Trip-Monitoring Survey: Downtown Travel Data Obtained by Following a Small Sample of Vehicles

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ABSTRACT

In this paper is outlined a unique type of survey that was developed to assess the impact of a new downtown "regional center" plan on traffic and parking and to facilitate the planning of improvements. It enabled essential information to be collected easily and economically, without interference with or disruption of traffic flow, for such items as the total number of persons and people parking in the downtown area, the number passing through without parking, the number of persons dropped off, and travel path data for analyzing the impact of circulation changes. This was accomplished by having observers follow a small unbiased sample of vehicles entering through a cordon line. The specific procedures for the trip-monitoring survey are described to enable others to use similar car-following methods in their own areas. There are also brief explanations of how data from this survey were combined with traditional parking and traffic survey information to analyze parking and traffic needs and a discussion of some areas where additional survey effort might further enhance the survey results.

The trip-monitoring survey was devised to provide central business district (CBD) "control" totals on vehicle and person trips and to provide travel path data in connection with traffic and parking analysis for a new regional center plan in downtown Buffalo. The author is not aware that this type of survey has been conducted in any other place. However, the survey appears to be such an efficient way of supplying much valuable information that it is being presented here in the belief that others will find it a useful procedure in other situations.

The development of the trip-monitoring survey came about when the central staff of the Niagara Frontier Transportation Committee [the metropolitan planning organization (MPO) for Erie and Niagara Counties, New York] was assigned responsibility for the transportation element in developing the new Buffalo Regional Center plan. Important information needed for the planning process included

- Total vehicles destined to downtown Buffalo with automobile destinations established on a block-by-block basis,
- Total persons destined to downtown Buffalo by transit and by automobile with person-trip destinations established on a block-by-block basis,
- Estimates of parking needs with development proposals and changes in parking facility locations, and
- Estimates of traffic volumes and capacity levels of service with development proposals and circulation and parking changes.

A typical parking inventory usage and turnover survey was programmed to establish existing parking conditions, including an interview survey of parkers to establish the origin, parking location, and ultimate destination of those who parked. Because a major parking survey of about half the desired study area had been performed by a consultant in 1980, and updated in 1983, the new survey, also in 1983, was designed to cover only the additional area and it was done in a manner consistent with that of the earlier survey for a similar 8-hr time period from 10 a.m. to 6 p.m. The boundaries of the parking study area, including the two parts totaling 146 blocks and 25,000 parking spaces in all, are shown in Figure 1 along with the cordon line encompassing the entire CBD.

Downtown cordon counts were conducted for 48 hr by machine and conducted manually with vehicle classification for 8 hr on typical weekdays. The cordon was designed not to intersect the heavy through traffic movement on I-190 but only that entering or exiting the CBD. Downtown intersection turning movement counts were conducted for 8 hr and supplemented with midblock machine counts to establish existing flows on the street system.

A regional on-board transit survey had also been scheduled at the same time to provide origin-destination information for downtown-destined transit passengers.

What was desired and not easy to establish was a firm figure for the total number of vehicles (cars and trucks) and persons parking in downtown compared with those just entering and passing through, the number of persons arriving as "drop-offs," and a convenient means of estimating traffic volumes and turning movements after circulation changes were made. Although figures on the total number of vehicles and persons coming downtown could theoretically be derived from the parking surveys and interviews, this was not satisfactory as the only source for such information for the following reasons:

- It did not provide any information about arrivals downtown outside the time period of the parking survey;
- It did not provide any information about arrivals in areas on the fringe of downtown outside the proposed parking study area;
- There was a desire to firmly resolve differences in total trips to the CBD indicated by the existing regional transportation model, ground counts, and various estimates of downtown employment and activity; and
- There was concern for the statistical reli-

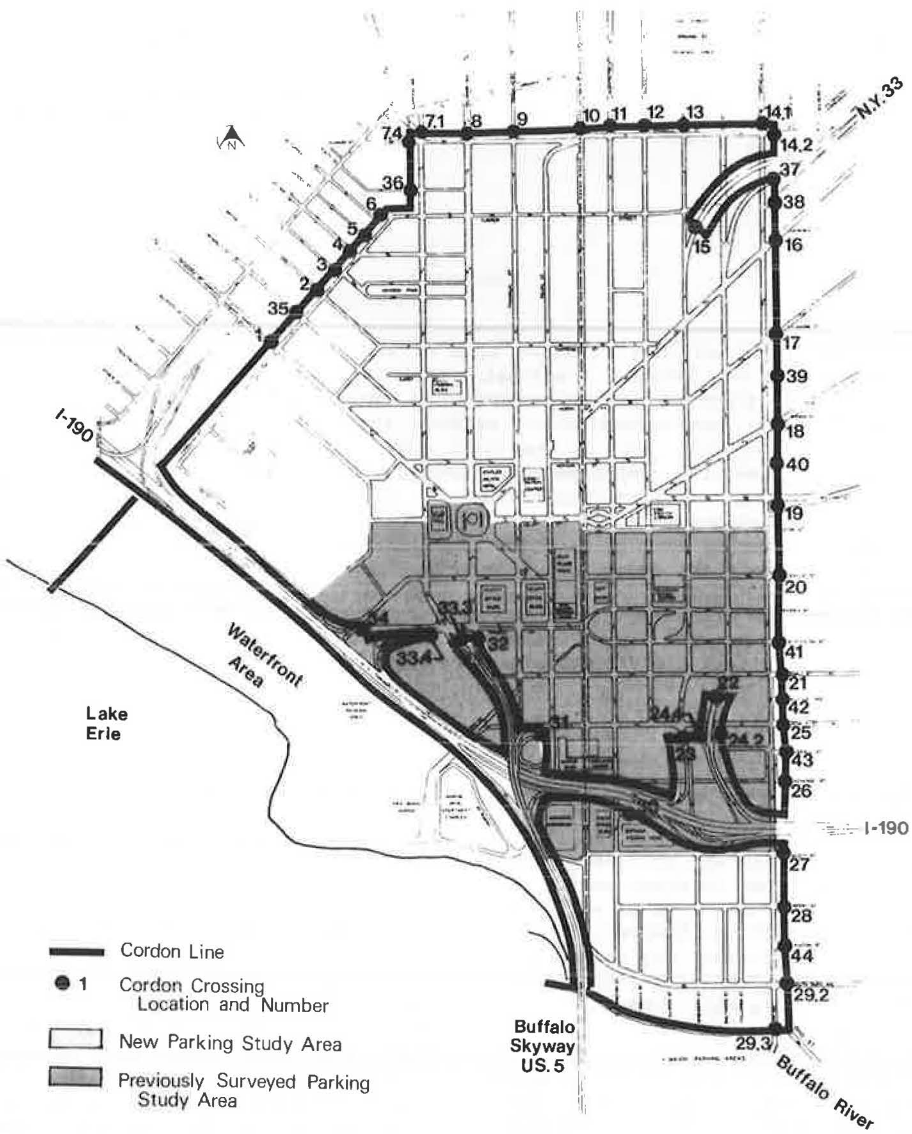


FIGURE 1 Buffalo CBD cordon and parking study area.

