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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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FREEWAY FLYER SERVICE IN SOUTHEASTERN WISCONSIN
A PROGRESS REPORT: 1964-1971

By Sheldon W. Sullivan, Chief of Data Collection

INTRODUCTION

In the more than eight years since freeway flyer service was established in southeastern Wisconsin, it has prospered despite a very great decline in the use of all other forms of mass transit in the Region. Begun as an experiment on March 30, 1964 by the Milwaukee and Suburban Transport Corporation, the principal mass transit carrier in the Region, the new service connected the Mayfair Shopping Center in the City of Wauwatosa and the Milwaukee central business district (CBD), a distance of about 10 miles. The service had a number of innovative qualities which were to spell its success, including:

1. Provision for the first time of direct, nonstop service each weekday during peak travel periods between the central business district of the City of Milwaukee and outlying portions of the Milwaukee urbanized area.

2. The ability to operate on completed segments of the developing freeway system, greatly reducing transit travel times.

3. Provision by shopping center management of ample free parking space in well-lighted, easily accessible sectors of shopping center parking areas.

4. Convenient scheduling of service; attractive, modern motor coaches used for the service; and the modest premium fare, which was five cents more than the regular fare, with full transfer privileges to all connecting regular bus lines.

The service, which experienced almost immediate success, has continued to grow in terms of increasing passenger volume and expansion of its services. The existing freeway flyer routes are shown on Map 1.

GROWTH IN RIDERSHIP

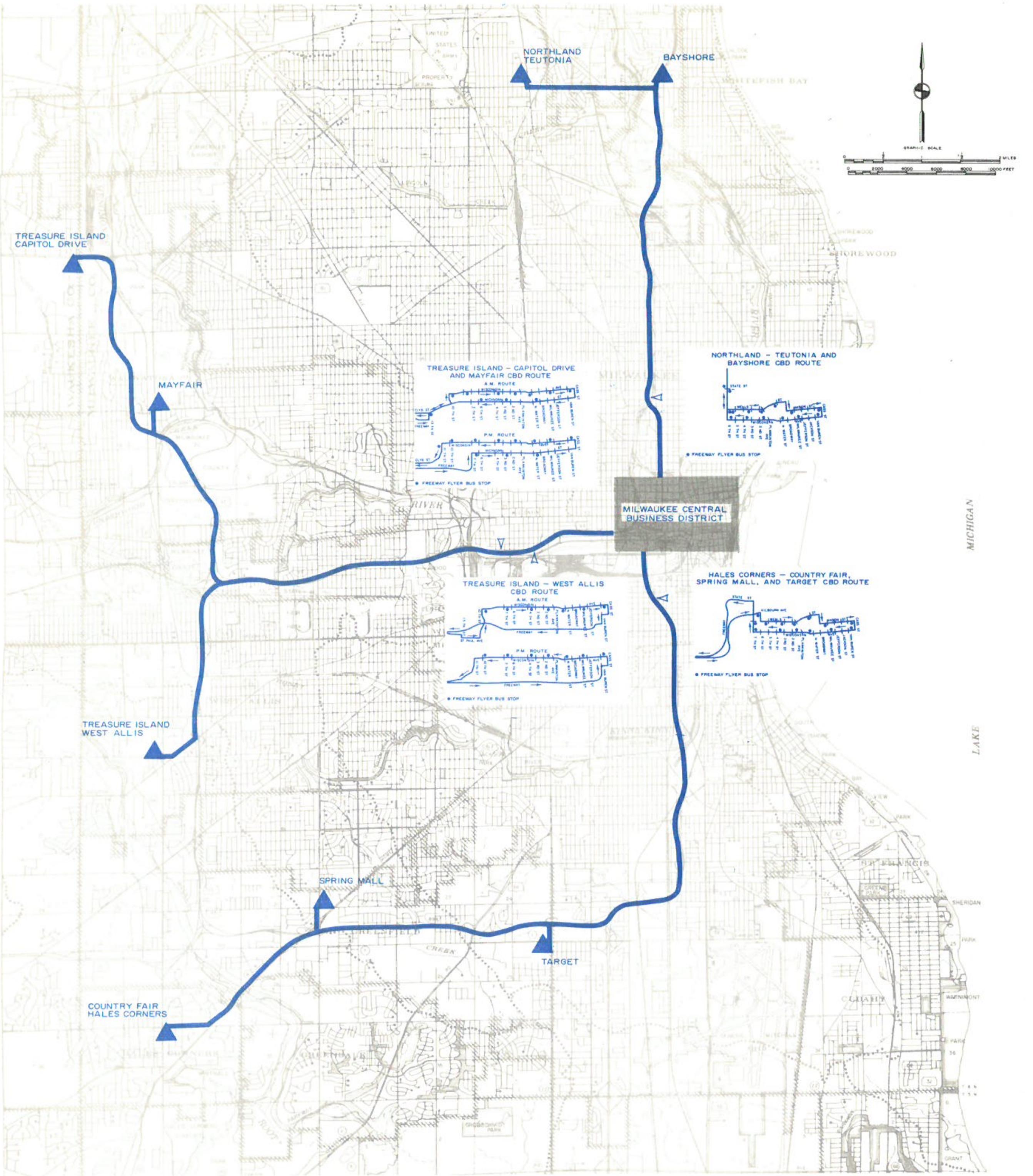
During the first nine months of operation of the Mayfair route in 1964, about 81,000 persons used the new system. Passenger volume more than doubled on the same route by 1965, totaling 165,000 passengers, and encouraged by this success, the Transport Corporation began a second service in November 1965 at the Bay Shore Shopping Center, located about seven miles north of downtown Milwaukee in the City of Glendale. Ridership on both routes continued to grow, totaling about 351,000 passengers in 1966.

In 1967, losses in freeway flyer ridership estimated at about 40,000 to 45,000 revenue passengers were incurred as a result of a 19-day strike against the transit carrier, a fare increase made necessary by the strike settlement terms, and 10 days of civil disorder in the City of Milwaukee. Despite these major losses, total ridership reached about 385,000 passengers, a gain of 34,000 from the previous year. This was helped in part by the establishment in November 1967 of a freeway flyer route at the Treasure Island Department Store in the City of West Allis, about 10 miles west of downtown Milwaukee.

A fourth route was added in April 1968, located at the Treasure Island Department Store on Capitol Drive in the City of Brookfield, about 12 miles northwest of downtown Milwaukee. The new route and the continued increase in ridership on the existing routes, especially the West Allis route, brought the total ridership to more than one-half million passengers in 1968.

Map 1

EXISTING FREEWAY FLYER ROUTES



Source: *SEWRPC.*

In late 1968, as a result of a series of robberies of bus drivers, a plan was begun which required boarding passengers other than pass holders to pay the exact fare. Although this plan is believed to have adversely affected transit ridership, passenger use in 1969 nevertheless increased to 560,000 persons, a gain of 59,000 passengers from 1968, due largely to the establishment in April 1969 of a fifth route at the Country Fair Shopping Center in the Village of Hales Corners, about 14 miles southwest of downtown Milwaukee.

There were some disappointments in 1969, however. For the first time in the history of the service, the number of revenue passengers carried annually on a freeway flyer route (Mayfair) declined, and failed to gain on another (Bay Shore). The growth rate on both of these routes had dropped considerably since 1966, but it now appears that ridership on both routes was in the process of stabilizing. Establishing the routes at the Treasure Island stores in Brookfield and West Allis resulted in the shift of several thousand passenger trips from the Mayfair route to the new routes, and narrowed the area of attraction and growth available to the Mayfair route.

In 1970, total freeway flyer ridership increased by about 44,000 passengers to a total of about 605,000 passengers, despite additional but relatively minor losses in ridership on the Mayfair and Bay Shore routes. Most of the net gain in ridership during 1970 resulted from a sizable increase in ridership on the Hales Corners route and from the establishment in July 1970 of the sixth freeway flyer service, located at the Spring Mall Shopping Center about 10 miles southwest of downtown Milwaukee in the City of Greenfield.

SPRING MALL FREEWAY FLYER TERMINAL

The establishment of a seventh freeway flyer service located at Target Stores Incorporated, about six miles southwest of downtown Milwaukee in the City of Greenfield, and the substantial increases in ridership experienced on the Spring Mall route were the principal factors in bringing the 1971 total freeway flyer ridership to nearly 675,000 in 1971, an increase of approximately 70,000 passengers over the previous year. Modest gains in ridership on the Hales Corners, West Allis, and Capitol Drive routes were offset for the most part by minor losses which continued on the Mayfair and Bay Shore routes in 1971 (see Table 1).

Table I

NUMBER OF FREEWAY FLYER REVENUE PASSENGERS BY ROUTE: 1964-1971

FREEWAY FLYER ROUTE	DATE ROUTE ESTABLISHED	NUMBER OF FREEWAY FLYER REVENUE PASSENGERS							
		1964	1965	1966	1967	1968	1969	1970	1971
MAYFAIR..........	MARCH 30, 1964	81,174	161,148	223,926	227,271	238,682	220,435	210,038	202,767
BAY SHORE........	NOVEMBER 29, 1965	--	7,369	127,816	150,133	164,397	164,307	153,658	149,796
TREASURE ISLAND- WEST ALLIS.....	NOVEMBER 6, 1967	--	--	--	7,762	73,237	97,084	104,255	112,547
TREASURE ISLAND- CAPITOL DRIVE..	APRIL 22, 1968	--	--	--	--	25,037	41,654	49,940	52,189
COUNTRY FAIR- HALES CORNERS..	APRIL 14, 1969	--	--	--	--	--	37,063	64,521	69,853
SPRING MALL......	JULY 6, 1970	--	--	--	--	--	--	22,469	63,859
TARGET...........	MAY 17, 1971	--	--	--	--	--	--	--	23,412
TOTAL	--	81,174	168,517	351,742	385,166	501,353	560,543	604,881	674,423

SOURCE- MILWAUKEE AND SUBURBAN TRANSPORT CORPORATION.

