient land use policies are entirely feasible, but the political status of planning is too weak for them to be implemented.

Ten years have passed since the 1973-1974 energy crisis signaled the end of an era in which it was confidently assumed that cheap motorized transport was a permanent feature of our society. Today, instead of seeking new and improved ways to accommodate high energy travel, transport planners are beginning to realize how unsustainable such a scenario is and are trying to promote more energy efficient transport methods. Yet, while energy conservation in most other fields has yielded significant savings, energy use in transport has increased (Table 1).

Two interrelated aspects of the inflexibility of the demand for motorized travel are examined in this paper. The first is the hypothesis that the long-term land use and social effects of low-cost motorized travel have produced a land use and transport system and cultural conditions that are dangerously inflexible to changing needs. A city structure that

TABLE 1 Energy Consumption in Great Britain 1971-1981 *(14)*

	1971	1981	Change (%)
Petroleum (m. tonnes)			
Cars and motorcycles	12.13	16.09	+33
Goods vehicles	2.52	2.35	-7
All transport	26.07	30.63	+18
Nontransport uses	38.52	22.84	-41
Total petroleum used	64.59	53.47	-17
All Energy Sources (m. therms)			
Transport uses	11,634	13,618	+17
Nontransport uses	45,367	41,302	-10
Total energy used by final consumers	57,001	54,920	-4

has adapted to low-energy-cost travel is virtually incapable of adapting to minimized travel needs in less than 50 to 100 years. To look at the nature of the operational conflict between the different transport modes, a study was made of the different land use and associated transport structures used in Britain's new towns. This method has been used in the past by researchers such as Hillman et al. (1); but it is only recently, with the near completion of several important new towns, that it has become possible to assess this experience fully.

The study of the new towns indicates that it is possible to provide a land use and transport system capable of accommodating widely differing transport needs. Such an approach has rarely been used; therefore, the second aspect of this paper addresses the question: If it is technically possible to provide an equitable, energy efficient, and flexible land use and transport system, why has this not been seen as a politically important objective?

INHERENT TRANSPORT CONFLICTS

Historically there have always been three main forms of travel (i.e., walking, public transport, and private vehicles), but the technology and availability of the latter two have changed dramatically in the last 100 years. This has had major implications for the way towns and cities have developed and the social and economic activities that occur within them. From the 1880s the development of public transport systems encouraged a separation and specialization of land uses. Those functions most dependent on good transportation links and high population hinterlands (e.g., government, commerce, and retailing) pushed other land uses toward the periphery of cities. Also those most able to pay for more spacious housing and the higher transportation costs at a city's edge did so, reinforcing patterns of social segregation.

This loosening of urban form and the greater specialization of land uses was reinforced and accelerated by the development and increasing availability of the private automobile. A more diffuse and fragmented city structure has emerged, replacing the traditional land use specializations, such as city center shops and offices, suburban industry, and residential areas. Public transport operators have found it difficult to adapt to such structural changes in their operational environment. Not only have they lost passengers because of rising car ownership, but their operating costs have increased because the environment has adapted to the needs of car users.

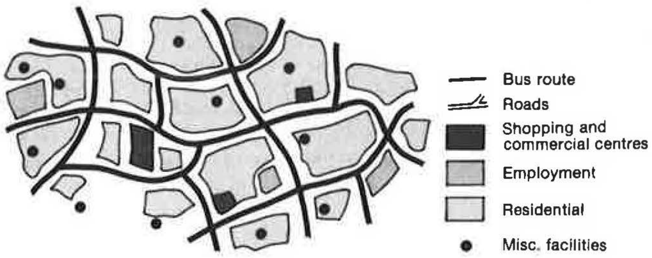
This process is familiar to planners throughout the world, yet it represents a frightening dilemma. To the affluent and politically influential car user such trends seem entirely beneficial, but to those dependent on public transport or pedestrian access, the hardships inherent in getting around in such car-oriented places are all too apparent. In addition, the planner may ask whether our cities are being molded into an urban form that may not be sustainable for many more years.

In Britain the question of whether there is a major urban conflict between the land use pattern and operational requirements of public and private transportation was not addressed before a series of theoretical urban form studies were made in the mid-1960s. One of the earliest of these was conducted by the planning consultants Jamieson and Mackay (2) who together with the new town plans for Redditch (3) and Runcorn (4) identified the conflict between land use and the operational requirements of public and private transportation to be a major concern.

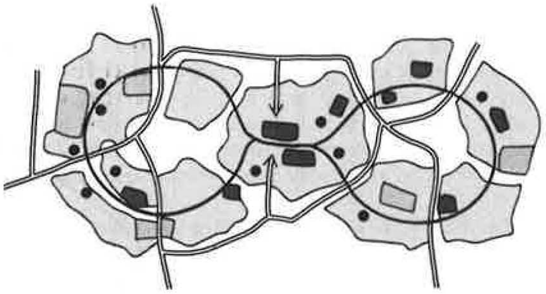
Jamieson and Mackay considered the operational requirements to be "diametrically opposed . . . public transport requires a concentration of generators and facilities to maximize the number of people and activities within easy reach of the transport route and thus induce a high level of use. On the other hand, the highway network for private transport requires a dispersal of generators and facilities to achieve maximum (vehicle) accessibility at low capital cost" (see Figure 1). Is this conflict absolute or are there ways of minimizing or resolving it?

EXAMPLES OF THE CONFLICT BETWEEN LAND USE AND TRANSPORT DESIGN

The British new towns have a tradition of being pioneers in planning techniques and among them can be found strongly contrasting land use and transport



(a) Optimal structure for private motorized transport. Uniformly low-density to reduce traffic intensity and random distribution of facilities to even-out loading on roads



(b) Optimal structure for public transport. Urban facilities located along corridors hence concentrating demand to maintain a high frequency service. Facilities located evenly along corridors to avoid peaks in loading. Increase in density towards public transport route to minimize distances

FIGURE 1 Optimal urban structures for private and public transport.

structures. These include towns in which plans have been predominantly influenced by the requirement to provide for high levels of car use and others in which plans have sought to resolve the conflict between transportation methods.

Full Motorization Designs

Planning studies show that the optimal urban form to accommodate high levels of car use is a low density urban fabric with a random distribution of facilities to spread vehicle loadings over as wide an area as is possible. The land use designs of the early new towns were largely an idealized imitation of existing towns. Typically a plan would consist of clusters of neighborhoods of about 5,000 population around a town center with a radial/concentric road network and a single industrial estate on the periphery. Although these towns functioned adequately with existing traffic flows, by the 1960s it was felt that such structures could not accommodate forecast levels of car ownership and use (Figure 2). In practice car ownership has not risen by as much as was forecast, but these forecasts did significantly influence new town plans.

The plan that took the operational requirements of the private car virtually as the design requirement for its land use and transport structure was the Plan for Milton Keynes (5). The land use and transport design of Milton Keynes consisted of a grid of dual carriage highways combined with the dispersal of all traffic generating land uses (Figure 3). Residential areas were planned at 70 persons per hectare, with an overall population density of 27 persons per hectare. With a reduction in Milton Keynes' population goal and a drop in household size, this overall density is now down to 22 persons per hectare.

Although the published plan referred to a high quality public transport service, with a 2.5 to 5 min frequency on all routes, the Transportation Technical Supplement (6) admitted that "in the light of the selected land use plan, the provision of a competitive form of public transport is not practical. This consideration . . . has therefore been discounted. The appropriateness of providing a public transport service beyond the minimum level necessary . . . is solely a matter of policy."

This clearly indicates that the designers of Milton Keynes did not consider this urban structure to be capable of supporting more than a minimal level of public transport without substantial subsidies. However, Milton Keynes Development Corporation was politically unwilling to change their strategic plan. Therefore, Milton Keynes was built to the original 1970 design. Over £100 million was spent on grid and trunk roads. The dispersed, low-density design of the town has added to the costs of housing and services unrelated to transport. (This aspect is considered below.) By the early 1980s it became clear that a policy of substantial subsidies would be needed not just to maintain a high-quality public transport service, but to maintain any service at all. In 1982-1983 subsidies totaling £997,000 (42 percent of running costs) kept a basic bus service (11 routes, 30 min frequency) in operation for the town's 107,000 people.

In the mid-1970s, Milton Keynes Development Corporation experimented with Dial-a-Bus in the hope that a technological solution could be found to the hostile operational environment of Milton Keynes. However, these buses experienced a larger loss than conventional services and were withdrawn by 1980. The focus has shifted from planning and technology to the promotion of existing services and endeavoring to find politically acceptable ways to maintain high subsidies. Clearly the design of Milton Keynes has produced extremely hostile operating conditions for public transport and those dependent on it are finding travel unnecessarily difficult.

Additionally the low density of development means that the population served by local facilities is small and only basic services such as a shop or two, a school for children under 12, playing fields, and a community hall, are within walking distance of the home. A good system of cycleways has been provided; but, nevertheless, such an urban structure means that a high proportion of journeys are required to be by motorized forms of travel.

An alternative approach, adopted in only a few new towns, has been to try to design an urban structure that is capable of resolving, or at least minimizing, the operational conflict between the private

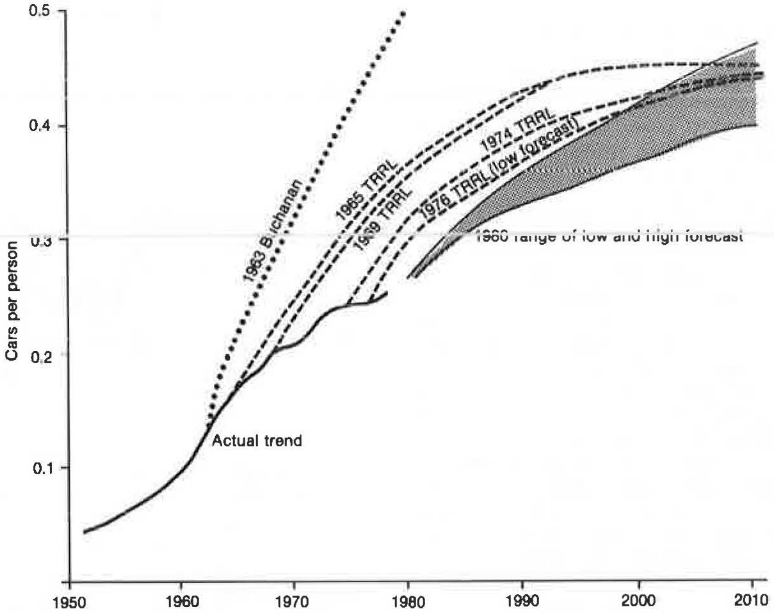


FIGURE 2 British car ownership levels and forecasts, 1950 to 2010.

FIGURE 3 The Milton Keynes Plan. Travel generating land uses are dispersed over the development area and traffic loads are spread evenly over a grid of dual carriageway roads.

car, public transport, and nonmotorized travel. In Milton Keynes the belief that there would be a massive rise in car ownership led to this factor dominating the design of the town. In another new town, Runcorn, the growth of car ownership was seen as a factor that required a design that emphasized public transport. What produced this seemingly opposite reaction to the same problem? Although the designer of Runcorn (Arthur Ling) accepted the car ownership forecasts, he recognized that this was potentially socially and economically divisive (4):

> To design the town dominantly for the motor car would require the maximum expenditure on highways to cater for peak-period traffic and a more extensive provision of car parking spaces at the Town Centre and in the industrial areas. In addition, public transport . . . would be little used and therefore it would be uneconomic to operate a frequent service. This would cause a sense of social isolation for those without the use of a car, such as children and old people, and also members of the family to whom the car is not available at a particular time.

It is interesting to compare this with the more recent writings of the French Marxist urban sociologist Castells (7):

> This extreme dependence on the automobile creates new sources of discrimination--all nondrivers are seen as virtually handicapped. Such is the case for the aged, for adolescents, for housewives when the husband has gone to work in the car, for the sick, but also for the great segment of the population not equipped with a car . . . so many immobile people destined to consume little else but television. So many "living dead."

Both authors, one from a traditional, the other from a Marxist planning viewpoint, express the same concern--that consumer demand for cars cannot be universally met, but the demand is sufficiently great to erode the operational environment of other travel methods and cause serious problems for a major sector of the population. Therefore the greater concern is not ways of accommodating high car ownership, for this is really quite easy, but addressing its social and economic consequences.

The Runcorn plan and those of some other new towns (Redditch, 1966; Peterborough, 1970; Irvine, 1967; and Stonehouse, 1974) are the only significant attempts at addressing the conflict between land use and transport by planning design (see Figures 4 and 5). The basic design principles of these plans were

1. Public transport and car flows are on separate networks, making it possible to concentrate

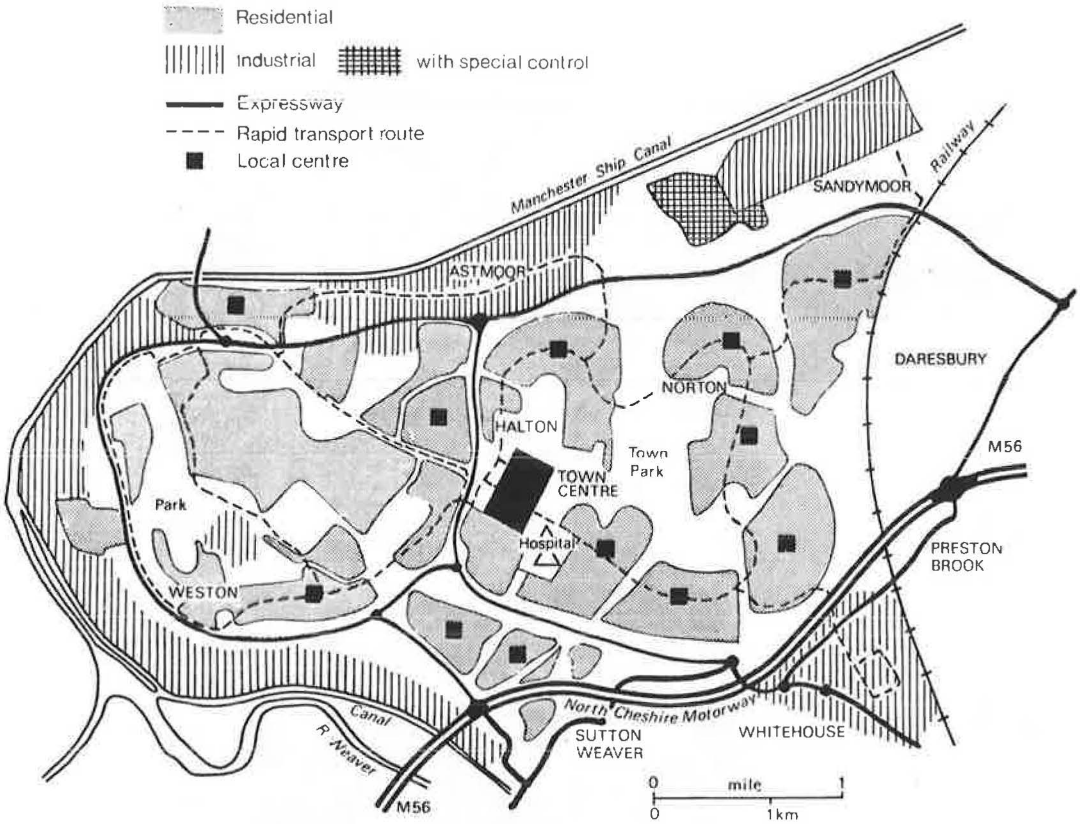


FIGURE 4 Runcorn land use and transportation plan.