ability of the figures for the total number of parkers derived from the parking surveys (at the completion of both the parking and trip-monitoring surveys, the latter consistently showed more vehicles parking downtown than the former, particularly illegally parked vehicles).

Initially it was proposed to seek the desired information by conducting typical cordon station interviews. This idea was rejected because of the extensive delays that would be caused to rush hour traffic and the resistance that motorists might register. A second idea was to simply hand out survey cards to a sample of motorists for response and mail-back, but this was thought to be statistically unreliable because of the likely bias due to greater response rates from well-educated motorists. Also, none of these methods would have aided in estimating the impacts of circulation changes.

In response to these concerns and needs, the idea of having observers in their own cars follow a selected sample of vehicles entering the CBD was born. Each selected vehicle would be followed until it either parked within the cordon or went back out of the cordon. Observers would count the number of persons in the car, plot the route on a downtown street map right on the survey form, note locations and number of persons picked up or dropped off, and note the final location of parking or the cordon station where the vehicle exited. A number of supervisory staff field tested the concept and found it to be a workable idea. In the process it was found that a far higher percentage of vehicles entering the CBD apparently passed through without parking then had been previously imagined; this explained some of the lack of consistency between existing data and further indicated the need to do the survey.

ELEMENTS OF THE SURVEY

Sample Selection and Statistical Reliability

The trip-monitoring survey sample must be drawn from recent data on total vehicles entering through a cordon line. In this case the primary objective in sample selection was to provide overall CBD data in accord with commonly accepted standards of reliability. Thus an overall sample size was proposed the confidence level of which was 95 percent that the

results were within ±5 percent of the true answer for the day of the survey.

The survey results were collected during many days and assembled to represent one "typical" Monday-through-Friday working day. The formula used in determining sample size is

$$D = Z \left\{[P(1 - P)/n]^{1/2}\right\} \quad [(N - n)/(N - 1)]^{1/2}$$

where

- D = allowable error,
- Z = standard normal point associated with the percentage confidence intervals (1.96 for 95 percent),
- P = proportion of time a given attribute occurs,
- N = population size, and
- n = sample size.

Because parking for automobiles was a major focus of the overall study, it was proposed to sample just automobile traffic sufficiently to provide the desired 95/±5 percent reliability for any data including those that might be split 50-50 percent. Such a split in survey results presents the most stringent condition for sampling and required an overall automobile sample of approximately 400 vehicles. This also permitted the apportioned sample of 19 (of the 400) at the lowest volume "major" entrance to the CBD to provide data about which it was possible to be 90 percent confident that the results were within ±20 percent of the true value.

It may be noted that there is some impact on reliability from day-to-day variations in traffic, but this was not thought to be significant for the purposes of this survey. Both the cordon and the trip-monitoring survey were conducted only on days that were considered to experience normal weekday traffic volumes.

A separate truck sample was proposed but not at the same level of statistical reliability as the automobile survey, which would require nearly as large a sample. A one hundred vehicle sample of trucks was selected, which would provide data to the overall CBD level about which it would be possible to be 95 percent confident that the results were within ±10 percent of the true value for the survey day. The CBD truck data could be subdivided into five relatively equal parts and it was possible to be 90 percent confident that the results in any part were within ±20 percent of the true value.

The proposed distribution of automobile and truck samples by cordon crossing is given in Table 1 for the major crossings (more than 5,000 inbound vehicles/24 hr). The second line (in italics) under the 24-hr volume figures indicates the number of vehicles to be sampled. Note that trucks were considered vehicles with six or more tires (Highway Capacity Manual definition) and for the purpose of the trip-monitoring survey included both single units and tractor-trailers. Thus they could be expected to be involved in "goods" movement. Vans and pickups were included in the "automobile" definition and were considered to be involved in passenger transportation or service.

Distribution of the Sample

The automobile sample for each cordon crossing had to be distributed by hour of the day. This was done using automatic traffic recorder (ATR) data given in Table 2. For the major cordon crossings, the percentage of traffic in each hour was determined; then the number of samples was distributed by hour according to the percentage of traffic (e.g., in Table 2, 13.70 percent of traffic occurs between 7:00 a.m. and 8:00 a.m.; this percentage of a sample of 19 is 2.6). Finally, the sample has to be defined by even integers in each hour such that they add up to the correct total sample (see column in Table 2 labeled "Final Sample").

Table 2 gives the sample distribution for the least used major crossing. Cordon crossings with volumes less than those of the major crossings had the sample distributed by groups because the number of samples needed had declined to the point where the assignment by hour became somewhat arbitrary at one location. Also, no individual data summaries would be prepared and used for those lower volume

TABLE 1 Major Cordon Crossings, 24-hr Inbound Volumes and Number of Samples

Order No.	Location No.	Location	24-hr Volume: Total	Automobiles	Trucks
1	15	Rt. 33 Oak Street ramp	17,490	17,020 *57*	420 *10*
2	22	Elm Street exit, I-190	13,380	12,890 *43*	410 *9*
3	1	Niagara Street	11,540	11,130 *39*	270 *6*
4	8	Delaware Avenue	10,830	10,520 *35*	160 *4*
5	14.2	Rt. 33 to Goodell Street	10,740	10,530 *35*	180 *4*
6	7.1	Elmwood Avenue	7,520	7,280 *25*	170 *4*
7	33.4	Church St. exit, I-190	7,210	7,010 *24*	160 *4*
8	14.1	Michigan at Goodell	6,800	6,330 *21*	390 *9*
9	32	Skyway to Delaware	5,850	5,780 *19*	60 *1*
All others			33,000	29,840 *102*	2,130 *49*
Total vehicles			124,360	118,330	4,350
Total sample				*400*	*100*

Note: Total volume = automobiles + trucks + buses (not shown); buses were not included in the trip-monitoring survey.