Thus, despite the effects of a major strike, fare increases, cutbacks in service, increasing numbers of autos available to residents of the Region, and the overall downward trend in transit travel in southeastern Wisconsin, freeway flyer ridership has grown from about 81,000 revenue passengers on a single route in 1964 to about 675,000 revenue passengers on seven routes in 1971. The continued increase in numbers of riders on the freeway flyer service from 1964 through 1971 is a marked contrast to the huge losses in transit ridership suffered in the Milwaukee transit service area during the same period of time on the regular bus service system. Such losses, amounting to nearly 29 million revenue passengers or about 34 percent of its riders, compared to revenue passenger losses nationally of about 16 percent during those years. It is in this perspective that current freeway flyer passenger volumes, representing little more than 1 percent of current total revenue passengers on the Milwaukee transit system, must be viewed.

SURVEY FINDINGS

Attraction of New Transit Patrons

The main concern of a private transit operator in establishing a new freeway flyer route is that it attract not only enough passengers to make it economically viable, but that it also attract a substantial number of new mass transit patrons. Little would be accomplished toward the goal of more balance among the various means of transportation if the success of the freeway flyer route was achieved at the expense of diverting passengers from one or more of the regular bus routes in the total transit system. If, however, a significant number of commuters could be converted from the private automobile to public mass transit, it would signify a major achievement by the service and a remarkable reversal of a 20-year trend.

A series of surveys conducted by the Southeastern Wisconsin Regional Planning Commission in cooperation with the Transport Corporation on the Mayfair route in 1964, the Mayfair and Bay Shore routes in 1966, and the West Allis, Capitol Drive, and Hales Corners routes in 1969 showed that this unique type of service had attracted a large percentage of new transit patrons on each route, ranging from 39 percent on the Mayfair route in 1964 to 59 percent on the Hales Corners route in 1969. The residual percentage on each route represented those who had changed from regular bus service to freeway flyer service (see Table 2).

Table 2

MODE OF TRAVEL OF FREEWAY FLYER PASSENGERS PRIOR TO FREEWAY FLYER SERVICE BY ROUTE: 1964, 1966, AND 1969

FREEWAY FLYER ROUTE	SURVEY YEAR	PRIOR MODE OF TRAVEL: AUTO DRIVER		AUTO PASSENGER		BUS RIDER		OTHER		TOTAL[a]
		NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	
MAYFAIR..........	1964	54	28.9	16	8.5	114	61.0	3	1.6	187
MAYFAIR..........	1966	182	41.2	37	8.4	215	48.6	8	1.8	442
BAY SHORE.......	1966	141	44.3	43	13.5	132	41.5	2	0.7	318
TREASURE ISLAND-WEST ALLIS....	1969	62	38.5	19	11.8	80	49.7	0	0.0	161
TREASURE ISLAND-CAPITOL DRIVE.	1969	29	38.7	13	17.3	33	44.0	0	0.0	75
COUNTRY FAIR-HALES CORNERS.	1969	28	32.9	22	25.9	35	41.2	0	0.0	85

[a]THE TOTAL DOES NOT INCLUDE EIGHT RESPONDENTS WHO DID NOT MAKE THE TRIP BEFORE AND TWO RESPONDENTS WHO DID NOT INDICATE PRIOR MODE OF TRAVEL ON THE MAYFAIR (1964) ROUTE, 109 RESPONDENTS WHO DID NOT MAKE THE TRIP BEFORE AND SIX RESPONDENTS WHO DID NOT INDICATE PRIOR MODE OF TRAVEL ON THE MAYFAIR (1966) ROUTE, 57 RESPONDENTS WHO DID NOT MAKE THE TRIP BEFORE AND 10 RESPONDENTS WHO DID NOT INDICATE PRIOR MODE OF TRAVEL ON THE BAY SHORE ROUTE, 38 RESPONDENTS WHO DID NOT MAKE THE TRIP BEFORE AND FOUR RESPONDENTS WHO DID NOT INDICATE PRIOR MODE OF TRAVEL ON THE WEST ALLIS ROUTE, 14 RESPONDENTS WHO DID NOT MAKE THE TRIP BEFORE AND THREE RESPONDENTS WHO DID NOT INDICATE PRIOR MODE OF TRAVEL ON THE CAPITOL DRIVE ROUTE, AND FOUR RESPONDENTS WHO DID NOT MAKE THE TRIP BEFORE ON THE HALES CORNERS ROUTE.

SOURCE- SEWRPC.

Conversion of Automobile Drivers to Mass Transit Passengers

To obtain a better balance among different means of transportation in southeastern Wisconsin and to help reduce traffic congestion, it was hoped that the freeway flyer service would induce a substantial number of persons to switch from driving private cars to riding the freeway flyer in commuting daily to and from downtown Milwaukee. Results of each survey were favorable in this respect.

INBOUND FREEWAY FLYER ON EAST-WEST FREEWAY

It was found that about 39 percent of freeway flyer passengers surveyed had previously commuted as auto drivers, ranging by route from 29 percent on the Mayfair route in 1964 to 44 percent on the Bay Shore route, as also shown in Table 2. These rates of conversion from auto driver to freeway flyer passenger indicate that about 250, 000 auto driver trips representing approximately 2. 5 million miles of travel per year, or about 1, 000 auto driver trips representing about 10, 000 miles of travel per average weekday, have been removed from the highways in the Region. The average daily freeway flyer use, while representing only 0. 06 percent of the average daily travel demand in the Region as measured by person trips, represents 0. 14 percent of the peak hourly demand in the Region, and 1. 51 percent of the peak hourly demand in the three most heavily used transit corridors of the Region. It is also estimated that about 1, 000 parking spaces formerly used each weekday in downtown Milwaukee by auto driving commuters have been relinquished as a result of these conversions.

Automobile Availability

It was found in the 1964 and 1966 passenger surveys on the Mayfair and Bay Shore routes that the majority of freeway flyer passengers, ranging from about 60 to about 66 percent, had automobiles available to them at the times the freeway flyer trips were made, and that they could, therefore, have made the trip as an auto driver to and from downtown Milwaukee if they had so desired. The 1969 surveys on the West Allis, Capitol Drive, and Hales Corners routes corroborated these findings, although with somewhat smaller majorities, ranging by route from about 51 percent to about 59 percent (see Table 3). In sharp contrast, findings from the initial SEWRPC origin-destination surveys of 1963 showed that only 14 percent of passengers on regular bus service had automobiles available to them when making trips to and from downtown Milwaukee.

Table 3

AUTOMOBILE AVAILABILITY AT TIME OF FREEWAY FLYER TRIP BY ROUTE: 1964, 1966, AND 1969

FREEWAY FLYER ROUTE	SURVEY YEAR	AUTOMOBILE AVAILABLE		AUTOMOBILE NOT AVAILABLE		TOTAL[a]
		NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	
MAYFAIR.........	1964	130	66.3	66	33.7	196
MAYFAIR.........	1966	345	62.8	204	37.2	549
BAY SHORE.......	1966	228	60.2	151	39.8	379
TREASURE ISLAND-WEST ALLIS....	1969	104	52.3	95	47.7	199
TREASURE ISLAND-CAPITOL DRIVE.	1969	51	58.6	36	41.4	87
COUNTRY FAIR-HALES CORNERS.	1969	43	51.2	41	48.8	84

[a]THE TOTAL DOES NOT INCLUDE ONE RESPONDENT ON THE MAYFAIR (1964) ROUTE, EIGHT RESPONDENTS ON THE MAYFAIR (1966) ROUTE, SIX RESPONDENTS ON THE BAY SHORE ROUTE, FOUR RESPONDENTS ON THE WEST ALLIS ROUTE, FIVE RESPONDENTS ON THE CAPITOL DRIVE ROUTE, AND FIVE RESPONDENTS ON THE HALES CORNERS ROUTE WHO DID NOT INDICATE WHETHER OR NOT AN AUTOMOBILE WAS AVAILABLE AT THE TIME THE TRIP WAS MADE.

SOURCE- SEWRPC.

Auto Driver Status

The differences in the percentage of licensed drivers among riders of freeway flyers as reported in the 1964, 1966, and 1969 surveys and riders of regular bus service in the 1963 travel surveys were significant. On freeway flyer routes a very large percentage of riders, ranging by route from 75 to 88 percent, were found to be licensed to drive an automobile, as shown in Table 4. In comparison, only 34 percent of total riders on the regular bus service traveling to and from downtown Milwaukee were found to be licensed drivers in the 1963 surveys.

The difference in automobile availability between these two kinds of bus service is largely explained by the differences found in the percentage of passengers who were: 1) members of households not owning an automobile; 2) members of households owning two or more automobiles; and 3) persons licensed to drive an automobile as reported in the 1963 survey of regular bus service and in the 1964, 1966, and 1969 surveys of freeway flyer passengers.

It was found, for example, that the overwhelming majority of freeway flyer passengers, ranging by route from 96 to 98 percent, were members of automobile-owning households as shown in Table 5. Passengers using regular bus service to travel to and from downtown Milwaukee in 1963 and who were members of auto-owning households, on the other hand, were found to total only 43 percent. It was found that the percentage of freeway flyer passengers who were members of households owning two or more automobiles was substantial, ranging by route from 41 to 61 percent, compared with only 9 percent of regular bus passengers reporting multi-auto ownership in 1963 trips to and from downtown Milwaukee.