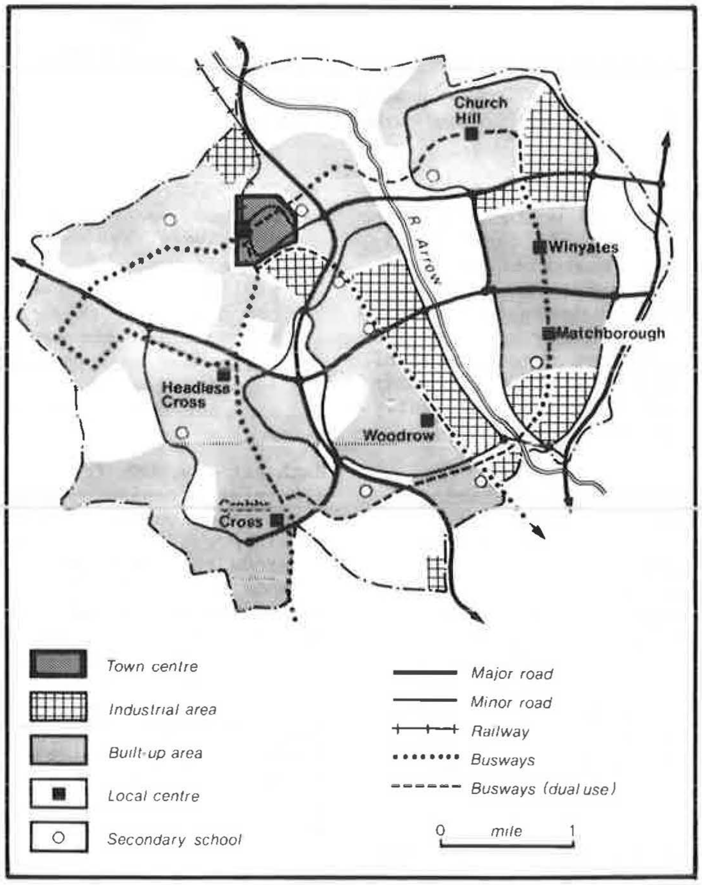


FIGURE 5 Redditch land use and transportation plan.

travel flows for public transport while dispersing car traffic.

2. The size of residential areas is determined by the population needed to maintain a frequent public transport service.

3. Residential densities are zoned so that they increase toward public transport routes.

4. Low-density uses (e.g., open space, warehousing, major roads, and parks) are zoned away from public transport routes so as not to increase walking distances to the routes.

5. Residential areas, employment, shopping, and other major travel-generating land uses are arranged so that they provide corridors of public transport movement conducive to high service frequencies.

6. The overall density of development is changed little, but land uses are rearranged to provide a pattern of development that is conducive to public transport operations.

The construction of Runcorn and Redditch is now essentially complete and in practice these towns have shown that a considerable amount can be done to address the inherent conflicts between land use and private and public transport, especially considering that these are relatively small towns where public transport operations are usually less viable than in cities.

In Runcorn a service frequency of 5 to 10 min is in operation and in Redditch a 10 min frequency has been achieved. However, what is of particular note is that these public transport systems require very little subsidy. In Redditch 6 percent of operating costs are subsidies and in Runcorn about 5 percent. These are considerably lower than the 42 percent subsidy in Milton Keynes for a 30 min frequency bus service (see Table 2).

In addition, the capacity of the highway networks of Redditch and Runcorn have proved to be ample with no restrictions on car use. The distance-minimizing techniques used to promote public transport viability have also enhanced pedestrian accessibility. To a large extent, urban structures that are conducive to a good quality public transport service enhance pedestrian and cycle access too, so long as local physical conflicts with traffic are recognized in the provision of highway crossings and separate foot and cycle paths. Indeed, in terms of energy conservation, this aspect is more important than the provision of good public transport services. A slight modification of the deign for Runcorn and Redditch to provide a larger population center for local facilities can make upwards of 60 percent of the journeys within walking distance of the home, compared with only 30 percent in a dispersed Milton Keynes-type urban structure. This elimination of the need for motorized travel could cut energy use by up to one-third. Further research is continuing on this aspect at the Open University (see Figure 6).

It seems that such urban structures are capable of providing good transport services under widely differing modal split assumptions; and with transport and energy availability presenting a very uncertain future, this flexibility is to be valued.

APPRAISING ALTERNATIVE URBAN DESIGNS

From the above empirical examples, it seems possible to address the inherent conflicts between the operational requirements of the private car and public transport. However, transport is only one aspect of the urban environment. The different designs have implications for development and servicing costs, the types of housing that can be provided, and so forth.

The development costs of the more structured, public-transport-oriented designs are lower, even allowing for the infrastructure costs of busways and the occasional need for grade-separated highway interchanges (see Table 2). When development is concentrated along public transport routes and unserviced areas (e.g., parkland) are to the periphery, these unserviced areas do not have to be crossed by water pipes, electricity cables, and so forth. The more dispersed urban structures require a greater quantity of piping and cables per person, as well as a larger provision of local roads. Costs of providing and maintaining urban services can be 10 to 25 percent lower than in a dispersed, car-oriented town. The amount of land used is 20 percent less and overall development costs can be almost 50 percent lower per person accommodated (10-12).

The main advantage of a fragmented and dispersed urban structure is that it can adapt to a wide range of changes in land use. It is essentially a nonplan that allows market forces to express themselves freely. These advantages are rather vague and the degree to which this flexibility is actually of significance over alternative urban structures is a matter of conjecture. It does not seem that this ultraflexibility is worth the additional transport, development, and servicing costs that such structures impose on their population and the taxpayer.

To be fair, plans such as that for Milton Keynes were conceived in an era when the main design problem was viewed as providing for extreme prosperity and that general affluence would eliminate any of the arising problems; that is, it would not matter that low-density, dispersed urban structures cost more to build and service as there would be ample funds to subsidize buses. In the context of an anticipated economic boom, the ultraflexible plan for Milton Keynes can be understood.

TABLE 2 Key Characteristics of the New Towns Under Study *(8,9)*

	Milton Keynes	Washington	Redditch	Runcorn	Peterborough
Population	107,000	55,000	68,000	65,000	124,000
Current gross density (ppha)[a]	12	24	23	32	19
Planned gross density (ppha)[a]	20	27	25	34	23
Development costs to state per person housed (£)	10,200	11,000	4,100	7,000	5,300
Average bus frequency (min)	30	20	10	5	15
Cost of bus season ticket per week (£)	2.40	1.65	3.50	2.50	3.50
Subsidy as percent of bus running costs	42	NA	6	5	14
Average number of shops at local center	5	9	15	7	23

Note: This table includes two new towns in addition to those considered in the text. Washington (in northeast England) is of comparable size to Redditch and Runcorn but was designed similarly to Milton Keynes. Peterborough is comparable in size to Milton Keynes but was designed to promote public transport.

[a] Persons per hectare.

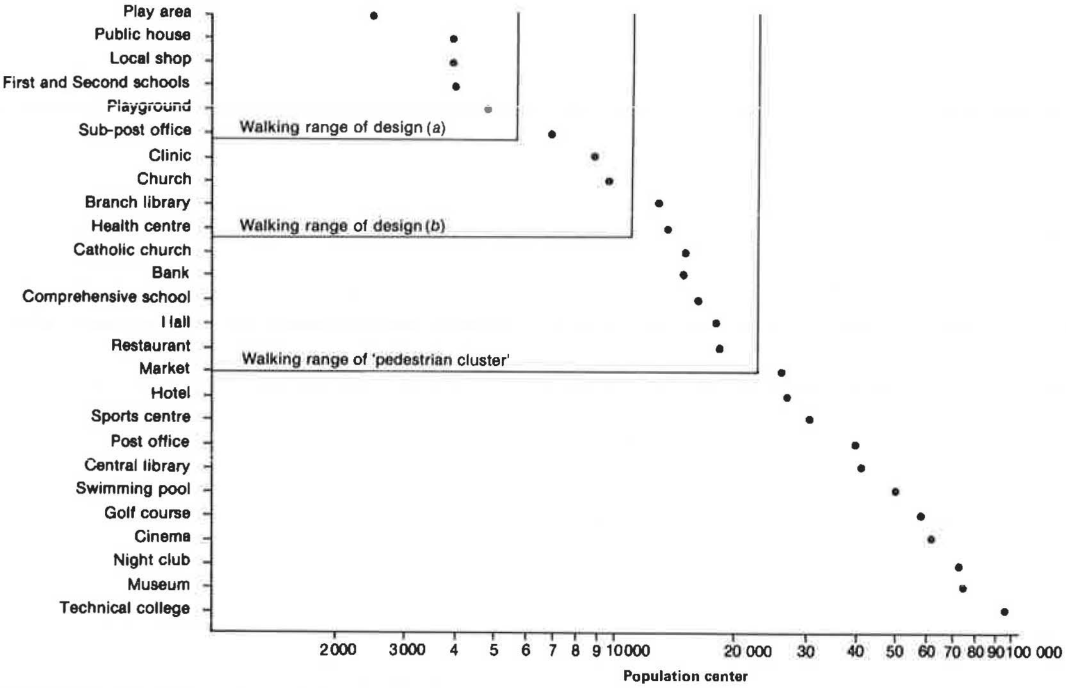


FIGURE 6 Facilities and population centers.

Today such an optimistic and confident view of the future is recognized to be naive and simplistic. Future trends in transport and economic growth are very unsure and increasingly planners have to recognize that their plans need to accommodate an uncertain future. Although low-density, fragmented urban structures are physically flexible under conditions of economic prosperity, they are inflexible to factors such as energy shortages, requirements to reduce travel needs, recession, and so forth.

General Application

This paper has used examples from the new towns because they provide the best examples of the conflicts between transport and land use. But this, of course, is also present in existing settlements. How the conflict expresses itself may vary according to the nature of the area, its culture, wealth, and political factors. It may be expressed by protests over high public transport fares, the closure of rail lines or the current political controversy in Britain over the use of subsidies to maintain public transport operations. At the extreme this transport conflict results in social segregation, as poorer groups are forced to move away from areas where they find travel difficult. This can only contribute to the severe social and economic problems found, for example, in most inner city areas where the poor are concentrated. The conflict between the operational requirements for different forms of travel can, therefore, be seen as a contributory factor to the social unrest and disturbance present in so many inner city areas.

Adapting the planning and state investment principles contained in this paper to existing towns and cities would, of course, be a long-term measure. A mixture of physical and fiscal measures would be needed: public transport subsidies to compensate for hostile operational conditions and to reduce the externalities of accidents, energy use, social costs, and so forth while the physical measures are implemented. But above all such a blend of measures would have to be firmly rooted in an understanding by planners and politicians of the complexities of the transport crisis faced by our society.

INHERENT POLITICAL CONFLICTS

It seems possible at least to lessen the conflicts between the private car and other travel methods and to aspire toward an urban form that may seem better suited to the uncertainties of the 21st century than the direction in which cities presently seem to be moving. Yet, despite this knowledge, rising energy costs, and the recession, there seems to be no particularly strong move in this direction. Why is this?

There seem to be several underlying causes. First, although transportation and land use planning are often regarded as a single process, it is carried out by a variety of government and state departments, each of which has its own professional and political stance to defend. For example, the combination of highway engineering, planning for other forms of transport, and land use planning has only occurred within the last decade in Britain. The integration of these three is often superficial. The degree of financial and political power held by these three groups is also markedly different.

Highway engineering is well established and benefits from considerable industrial support and lobbying, something that is not true of planning in general. Highway engineering represents a market-oriented approach, which is carried out by the state not because of a desire for planning (in the social and economic sense of the word) but because it is an essential activity that private enterprise cannot practically fulfill. The tradition of highway engineering is more closely akin to that of the private developer than the environmental planner. It is a tradition that is remote from the basic ideology of planning, which presumes that a market failure is as good an environment as one in which the same resources are properly coordinated.

The traditional highway engineering approach has been that of responding to the market demand for roadspace. Environmental planning and state intervention for other travel methods holds the contrasting philosophy of the comprehensive optimal approach, compensating for externalities, the inclusion of wider economic and social criteria, forward planning, and all that is associated with the concept of planning. The approach discussed in the first part of this paper is considered to be capable of reducing inherent transport conflicts.

Compared with the real political, industrial, and economic power of traditional highway planning, however, it matters little whether environmental planning is intellectually superior. Planning in Britain is a political weakling [and this is true even in Eastern Europe where environmental planning carries remarkably little influence (13)]. The two may technically be coordinated but in practice one carries a hundred times the influence of the other.

So one branch of state intervention (highway engineering) is creating externalities that another branch (planning) tries, but has neither the power nor the influence, to correct. It is an inefficient, unnecessarily costly process that creates avoidable problems, inconvenience, and often hardship for millions. The key to changing this situation is not to improve planning techniques, for they are adequate, but to improve the political status of the concept of planning. Without such a change integrated planning for transport and land use will always be an activity of marginal relevance.