TABLE 2 Distribution of Sample, Skyway to Delaware Cordon Crossing (Location 32)

Hour	Average Inbound Volume (ATR)	Percentage by Hour	Initial Automobile Sample	Final Automobile Sample
12-1 a.m.	70	1.20	0.2	
1-2	30	0.51	0.1	
2-3	20	0.34	0.1	
3-4	20	0.34	0.1	
4-5	20	0.34	0.1	
5-6	40	0.68	0.1	
6-7	290	4.97	0.9	1
7-8	800	13.70	2.6	3
8-9	970	16.61	3.2	3
9-10	420	7.19	1.4	1
10-11	310	5.31	1.0	1
11-12	280	4.79	0.9	1
12-1 p.m.	280	4.79	0.9	1
1-2	290	4.97	0.9	1
2-3	320	5.48	1.0	1
3-4	310	5.31	1.0	1
4-5	270	4.62	0.9	1
5-6	200	3.43	0.7	1
6-7	190	3.25	0.6	1
7-8	180	3.08	0.6	1
8-9	120	2.06	0.4	
9-10	120	2.06	0.4	
10-11	150	2.57	0.5	1
11-12	140	2.40	0.4	
Total	5,840	100.00	19.0	19

TABLE 3 Automobile Sample Selection, 1,000 to 2,000 Inbound ADT Group

		Cordon Crossing Samples					
Hour	Total Sample	Michigan at S. Park (29.3)	W. Seneca Exit, I-190 (24.4)	Sycamore (17)	Skyway to Seneca and Pearl (31)	South Park (29.2)	West Avenue (4)
6-7 a.m.	1	1					
7-8	3		1		1		1
8-9	3	1		1		1	
9-10	2		1		1		
10-11	1			1			
11-12	2	1					1
12-1 p.m.	2		1		1		
1-2	2			1		1	
2-3	2	1					1
3-4	2		1		1		
4-5	2			1		1	
5-6	1	1					
6-7	1		1				
7-8	1			1			
8-9	1				1		
Total	26	5	5	5	5	3	3

crossings. In each of the groups, the hourly distribution of traffic at one location was considered representative of the group as a whole.

When the total sample for one of these lesser volume groups of crossings had been designated by hour by the method shown in Table 2 (e.g., 26 total automobiles to be sampled), that sample was distributed as smoothly as possible among the various crossings given in Table 3. Note that the total number of samples at each cordon crossing was made to add up to the appropriate number previously designated for its sample size.

A truck sample was also selected and that entire sample was assigned to locations by hour using the ATR counts and the grouping approach just described. In this case a street was also picked as "representative" of the hourly distribution at major cordon crossings.

At four locations, heavy traffic, with the sorting into lanes occurring well upstream, appeared to suggest sampling by lane as well as by street to ensure unbiased representation of turning movements from the approach. These locations were

- Location 15, Route 33 ramp to Oak Street--two lanes;
- Location 22, Elm Street exit of I-190 at Swan Street--four lanes;
- Location 14.2, Route 33 ramp to Goodell Street--four lanes; and
- Location 33.4, Church Street exit of I-190--three lanes.

Table 4 gives the appropriate total automobile and truck samples by lane at each of the four locations where lane designations were used. These were based on allocating the cordon crossing sample proportionally to the split in ADT volumes by lane.

In the case of Location 15, each of the two lanes had a high enough volume to be treated as a "major" cordon crossing by itself. The total automobile sample for each lane was allocated by hour on the basis of the ATR data in the manner of Table 2.

At the other locations, lane volumes are smaller and the grouping approach was used to designate the sample by lanes in a manner similar to that of Table 3. In these cases the "Total Sample" came from the ATR-based distribution for the particular location by hour as given in Table 2 and the "Cordon Crossing Samples" became "Lane Samples." The actual sample by lane and by hour was derived in the same manner used for Table 3. The total sample in each lane had to equal the appropriately proportional portion of the total sample for the cordon crossing. The truck samples had to all be allocated by lane and hour in the manner just discussed for the automobile sample at Locations 22, 14.2, and 33.4.

TABLE 4 Automobile and Truck Samples by Lane at Four Locations

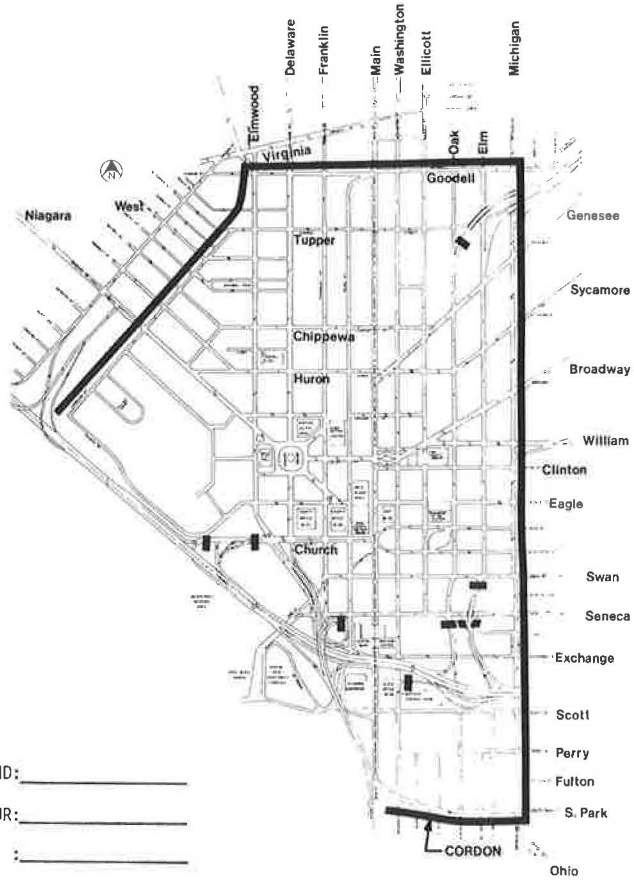
Location	Automobile Volume	Automobile Sample	Truck Volume	Truck Sample
15—Route 33 ramp to Oak Street	17,020	57	420	10
Lane 1	9,570	32	300	7
Lane 2	7,450	25	120	3
22—Elm Street exit of I-190 at Swan Street	12,890	43	410	9
Lane 1	2,760	9	140	3
Lane 2	3,910	13	120	3
Lane 3	3,710	13	80	2
Lane 4	2,510	8	70	1
14—Route 33 ramp to Goodell Street	10,530	35	180	4
Lane 1	2,470	8	30 }	1
Lane 2	1,800	6	20 }	
Lane 3	3,780	13	60	1
Lane 4	2,480	8	70	2
33—Church Street exit of I-190	7,010	24	160	4
Lane 1	2,750	10	100	2
Lane 2	1,810	6	30	1
Lane 3	2,450	8	30	1

Note: Lanes are numbered from right to left when facing in the direction of traffic movement. Volumes are for a 24-hr period.