Table 4

AUTO DRIVER STATUS OF FREEWAY FLYER PASSENGERS BY ROUTE: 1964, 1966, AND 1969

FREEWAY FLYER ROUTE	SURVEY YEAR	AUTO DRIVER STATUS: LICENSED NUMBER	LICENSED PERCENT OF TOTAL	UNLICENSED NUMBER	UNLICENSED PERCENT OF TOTAL	TOTAL[a]
MAYFAIR.........	1964	163	83.6	32	16.4	195
MAYFAIR.........	1966	474	85.6	80	14.4	554
BAY SHORE.......	1966	305	80.7	73	19.3	378
TREASURE ISLAND-WEST ALLIS....	1969	170	84.6	31	15.4	201
TREASURE ISLAND-CAPITOL DRIVE.	1969	80	87.9	11	12.1	91
COUNTRY FAIR-HALES CORNERS.	1969	63	75.0	21	25.0	84

[a]THE TOTAL DOES NOT INCLUDE TWO RESPONDENTS ON THE MAYFAIR (1964) ROUTE, THREE RESPONDENTS ON THE MAYFAIR (1966) ROUTE, SEVEN RESPONDENTS ON THE BAY SHORE ROUTE, TWO RESPONDENTS ON THE WEST ALLIS ROUTE, ONE RESPONDENT ON THE CAPITOL DRIVE ROUTE, AND FIVE RESPONDENTS ON THE HALES CORNERS ROUTE WHO DID NOT INDICATE AUTO DRIVING STATUS.

SOURCE- SEWRPC.

The very significant differences in auto availability and in auto driver status between freeway flyer riders and regular bus riders as reported in the various surveys indicate that freeway flyer service has attracted a new kind of mass transit rider in substantial numbers, a rider who has one or more automobiles available for use, is licensed to drive, but who nevertheless has chosen to commute by mass transit.

Trip Purpose

The freeway flyer service has been directed from the beginning primarily toward providing fast and convenient service to and from downtown Milwaukee only during peak commuting hours. Therefore, it is not surprising that the large majority of trips made via the service, ranging by route from about 83 to 91 per-

Table 5

NUMBER OF AUTOMOBILES OWNED PER HOUSEHOLD BY FREEWAY FLYER PASSENGERS BY ROUTE: 1966 AND 1969

FREEWAY FLYER ROUTE	SURVEY YEAR	NUMBER OF AUTOMOBILES OWNED PER HOUSEHOLD[a]: NONE NUMBER	NONE PERCENT OF TOTAL	ONE NUMBER	ONE PERCENT OF TOTAL	TWO NUMBER	TWO PERCENT OF TOTAL	THREE OR MORE NUMBER	THREE OR MORE PERCENT OF TOTAL	TOTAL[b]
MAYFAIR..........	1966	24	4.4	268	48.6	221	40.1	38	6.9	551
BAY SHORE........	1966	14	3.8	206	55.5	124	33.4	27	7.3	371
TREASURE ISLAND-WEST ALLIS.....	1969	6	3.0	91	45.5	87	43.5	16	8.0	200
TREASURE ISLAND-CAPITOL DRIVE..	1969	2	2.3	32	36.8	43	49.4	10	11.5	87
COUNTRY FAIR-HALES CORNERS..	1969	2	2.4	35	42.2	35	42.2	11	13.2	83

[a]DATA CONCERNING THE NUMBER OF AUTOMOBILES OWNED PER HOUSEHOLD WERE NOT OBTAINED ON THE MAYFAIR ROUTE IN THE 1964 SURVEY. DATA WHICH WERE OBTAINED IN THAT SURVEY INDICATED THAT 180 PATRONS, OR 91 PERCENT, WERE MEMBERS OF HOUSEHOLDS OWNING AT LEAST ONE AUTOMOBILE.

[b]THE TOTAL DOES NOT INCLUDE SIX RESPONDENTS ON THE MAYFAIR (1966) ROUTE, 14 RESPONDENTS ON THE BAY SHORE ROUTE, THREE RESPONDENTS ON THE WEST ALLIS ROUTE, FIVE RESPONDENTS ON THE CAPITOL DRIVE ROUTE, AND SIX RESPONDENTS ON THE HALES CORNERS ROUTE WHO DID NOT INDICATE THE NUMBER OF AUTOMOBILES OWNED.

SOURCE- SEWRPC.

cent, directly connected home and work. Trips made for all other purposes on any route were found to be numerically inconsequential, except for a fairly significant number of trips made from home to school on the Mayfair and Bay Shore routes. Even these school trips were made for the most part in one direction only, because, as many of the respondents noted on their forms, the reciprocal trip from school to home occurred before freeway flyer afternoon service began (see Table 6).

FREEWAY FLYER UNLOADING AT MILWAUKEE CBD STOP

Areas of Attraction

Maps 2 through 7 show the density of freeway flyer passenger trips at the non-CBD end of the trips for each of the routes, that is, the point of origin of inbound trips to and the points of destination of outbound trips from downtown Milwaukee. Since these origins and destinations represent for the most part trips beginning or ending at home, ranging by route from 94 to 98 percent, the trip densities shown on these maps represent almost entirely the residences of freeway flyer patrons, as well as the area of patron trip generation for each of the several routes. The area shown within the heavy outline on each map represents the principal area of attraction for that route, the principal area of attraction being defined here as contiguous U. S. Public Land Survey sections in which more than 10 trip origins and destinations were found.

Table 6

NUMBER OF FREEWAY FLYER TRIPS BY TRIP ORIGIN AND DESTINATION BY ROUTE: 1964, 1966, AND 1969

			FREEWAY FLYER TRIP DESTINATION									
			HOME		WORK		SCHOOL		OTHER		TOTAL	
FREEWAY FLYER ROUTE	SURVEY YEAR	FREEWAY FLYER TRIP ORIGIN	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF ROUTE TRIPS
MAYFAIR	1964	HOME	0	0.0	132	46.3	3	1.0	6	2.1	141	49.4
		WORK	117	41.1	1	0.4	0	0.0	12	4.2	130	45.7
		SCHOOL	3	1.0	2	0.7	0	0.0	0	0.0	5	1.7
		OTHER	6	2.1	1	0.4	0	0.0	2	0.7	9	3.2
TOTAL		--	126	44.2	136	47.8	3	1.0	20	7.0	285	100.0
MAYFAIR	1966	HOME	0	0.0	345	43.3	39	4.9	9	1.1	393	49.3
		WORK	353	44.4	17	2.1	3	0.4	10	1.3	383	48.2
		SCHOOL	13	1.6	2	0.3	0	0.0	0	0.0	15	1.9
		OTHER	3	0.4	1	0.1	1	0.1	0	0.0	5	0.6
TOTAL		--	369	46.4	365	45.8	43	5.4	19	2.4	796	100.0
BAY SHORE	1966	HOME	0	0.0	224	42.6	50	9.5	2	0.4	276	52.5
		WORK	212	40.3	8	1.5	2	0.2	8	1.5	230	43.5
		SCHOOL	5	1.0	5	1.0	0	0.0	1	0.2	11	2.2
		OTHER	1	0.2	0	0.0	1	0.2	7	1.4	9	1.8
TOTAL		--	218	41.5	237	45.1	53	9.9	18	3.5	526	100.0
TREASURE ISLAND-WEST ALLIS	1969	HOME	0	0.0	145	46.2	15	4.8	2	0.6	162	51.6
		WORK	139	44.3	3	1.0	0	0.0	2	0.6	144	45.9
		SCHOOL	4	1.3	0	0.0	1	0.3	1	0.3	6	1.9
		OTHER	2	0.6	0	0.0	0	0.0	0	0.0	2	0.6
TOTAL		--	145	46.2	148	47.2	16	5.1	5	1.5	314	100.0
TREASURE ISLAND-CAPITOL DRIVE	1969	HOME	0	0.0	64	45.4	5	3.5	2	1.4	71	50.4
		WORK	64	45.4	0	0.0	0	0.0	2	1.4	66	46.8
		SCHOOL	2	1.4	0	0.0	0	0.0	1	0.7	3	2.1
		OTHER	1	0.7	0	0.0	0	0.0	0	0.0	1	0.7
TOTAL		--	67	47.5	64	45.4	5	3.5	5	3.5	141	100.0
COUNTRY FAIR-HALES CORNERS	1969	HOME	0	0.0	72	51.8	8	5.8	0	0.0	80	57.6
		WORK	51	36.8	2	1.4	0	0.0	2	1.4	55	39.5
		SCHOOL	3	2.2	0	0.0	0	0.0	0	0.0	3	2.2
		OTHER	0	0.0	0	0.0	0	0.0	1	0.7	1	0.7
TOTAL		--	54	38.8	74	53.2	8	5.8	3	2.2	139	100.0

THE TOTAL DOES NOT INCLUDE TWO TRIPS ON THE MAYFAIR (1964) ROUTE, 16 TRIPS ON THE MAYFAIR (1966) ROUTE, AND 42 TRIPS ON THE BAY SHORE ROUTE FOR WHICH RESPONDENTS DID NOT INDICATE ONE OR BOTH TRIP PURPOSES.