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Roadway Improvements and Traffic Circulation Patterns for the 1982 World's Fair in Knoxville, Tennessee

RICHARD A. MARGIOTTA and SAMUEL L. PARNELL

ABSTRACT

The 1982 World's Fair in Knoxville, Tennessee, was a major special event for which a variety of transportation improvements and programs were implemented in the hope of averting severe traffic congestion. Historically, Knoxville's road system was inadequate to handle existing regional and local traffic, so planners, engineers, and administrators had to assume an aggressive posture to effect needed improvements. The nature of these improvements, including their expected and actual impacts, is explored. Also included is an analysis of daily and hourly traffic distribution patterns. Overall the transportation system surrounding the 1982 World's Fair performed excellently. Many roadway improvements initiated for the fair will have residual benefits to Knoxville for several years to come. Other projects implemented solely for the fair performed well. The capital improvements were complemented by a favorable transportation modal split and temporal traffic distribution characteristics. Planners of future special events can benefit by applying some general principles that arose from the Knoxville experience including realistic estimates of travel demand and transportation modal split, providing motorists with guidance to parking areas, gate location and number, knowledge of the event's expected arrival and departure patterns, and fostering a high degree of agency cooperation.

The information presented in this paper was prepared as part of a project funded by UMTA entitled 1982 World's Fair Transportation System Evaluation. This project was conceived in August 1982 as an UMTA Section 8 Planning Grant during the height of the 1982 World's Fair. At that time, the successful operation of the transportation system for the World's Fair and the need to document planning efforts prompted UMTA officials to initiate the project. Heretofore there had been little transportation-related study of large-scale special events, and the results could be used in preparing for the forthcoming Olympics in Los Angeles and the New Orleans World's Fair (both in 1984).

All aspects of the transportation system were studied, including roadway improvements, parking, access, tour and shuttle buses, local bus service, interagency involvement, and design parameters. The study was divided into two phases. Phase I was a quick overview of the lessons learned by the various agencies involved and was completed within 90 days of the start date. Phase II covered the same material in much greater detail and included analysis of the available data. For a complete picture of the transportation system the reader is referred to those reports (1,2).

SETTING OF THE 1982 WORLD'S FAIR

Knoxville is located in the geographic heart of the eastern United States in a broad valley between the Cumberland Mountains to the northwest and the Great Smoky Mountains to the southeast. It is located at one of the Interstate system's busiest intersections, I-40 and I-75; it is served by an inland waterway and surrounded by five of the Tennessee Valley Authority (TVA) lakes on the south. Figure 1 shows the area's road network and the location of the fair site adjacent to the Knoxville central business district (CBD). Nearby institutional energy resources, including TVA, the University of Tennessee, and Oak Ridge National Laboratory, helped precipitate selection of the fair's energy theme. In 1980 the populations of the city of Knoxville, Knox County, and the Knoxville standard metropolitan statistical area (SMSA) were 175,045, 319,694, and 476,517, respectively.

During the planning stages of the 1982 World's Fair many citizens and government officials feared that the fair would cause 6 months of constant traffic congestion. This fear was based on the more than 60,000 people per day that had been projected to attend the fair. This was compounded by the inadequacy of Knoxville's Interstate and street system, which historically had not been able to meet traffic needs even without such an event occurring in town. Further, the traffic problems that occur in conjunction with University of Tennessee home football games, which take place in the 94,000-seat Neyland Stadium, led many people to equate the fair with a 6-month long football game. These perceptions strongly motivated fair organizers and city and state officials to take an aggressive posture in implementing planned roadway improvements before the opening of the fair. Fair planners strove to provide good access to the fair and its bus terminal and parking facilities while maintaining good levels of service on central area streets. As it turned out, the roadway improvements were well planned and traffic operations were aided by the traffic patterns that materialized during the fair.

ROADWAY PROJECTS IMPLEMENTED FOR THE WORLD'S FAIR

Table 1 lists the various roadway improvements and projects that were planned and implemented for the fair; these can be located by number on Figure 2. In some cases, the projects were part of the long-range transportation plan for the Knoxville area but schedules were advanced for the fair. This was a positive impact of the fair on the overall transportation system; Knoxville received several large-scale road improvements in a short span of time that will continue to operate efficiently well into the future. Table 1 gives project scheduling and costs, as well as the approximate increase in capacity effected by the projects. Also included are comments about what the projects were expected to do and reflections on their effectiveness. The remainder of this section will deal with the most important projects listed in Table 1.

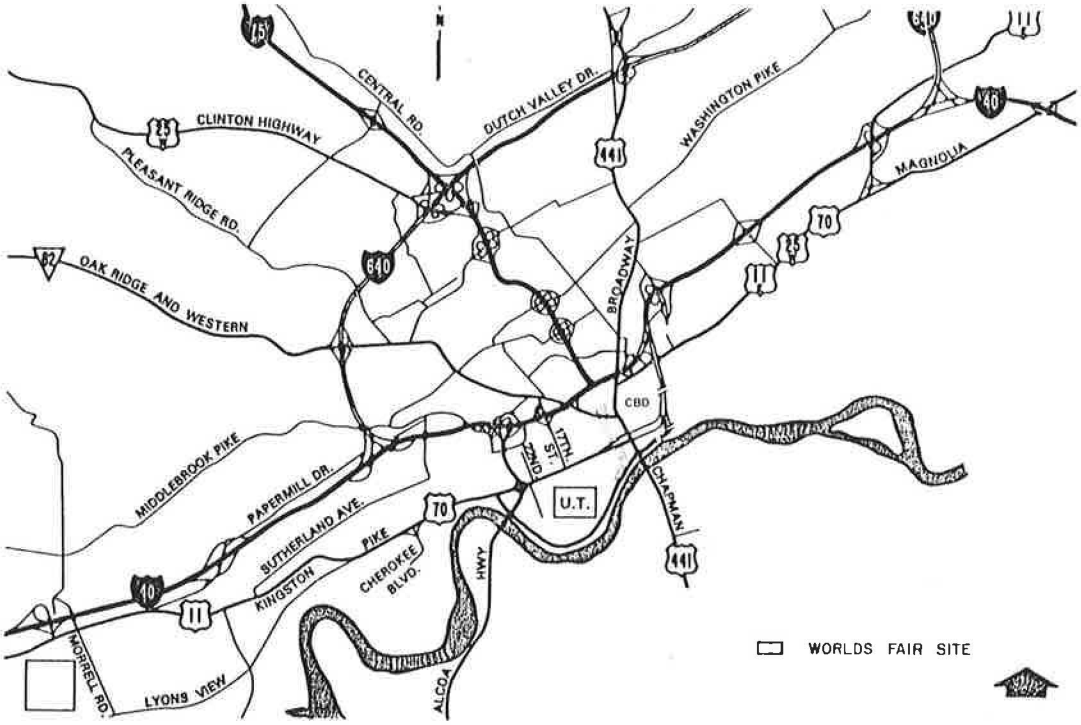

FIGURE 1 General setting of 1982 World's Fair site.

Interstate Improvements

By far the most important set of transportation improvements to occur in conjunction with the 1982 World's Fair were those to the Interstate system. To understand their significance it is necessary to know what conditions were like before the fair.

When the Interstate system was constructed in Knoxville it followed the alignment of an already existing expressway system located on the northern border of the CBD. It was heavily traveled because I-40 (an east-west route) traversed the midtown area and I-75 (a north-south route) interchanged with I-40 immediately north of the CBD. As both regional

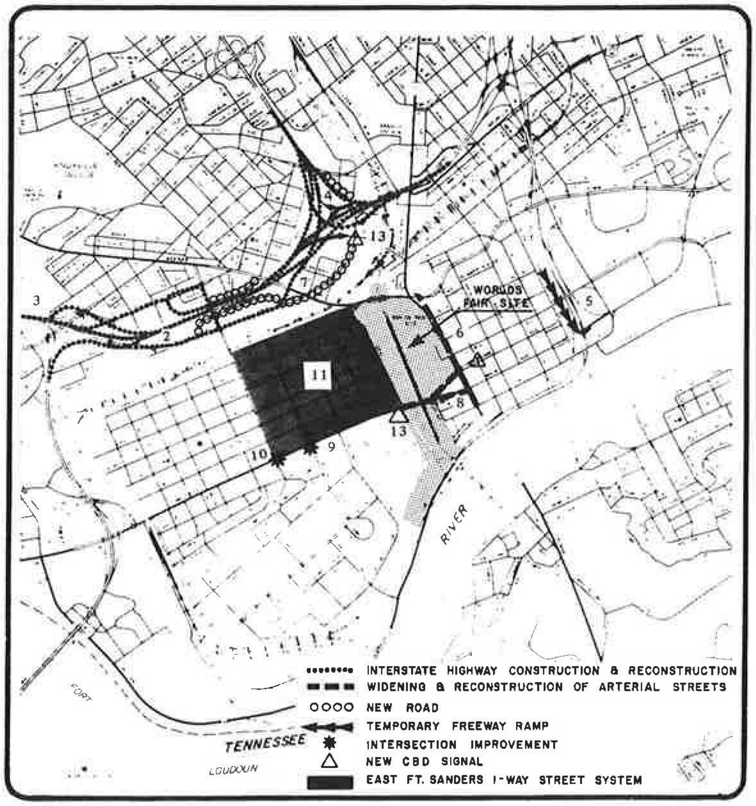

FIGURE 2 Local roadway improvements.

TABLE 1 Summary of Transportation Projects Implemented for the World's Fair

		SCHEDULING				ACTUAL IMPACT	
ROADWAY/ PROJECT	DESCRIPTION	START	END	COST	EXPECTED IMPACT RELATED TO FAIR	INCREASE IN CAPACITY	COMMENTS
1. I-640	Construction of 6 lane bypass route around central city.	10-77	4-82	State $115 million (includes interchanges)	Remove through I-75 traffic from central area; provide alternative for through I-40 traffic.	(new route)	Although completed before Fair, I-640 will have long range benefits to area; worked well during the Fair; handled all through trucks during Fair.
2. I-40	Widening to 4-5 lanes each direction between I-275 and Alcoa Highway; redesign of interchanges between I-275 and Alcoa Highway; construct Dale/ Ailor one-way pair as a frontage road for the interstate.	11-79	4-82	State $57 million	Increase freeway capacity. Reduce conflicts at interchange due to short weaving sections.	3500-5250 vph (one direction, mainline only)	Worked well during the Fair. Total number of interstate accidents reduced.
3. I-40	Widening to 3 lanes each direction between Alcoa Highway and Papermill Road.	11-79	4-82	State $6 million	Increase freeway capacity.	1750 vph (one direction)	Worked well during the Fair.
4. Temporary Interstate Ramps	Addition to entrance ramps to I-275 North and I-40 West and exit ramp from I-40 East.	10-81	3-82	Included in item (2)	Increase access to Fair and CBD; distribute traffic over larger area.		Valuable additions to interstate system that will continue to function well into the future; much Fair-related traffic used them.
5. Temporary Ramp from Business Loop	Addition to exit ramp from Business Loop to Hill Avenue.		N/A		Provide access to Coliseum Parking Area.		Used during Fair; probably reduced accidents; removed after Fair.
6. Henley Street	Widen to 3 basic lanes each direction with a median; addition of exclusive left turn and dual left turn lanes at intersections.	9-80	10-81	$1,613,000	Increase capacity; limit driveway access; increase pedestrian safety; improve main entrance appearance.		Worked well during the Fair even with drastic increases in volumes. Reduced total accidents; median provided refuge for pedestrian crossing; acquisition of ROW for east side of Fair, which was also used to widen Henley, greatly helped in the completion of this project.
7. Blackstock Avenue	Construct new roadway from Dale Avenue to Oak Street	11-81	5-82	State $102,000	Improve access to north gate (tour bus terminal).	(new route)	Essential for tour bus access; residual use as a frontage road.
8. Cumberland and Main Avenues	Realign and reconstruct between Henley and 11th Streets; add a Texas U-turn.	9-80	10-81	Cost included under item 6	Provide adequate site for U.S. Pavilion; reduce separation of north and south sections of Fair site.	N/A	Reduced travel time along the Cumberland/Main one way pair. Better connection for pedestrians between the UT main campus and CBD since an industrial slum was removed.
9. Cumberland Avenue/16th Street	Widen Cumberland on west side of intersection to provide left turn storage for east bound vehicles.	7-81	10-81	State $47,000	Increase roadway, capacity; reduce accidents.	600 vph	Provided some of the necessary capacity increase for the Fair. This allowed prohibition or left turns at 17th which assists in reducing travel time along the corridor.
10. Cumberland Avenue/17th Street	Prohibit left turns from both approaches to Cumberland Avenue.				Increase roadway capacity. Reduce accidents.	600 vph	Reduced travel time along Cumberland Avenue.
11. One-way street designations (includes Eastern Fort Sanders, Poplar Street, Heins Street, Tulip Street, Blackstock Avenue and Ramsey Street.	Convert existing two way streets to alternating one-way streets.			N/A	Increase roadway capacity and curb parking potential.		Seemed to work well during the Fair; possibly held down accidents; promoted pedestrian safety.
12. Prohibition of through I-40 trucks.	Require through trucks to use I-640 bypass.	4-82	5-82	$8,000	Increase CBD freeway capacity; decrease truck/automobile conflicts near CBD interchanges. Safety from potential hazardous materials accidents.		Required trucks to travel an extra 4 miles; prohibition ended with Fair.