Field Procedure

After all automobile and truck samples had been designated by cordon crossing, hour, and lane, a survey form, shown in Figure 2, was partly filled in for each sample vehicle. The cordon crossing, lane if necessary, hour, and vehicle type (automobile or truck) were designated on each form.

Each survey driver-observer (one person in car) then took a file of forms appropriate for the hours he expected to work each day or evening so that he could select the most convenient sample to pursue each time among those still needing to be done, depending on where the previous observed trip ended. The driver-observers were instructed to select the particular vehicle to follow for the designated hour,



CORDON CROSSING INBOUND:____________

HOUR:____________

LANE*(If applicable) :____________

Vehicle Type:__________ License:______

No. Occupants:____________

Parking Location:
(mark on map)

Parking Type: on street free lot
metered ramp

Parking Cost:
(if visible)

CORDON CROSSING OUTBOUND:
(through trips only)

Time In:____________

Drop-off or
Pickup location:
(mark on map)
&
No. of persons:

*Lanes are numbered from right to left when facing in direction of traffic movement.

FIGURE 2 Survey form.

lane, and vehicle type by a random selection method; in the case of automobiles, by counting to the fifth after reaching position and readiness to start. Trucks were infrequent enough that the first to come was normally picked. If the driver-observer lost a vehicle in traffic, he merely returned to pick another sample for the same location, hour, and vehicle type. This was a rare occurrence.

As each sampled vehicle completed its trip either by stopping and parking or by passing on through the cordon, the survey form was appropriately completed.

If a vehicle stopped and picked up, or dropped off, persons but did not park, the pick-ups and drop-offs were recorded and became part of the total regional CBD trip data; but the vehicle was still treated as a "through trip." The map that was part of the survey form was marked to show the route of each vehicle and the location of parking or passenger pick-ups and drop-offs. The entire survey of 500 vehicles was fully completed without incident by two persons in 2 working weeks. The complete instructions to driver-observers are included at the end of this paper as Appendix A.

PROCESSING THE SURVEY DATA

Coding Format and Procedure

It was desirable to code the data for computer processing and summary. The format needed to be set up to accomplish two basic objectives:

1. Provide the ability to summarize both vehicle and person trips to the CBD by their origin at the cordon line and their destination block and type of parking, whether curb or off-street. (Although data by block would not be statistically reliable for this survey, coding destinations to block locations provided maximum flexibility in how the study area could be divided for subarea summaries.)
2. Provide the ability to trace vehicle paths on the downtown street network and to pull out of the file data on all paths through any one or more links.

The first step in processsing the survey information was to put a serial number on each completed survey form so that the appropriate field sheets

could be identified for any piece of information drawn from the computer.

Consideration of Item 1 indicated that separate coding lines might be needed to indicate separate destinations of persons dropped off as distinct from those who continued in an automobile until it parked, in which case both activities are shown on a single form.

Consideration of Item 2 appeared to require two special steps.

- The data set from the trip-monitoring survey included all trips traveling through the CBD without parking and trips inbound that parked. This left missing only the outbound trips of those who parked to have a "complete" record of all of a typical day's downtown travel paths. It was decided to synthesize the most likely outbound trips to complete the trip file. This was done by having coders (who were the same persons who had been driver-observers) generate a trip record for the most likely return trip outbound to the same or nearby cordon crossing for each trip they encountered in coding that came inbound and parked.
- Links in the downtown street network needed to be numbered so they could be identified in a computer listing. Each direction on two-way streets was given a separate link number. Three-digit numbers were used and the travel paths were simply listed out link by link at the end of the coded data, including the link in which, or off of which, the vehicle parked. For curb parking the link number was also coded as the parking location.

When all of the possible trip types had been listed for coding, there were 9:

- Type 0--Vehicle went through CBD without parking, dropping off, or picking up passengers.
- Type 1--Vehicle parked in CBD and driver and other persons in automobile (if any) left automobile together (i.e., no picking up or dropping off).
- Type 2--Vehicle parked in CBD and dropped off persons before reaching the parking location.
- Type 3--Vehicle dropped off passengers in CBD but did not park or pick up passengers.
- Type 4--Vehicle picked up passengers in CBD but did not park or drop any passengers.
- Type 5--Vehicle picked up and dropped off passengers but did not park. (Pick-ups are disregarded if automobile subsequently parks. This survey does not include intra-CBD trips.)
- Type 6--Synthesized return vehicle trip from parking location to exit cordon crossing, same or logical pair to entrance crossing (reverse of 1).
- Type 7--Synthesized return vehicle trip from parking location to exit cordon crossing (same or logical pair to entrance crossing) with passenger pick-ups on the way (reverse of 2).
- Type 8--Additional inbound person trips not ending in the same location as those recorded on the same coding line as the vehicle trip.

The coding card layout is shown in Figure 3. The complete coding instructions are included at the end of the paper as Appendix B. Of particular interest may be the use of the "factor" (Columns 31-33) to expand the sampled data to represent the full universe of CBD trips. The factor for each sample represented the 24-hr volume of vehicles (automobiles or trucks) divided by the number of sample vehicles at each inbound crossing. Synthesized outbound trips carried the same factor as the inbound trips with which they were paired. Person trips become the number of persons in the car, or dropped off, multiplied by the factor. It also may be noted that the hour of the trip (crossing the cordon) was coded to permit data to be summarized by hour if desired. Of course, the hour of travel was not available for the synthesized outbound trips.