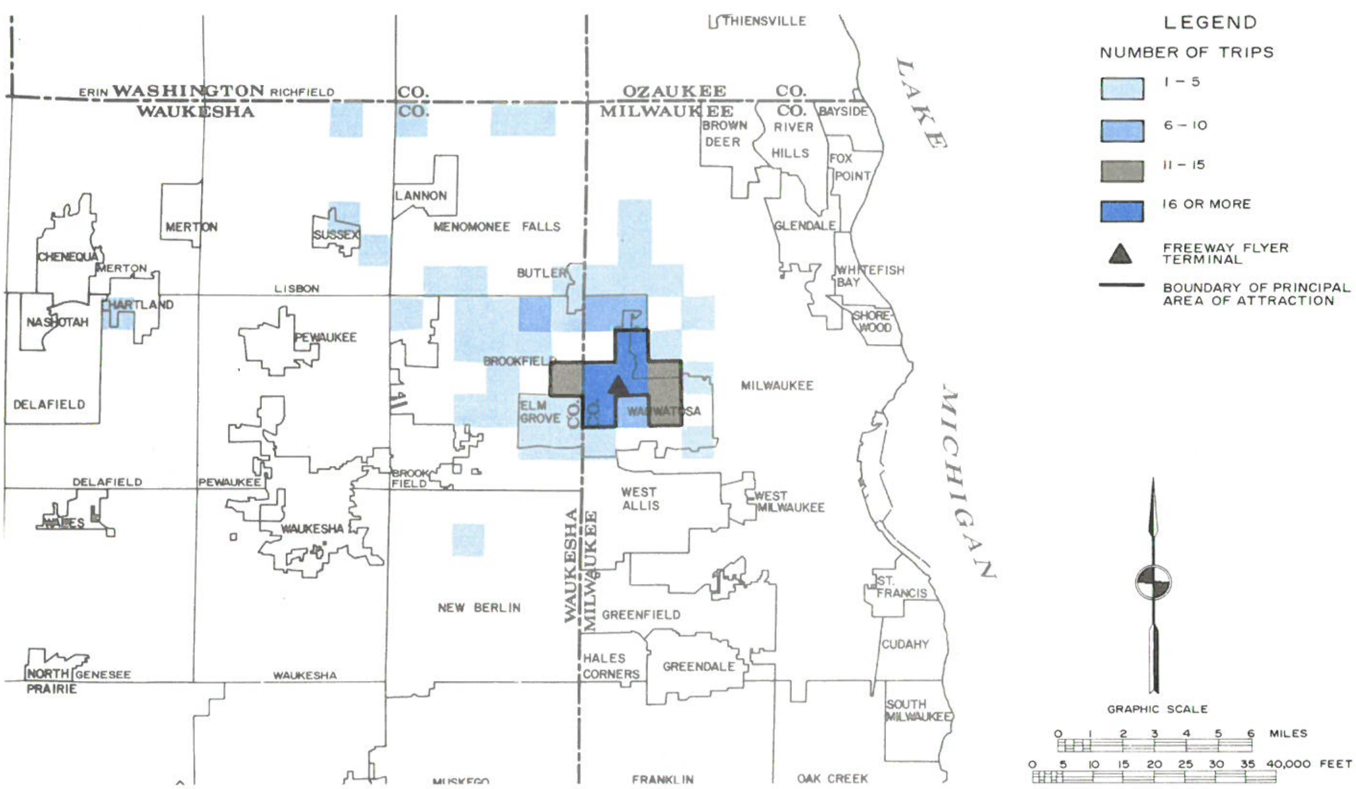
SOURCE- SEWRPC.

The principal area of trip attraction on the Mayfair route, as reported in the April 1964 survey conducted approximately two weeks after inauguration of service on the route, was found to be in close proximity to the Mayfair Shopping Center terminal in the City of Wauwatosa, just to the northeast in the City of Milwaukee, and just to the west in the City of Brookfield. This area, consisting of seven U. S. Public Land Survey sections, or seven square miles, generated 182 trips, or about 63 percent of total trips made on the route. Smaller clusters of patrons were found elsewhere in the City of Brookfield and in the Village of Elm Grove, in other areas in Waukesha County, and in the Town of Granville in Milwaukee County (see Map 2). The average daily ridership on the Mayfair route during the first month of operation was approximately 290 passengers.

By November 1966, when the second survey was conducted on the Mayfair route, average daily ridership had increased more than threefold to an average of approximately 930 daily passengers. The principal area of attraction had also expanded from seven sections in 1964 to 17 sections in 1966, while trips generated within the principal area increased from 182 in 1964 to 538 in 1966, totaling about 60 percent of

Map 2

INBOUND TRIP ORIGINS AND OUTBOUND TRIP DESTINATIONS GENERATED BY THE MAYFAIR FREEWAY FLYER ROUTE ON AN AVERAGE WEEKDAY: APRIL 1964



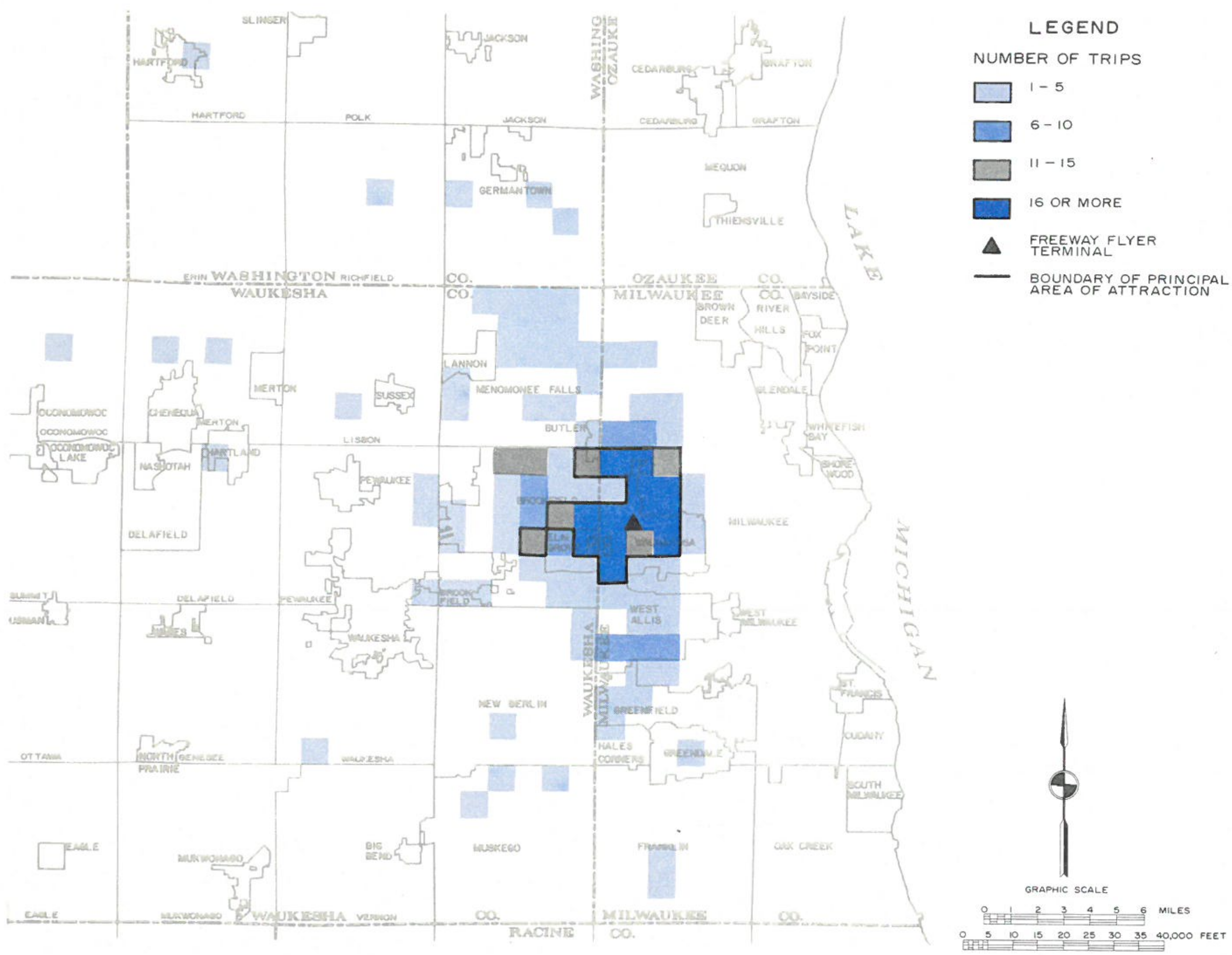
Source: SEWRPC.

total daily trips. Outside of the principal area, smaller clusters of trips were found in the City of West Allis to the south, in the Village of Menomonee Falls to the northwest, and in the City and Town of Brookfield to the west. Scattered trips were found elsewhere in Milwaukee and Waukesha Counties and in lower Washington County (see Map 3).

Since the 1966 survey, the area of attraction of the Mayfair route has been curtailed and a number of passengers have been lost, first by the establishment of the West Allis route in November 1967 and later by the establishment of the Capitol Drive route in April 1968. Ridership on the Mayfair route, after reaching a peak of approximately 1,000 passengers per day early in 1967, stood at approximately 800 daily passengers by January 1972.

Map 3

INBOUND TRIP ORIGINS AND OUTBOUND TRIP DESTINATIONS GENERATED BY THE MAYFAIR FREEWAY FLYER ROUTE ON AN AVERAGE WEEKDAY: NOVEMBER 1966