TABLE 1 (continued)

		SCHEDULING				ACTUAL IMPACT	
ROADWAY/ PROJECT	DESCRIPTION	START	END	COST	EXPECTED IMPACT RELATED TO FAIR	INCREASE IN CAPACITY	COMMENTS
13. Traffic signal installations	1. Cumberland/Locust 2. Cumberland/11th 3. Blackstock/Oak/ I-40 Exit.				Decrease delays; increase pedestrian safety.		Blackstock/Oak/I-40 Exit signal facilitated tour bus movements. Blackstock Oak/I-40 signal removed after Fair. Cumberland/ Locust and Cumberland/11th may be removed depending on World's Fair site development.
14. Computerized traffic signal control system.	Coordination of traffic signals adjacent to World's Fair site.	5-79	10-83	Fed/State/City $3,500,000	Decrease delays at signals; promote progressive traffic flow.		Improved air pollution and energy use; travel time was decreased even through the traffic volumes increased on major arterials.
15. CBD street system.	Resurface and replace pavement markings.	10-81	11-81	City $250,000	Improve appearance and driving quality; increase intersection capacity.	Additional left turn capacity and less delay to thru traffic.	Pedestrian crosswalk marked for safety.
16. Replace 500 street name signs; add block address numbers.	---	12-81	3-82	$40,000	Improve appearance and tourists' orientation.	N/A	Primarily on amenity.
17. Install 1400 regulatory and traffic control signs (mostly "Parking/No Parking").	---	2-82	5-82	$42,000	Provide adequate information to motorists.	N/A	Parking regulatory signs were essential to facilitate traffic movement on important access routes.
18. Upgrade street lighting in CBD.	---	6-81	4-82	City $10,000	Increase pedestrian security.	N/A	More efficient lighting sources (high pressure sodium) were installed.
19. CBD Landscaping, Street Furniture and Sidwalk Improvements.	27,000 sq.yds. of sidewalk, trees, benches, and trash receptacles.	2-81	4-82	City $375,000	Reduce pedestrian vehicle conflicts; improve appearance.	N/A	Only necessary sidewalk improvements were immediately adjacent to Fair site.
20. Pedestrian signals at selected locations.		1-81	12-81	City $40,000		N/A	Provide protection for pedestrians.
21. World's Fair trailblazer signing.	Install signs on major approach routes directing tourists to parking areas (over 80 locations).	1-82	4-82	State $60,000 City (includes removal $40,000)	Distribute traffic to various parking areas.	N/A	People tended to follow the first trailblazer exit that they encountered; overall very useful, but certain improvements could have made trailblazing work better (see text).
22. New taxi, passenger, bus loading, and no-parking zones.	---	3-82	4-82	City $3,000	Facilitate necessary curb usage.		

and local traffic grew during the late 1960s and 1970s the sections of interstate adjacent to this cloverleaf design interchange experienced frequent and severe traffic congestion. This led to its nickname of "malfunction junction."

Figure 3 shows the CBD section of I-40 before and after improvements were made. Some of the major differences are the redesign of the I-275 and I-40 interchange (formerly malfunction junction), the elimination of the Western Avenue interchange, the incorporation of Dale and Ailor avenues as a one-way pair of frontage roads, and the redesign of the Alcoa Highway interchange.

The addition of Blackstock Avenue had a specific use during the fair as an access route to the tour bus terminal and north parking lot and is now functioning as a frontage road to the temporary Interstate ramps. These ramps were constructed to provide access to the CBD area during the fair because it was not possible to build the final I-275 and I-40 interchange, which was designed with several ramps tying directly into Henley Street, before the fair opened. The ramps were not designed to FHWA standards but were allowed to be constructed as temporary ramps. They will remain until the final design is implemented.

Another change that occurred in the CBD section of the Interstate system was that signs were placed on I-75 along the western leg of I-640, the semicircumferential bypass route. This removed through

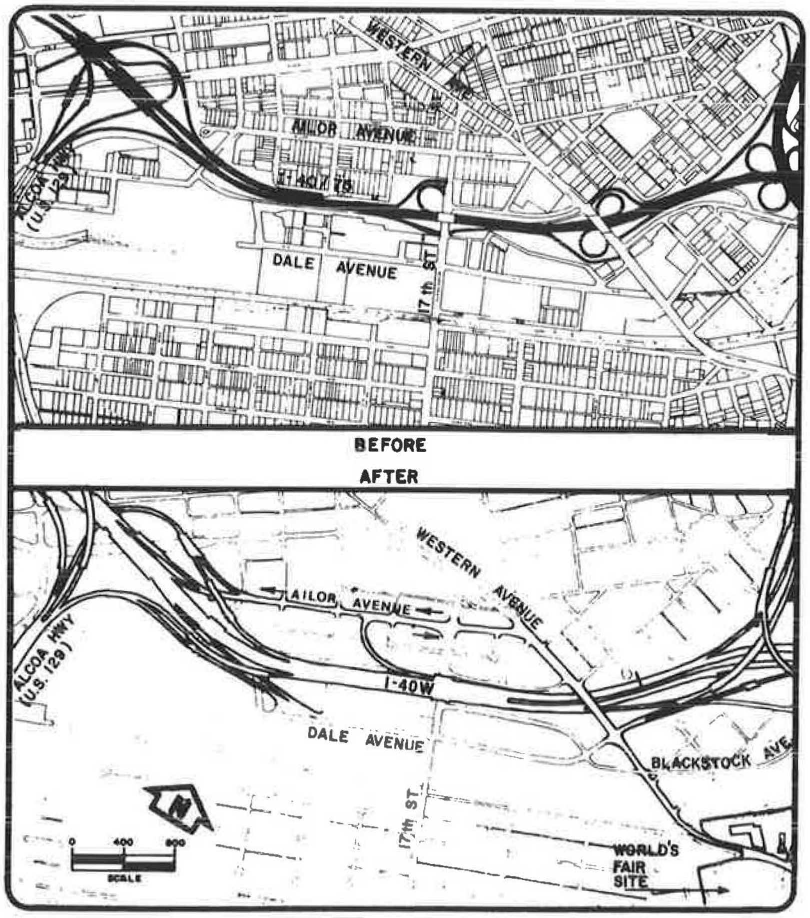

FIGURE 3 Comparison of CBD Interstate system before and after World's Fair.

I-75 traffic from the downtown area. The section of Interstate that previously had been I-75 was designated as I-275 (see Figure 3).

Local Street Improvements

Perhaps the most important of the local street improvements in the vicinity of the fair were those to Henley Street, which forms most of the eastern border of the fair site. Prior to the fair this street suffered from congestion due to the large number of signalized intersections with inadequate numbers of lanes (the old cross section was five lanes, undivided, with a continuous center turn lane). The improvements on Henley Street were crucial to handle the substantial amount of fair-related traffic.

The "trailblazer" signing system was developed to direct motorists, particularly those arriving by the Interstate, to parking areas. The intent was to distribute traffic and to keep vehicles from unnecessarily cruising by the fair site. The system consisted of two separate signs placed side by side: one with the fair's logo on it (a symbolic flame design) and one indicating parking. These were placed at more than 80 locations on fair approach routes and local streets. Two problems arose in relation to the trailblazer system, however. First, vandalism and theft were considerable; apparently many people regarded the signs as ideal souvenirs. Second, motorists tended to follow the first occurrence of the trailblazers even though several exits were signed with them. This resulted in an uneven distribution of traffic and parking lot use. Although serious problems did not arise, this is a noteworthy item for future special events planning; it is generally agreed by fair planners that more time should be devoted to the conception and installation of a guidance system of this type.

ANALYSIS OF TRAFFIC PATTERNS

Daily Traffic Volume Comparisons

Figure 4 shows the projected and actual daily increases in traffic on major approach routes to the 1982 World's Fair. During the planning stages of the fair, traffic was projected to increase by approximately 33,000 vehicles per day on major approach routes (4). This figure was determined by first estimating a design day, based on the 90th percentile of expected attendance variation, and applying estimates of transportation modal split (attendance variation data were borrowed from previous world's fairs of similar size).

Table 2 gives a comparison of expected and actual values for modal split. The "actual" percentages are estimates based on daily counts of tour buses, selected counts of shuttle bus passengers, and changes in local transit use (no formal modal split study was conducted). Modal utilization was observed to vary during the course of the fair. In the first 2 months the use of tour bus and shuttle bus service was high, but this decreased over the final 4 months in favor of increased personal vehicle use. This pattern may be attributable to patrons' prior per-

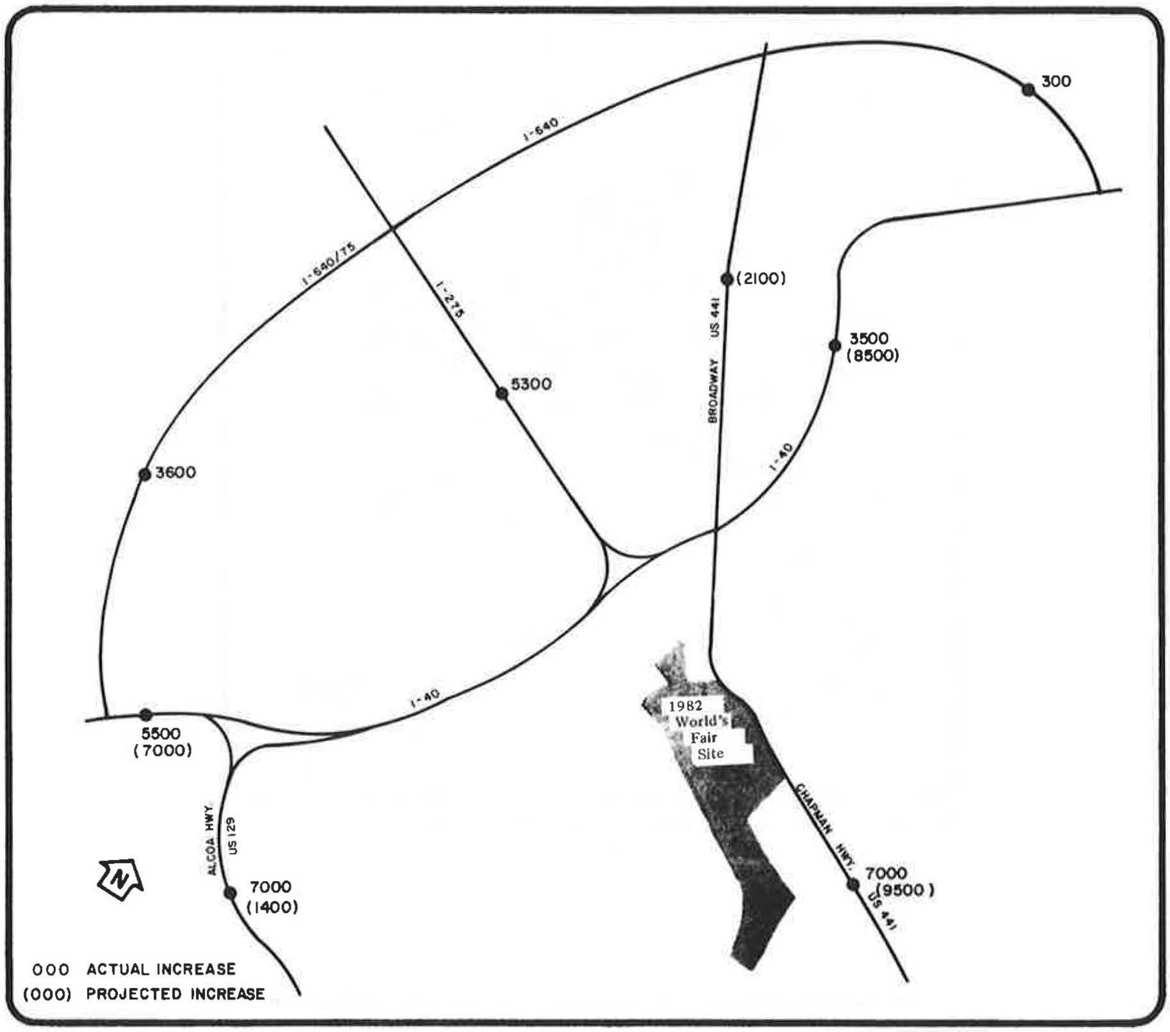

FIGURE 4 Projected versus actual traffic increases (vehicles per day) on major approach routes.

TABLE 2 Percentages of Projected and Actual (Estimated) Modal Split for the 1982 World's Fair

Mode	Projected (%)	Actual (%)[a]
Personal vehicle	65	65
Tour bus[b]	15	18
Shuttle bus[b]	15	7
Local transit	2	2
Walk	3	8

Note: The larger than expected use of tour buses can be traced directly to the fair's strong marketing in this area.

[a] Estimated using available data.

[b] Tour buses were defined to be organized group tours from outside of the Knoxville area; shuttle buses carried patrons who had previously driven to the area and parked at remote lots.

ception of severe traffic congestion; when this did not materialize, they chose to drive instead of using tour and shuttle buses. Overall, when the values in Figure 4 and Table 2 are compared, it is apparent that the estimates of modal split and total vehicles on all approach routes were highly accurate. (Although there were discrepancies on individual routes between projected and actual volume increases, total volume increase was well estimated.)

Extensive traffic count data were available for the local street system. These data were collected by the City Department of Engineering during and after the fair in two forms: (a) tube counts at selected locations and (b) one-way counts made downstream from intersections by the newly installed computerized signal control system. Figure 5 shows overall average daily traffic (ADT) volumes on the local street system adjacent to the fair site during and after the fair (these are average counts for both weekdays and weekends). Fair planners had originally expected slight gains in volume in the immediate vicinity of the site because of the distribution of parking space (4) but, as can be seen, significant increases materialized. Much of this can be attributed to people driving close to the fair site to get a glimpse of it before parking. This situation was perpetuated by the overall lack of traffic congestion around the site. (As will be shown later, the increases did not significantly affect traffic operations because of roadway improvements and fair arrival and departure patterns.)