When coding was completed, the information was keypunched onto computer tape for further processing.

Preparing the Data for Use (person and vehicle trip ends)

Five tabulations were prepared initially from the data to be used first for review and correction and then for summaries of downtown trip activity and expansions of the parking data. These are listed as follows with the total 24-hr trips (expanded by the factor) for the Buffalo CBD as a whole:

1. Dropped-off passengers by block of destination

By vehicles later parking (Type 8 trips)	2,070
By vehicles passing through (Types 3 and 5)	4,190
Total	6,260

2. Vehicles destined downtown and persons arriving by automobile at their block of parking (Trip types 1 and 2)

Automobiles	61,420
Trucks	1,760
Persons with automobiles	79,970

3. Inbound vehicles parking and passing through the CBD by cordon crossing

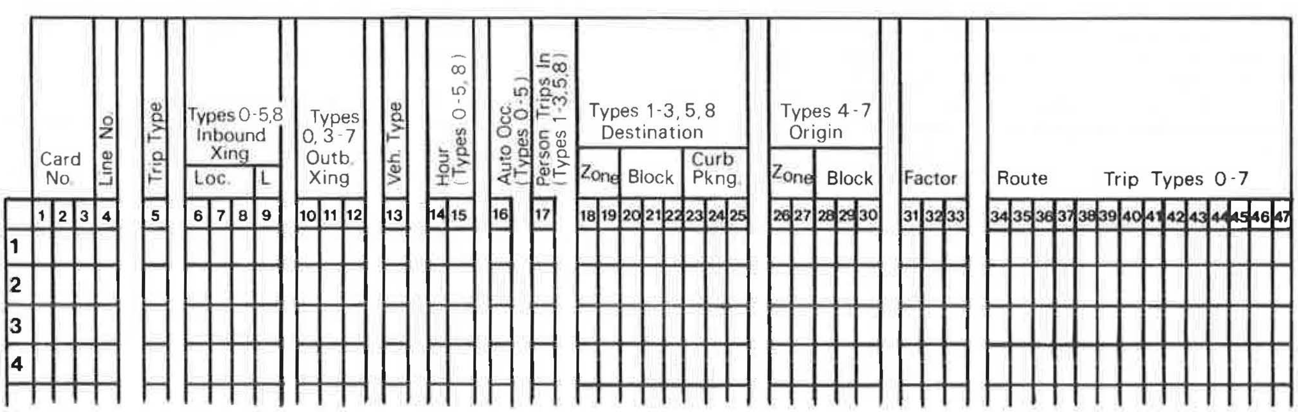


FIGURE 3 Card format for coding.

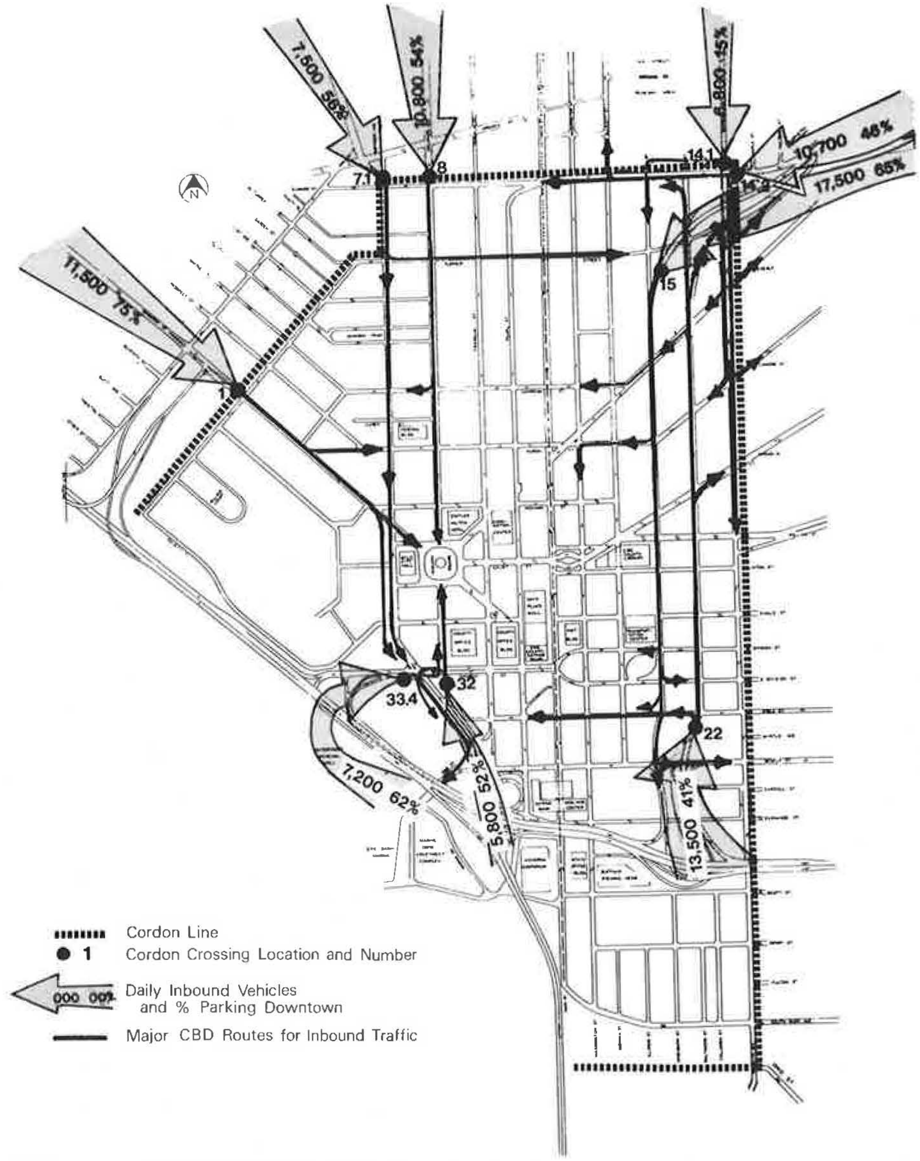


FIGURE 4 Buffalo CBD cordon distribution of major flows.