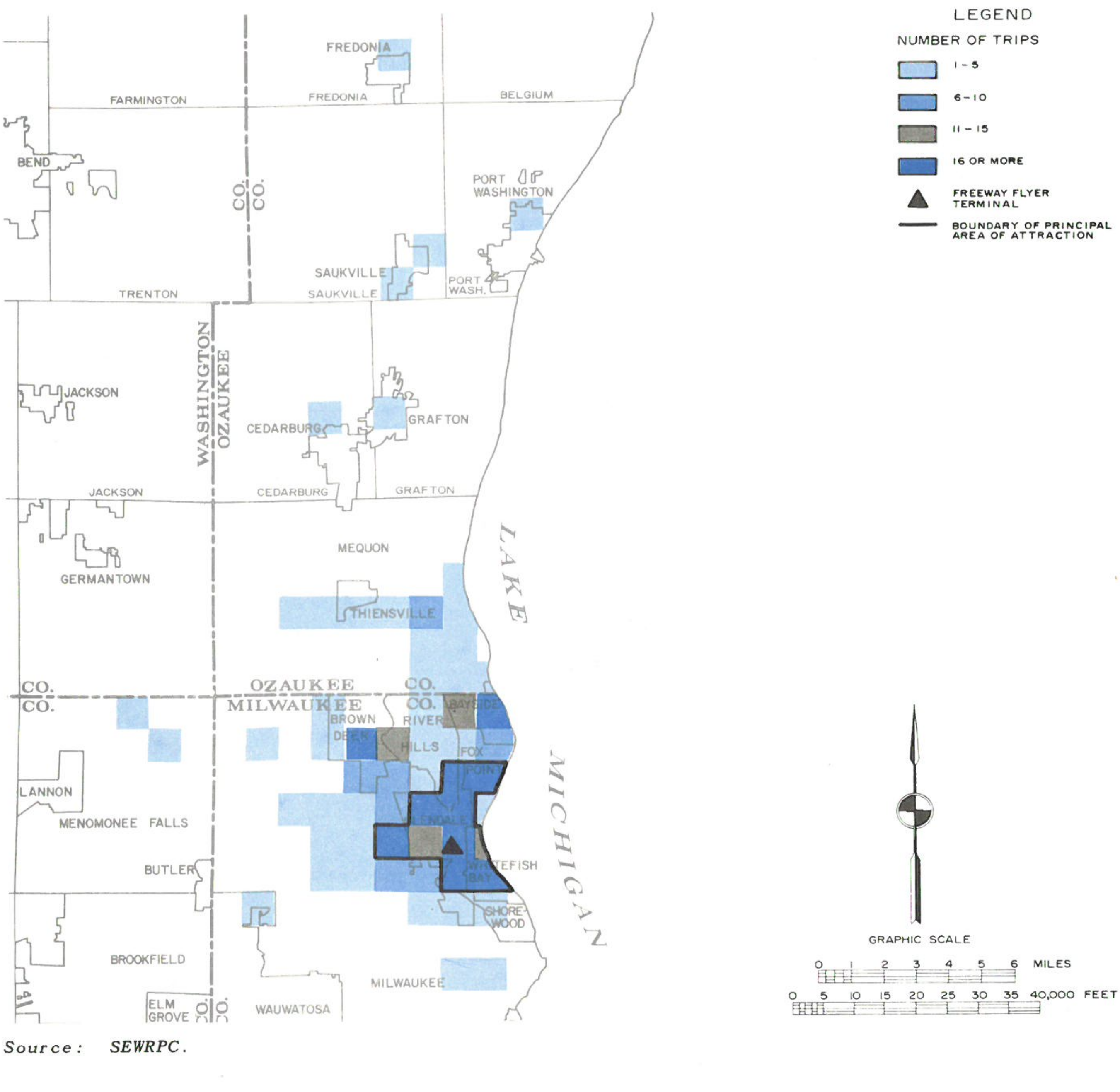


Source: SEWRPC.

The principal area of attraction on the Bay Shore route, also surveyed in November 1966, consisted of 10 sections located mainly in the City of Glendale and in the Villages of Fox Point and Whitefish Bay. Within this area 341 trips were generated, representing about 60 percent of the total trips made on the route. Substantial numbers of trips were also generated in the Villages of Bayside and Brown Deer to the north, while scattered trips were found mainly in the City of Milwaukee to the west and south, in the City of Mequon to the north, and in points farther north within Ozaukee County (see Map 4). Beginning in late

Map 4

INBOUND TRIP ORIGINS AND OUTBOUND TRIP DESTINATIONS GENERATED BY THE BAY SHORE FREEWAY FLYER ROUTE ON AN AVERAGE WEEKDAY: NOVEMBER 1966



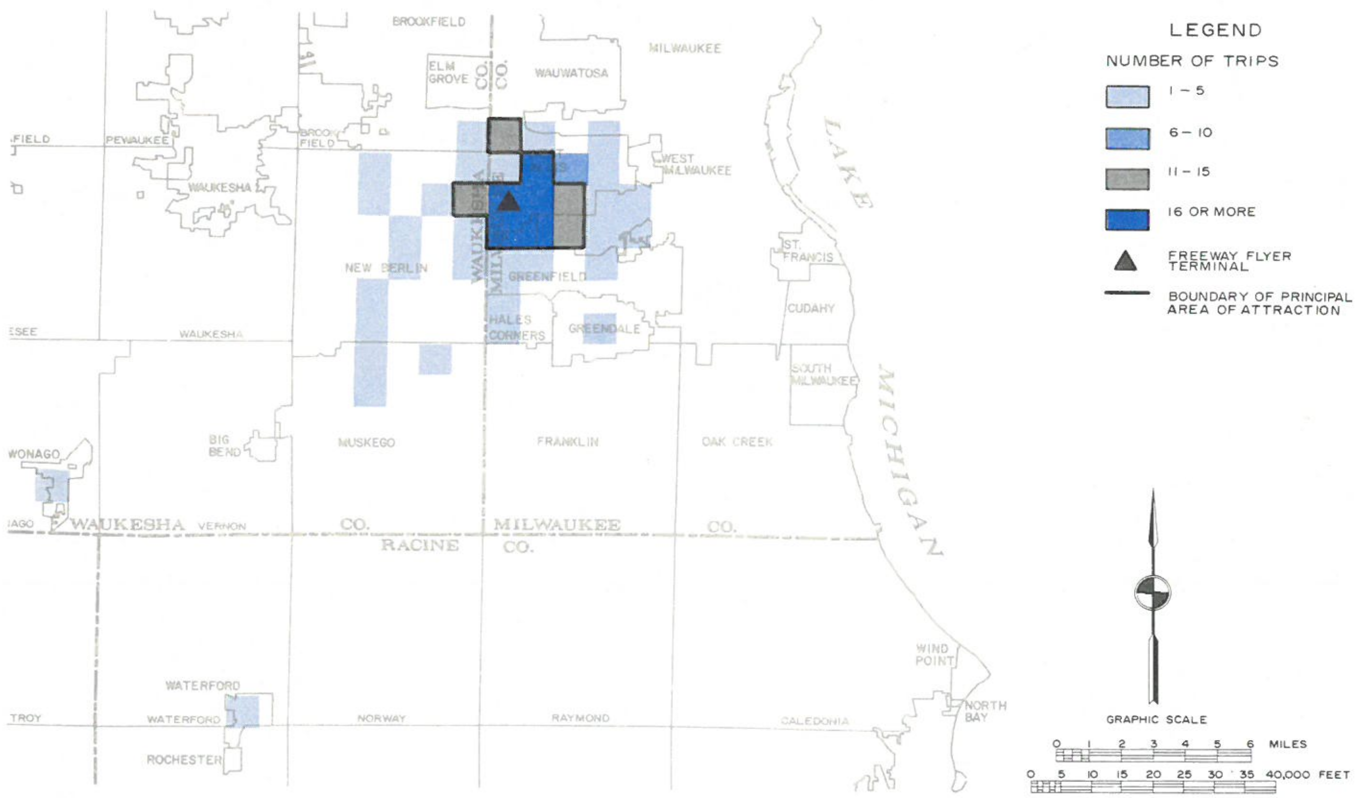
Source: SEWRPC.

1965 with a daily average of approximately 300 passengers, ridership at Bay Shore approached an average of approximately 700 daily passengers in July 1969, and decreased to an average of approximately 600 daily passengers by January 1972.

The principal area of attraction of the West Allis route as observed in the May 1969 survey findings consisted of nine sections located mostly within the City of West Allis but partly within the Cities of Greenfield, Milwaukee, and New Berlin. Patron trips generated by the principal area totaled 228, or approximately 73 percent of the 314 daily trips made on the route. Outside of the principal area, small numbers of trips were found to be generated in other parts of the City of New Berlin in Waukesha County, in the Village of Hales Corners in Milwaukee County, and as far away as the Village of Mukwonago in Waukesha County and the Village of Waterford in Racine County (see Map 5). During November 1967, the first month of operation, average daily ridership totaled approximately 200 passengers, and by the end of 1971 it reached its highest point with an average of approximately 500 daily passengers.

Map 5

INBOUND TRIP ORIGINS AND OUTBOUND TRIP DESTINATIONS GENERATED BY THE TREASURE ISLAND-WEST ALLIS FREEWAY FLYER ROUTE ON AN AVERAGE WEEKDAY: MAY 1969