The comparison of overall ADT counts does not give a full picture of the impact of fair traffic on daily commuting and business travel by area residents. Figures 6 and 7 show the ADT volumes derived from weekday and weekend counts during and after the fair. In nearly every case, the difference in weekend traffic is far greater than the difference in weekday traffic. This indicates that the differences shown in Figure 6 are attributable to large increases in weekend traffic during the fair. The weekday ADT map shows that, in most cases, the weekday effects of fair traffic are minimal. For ex-

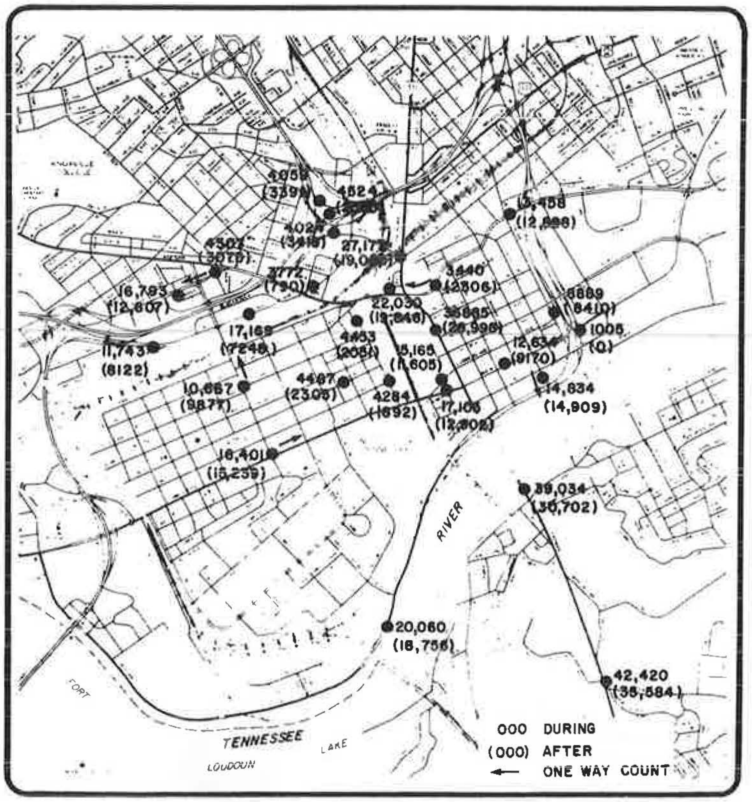

FIGURE 5 Overall average daily traffic on selected routes.

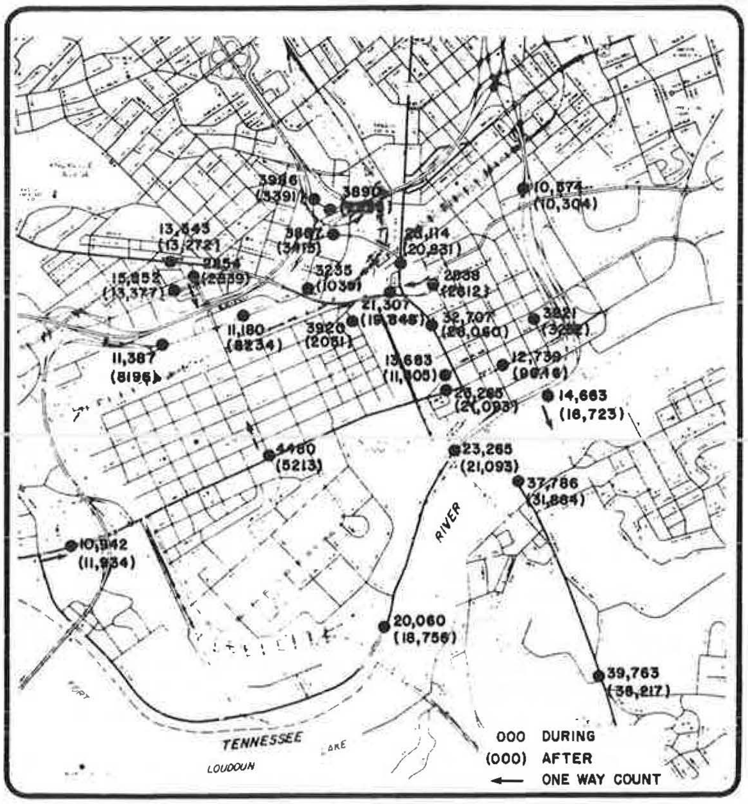

FIGURE 6 Weekday average daily traffic on selected routes.

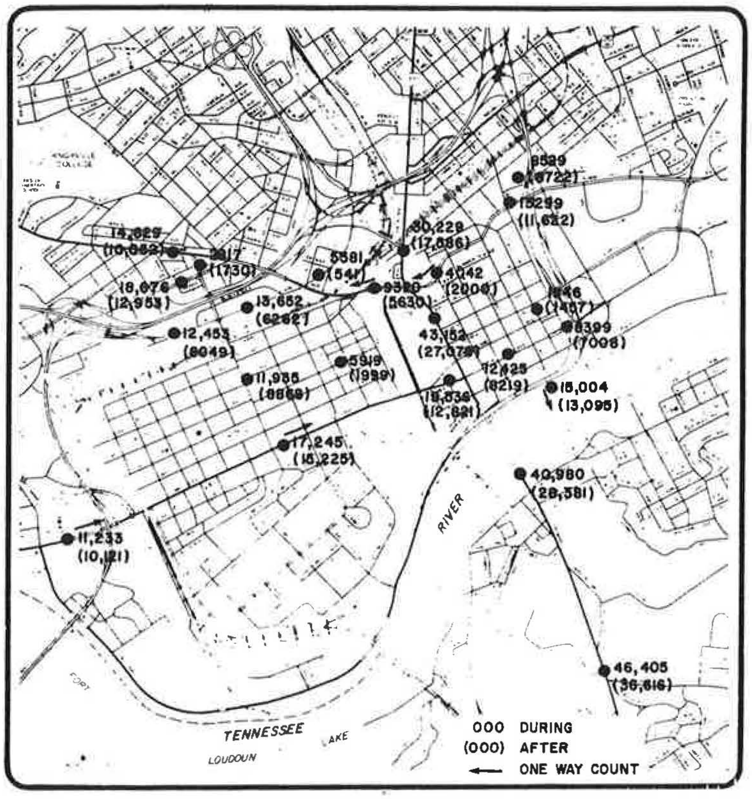

FIGURE 7 Weekend average daily traffic on selected routes.

ample, the weekday increase on Henley Street was 17 percent but the weekend increase was 60 percent.

If weekday versus weekend ADT counts during the fair are compared with weekend versus weekday ADT counts after the fair, it is found that traffic varied much more after the fair than during the fair. This implies that traffic during the fair distributed itself more evenly through the week. Thus, the excess in capacity that normally exists on weekends because of lack of commuters and business travel was used by fair traffic. Weekend fair traffic was generally higher than weekday fair traffic because weekend attendance was higher than for weekdays (the average weekday accounted for 13.8 percent of total weekly attendance whereas weekend days experienced 15.5 percent).

Hourly Traffic Volume Comparisons

Graphs of hourly variations in traffic during and after the fair were compiled from both tube and com-

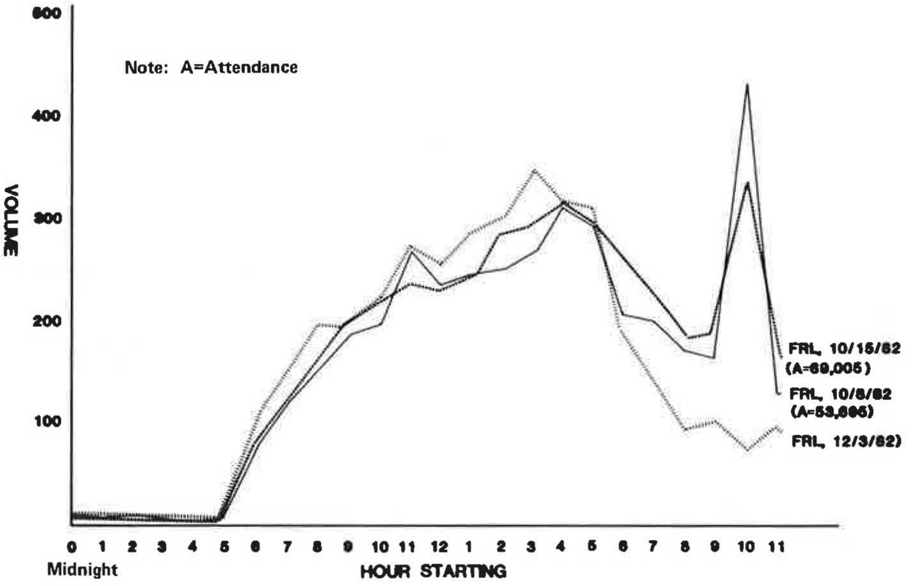

FIGURE 8 Traffic volume variations for Ailor Avenue at Western Avenue, westbound weekdays (street serving outbound fair traffic).

puter counts and they represent traffic volumes factored for day and month. These show the variations in traffic patterns caused by the fair.

Figure 8 shows Friday traffic on westbound Ailor Avenue just west of its intersection with Western Avenue. As previously mentioned, this route serves as a collector and distributor to I-40. Hourly variations were similar for low and high fair attendance days as well as for after the fair. The exception is the sharp peak between 10 and 11 p.m. during the fair. This represents traffic leaving the fair after it closed at 10 p.m. Figure 9 shows westbound Summit Hill Drive just west of Locust Street one block from the fair site. This also exhibits the 10 to 11 p.m. peak as well as the normal afternoon peak around 4 p.m. However, the 10 to 11 p.m. peak is more pronounced for Ailor Avenue, which was expected because it leads away from the site. The increased traffic during the fair between 8 a.m. and noon on Summit Hill Drive represents the morning CBD inbound peak and visitors arriving at the fair.

Figure 10 shows southbound Henley Street at Clinch Avenue. Again there are the normal morning and afternoon peaks, the morning inbound visitor peak, and the 10 to 11 p.m. peak. As with Summit Hill Drive, there is the continuation of the morning peak during the fair, indicating that most fair visitors arrived after morning rush hour traffic had cleared (opening time for the fair was 10 a.m.). This contention is verified by gate information that showed nearly 60 percent of inbound attendees arrived before noon. These graphs are typical of weekday hourly variations of traffic at locations that showed increases during the fair in that (a) the morning peak was extended over several hours to accommodate visitors arriving to the fair, (b) the afternoon peak was generally not affected, and (c) many fair visitors tended to leave around fair closing time causing a third traffic peak between 9 and 11 p.m.

Figure 11 shows the variation in traffic on southbound Gay Street at Church Avenue. As mentioned

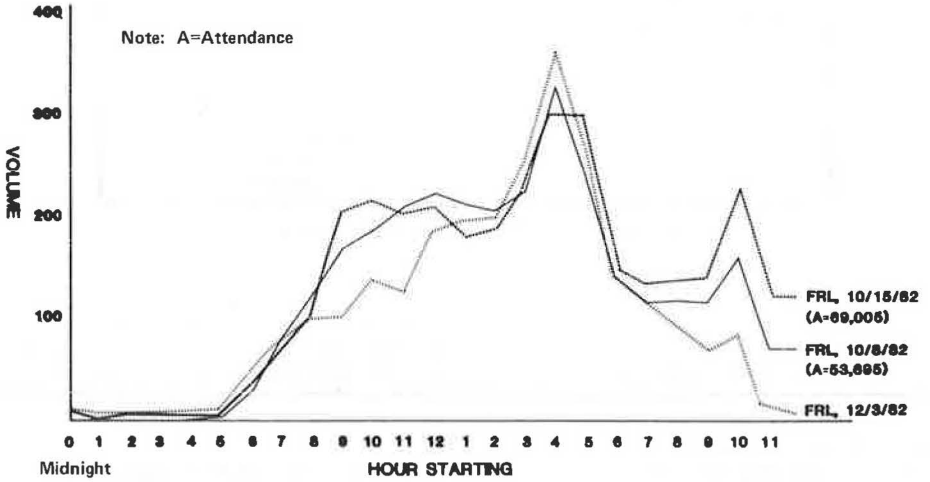

FIGURE 9 Traffic volume variations for Summit Hill Drive at Locust Street, westbound weekdays (street serving inbound fair traffic).

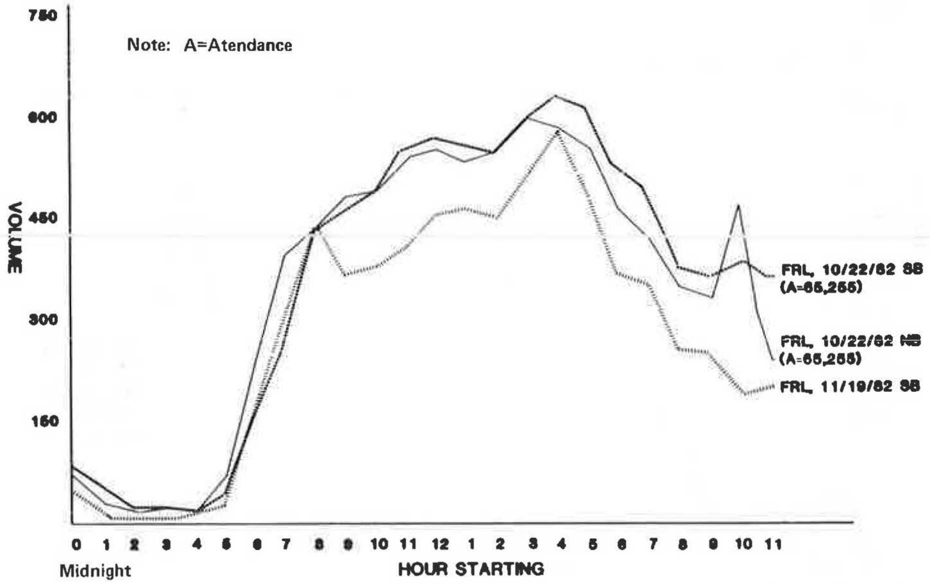

FIGURE 10 Traffic volume variations for Henley Street 200 feet north of Clinch, southbound weekdays (major arterial adjacent to fair site).