	Number	Percentage
Automobiles parking	61,420	52
Automobiles passing through	56,910	48
Total automobiles	118,330	100
Trucks parking	1,760	40
Trucks passing through	2,590	60
Total trucks	4,350	100
Total vehicles parking	63,180	51
Total vehicles passing through	59,500	49
Total vehicles (except buses) entering CBD	122,680	100

4. Routes (link by link) traversed by more than 500 inbound vehicles from each cordon crossing. (Although no meaningful total number could be provided here, the results of this tabulation with 3 were combined to produce Figure 4.)
5. Automobiles and trucks by location of parking, curb or off-street, by block (this was tabulated only for the parking study area)

	Number	Percentage
Automobiles at curb	13,790	25
Automobiles off street	40,330	75
Total automobiles parking	54,120	100
Trucks at curb	560	34
Trucks off street	1,080	66
Total trucks parking	1,640	100
Total vehicles at curb	14,350	26
Total vehicles off street	41,410	74
Total vehicles parking	55,760	100

The information from the trip-monitoring survey, combined with the results of the transit on-board survey, made it possible to establish the total person trip arrivals downtown on a typical weekday by mode as follows:

	Number	Percentage
Drivers	61,420	56
Passengers arriving with driver	18,550	17
Passengers dropped off	6,260	6
Transit passengers	23,390	21
Total	109,620	100

To provide appropriately detailed parking information, adjustments in the parking survey data were required to bring it into a consistent relationship with the trip-monitoring survey. Vehicle totals, derived block by block from the parking survey, were summed within the two portions of the study area and compared to trip-monitoring survey vehicle totals for vehicles parking in the same portions. This required adjustment of the trip-monitoring data to include only trips that would be present during the 8 hr of the parking survey. (See discussion of the adjustment in the next section of the paper.)

The parking survey figures, block by block, were adjusted upward by the ratio of the adjusted trip-monitoring total divided by the parking survey total. These figures for vehicle trips were then converted to person trips by multiplying each block's vehicle total by the trip-monitoring survey's ratio of person trips to vehicle trips. Finally, these person trips were distributed to their blocks of final destination on the basis of the results of the parker interviews. Transit passengers and automobile drop-offs were added as appropriate.

Thus downtown block, zone, and district summaries could be prepared of final person trip ends (one way) from the various surveys. These data, including the parking walkers' trip table (parking lots to final destinations) were extremely helpful in analyzing the impact on parking needs of the possible changes in the location of business activity or of the elimination or relocation of parking facilities.

Preparing the Data for Use (travel paths)

The use of the data for travel path analysis does not lend itself so well to statistical summary here. The process called for printing out the full card data on every trip passing through a street section that might be closed or changed, such as a case in which it was proposed to reverse the direction of one-way traffic. The travel paths were then plotted manually on large maps of the CBD. Then new paths were drawn that represented the new routes traffic could be expected to take after the proposed change. Considerable judgment had to be used in estimating the amount of traffic shifted in the peak hours for the purpose of capacity analysis of the changed flows. This is discussed further in the next section of the paper.

It had not been assumed that flows on individual streets could be accurately estimated from the trip-monitoring survey data. This was due to the small sample in the survey and the synthesized trips generated from that sample; nevertheless, it was of considerable interest just how well the survey did reproduce ground count flows on individual streets. Table 5 was prepared to show such a comparison on a selection of links, many of which were involved in proposed circulation changes in the Regional Center Plan study.

Street locations relatively near the cordon line are labeled "in" or "out" in Table 5 as appropriate to show their direction of flow toward or away from the center of downtown. Those not so labeled may be considered more or less in the heart of the CBD. It may be seen that almost all of the significant differences in link volumes occur on outbound links near the cordon. This presumably reflects errors in generating the synthesized trips. Even the 56 percent difference shown for Ellicott Street in the heart of downtown is most likely due to the routing of the synthesized trips.

With more time it might have been possible to adjust the routings and choice of exit cordon crossing for synthesized trips to make trip-monitoring path volumes conform much better to ground counts. It would appear that if a survey or other means could be used to improve the synthesized trip data, good correspondence to ground counts might be possible.

Another interesting aspect of the comparison in Table 5 is that the overall volumes of the trip-monitoring survey did not come out less than the ground counts as has been expected. A shortfall was expected because the trip-monitoring survey did not include intra-CBD trips, nor did the coding of paths include circuitous travel of people obviously just looking for close-to-destination parking space. However, that the last street link of a trip that parked was coded as if the entire link had been traversed, and then coded again as a travel link for the synthesized return trip, may have helped to make up in volume of travel for the missing types of activity.

TABLE 5 Comparison of ADT on CBD Streets (trip-monitoring survey travel path data and ground counts)

Selected Streets	Location	Link No.	Ground Count	Trip Monitoring	Percentage Difference
Elm Street	N. of Swan	251 (in)	11,800	12,300	+4
Elmwood Avenue	N. of Chippewa	263 (in)	6,200	6,400	+3
		273 (out)	3,900	4,900	+26
Total			10,100	11,300	+12
Seneca St.	E. of Washington	674	9,700	8,100	-16
Delaware Ave.	N. of Church	186 (out)	3,000	5,500	+83
		191 (in)	10,400	9,300	-11
Total			13,400	14,800	+10
Niagara St.	E. of Elmwood	563 (out)	7,000	11,700	+67
		573 (in)	4,500	4,300	-4
Total			11,500	16,000	+39
Washington St.	S. of Clinton	825	5,200	5,900	+13
Ellicott St.	S. of Clinton	243	7,800	3,400	-56
Oak Street	S. of Swan	589 (out)	11,400	12,600	+11
Chippewa St.	W. of Washington	092	6,800	5,100	-25
Total			87,700	89,500	+2

SURVEY CONCERNS

Safety and Privacy Aspects of the Survey

When there is discussion of this type of survey in a group for the first time, there is generally some concern expressed about possible incidents or accidents that might arise. Although such things are always possible, the selection of intelligent and responsible driver-observers who believe that they can do the survey in the desired manner appears to be the most important step in minimizing the chances of this sort of misfortune. With such people available, there were no accidents or incidents of any type to mar the conduct of the Buffalo survey.

A second concern sometimes raised is whether this survey constitutes an invasion of privacy. It is not believed that it does, as described here, because all the observing is done in public areas and there is no attempt to determine the purpose of trips. Follow-up questioning could trigger such concerns. It would not appear to be advisable, for instance, to send questionnaires to home addresses of automobile owners (determined from license plate numbers) about observed trips of their vehicles. The leaving of a postpaid reply card on an observed vehicle asking for data on the outbound trip might be more acceptable because the driver could choose to respond or not.