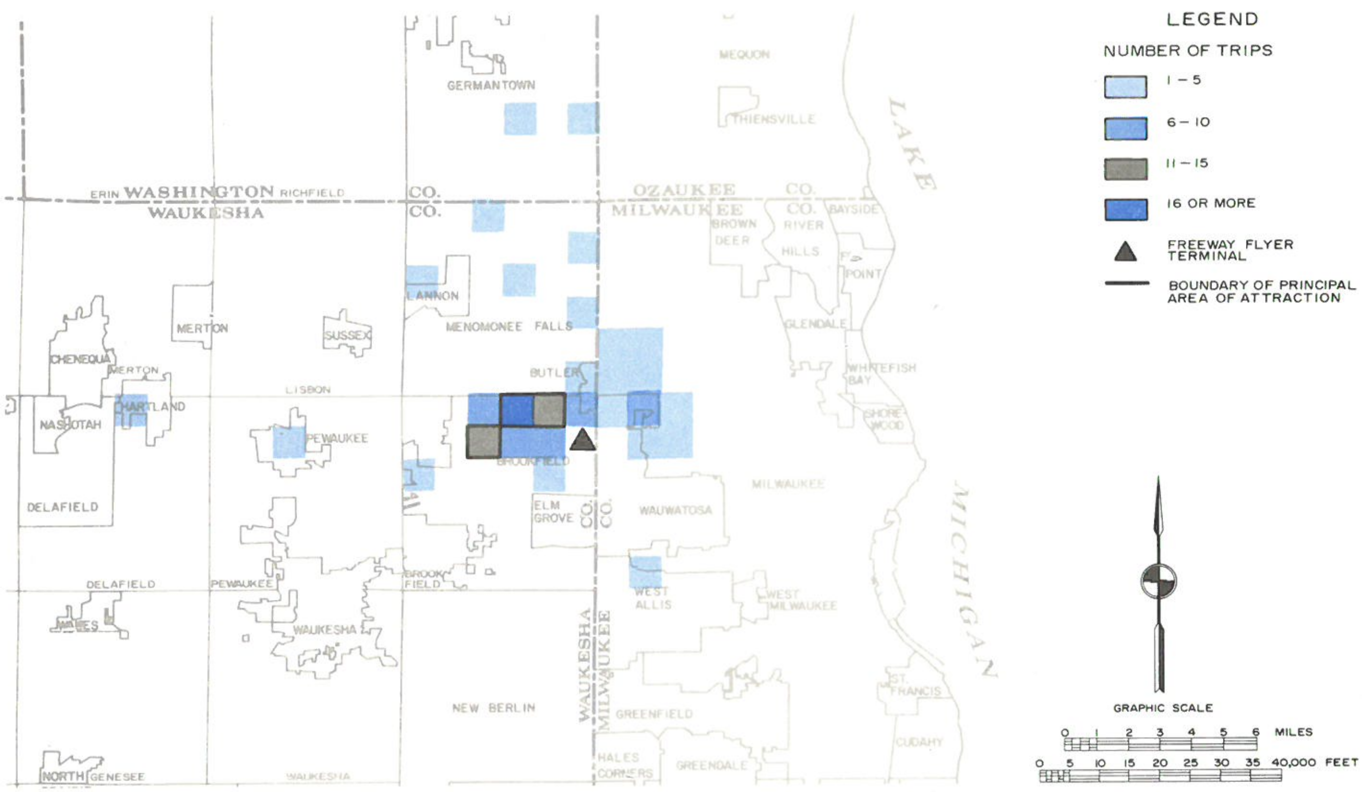


Source: *SEWRPC.*

The principal area of attraction on the Capitol Drive route as derived from the May 1969 survey data consisted of only three sections, located to the west of the shopping center terminal on Capitol Drive in the northern portion of the City of Brookfield. These three sections accounted for 41 patrons trips, or only 29 percent of total daily trips made on the route. Fairly substantial numbers of trips were found in other nearby sections, and smaller clusters were found in the Villages of Butler, Menomonee Falls, Lannon, and Germantown. Small clusters were also found in the Cities of Milwaukee and Wauwatosa to the east and in the Villages of Hartland and Pewaukee to the west (see Map 6). Ridership on the Capitol Drive route, serving almost entirely a low-density residential area, has experienced a very gradual growth from an average of approximately 150 daily passengers at its beginning in April 1968 to an average of approximately 200 daily passengers by January 1971.

Map 6

INBOUND TRIP ORIGINS AND OUTBOUND TRIP DESTINATIONS GENERATED BY THE TREASURE ISLAND-CAPITOL DRIVE FREEWAY FLYER ROUTE ON AN AVERAGE WEEKDAY: MAY 1969



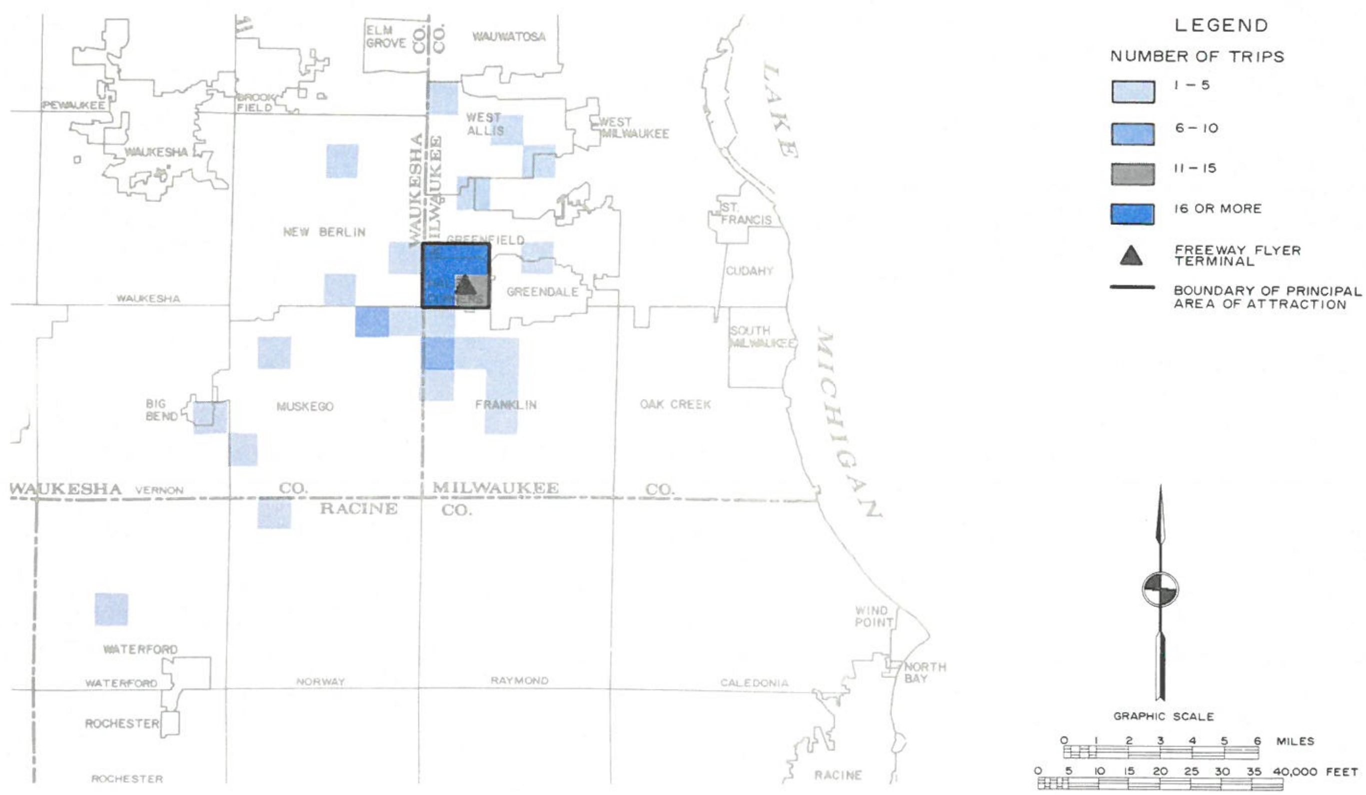
Source: *SEWRPC.*

On the Hales Corners route, also surveyed in May 1969, the principal area of attraction consisted of four sections which generated 83 patron trips or approximately 60 percent of total daily trips made on the route. This area was found to lie mostly within the Village of Hales Corners and partly within the City of Greenfield. Outside of the principal area, scattered trips were found to be generated mainly in the Cities of Franklin, New Berlin, and Muskego, in the Village of Big Bend, and in the Towns of Waterford and Norway (see Map 7). In the first months of operation in the spring of 1969, daily ridership on the Hales Corners route totaled about 140 passengers per weekday, and increased to its highest ridership of approximately 300 passengers per weekday by January 1972.

Surveys have not as yet been conducted on either the Spring Mall or Target Stores Incorporated routes, and the areas of attraction of these routes have therefore not been identified. It can be reported, however, that ridership on the Spring Mall route during its first full month of operation in August 1970 totaled about 160 daily revenue passengers, and reached its highest level of approximately 380 daily passengers in March 1972. Ridership on the Target Stores route during its first full month of operation in June 1971 totaled about 100 daily revenue passengers, and reached its highest level of about 225 daily passengers in September 1972.

Map 7

INBOUND TRIP ORIGINS AND OUTBOUND TRIP DESTINATIONS GENERATED BY THE COUNTRY FAIR-HALES CORNERS FREEWAY FLYER ROUTE ON AN AVERAGE WEEKDAY: MAY 1969



Source: SEWRPC.

It should be reported here that after nearly seven years of operation, during which more than one million passengers were carried, the Bay Shore freeway flyer route was terminated on August 11, 1972 when the Bay Shore Shopping Center management preempted parking space provided theretofore to the Transport Corporation. No adequate available alternative location in the same corridor could subsequently be found at this time.[1]

On August 14, 1972 a new freeway flyer route, the Northland-Teutonia route located approximately eight miles north of downtown Milwaukee at the Northland Shopping Center, began operation. The outlying terminal of the new route, located about two miles west of the vacated Bay Shore terminal, serves a portion of the Capitol Drive route and a portion of the patrons previously served by the Bay Shore route. During its first full month of operation in September 1972, the new route carried an average of approximately 400 daily revenue passengers.

Table 7 shows that with the exception of the Capitol Drive route, the majority of inbound trip origins and outbound trip destinations on the various surveyed routes, ranging by route from about 69 percent to 88 percent, were attracted from within a distance of three airline miles of the outlying terminals of the respective routes. On the Capitol Drive route only about 46 percent of such trip origins and destinations were attracted from within three airline miles, and only about 65 percent from within four airline miles from the outlying terminal, compared to about 83 percent to 92 percent on the other routes from within four airline miles. Most of the differences shown here can be attributed to the fact that the outlying terminal of the Capitol Drive route is located at some distance from any significant amount of residential development, and that the residential areas from which it attracts patrons for the most part are low-density in character.

Table 8 summarizes, for each route surveyed: 1) the number of U. S. Public Land Survey sections in which freeway flyer trip origins and destinations were found; 2) the number of trips generated in the route on the survey date; 3) the number of U. S. Public Land Survey sections contained in the principal area; 4) the number of trips generated in the principal area; 5) the percent of principal area trips generated to total trips; 6) the estimated population of the principal area; and 7) the estimated population density of the principal area per square mile.

Table 8 shows that the Mayfair route in 1966 led all other routes in the number of Public Land Survey sections contributing trips, in the number of sections in the principal area, and in the estimated population, and as could therefore be expected, in the number of trips generated both in the entire route and in the principal area of attraction. The fact that the average number of trips generated per Public Land Survey section in the Mayfair (1966), Bay Shore, and West Allis routes was approximately seven to eight, compared to an average of four to five trips per Public Land Survey section in the Capitol Drive and Hales Corners routes, very probably relates to the difference in population densities between the two groups, as shown in Table 8.