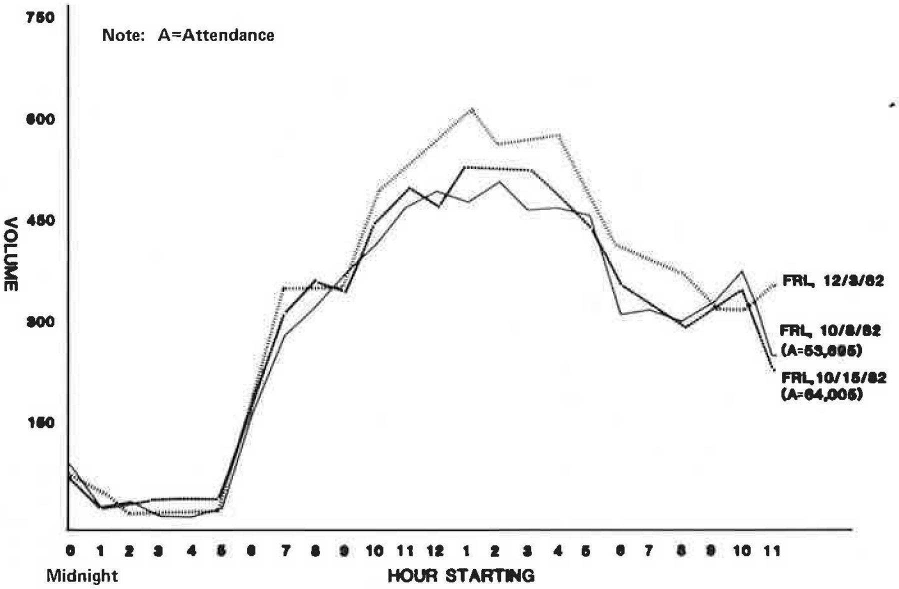

FIGURE 11 Traffic volume variations for Gay Street at Church Street, southbound weekdays (major CBD street not serving as fair approach or departure route).

in the previous section, traffic impacts on the CBD were minimal. The small differences in variations during and after the fair imply that fair visitors concentrated their driving on the fair approach routes and around the fair itself rather than the CBD.

CONCLUSIONS

The capacity of Knoxville's street system was greatly increased during the 1982 World's Fair because of aggressive planning and construction efforts. Planners, engineers, and administrators from a variety of agencies cooperated in identifying and implementing needed projects. Almost all of the major improvements will have residual benefits to Knoxville. Many of these projects were necessary to accommodate future traffic; however, the presence of the World's Fair accelerated their implementation. Certain other improvements that were conceived specifically for the fair functioned very well (e.g., Blackstock Avenue and temporary Interstate ramps). Most of these projects were in the immediate vicinity of the several gates used for access to the fair site.

Analysis of traffic during and after the fair reveals that the hourly and daily distribution of traffic patterns worked in conjunction with roadway and system improvements to avert the serious congestion that many anticipated. The results of this analysis can be summarized as follows.

1. Traffic volumes on the Interstate system increased only between 2 and 9 percent. The mainline improvements that were implemented, including completion of the I-640 loop and widening of I-40 in the downtown area, were more than adequate to meet the needs of fair-generated traffic. The exception was tour buses backing up onto the mainline of I-40; this was rectified by staggering arrival times. Overall, forecasts of increased traffic on major approach routes and modal split were accurate.

2. Traffic volumes generally showed significant increases on roadways in the vicinity of the fair site. New roadways constructed to handle fair traffic, such as the temporary Interstate entrance ramps and Blackstock Avenue, were heavily used during the fair. Non-Interstate approach routes including US-129 and US-441 also showed marked increases.

3. There were main arterials in the area that did not exhibit notable increases in traffic. The western portion of Cumberland Avenue (an east-west arterial) and 17th Street (an Interstate collector) saw little change, probably because the trailblazer system directed traffic elsewhere. Gay Street (a major CBD street) also did not experience increases in traffic because most fair visitors concentrated on the fair. This contradicts early expectations that the fair would cause not only a growth in traffic but also in business in general. Neyland Drive (an arterial on the southern border of the fair site) showed only marginal increases, even though it was on the trailblazer system and used by shuttle buses for access to their terminal.

4. Traffic in the Fort Sanders residential neighborhood increased markedly because of its location adjacent to the fair site and the abundance of small parking lots and curb parking.

5. Most of the traffic generated by the fair occurred during weekends, which minimized interference with local commuting and business travel. Analysis of weekday hourly variations in traffic reveals that arriving and departing trips generated by the fair occurred after the normal morning peak and did not conflict with the afternoon peak. Hourly distributions of weekend traffic during and after the fair were similar, although volumes during the fair were much heavier.

IMPLICATIONS FOR FUTURE SPECIAL EVENTS

Based on the experiences of the 1982 World's Fair in Knoxville several general guidelines for the planning of future large-scale special events can be formulated. These are given below.

1. Some estimate of expected travel demand needs to be made. This process is simplified for transportation planners because attendance estimates are usually available from other sources (e.g., the economic feasibility study). The planners task then is to derive modal split and regional arrival patterns.

Planners need to be aware that the modal split can be affected by the event's promoters, at least to a small degree.

For instance, the Knoxville World's Fair developed an aggressive marketing program geared toward attracting organized tours. Other factors affecting modal split are the provision of remote parking lots and shuttle services; hotel accommodations in the vicinity of the site; the extent to which local fixed-route transit can be used; and decisions concerning the supply and price of parking in the vicinity of the site. [The information for the 1982 World's Fair (2), as well as data from past events of similar scope, can be obtained and adapted to local conditions.]

2. There appears to be a two-tiered system for which transportation improvements must be made. The first is concerned with providing regional access to the general area where the event occurs. In Knoxville this was focused on improvements to the Interstate system, namely, completion of the I-640 circumferential highway and improvements to the Interstate system near the CBD. The second tier involves improvements to local streets in the immediate vicinity of the site. These improvements need to consider not only access to parking lots close to the site but also that many patrons will choose to drive by the periphery of the site particularly if the site is noticeably visible. The interface between the two tiers of improvements can be achieved by using some sort of guidance system. The trailblazer signing system in Knoxville proved not to be very effective because of sign vandalism and people's inclination to follow the first sign they saw. Ideally a system of variable messages could be implemented directing motorists to the proper places at the proper time. However, such a system would be costly to construct and operate and would be advisable only when traffic congestion is expected to be great.

3. The number and location of access gates can affect the distribution of traffic on surrounding local streets. Further, by targeting different gates for specific modes, separation of buses and cars can be obtained; this is especially important when space is at a premium. In Knoxville four gates were used for general access to the fair site (there were also gates expressly for employees and service and delivery). The north gate was used by tour buses; the east and west gates were serviced by local transit; and the south gate was used by shuttle buses (auto parking facilities were located close to all gates).

4. Knowledge of the peaking characteristics of an area can be used to avoid conflicts between commuter and event traffic in that opening and closing times can be arranged so that event traffic arrives and departs after normal peak periods. In Knoxville, the 10 a.m. and 10 p.m. opening and closing times caused little conflict during peak hours (although the morning peak was in effect extended) and created a third but smaller peak around closing time. Further, although more attendance can be expected on weekends, normal excess capacity can usually absorb the increase in traffic (if indeed it exists). Also, the Knoxville experience indicates that fair patrons tend to concentrate on the fair itself and devote little time to other activities.

5. In planning for projects with the scope of a world's fair many projects will cross jurisdictional boundaries necessitating that there be a high degree of cooperation between agencies. This means that representatives of federal, state, and local governments, as well as event promoters and providers of private transportation, must all work together to ensure efficient operation of the transportation system.

ACKNOWLEDGMENT

The authors wish to acknowledge the efforts of several people who participated in the larger study of the 1982 World's Fair Transportation System, funded by the Urban Mass Transportation Administration as a Section 8 Planning Grant, of which this paper represents only a small part. Brian Bochner of Barton-Aschman Associates not only offered excellent guidance in the analysis and presentation but he, along with Dave Miller and other Barton-Aschman employees, was responsible for much of the transportation planning that was accomplished specifically for the fair. Terry Grubb of the Tennessee Department of Transportation contributed his insights on travel patterns, where traffic counts were not available, as well as project information. Wayne Blasius of the Knoxville/Knox County Metropolitan Planning Commission had the monumental task of managing the entire project and offered helpful substantive and editorial comments on the work presented here.

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Use of IRPM for Transportation and Land-Use Planning in National Forests

FONG-LIEH OU and JOHN RUPE

ABSTRACT

For more than a decade the U.S. Department of Agriculture (USDA) Forest Service has been developing the Integrated Resource Planning Model (IRPM) as a planning tool for integrating transportation systems and land use. IRPM is composed of several mathematical programs, including linear programming, mixed-integer linear programming, and goal programming. Its purpose is to optimize transportation systems in conjunction with resource allocation and scheduling. The model and its application procedure are presented, along with a case study. The result of the study indicates that IRPM is capable of evaluating various transportation system options, land use strategies, and environmental scenarios. Although the model was developed primarily for use by Forest Service transportation planners and land management analysts, its utilization for planning a cost-effective transportation system and optimum land use patterns could extend beyond National Forest System lands.

The use of optimization methods in developing cost-effective road networks is an increasingly important area of research in transportation and land use planning. The potential benefits of optimization models include fast response to planning issues and the capability to evaluate various resource development scenarios and transportation policies. However, an optimization model requires that both transportation and land use policies be tied together and that their related variables be considered simultaneously.

SURVEY OF EFFORTS TO MODEL TRANSPORTATION AND LAND USE PLANNING

Although the need for transportation and land use optimization models is evident (1-3), the area has not yet been adequately developed. Several transportation researchers have attempted to model a transportation-oriented planning technique. However, theory often falls short of considering transportation as one of the principal factors in formulating land use policies. Previous efforts in the field include those by Lowry (4), Herbert et al. (5), Lathrop et al. (6), Wilson (7), Bagby et al. (8), and Bammi et al. (9) in urban area planning; and those by Kirby et al. (10), Barnes et al. (11), Sullivan (12), Kirby (13,14), and Kirby et al. (15) in wild land planning. These efforts focused on forecasts of land use patterns, and their emphasis was to find the optimal transportation network for supporting a land use allocation pattern. It was assumed that the role of a transportation system is to execute the land use plan by allocating various activities. The allocations are based on simplistic descriptions of the spatial relationships between the activities involved and on existing transportation networks and trip-making behavior in a base year.

The concept of integrating land use and the transportation system for a target urban land use plan was initiated by Creighton et al. (16). Based on two sets of criteria, the researchers used a benefit-cost analysis technique to optimize the spacing of arterials and expressways for the Chicago metropolitan area. One set of criteria is related to land development issues, such as desirable relationships of land use to roads and desirable land development densities, whereas the other set is related to transportation in terms of construction and travel costs. Creighton's work has been further expanded by Schlager (17), who used a hill-climbing procedure to find a minimum for combined site and network costs. A similar effort made by Black (18) considered both land use and transportation facilities as controllable variables. To find a best combination of land use density and highway spacing, Black developed a mathematical model for optimization to relate land use planning and transportation planning. By using a random-search technique, Sinha et al. (19) also developed an optimization model for deriving a land use plan representing the optimum combination of public and private costs. Brotchie et al. (20) developed a technique for the optimum placement of activities in zones (TOPAZ) that was adopted by Dickey et al. (21) for the Blacksburg, Virginia, application and by Dickey et al. (22) for the Prince William County, Virginia, case study. The purpose of TOPAZ is to determine where to allocate the needed land use areas to minimize the public service and travel costs.

The attempt to integrate transportation and land use in wild land planning was first made by Buongiorno et al. (23). They used a separable goal-programming model to determine the geographic pattern of forest exploitation, industrial processing, and transportation that minimizes total costs. Their work has been expanded by Weintraub et al. (24), who developed a procedure for integrating silvicultural treatment alternatives and timber transport routes.

All the above efforts focused mainly on physical planning. Although there is a strong connection between physical, economic, social, environmental, and political factors, most of them were intended to be prototype endeavors.

INTEGRATED RESOURCE PLANNING MODEL

The purpose of this paper is to describe the Integrated Resource Planning Model (IRPM), which was developed by the U.S. Department of Agriculture (USDA) Forest Service based on linear programming (LP), mixed-integer linear programming (MILP), and goal programming techniques. The model can be used to obtain an optimum land use plan with minimal resource management cost, including logging cost, transportation cost, and transportation-related environmental impact cost. Its applicability has been demonstrated by a case study that analyzed resource development alternatives in a drainage of the Payette National Forest in Idaho that is susceptible to erosion.

IRPM is a tool for assisting in the design and evaluation of alternative forest road systems along with land allocation and resource scheduling (25). IRPM is designed to be used where complex information, a large variety of possible investment costs, and a wide variety of transportation possibilities complicate a planning problem. The model can analyze and display the results of the interaction between production and financing. It is site specific and emphasizes investment analysis and the analysis of environmental and physical impacts of road traffic and transportation access. At the heart of IRPM are a land allocation model (13,14) and a capacity-constrained traffic assignment model (10,15). For any given set of goals, management strategies, and road network alternatives, the model can select an optimum combination of transportation routes, resource allocations, and management scheduling.

Although the mathematical programming of IRPM is presented elsewhere (25), several features of the model are described below. The model--

1. Considers either LP, MILP, or goal programming in the optimization algorithm.
2. Provides a method of stating for the computer certain restrictions on the inclusion of projects in the final solutions, including companion projects, mutually exclusive projects, and contingent projects.
3. Permits several alternative investment proposals for each parcel of land.
4. Permits several alternative roads to gain access to each parcel, each alternative road being an investment proposal.
5. Allows each investment proposal to be defined in terms of a mixture of several activities and corresponding costs and in terms of the resulting resource and economic responses.
6. Allows investment proposals to be defined as a multiperiod, fixed sequence of activities and identifies the period in which each activity occurs including the starting time, which is predetermined.
7. Permits alternative road construction standards--for example, number of lanes--to be governed by the amount and composition of traffic, including resource protection and maintenance, hauling of commodities, and recreational travel.
8. Allows for several classes of investment proposals: vegetative management, construction, and maintenance.
9. Permits investment proposals for land parcels to be combined into a plan in such a way that the corresponding road link investment proposals are also part of the plan.
10. Permits a variety of constraints on the investment combinations: activity levels, costs, resource responses, and economic responses.
11. Achieves an optimum solution for multiple goals at the same time.

Although most of the aforementioned features of the IRPM are self-explanatory, the first feature was designed to use decision variables for road projects that can take only values of zero for No or one for Yes. These integer variables can be included in an MILP model, which is basically a two-stage model using the branch and bound algorithm. First, an LP program is run, and, second, variables that must be integers are rounded up and down one at a time--where the LP model essentially built half a road, for instance. The value of the objective function when the variable is rounded up, and when it is rounded down, is compared with the value of the objective function for the optimum LP solution, and the closest feasible value is selected. This is repeated for all the other integer variables.