Vehicle and Person Trip Ends

The principal concern that developed in using the trip-monitoring data for expansion of the parking survey was the adjustment of volumes for the time period of the parking survey. The appropriate volume of trip ends applicable to the parking survey had to represent not only those who parked in the appropriate area but also those who would be in that area between the hours of 10 a.m. and 6 p.m. when the parking survey was conducted. It was easy enough to exclude all the trip-monitoring survey trips that came into the CBD after 6 p.m. because the hour of entry was coded. The tougher question was which of those trips that entered the CBD before 10 a.m. were still there at 10 a.m.

This parking duration question was answered by going back to the field sheets and making a judgment based on when and where the vehicle parked. If the time was before 9 a.m., a vehicle that parked at a restaurant was excluded; one that parked in an all-day lot was included. Those that parked illegally, or at metered spaces before 8 a.m. (for 2-hr meters) were excluded, those that parked in free curb spaces on the fringe of the CBD and headed off on foot toward the central area were included. Unfortunately, there was a group about which it was impossible to be sure, and the best judgment possible had to be accepted.

In a similar case in the future on these early morning trips, it would probably be helpful to have the survey observer indicate directly on the field sheet whether or not the vehicle was likely to remain in the time period of the parking survey. Leaving a postpaid reply card on the windshield of each observed car after it parks (for early morning arrivals) might be a means of picking up some information or some sample of the original sample regarding length of parking, but this would probably require either additional time or an assistant with the driver-observer. Also, "carding" cars that enter large parking ramps or private or guarded areas would pose the problem of gaining access and finding the parked vehicle.

Travel Path Data

A similar type of concern about the time of trips arose in using the travel path data. The analysts using the data wanted travel paths of just the peak rush hour trips identified to aid in adjusting peak-hour flows for capacity analysis of new circulation proposals. The morning trips inbound between the hours of 6 a.m. and 10 a.m. appeared to be "typical" enough for that purpose in that time period, but what travel paths would be most representative of the evening rush hour? All of the paths of those entering the CBD between the hours of 3 p.m. and 6 p.m. appeared to be a natural enough choice, but what others? A large component of this group should be the synthesized trips, which are the most speculative data in the survey. Here again, the desirability of finding some way to better establish the time and route of travel for the outbound travel component was pointed out. In this particular study the analysts looked at the travel patterns of all the synthesized trips using the street links under study for their evening rush period analysis.

A means of getting a firmer hold on outbound travel path data could include following a sample of outbound trips from point of origin at curbs and in off-street lots and ramps. Key points in setting up the sample framework would involve determination of the total quantity of cars (the universe) leaving designated areas and establishing the pattern of departures by hour. Parking survey turnover data adjusted to match inbound trip-monitoring survey control totals would provide the universe of automobiles previously described.

The overall hourly pattern of CBD departures could be derived from outbound cordon crossing data. The process would require splitting the measured outbound hourly flows into two parts: that due to "through" outbound trips and that due to outbound trips originating within the CBD, which would represent the trips to be sampled. The hourly pattern of the through trips could be estimated from the through trips sampled in the inbound trip-monitoring survey and the appropriate volumes subtracted from the total outbound volumes to give the hourly pattern for outbound sampling. Cordon classification counts for outbound traffic, as well as inbound, would be desirable for such an outbound trip-monitoring survey.

CONCLUSIONS AND RECOMMENDATIONS

The trip-monitoring survey exceeded all expectations both in the smoothness and the uneventfulness of the actual conduct of the survey and in the usefulness of the data that were collected. It was particularly beneficial to have reliable data on total travel into downtown Buffalo for the first time. There are frequent requests for such information and it was extremely useful in the Buffalo Regional Center study. Time and time again in that study the trip table data for persons walking to their destinations from their parking locations were used to analyze the impact of replacing existing parking facilities with new development and to determine the most desirable locations for additional parking facilities. Without the trip-monitoring survey, it would have been much more difficult to provide such data with confidence. Similarly, the travel path information was used frequently to analyze many different roadway proposals and changes in circulation patterns.

Use of the trip-monitoring survey is fully recommended to others with need for this type of information with one proviso: that competent and responsible driver-observers be available. It would not be

recommended to send out anyone as a driver-observer who does not want to do it or who does not believe it can be done safely. Questions of adequate insurance coverage and what to do in case of accident should be resolved to everyone's satisfaction in advance.

It may be of interest that the Buffalo trip-monitoring survey and cordon counting program altogether cost $15,000 in 1983 and took 49 manweeks of staff time. Most of the staff time involved temporary field workers at $4.00 per hour who took the 8-hr manual classification counts at the cordon stations.

For future trip-monitoring surveys conducted in conjunction with parking surveys, the leaving of postpaid reply cards on the windshelds of sampled early morning arrivals is suggested where practical. These would request departure times for the return trip and perhaps also the exit cordon station if travel path data are sought. Reply cards should be as brief and to the point as possible to maximize the response. Any additional information of this type that is received would be helpful. If there is a need for high reliability in the travel path data, the trip monitoring of exiting drivers from their points of origin in the CBD may be justified.

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APPENDIX A--INSTRUCTIONS FOR CAR-FOLLOWING PROCEDURE, BUFFALO CBD TRIP-MONITORING SURVEY

The survey will be conducted by having driver-observers in their cars follow vehicles from a designated cordon crossing point until they either stop and park or exit through the cordon.

Safety and accident avoidance is always the primary concern. Follow at safe distances. If a vehicle is lost, simply restart the procedure with a new vehicle. Do not attempt to write while automobile is in motion.

Driver-observers should have a file of survey field sheets from which the most convenient sample may be taken for the next trip after the previous trip is completed. The survey form should have the following information on it before the survey is started:

- Cordon crossing point from which sample is selected;
- The hour period within which the sample is selected;
- The lane in which the sample is to be selected, if applicable; and
- The vehicle type of the sample: (a) automobile (a vehicle with four tires including vans or pickup trucks and motorcycles and automobiles with trailers) and (b) truck (any vehicle with six or more tires and slow-moving, truck-like four-tired vehicles).