Modes of Inbound Travel to the Shopping Center Terminal

Freeway flyer patrons used four principal modes of travel to reach shopping center terminals enroute to downtown Milwaukee. By route, the percentage of patrons driving an automobile to the terminals ranged from about 37 percent at the Hales Corners terminal to about 59 percent at the Capitol Drive terminal; the percentage of patrons riding as automobile passengers ranged from about 29 percent at the Bay Shore terminal to about 46 percent at the Mayfair terminal (1964); the percentage of patrons walking to the terminals ranged from 0 percent at the Capitol Drive terminal, which is not within convenient walking distance to any sizable amount of residential development, to about 28 percent at the Hales Corners terminal, which is within convenient walking distance to a considerable amount of residential development; and the percentage of patrons riding a bus to the terminal and transferring to a freeway flyer ranged from a little more than 1 percent at the Hales Corners terminal to about 7 percent at the Bay Shore terminal (see Table 9).

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[1] *Subsequent to the writing of this article, the Bay Shore Freeway Flyer was reestablished in January 1973 as the North Shore Freeway Flyer. The terminal for this flyer is being provided by the Wisconsin Department of Transportation and Milwaukee County and is located at the interchange of W. Silver Spring Drive and the North-South Freeway, adjacent to the Bay Shore Shopping Center.*

Table 7

AIRLINE DISTANCE OF INBOUND ORIGINS AND OUTBOUND DESTINATIONS OF FREEWAY FLYER TRIPS FROM THE SHOPPING CENTER TERMINAL BY ROUTE: 1964, 1966, AND 1969

FREEWAY FLYER ROUTE	SURVEY YEAR	NUMBER OF MILES							
		0-1.0		1.1-2.0		2.1-3.0		3.1-4.0	
		NUMBER OF TRIPS	PERCENT OF TOTAL	NUMBER OF TRIPS	PERCENT OF TOTAL	NUMBER OF TRIPS	PERCENT OF TOTAL	NUMBER OF TRIPS	PERCENT OF TOTAL
MAYFAIR...........	1964	103	37.1	84	30.2	46	16.5	23	8.3
MAYFAIR...........	1966	124	15.8	266	34.0	192	24.4	77	9.9
BAY SHORE.........	1966	133	26.2	169	33.4	47	9.2	71	14.0
TREASURE ISLAND- WEST ALLIS......	1969	113	36.3	128	41.2	31	10.0	11	3.5
TREASURE ISLAND- CAPITOL DRIVE..	1969	15	10.9	21	15.2	28	20.3	26	18.8
COUNTRY FAIR- HALES CORNERS..	1969	50	41.9	37	22.1	18	13.2	14	10.3

FREEWAY FLYER ROUTE	SURVEY YEAR	NUMBER OF MILES						TOTAL TRIPS
		4.1-5.0		5.1-6.0		MORE THAN 6.0		
		NUMBER OF TRIPS	PERCENT OF TOTAL	NUMBER OF TRIPS	PERCENT OF TOTAL	NUMBER OF TRIPS	PERCENT OF TOTAL	
MAYFAIR...........	1964	6	2.2	2	0.7	14	5.0	278
MAYFAIR...........	1966	51	6.5	9	1.1	65	8.3	784
BAY SHORE.........	1966	20	4.0	46	3.1	51	10.1	537
TREASURE ISLAND- WEST ALLIS......	1969	7	2.2	3	1.0	18	5.8	311
TREASURE ISLAND- CAPITOL DRIVE..	1969	24	17.4	2	1.5	22	15.9	138
COUNTRY FAIR- HALES CORNERS..	1969	6	4.4	2	1.5	9	6.6	136

THE TOTAL DOES NOT INCLUDE NINE TRIPS ON THE MAYFAIR (1964) ROUTE, 28 TRIPS ON THE MAYFAIR (1966) ROUTE, 61 TRIPS ON THE BAY SHORE ROUTE, THREE TRIPS ON THE WEST ALLIS ROUTE, THREE TRIPS ON THE CAPITOL DRIVE ROUTE, AND THREE TRIPS ON THE HALES CORNERS ROUTE FOR WHICH RESPONDENTS DID NOT PROVIDE LOCATIONS OF THE TRIP ORIGINS AND DESTINATIONS.

SOURCE- SEWRPC.

Table 8

SUMMARY OF FREEWAY FLYER TRIP AND POPULATION DATA BY ROUTE: 1964, 1966, AND 1969

FREEWAY FLYER ROUTE	SURVEY YEAR	NUMBER OF U.S. PUBLIC LAND SURVEY SECTIONS CONTRIBUTING TRIPS	NUMBER OF TRIPS GENERATED IN ROUTE ON SURVEY DAY	NUMBER OF U.S. PUBLIC LAND SURVEY SECTIONS IN PRINCIPAL AREA	TRIPS GENERATED IN PRINCIPAL AREA		ESTIMATED POPULATION OF PRINCIPAL AREA	ESTIMATED POPULATION DENSITY OF PRINCIPAL AREA PER SQUARE MILE
					NUMBER	PERCENT OF TOTAL TRIPS ON SURVEY DAY		
MAYFAIR..........	1964	50	287	7	182	63	34,400	4,914
MAYFAIR..........	1966	109	812	17	538	66	73,800	4,341
BAY SHORE........	1966	69	568	10	341	60	34,400	3,440
TREASURE ISLAND- WEST ALLIS....	1969	43	314	9	228	73	37,600	4,178
TREASURE ISLAND- CAPITOL DRIVE.	1969	32	141	3	41	29	4,900	1,633
COUNTRY FAIR- HALES CORNERS.	1969	27	139	4	83	60	8,400	2,100

SOURCE- SEWRPC.

Table 9

MODES OF INBOUND TRAVEL OF FREEWAY FLYER PASSENGERS TO SHOPPING CENTER TERMINAL BY ROUTE: 1964, 1966, AND 1969

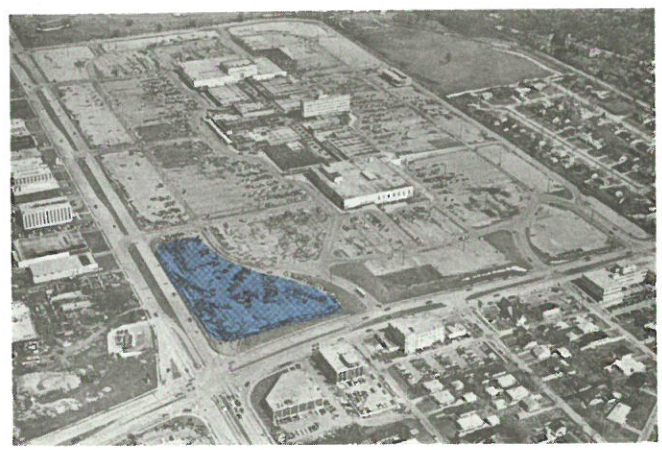
FREEWAY FLYER ROUTE	SURVEY YEAR	MODE OF INBOUND TRAVEL								TOTAL
		AUTO DRIVER		AUTO PASSENGER		BUS RIDER		WALKED		
		NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	
MAYFAIR..........	1964	54	39.7	62	45.6	7	5.1	13	9.6	136
MAYFAIR..........	1966	180	44.4	139	34.3	20	4.9	66	16.4	405
BAY SHORE.......	1966	149	49.0	88	28.9	21	6.9	46	15.2	304
TREASURE ISLAND-WEST ALLIS....	1969	69	43.4	59	37.1	5	3.1	26	16.4	159
TREASURE ISLAND-CAPITOL DRIVE.	1969	41	59.4	25	36.2	3	4.4	0	0.0	69
COUNTRY FAIR-HALES CORNERS.	1969	29	36.7	27	34.2	1	1.3	22	27.8	79

SOURCE- SEWRPC.

Automobile Parking at Shopping Center Terminals

A total of 522 automobiles were driven to shopping center terminals by patrons of the combined freeway flyer routes surveyed. Of these, 446 automobiles, or approximately 85 percent, were parked at the terminals so that they would be available for patrons upon their return trips, ranging by route from about 79 percent at the West Allis terminal to 100 percent at the Mayfair (1964) terminal. The remaining 76 automobiles, or approximately 15 percent, were driven from the terminal soon after arrival, either by those who had driven freeway flyer passengers to the terminal or by passengers in the automobiles after the drivers transferred to a freeway flyer, as shown in Table 10. It is interesting that only at the Bay Shore terminal did the number of automobiles parked approach the number of parking spaces provided by the shopping center management, a condition which apparently led to the preemption in 1972 of such parking space by the Bay Shore Shopping Center management, as previously noted.

MAYFAIR FREEWAY FLYER PARKING AREA



Round Trips and One-Way Trips

The initial freeway flyer survey produced one unexpected finding which was later corroborated in the findings on other freeway flyer routes surveyed. Contrary to what had been expected by transportation technicians involved in the survey, namely, that nearly all freeway flyer patrons made round trips on the service on a given weekday, it was found that in fact about half of the patrons made round trips and approximately one-fourth each made trips in one direction only. Thus it was found that of a total of 2,260 trips recorded on the combined routes, 1,523 different persons were involved in making trips, instead of a lower number which would have occurred if the total trips had consisted mostly of round trips.

Table 11 shows that of total patrons, 737, or about 48 percent, made round trips; 441, or about 29 percent, made inbound trips only; and 345, or about 23 percent, made outbound trips only. By route, patrons making round trips ranged from about 45 percent on the Mayfair (1964) route to about 56 percent on the Hales Corners route; those making inbound trips only ranged from about 24 percent on the Mayfair (1964) route to about 35 percent on the Bay Shore route; and those making outbound trips only ranged from about 10 percent on the Hales Corners to about 30 percent on the Mayfair (1964) route.