THE IRPM APPLICATION PROCESS

The process of applying IRPM to forest transportation and land-use planning can be divided into two major phases. The first phase is data preparation, which provides a data base for computer processing. The second phase is alternative evaluation, which results in the selection of a preferred alternative. The process is illustrated in Figure 1, and the steps are listed below:

1. Define problems.
2. Establish goals and objectives.
3. Collect data.
4. Develop management unit map.
5. Develop composite map.
6. Define logical relationship among projects.
7. Select units of measure.
8. Define constraints.
9. Develop planning and management strategies.
10. Formulate mathematical relationships.
11. Execute computer processing.
12. Select preferred alternative.

The first step involves defining the boundary and establishing convenient divisions of the area to be studied, and determining issues and concerns. The second step is to determine the planning and management objectives, such as maximizing timber production with heavy clearcuts or enhancing wilderness by minimizing road construction. It also requires the determination of output goals and targets, such as the volume of timber production in a specific time period.

The third step is to collect the necessary data. The data base includes information concerning soil, slope, aspect, landform, water elevation, timber stand composition, timber age class, trees per acre (or hectare), logging cost per acre (or hectare), brush disposal cost per acre (or square mile), existing road network, existing level of erosion sediment, and other characteristics.

The fourth step is to develop a management unit map based on one or more of the following elements: soil condition, slope class, topography, vegetation type, capability area, road network, and related issues. Efforts involved in developing a management unit map are selecting elements related to issues and objectives, ranking the selected elements according to their importance to the defined issues and objectives, drawing a series of overlays for each of these elements, and redrafting each overlay onto one composite overlay based on the assigned ranks.

Shown in Figure 2 is an example of three selected elements with a ranking order of soil condition, slope class, and timber age class. The composite overlay is simply redrawn from Figure 2(a) as the first step of developing a management unit map. The next step is to overlay the composite map on Figure 2(b) and draw additional subdivisions, as shown in Figure 2(d). The overlay of Figure 2(d) on Figure 2(c) resulted in a composite map, illustrated in Figure 2(e). However, the subdivision line is drawn only when the unit created is greater than the minimum size of a unit. As shown in Figure 2(f), three units were assumed to be smaller than the minimum unit size and were eliminated from Figure 2(e). The criterion for determining the minimum unit size is that the land within it can be managed in the same way, based on the capability of the land and the issues (conflicts of interest) that affect it.

After the management unit map is developed, the fifth step is to complete a composite map by identifying the possibilities for management actions on each unit. From the identified management actions,

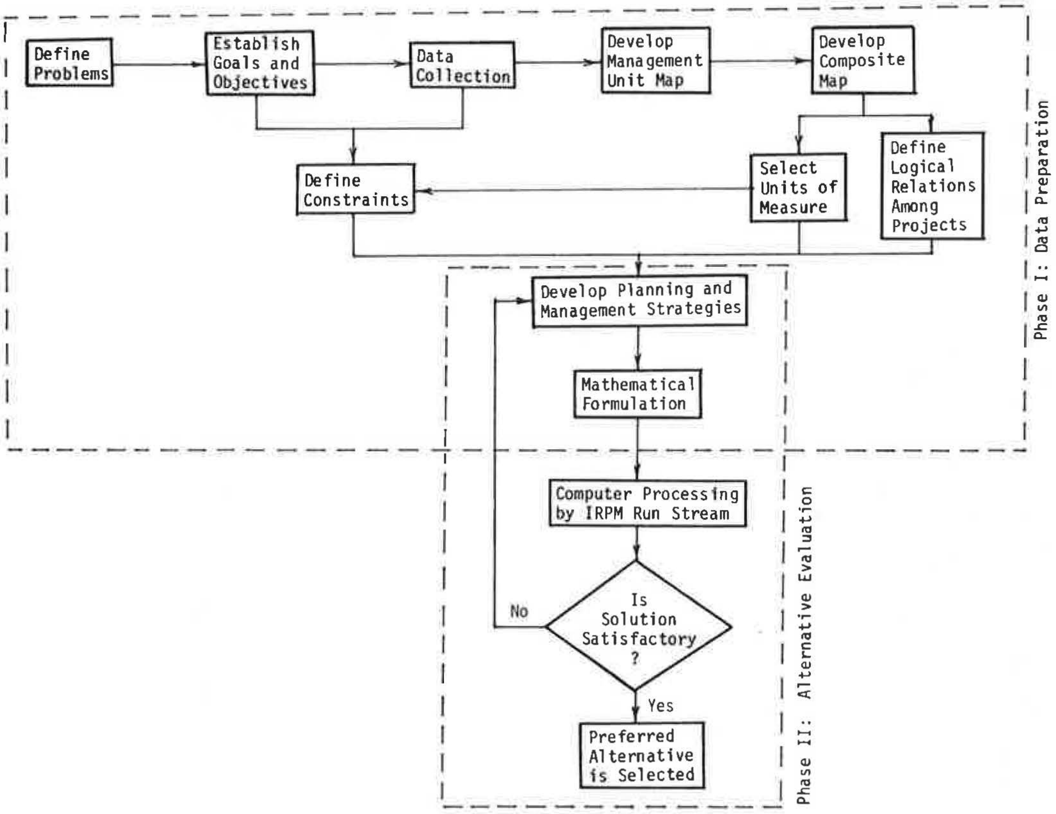

FIGURE 1 IRPM application process.

the available or feasible road network associated with any or all actions becomes clear and may be defined by nodes and links.

In the sixth step, the effort is to determine the logical relationships between the road network and the proposed resource projects--that is, where the estimated traffic generated by each project can enter the network. These relationships can fall into one of three categories: two or more companion projects must be selected as a group; only one of two or more projects that are mutually exclusive can be selected; and one of two contingent projects is required only if the other is selected.

In the seventh step, variables are defined by work, cost, outputs or effects, and benefits. Work includes the tasks or activities necessary for com-

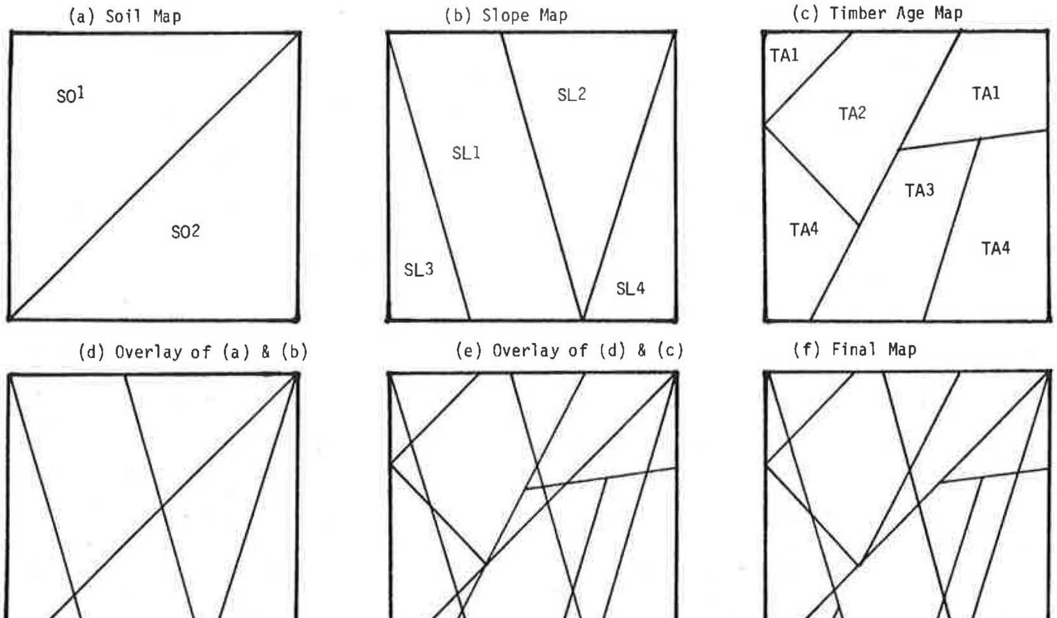

FIGURE 2 Element maps and management unit maps.

pletion of a project. Cost is determined by unit of work. Output and effect include both expected yield and expected environmental response associated with the project. Benefit is the monetary value of the output or effect.

After the variables are defined, it is possible to determine the constraints. Thus, based on the identified issues and objectives, the eighth step is to suggest possible quantitative targets or limits to be tested for their effects on the overall selection of alternatives.

The ninth step is to develop planning and management strategies. The four factors considered in strategy formulation are the time frame, management options, logging methods, and brush disposal methods. Because each timber age class can be treated differently, resource projects are defined for multiple time periods; each period is specified by a particular management option. For example, a young growth may be treated by commercial thinning in the first period and by clear-cutting in the third period. The management options include wilderness preservation, commercial thinning, partial-cut, clear-cut, and so forth, and the logging method consists of tractor, skyline, high-lead, and helicopter. Brush disposal is determined by both management option and logging method with consideration of such geographical factors as soil condition and slope.

Based on the formulated scenarios, the tenth step is to develop the relationships between variables and their constraints into equations for obtaining the highest benefit at the lowest cost. The eleventh step is to execute IRPM for alternative evaluation. It involves writing card statements, establishing files, and using runstreams.

The final step is to interpret the output of IRPM, which lists projects and summaries of work, costs, and outputs according to the conditions set up for each run. A map of the area is prepared showing allocation of various types of projects and the road network chosen. If no solution is selected, management policy must be redefined. In other words, the ninth through twelfth steps must be repeated until a preferred solution is selected.

Although the above process was developed to provide a better understanding of the IRPM algorithm, data preparation does not necessarily follow the steps in sequence. Sometimes a single task may accomplish the requirements of several steps.

USE OF IRPM IN PAYETTE NATIONAL FOREST

The first step of IRPM was to select the South Fork of the Salmon River drainage of Idaho's Payette National Forest as the study area. As shown in Figure 3, the study area is located east of McCall, Idaho, in the Boise and Payette National Forests. The South Fork flows north and drains into the main fork of the Salmon River at Mackey Bar. The northern, lower end of the South Fork drainage is essentially roadless, and current management direction is that the area will remain basically without roads. The upper portion of the drainage has a skeletal road system in place, and some timber harvest activities have occurred in the past. This study will analyze the Payette National Forest portion of the upper end of the drainage which covers part of the Krassel Ranger District, a 160-square-mile area south of the confluence of the South Fork with the Secesh River.

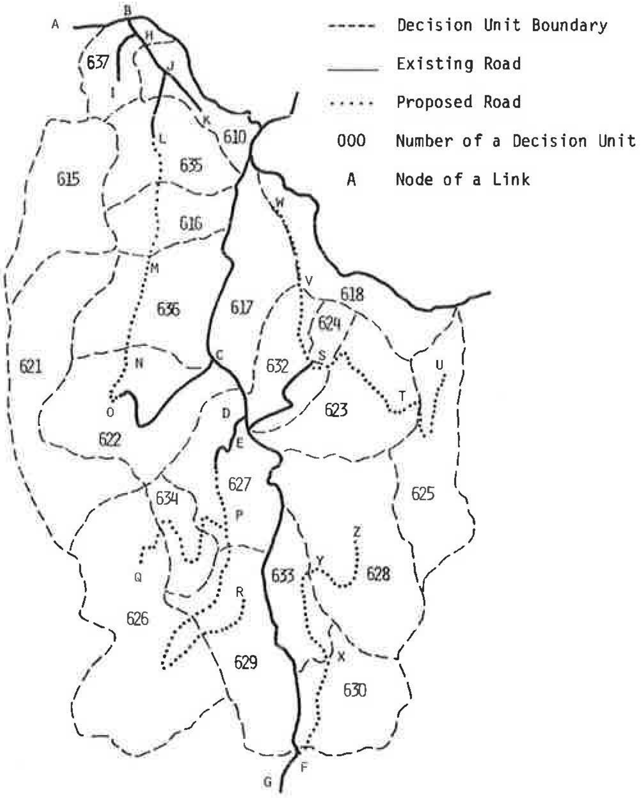

FIGURE 3 The study area.

Most of the existing roads were constructed and most of the timber harvest occurred in the drainage before 1964. In the winter of 1964-1965 a major storm caused excessive amounts of road surface erosion and mass stability failures. The storm completely destroyed much of the fishery, which is just now recovering. After the 1965 storm, the Forest Service began a self-imposed moratorium on road construction and timber harvest in the drainage. Ten years later, the South Fork Unit Management Plan was implemented, allowing for a minimal level of activity. This plan has been in effect to the present. As needs for wood products increase, added pressure will be placed on the Payette National Forest to allow road building and timber harvest within the South Fork drainage.

Based on the defined problems, the second step established the objective of this application. Because timber production has been established as the desired goal, it is important to evaluate the impact of timber production and the required transportation network on erosion, which has a critical effect on anadromous fisheries in the area.

The third step was data collection. The data used in this evaluation were collected for the Forest Plan. Most of the basin has side slopes in excess of 45 percent, and some areas are more than 60 percent. This makes tractor logging of most timber impossible because tractors cannot maneuver on slopes this steep. Much of the timber will be harvested by skyline or cable logging.

The soil is almost entirely decomposed granitic sandy loam. The area is part of the Idaho Batholith, a large intrusive granite formation covering most of central Idaho. The sandy soil has low cohesion and easily crumbles and erodes when exposed to air. The lack of cohesion is attributed to the low bearing capacity of the soil. Mass stability problems are acute. In this context, road building activities need to be limited to minimize the possibility of clogging adjacent streams. Early logging on steep ground in the area was done by jammer, with closely spaced roads. The intensity of roading was so great that the impacts of sediment were especially high.

As indicated previously, the fourth step developed the management unit map by overlaying the influencing factors based on their importance to the issues. In this application, the two most important factors are soils and land slope. Because these two factors do not vary much throughout the area, the 160-square-mile river drainage was divided into 17 decision units according to tributary stream drainage and collector road influence zones. As shown in Figure 3, each of the 17 decision units is numbered with a three-digit number starting with a 6.