Select sample vehicle in an unbiased method. If lane is not designated and there is more than one lane on the approach, select sample vehicle before its lane becomes known. The suggested method of sample selection is, after being in position and ready, count off five vehicles taking the fifth that meets the sample criteria. With trucks, in some locations it may be necessary to use a lower count, perhaps even the first truck to come. Write down the correct time on the survey form when the sample is selected but before putting automobile in motion.

Follow the sample vehicle safely, noting the license number and number of occupants. When vehicle parks or exits the cordon, stop in a safe location and write down the information requested on the survey form. Trace the vehicle's route in ink on the map on the survey form.

If passengers are dropped off or picked up, note the location and number of persons involved on the map and in the appropriate blank on the survey form. Show whether it is a pick-up or a drop-off.

APPENDIX B--CODING INSTRUCTIONS, CBD TRIP-MONITORING SURVEY

General

All coding blocks are to be filled in accord with the instructions. There are to be no blank blocks except beyond Column 33.

Survey Form Number (Columns 1-3)

Survey forms are to be numbered consecutively through the survey and numbers coded. Write numbers at the top of the survey field sheets as well as on coding sheets. Fill all blocks (i.e., survey form 1 is coded 001). Survey form numbers are repeated when additional coding lines are filled out for extra trip activity connected with a single vehicle trip.

Line Number (Column 4)

Code 1 for the first line filled out, which will record the inbound vehicle trip and person data if vehicle parked, dropped off, or picked up passengers. Code 2, 3, and so forth for additional lines filled out for extra person trip activity connected with the single vehicle trip. A final line (same form number) will be filled out for the synthesized return vehicle trip if vehicle parked inbound.

Trip Type (Column 5)

- Code 0--Vehicle went through CBD without parking, dropping off, or picking up passengers.
- Code 1--Vehicle parked in CBD and driver and other persons (if any) in car left car together (i.e., no picking up or dropping off).
- Code 2--Vehicle parked in CBD and dropped off persons before reaching the parking location.
- Code 3--Vehicle dropped off passengers in CBD but did not park or pick up passengers.
- Code 4--Vehicle picked up passengers in CBD but did not park or drop off any passengers.
- Code 5--Vehicle picked up and dropped off passengers but did not park (pick-ups are disregarded if car subsequently parks; this survey does not include intra-CBD trips).

• Code 6--Synthesized return vehicle trip from parking location to exit cordon crossing, same or logical pair to entrance crossing (reverse of 1).

• Code 7--Synthesized return vehicle trip from parking location to exit cordon crossing (same or logical pair to entrance crossing) with passenger pick-ups on the way (reverse of 2).

• Code 8--Additional inbound person trips not ending in the same location as those recorded on the same coding line as the vehicle trip.

Inbound Cordon Crossing Location (Columns 6-8)

Code the number of the crossing location in the two spaces before the dot. In some cases, such as Michigan and Goodell, there are two roadways on which vehicles may enter. Use N = 1, E = 2, S = 3, W = 4 in Column 8 for this designation where applicable. Otherwise code a 0 (e.g., entering the CBD on Michigan from the north would be coded 14.1; code 0s for trip types 6 and 7).

Inbound Crossing Lane (Column 9)

Code the number of the lane at an inbound cordon crossing where applicable; otherwise, code 0. Lanes are numbered from right to left when facing in the direction of traffic movement.

Outbound Cordon Crossing (Columns 10-12)

For trip types 0, 3, 4, 5, 6, and 7 the location at which the trip went back through the cordon is coded in the same manner as the inbound cordon crossing (Columns 6-8). For trip types 1, 2, and 8, code 0s in all spaces.

Vehicle Type (Column 13)

Code 1 = automobile; Code 2 = truck.

Hour (Columns 14-15)

Code the hour of the inbound cordon crossing in military time (e.g., 4:10 p.m. = 16:10). Code 0 for trip types 6 and 7.

Automobile Occupancy (Column 16)

Code the number of persons in the automobile when it went inbound across the CBD cordon. Code 0 for trucks and for trip types 6, 7, and 8.

Person Trips (Column 17)

Code the number of persons having trips ending in the Buffalo CBD represented by this particular coding line. Code a separate line for each drop-off having a different CBD origin or destination block. Code 0 for trip types 0, 4, 6, and 7 (all vehicles). Also code 0 for all truck trips except types 3, 5, and 8 (drop-offs).

Destination Zone (Columns 18-19)

Code the traffic analysis zone where vehicle and/or person trips represented by the coding line ended. Code 0s for trip types 0, 4, 6, and 7. For trip type 2, the destination is always where the vehicle trip ended. The person trips dropped off before parking are shown on separate lines as trip type 8.

Destination Block (Columns 20-22)

Code the parking survey block number where the vehicle trip ended for trip types 1 and 2 and where person trips ended for trip types 3, 5, and 8. Code 0s for trip types 0, 4, 6, and 7. If the trip ended outside the area of the numbered blocks, code 0s.

Destination Curb Parking (Columns 23-25)

This section is only for vehicles that park downtown on the street (trip types 1 and 2). For all others, code 0s. If a vehicle parks downtown on the major street network, code the number of the link on which the vehicle parks. Note that the links are directional and the link for the direction in which the vehicle is headed should be used on two-way streets. If the vehicle parks on a street not on the major network, code the number of the street in blocks 23-24 and code a 0 in block 25. If street numbers cannot be found in the "Downtown Directory," code 0s.

Origin Zone (Columns 26-27)

This section only applies to trip types 4, 5, 6, and 7. For all others, code 0s in Columns 26-27. For trips having origins in the Buffalo CBD, code the traffic analysis zone of origin. It is not necessary to code additional pick-ups beyond those that can be shown with the vehicle trip.

Origin Block (Columns 28-30)

This section also applies only to trip types 4, 5, 6, and 7. For other types, code 0s in Columns 28-30. For trips having origins in the area where blocks are numbered, code the appropriate block number. Otherwise, code 0s.

Factor (Columns 31-33)

Code the appropriate factor. For automobiles it will be between 142 and 385. For trucks it will be between 16 and 74. If a truck factor is 40, code it 040. The same factor applies to all trips from a single survey form.

Route (Columns 34-78)

This section applies only to vehicle trips; it does not apply to trip type 8 (leave blank). Code in sequential order the major network links traversed by the vehicle. If the trip is not fully on the major network, code those links that are used in the order in which traversed.

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