The fifth step identifies the projects. The road projects shown in Figure 3 represent all the collector roads that would be necessary if the entire drainage were allocated to timber harvest. Of course, this is not likely to happen because of competing fishery goals. Instead, only the roads necessary to reach the selected areas for timber harvest are mandated. The nodes are labeled alphabetically. Loaded truck traffic is assumed to be unidirectional except on the main road A-B-C-D-E-F-G, and on the loop road B-H-J-L-M-N-O-C.

Although these roads provide the major access for the area, they actually are intended to be single-lane, dirt facilities because maximum traffic for the roads will be less than 50 vehicles per day, consisting almost entirely of logging trucks, Forest Service administrative vehicles, and other vehicles related to timber sales. The roads are intended to contour along the hillsides as much as possible to minimize large cuts and fills and thus reduce total impacts on the land. As such, the collector roads basically will conform to the same standard as local roads, with the design standard established by a concern for minimizing surface erosion and mass stability failures and improving trafficability.

The sixth step was performed to define logical relationships among projects. Because basically the same standards will apply to local and collector roads, some assumptions can be made about road links for each land unit and about where the harvested timber will enter the road network. It will be assumed that the entire road will be constructed to the end of the decision unit if timber is harvested within the area. In reality, the average trip on the segment will be about halfway along the link, as very few logging trucks will enter the collector road at the far end of the unit. The road on the far end is essentially a local facility. However, because the local road and collector road standards will be the same, nodes can be set where roads cross unit boundaries. It will be assumed that trucks enter the road network at the nodes because two trucks entering in the middle of the unit between two nodes is the truck-mile equivalent of one truck at each node.

Table 1 shows the impacts of each road segment if it were selected. Construction costs are for new segments of the route, and reconstruction costs are for reuse of existing roads. Reconstruction could vary from simply blading and reconditioning the road to virtually rebuilding it.

The sediment impacts are listed according to a scale developed by the Payette National Forest. The Forest is using a scale based on the activities that occurred during the large 1964 flood, which destroyed the fish population in the river, and natural rates. It assumes that one scale unit is equivalent to the amount of natural sedimentation from 1 acre of loamy clay soil on side slopes less than 45 percent. As soils vary from clay to sand, and as slopes get steeper, particularly on south-facing aspects, the natural rate is as high as 50 scale units per acre. Harvesting timber approximately triples the sediment rate, mainly from local road construction. The impact of access roads varies from 500 scale units to as high as 20,000 scale units for a particular link. These calculations are based on an estimate of cut and fill and road surface erosion, plus the effects of probable mass failures.

A high-intensity and a low-intensity timber harvest option was chosen for each decision unit. Either one option or the other, a percentage or split of both, or neither of the options can be selected for each decision unit. The high-intensity option takes 25 to 30 percent of the standing timber volume in the area. The low-intensity option takes 10 to 20 percent of the volume. The amount of timber in each option plus the sediment and cost impacts are displayed in Table 2.

In choosing which timber would be taken in each option, it was estimated that about 50 to 60 percent of the high-production site old-growth stands on flat ground would be taken first, followed by moder-

TABLE 1 Road Construction and Reconstruction Cost and Sediment by Management Unit

Unit Name	Construction Link	Construction Miles	Construction Cost ($)	Reconstruction Miles	Reconstruction Cost ($)	Sediment Impacts (scale units)
Secesh Face	HI	NA	NA	5.6	28,000	3,716
Cow Creek	HJ, JK, JL	3.2	133,000	4.6	53,000	19,424
North Fork Fitsum	LM	NA	NA	6.3	31,500	1,772
Fitsum Creek	MN	2.1	100,000	1.0	50,000	2,832
North Fork Buckhorn	NO	4.3	166,000	NA	NA	541
Buckhorn	OC	2.7	123,000	9.0	45,000	18,953
Cougar Creek	PD	3.3	152,000	7.7	54,000	8,344
South Fork Cougar Creek	QP	4.6	253,000	NA	NA	4,158
White Rock Peak	RP	3.0	123,000	NA	NA	16,745
Indian Ridge	WV	2.6	123,000	NA	NA	1,489
Krassel Creek	WV	2.6	123,000	NA	NA	1,480
Phoebe Creek	VS, SE	3.5	172,000	5.8	29,000	5,898
Camp Creek	TS	8.5	283,000	NA	NA	2,570
Caton Lake	TU	5.0	188,000	NA	NA	2,333
Fourmile Creek	YZ	3.6	176,000	NA	NA	3,601
Silver Creek	XY	3.1	176,000	NA	NA	7,369
Goat Creek	FX	5.4	269,000	NA	NA	10,486

Note: NA = not applicable.

TABLE 2 Sediment and Road Cost by Resource Project

Unit Name	Timber Intensity	Timber Volume (MMBF)[a]	Sediment Impact (scale units)	Cost (million $)
610 Cow Creek	High	19.2	4,600	3.10
	Low	6.1	2,000	1.55
616 Fitsum Creek	High	19.5	25,000	5.10
	Low	11.6	5,660	3.01
617 Krassel Creek	High	20.0	66,400	5.66
	Low	9.1	24,500	2.57
618 Indian Ridge	High	14.3	67,600	4.68
	Low	8.4	24,800	2.46
622 Buckhorn Creek	High	37.2	45,000	9.71
	Low	18.5	5,900	4.81
623 Camp Creek	High	21.2	23,700	6.13
	Low	11.1	17,600	3.19
625 Caton Lake	High	19.7	18,000	5.72
	Low	10.4	14,000	3.03
627 Cougar Creek	High	27.4	29,300	7.17
	Low	13.2	8,900	3.44
628 Fourmile Creek	High	40.6	106,200	11.91
	Low	23.1	17,300	6.63
629 White Rock Peak	High	26.8	23,900	7.83
	Low	13.2	10,600	3.84
630 Goat Creek	High	16.0	17,900	4.37
	Low	10.3	6,400	2.75
632 Phoebe Creek	High	12.4	10,400	3.33
	Low	6.6	6,900	1.79
633 Silver Creek	High	14.8	37,300	4.41
	Low	7.5	10,200	2.22
634 South Fork Cougar	High	10.8	6,100	3.06
	Low	4.7	3,900	1.28
635 North Fork Fitsum	High	18.6	19,300	5.08
	Low	11.5	7,100	3.05
636 North Fork Buckhorn	High	29.0	35,800	7.55
	Low	13.8	15,100	3.58
637 Secesh Face	High	12.5	20,800	3.72
	Low	7.1	13,900	2.08

[a] Million board feet.

ate-production site old growth, then younger age classes and less productive sites. The estimated board feet and cubic feet for each option are entered into the model as if 100 percent of the option was selected for an area. If a lesser percentage of the option were selected, the model would take a lesser percentage of the timber. Splits of high and low intensity allow a great degree of flexibility in interpreting the results of the model. Essentially, such a split would represent a moderate intensity.

The seventh step was to select the unit of measure. Table 3 shows the timber coefficients that were selected. These vary according to the different classifications that have been mapped in the forest. Two major classifications are (a) mixed conifer, consisting of Douglas fir, ponderosa pine, and Engelmann spruce on high or very productive sites, and (b) mixed conifer on other, less productive sites.

TABLE 3 Timber Stand by Species and Condition

Species[a]	Condition[b]	Board Feet per Acre	Cubic Feet per Acre
MCH	MS	20,333	4,333
MCH	IS	11,621	2,754
MCH	PS	3,741	1,287
MCH	SS	1,960	590
MCO	MS	14,415	3,085
MCO	IS	9,343	2,238
MCO	PS	2,542	1,761
MCO	SS	1,960	590
MCH-MCO	LS	8,311	2,026

[a] MCH represents mixed conifer with Douglas fir, ponderosa pine, and Engelmann spruce on high or very productive sites, and MCO denotes mixed conifer on other, less productive sites.

[b] MS is the mature and overmature sawtimber, IS specifies immature sawtimber, PS describes poles with saplings, and SS denotes seedlings and saplings.

Each classification consists of one or more condition classes; these would include (a) mature and overmature sawtimber (more than 140 years old), (b) immature with some overmature sawtimber (more than 80 years old), (c) poles with some saplings (more than 40 years old), and (d) seedlings and saplings (less than 10 years old).

Sediment yield depends on the type of land affected. Land types were classified according to natural sediment production, which is a function of slope, aspect, and soil type (clay to sand). Land types also were mapped in slope classes to determine how the unit would be logged because tractor logging does not occur on side slopes of more than 45 percent, where cable logging is performed. In addition, harvest is very difficult on sustained slopes of more than 60 percent.

Cost data were developed on a per-acre basis depending on the slope class. Local roads were estimated to cost $6,000 per mile. Logging costs were estimated according to the costs of felling, bucking, yarding, and loading, as well as costs associated with manufacturing.

Coefficients used in the model were $1.20 per truck per mile for hauling and $3.00 per truck per mile per year for maintenance of the double-lane, graveled main road. For the dirt penetration roads, costs were $2.40 per truck per mile for hauling and $1.00 per truck per mile per year for maintenance. One truck is assumed to haul 5,000 board feet of timber.

In this application, steps eight and nine--defining constraints and developing management strategies--were performed simultaneously. Although IRPM is capable of dealing with multiple time period problems, this study used a single 20-year period to keep the model size small enough to allow several runs. This assumption is reasonable because it is a generalized first cut analysis for the South Fork and because cumulative impacts influence much of the decision making. Therefore, an analysis can be based on total impacts rather than on yearly impacts. As such, this application is essentially a study in land allocation, not in scheduling.

Several scenarios were created by varying the target for timber harvested in the 20-year planning period and then by attempting to minimize either cost or sediment. In the IRPM runs, a timber constraint was set for the timber target, and the objective function was either minimize cost with no constraint on sediment or minimize sediment with no constraint on cost. These two runs essentially set upper and lower bounds of sediment and cost for each level of timber. The minimize-cost run produces an upper level of sediment and the minimize-sediment run produces an upper level of cost.

Although the performance of step ten for formulating mathematical relationships and step eleven for executing computer programs is not discussed in this report, the selection of a preferred alternative in the last step of IRPM application remains a task for the decision maker.

RESULTS OF THE APPLICATION OF IRPM TO PAYETTE NATIONAL FOREST

The scenarios that minimized cost and minimized sediment were examined for various levels of harvesting timber. At low levels, both the minimize-cost and minimize-sediment runs selected similar projects. The minimize-sediment runs chose Cougar Creek units 627 and 634 at 25 million board feet (MMBF) and Cow Creek unit 610, Buckhorn Creek unit 622, and Fitsum

Creek unit 616 at 50 MMBF. The minimize-cost runs chose Cow Creek unit 610 and the adjacent Secesh Face unit 637 at 25 MMBF and included Cougar Creek unit 627 at 50 MMBF.

The significant feature about the Cow Creek and Cougar Creek drainages is that access roads already exist; thus sediment and cost impacts for the amount of timber harvested are minimized. The reason these areas have roads is that harvest techniques are easier, so harvest costs are lower, which further drives the minimize-cost runs to these areas.

As timber-harvesting levels are increased, new roads must be built because the planning area is largely without roads. Thus, the model had more choices, and the minimize-cost and minimize-sediment runs produced different results. The minimize-cost runs selected Goat Creek units 628, 630, and 633, Phoebe Creek unit 632, and the remainder of the area on the east side of the planning area. The model picked the Fitsum Creek and Buckhorn Creek drainages only at very high harvesting levels.

The minimize-sediment runs did the opposite. The model picked Fitsum Creek and Buckhorn Creek at moderate timber levels, and as the target level was increased, Phoebe Creek was selected, and Goat Creek was selected at higher levels.

Figure 4 shows sediment as a function of timber, and Figure 5 shows cost as a function of timber. The minimize-cost and minimize-sediment curves enclose the range of programs that might be selected. A decision maker could select any program within this envelope. As can be expected, the envolope is narrow at low volumes because both objectives harvest timber in the areas with roads. At moderate volumes, the envelope is wide, representing the maximum range of choices among projects. At high volumes nearly all the projects need to be included; therefore, there will not be a wide variation in the runs.

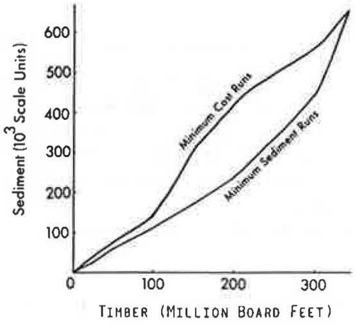

FIGURE 4 Sediment produced for different timber volumes.

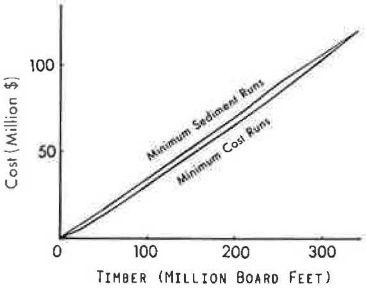

FIGURE 5 Cost for different timber volumes.

A series of runs was made to show the trade-offs between cost and sediment when the target for harvesting timber was set at 200 MMBF for the 20-year period, or 10 MMBF per year. At this timber level, the minimize-cost run resulted in heavy cutting in Cow Creek 610, Goat Creek 628, 630, and 633, and Phoebe Creek and Indian Ridge 617, 618, 623, and 632. The minimize-sediment scenario has a more developed road system and resulted in fairly even cutting across the planning area, except for Secesh Face 637, White Rock Peak 629, and Indian Ridge 617 and 618. At cost and sediment levels between the above two scenarios, the model selected a composite of the two scenarios at differing degrees.

CONCLUSIONS

This study has demonstrated the capability of IRPM to evaluate transportation and land use alternatives in Idaho's Payette National Forest. The model also can be applied to wild land outside of National Forest System lands. The results of the computer runs can provide land managers with a general idea of the impacts on stream sedimentation that result from timber harvest and road construction at various levels of investment.

The results can aid in the development of a basinwide environmental assessment that addresses total impacts on the stream. This can help in showing the trade-offs in cost and timber harvest when a sediment constraint is imposed to meet state water-quality guidelines. The results will also show which timber and road projects are generally preferred.

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