Table 10

UTILIZATION OF PARKING SPACE AT SHOPPING CENTER TERMINAL BY FREEWAY FLYER PASSENGERS BY ROUTE: 1964, 1966, AND 1969

FREEWAY FLYER ROUTE	SURVEY YEAR	NUMBER OF PARKING SPACES PROVIDED	AUTOMOBILES DRIVEN TO TERMINAL				
			PARKED		NOT PARKED		
			NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	TOTAL
MAYFAIR.............	1964	300	54	100.0	0	0.0	54
MAYFAIR.............	1966	300	157	87.2	23	12.8	180
BAY SHORE...........	1966	150	119	79.9	30	20.1	149
TREASURE ISLAND- WEST ALLIS........	1969	100	54	79.4	15	20.6	69
TREASURE ISLAND- CAPITOL DRIVE.....	1969	100	39	95.1	2	4.9	41
COUNTRY FAIR- HALES CORNERS.....	1969	50	23	82.1	6	17.9	29
TOTAL	--	1,000	446	85.4	76	14.6	522

SOURCE- SEWRPC.

Table 11

FREEWAY FLYER PASSENGERS MAKING ROUND TRIPS AND ONE-WAY TRIPS BY ROUTE: 1964, 1966, AND 1969

FREEWAY FLYER ROUTE	SURVEY YEAR	NUMBER OF PASSENGERS MAKING TRIPS						
		ROUND TRIPS		INBOUND TRIPS ONLY		OUTBOUND TRIPS ONLY		
		NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	TOTAL
MAYFAIR.........	1964	89	45.2	48	24.4	60	30.4	197
MAYFAIR.........	1966	255	45.8	154	27.6	148	26.6	557
BAY SHORE.......	1966	183	47.5	136	35.3	66	17.2	385
TREASURE ISLAND- WEST ALLIS....	1969	112	55.2	50	24.6	41	20.2	203
TREASURE ISLAND- CAPITOL DRIVE.	1969	48	52.2	23	25.0	21	22.8	92
COUNTRY FAIR- HALES CORNERS.	1969	50	56.2	30	33.7	9	10.1	89
TOTAL	--	737	48.4	441	29.0	345	22.6	1,523

SOURCE- SEWRPC.

The two principal reasons given by survey respondents for not making round trips were that freeway flyer schedules did not coincide with desired travel times in a given direction, and that automobile rides were often obtained in one direction with family members, friends, or fellow workers. The fact that a sizable number of patrons found freeway flyer schedules inconvenient in one direction or the other might well argue for consideration of expanding the periods of service during certain portions of the day. Such expansion could, moreover, attract new riders who now find the existing schedules inconvenient in both directions.

Influence of Freeway Flyer Terminals on Shopping at Shopping Centers

Freeway flyer patrons on each route were asked whether the location of the freeway flyer terminal at the shopping center changed their personal shopping habits at that center. Of the nearly 1,200 respondents

Table 12

IMPACT OF TRANSIT TERMINAL LOCATION ON SHOPPING HABITS OF FREEWAY FLYER PASSENGERS BY ROUTE: 1966 AND 1969

FREEWAY FLYER ROUTE	SURVEY YEAR	PASSENGER SHOPPING HABITS[a]						TOTAL PASSENGERS
		SHOPPING INCREASED CONSIDERABLY		SHOPPING DECREASED SLIGHTLY		SHOPPING DID NOT CHANGE		
		NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	
MAYFAIR.........	1966	104	19.4	139	25.9	293	54.7	536
BAY SHORE.......	1966	59	16.4	113	31.4	188	52.2	360
TREASURE ISLAND-WEST ALLIS....	1969	20	12.8	36	23.1	100	64.1	156
TREASURE ISLAND-CAPITOL DRIVE.	1969	6	8.7	20	29.0	43	62.3	69
COUNTRY FAIR-HALES CORNERS.	1969	2	2.9	11	15.7	57	81.4	70
TOTAL	--	191	16.0	319	26.8	681	57.2	1,191[b]

[a]THIS QUESTION WAS NOT ASKED ON THE MAYFAIR ROUTE IN 1964.

[b]THE TOTAL DOES NOT INCLUDE 21 RESPONDENTS ON THE MAYFAIR ROUTE, 25 RESPONDENTS ON THE BAY SHORE ROUTE, 47 RESPONDENTS ON THE WEST ALLIS ROUTE, 23 RESPONDENTS ON THE CAPITOL DRIVE ROUTE, AND 19 RESPONDENTS ON THE HALES CORNERS ROUTE WHO DID NOT ANSWER THE QUESTION.

SOURCE- SEWRPC.

on the combined routes, approximately 43 percent indicated their shopping had increased—16 percent indicating a considerable increase and 27 percent indicating a slight increase—while 57 percent said that there had been no significant change in their shopping habits (see Table 12). By route, those reporting a considerable increase in shopping at the centers ranged from about 3 percent at the Hales Corners Shopping Center to 19 percent at the Mayfair (1966) Shopping Center; those reporting a slight increase in shopping habits ranged from about 16 percent on the Hales Corners route to about 31 percent on the Bay Shore route; and those reporting no change in shopping habits ranged from about 52 percent on the Bay Shore route to about 81 percent on the Hales Corners route. The fact that the Hales Corners route was surveyed shortly after the route was established probably accounts for the small percentage of patrons indicating change in shopping habits at the shopping center.

Comments by Riders on Freeway Flyer Service

In the 1964 and 1966 passenger surveys on the Mayfair and Bay Shore routes, freeway flyer patrons were encouraged to suggest improvements to the service. Of the 1,139 passengers in these surveys, a total of 520, or about 46 percent, made such suggestions. The wording of the invitation for patron response in the 1969 survey of the West Allis, Capitol Drive, and Hales Corners routes was slightly altered to encourage suggestions, comments, or criticisms, and the new wording appeared to elicit a relatively greater response. Of the 384 respondents on the three routes in the 1969 surveys, 232, or about 60 percent, responded.

Of the 1,523 respondents in all six routes surveyed, 407 patrons, or about 27 percent, suggested improvements for the service; 288 patrons, or about 19 percent, made complimentary comments; 57 patrons, or about 4 percent, were critical of some part of the service; and 771 patrons, or about 50 percent, made no suggestion, comment, or criticism (see Table 13). Although suggestions for improving the service were many and varied, the majority dealt with extending afternoon service into the early evening; establishing service on weekends, particularly on Saturdays; extending service beyond the existing outlying ends of routes; and establishing an intermediate stop on given routes.

Those commenting favorably about the service appeared enthusiastic, often using adjectives such as "excellent," "wonderful," and "marvelous" to convey their appreciation of it. Some interesting comments included such remarks as, "I would be unable to work in downtown Milwaukee without the service," "best thing that could happen—beats driving," "good asset of Milwaukee," "I accepted my present job because of this service," and the low-keyed statement, "I am glad to be able to take the flyer." The relatively small percentage of respondents commenting unfavorably about the service consisted mainly of those who thought that fares were too high, local bus connections to freeway flyer buses were unsatisfactory, a seat should be provided for each patron, and certain bus drivers needed additional training for their jobs.

RELATIONSHIP OF FREEWAY FLYER SERVICE TO THE ADOPTED REGIONAL TRANSPORTATION PLAN

The existing freeway flyer service in operation between each of seven outlying regional shopping centers and downtown Milwaukee can be considered a prototype of the rapid transit service proposed for this Region by the Southeastern Wisconsin Regional Planning Commission. It is with considerable satisfaction that the Commission has observed, through annual monitoring, the continued growth in freeway flyer ridership and the expansion of its services. Particularly, the Commission has been encouraged by the ability of the service not only to attract substantial numbers of new transit riders, but to convert a high proportion of these new transit riders from the use of private automobiles.

In considering the numerous and important innovations in the rapid transit system plan proposed for this Region, much higher utilization of this special transit service could be anticipated upon plan implementation. One of its advantages would be the ability of motor coaches to travel quickly and freely over freeway facilities in outlying areas and to move onto an exclusive grade-separated transitway for uninterrupted travel to downtown Milwaukee, avoiding congested portions of freeways and gaining travel time over the private automobile. Other major advantages of the rapid transit proposals include: 1) the provision of attractively designed, new, air-conditioned, turbine powered motor coaches, roomier and smoother in operation, which, when combined with the guarantee of a seat for each rider, would provide substantially increased passenger comfort and convenience; 2) the expansion of the system by 1990 to include 40 or more rapid transit lines each with its own feeder system, thereby broadening rapid transit service throughout the most highly urbanizing parts of the Region; 3) the provision of higher levels of transit service through closer headway spacings each weekday to provide service throughout the day as well as during peak hours and on Saturdays; and 4) the provision of transfer stations at key locations on the system, thus making possible faster and more direct across town travel. Adequate facilities at the transfer sta-

Table 13

PASSENGER COMMENTS ON FREEWAY FLYER SERVICE BY ROUT
1964, 1966, AND 1969

FREEWAY FLYER ROUTE	SURVEY YEAR	PASSENGER COMMENTS								
		SUGGESTED IMPROVEMENTS		FAVORABLE		UNFAVORABLE		NO COMMENT		TOTAL
		NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	NUMBER	PERCENT OF TOTAL	
MAYFAIR.........	1964	52	26.4	19	9.7	6	3.0	120	60.9	197
MAYFAIR.........	1966	184	33.0	69	12.4	21	3.8	283	50.8	557
BAY SHORE.......	1966	104	27.0	53	13.8	12	3.1	216	56.1	385
TREASURE ISLAND– WEST ALLIS....	1969	41	20.2	72	35.5	9	4.4	81	39.9	203
TREASURE ISLAND– CAPITOL DRIVE.	1969	15	16.3	36	39.1	6	6.5	35	38.1	92
COUNTRY FAIR– HALES CORNERS.	1969	11	12.4	39	43.8	3	3.4	36	40.4	89
TOTAL	--	407	26.7	288	18.9	57	3.8	771	50.6	1,523

SOURCE- SEWRPC.

tions for passenger parking and passenger pickup and dropoff would be provided. Implementation of the proposed rapid transit plan would, therefore, achieve a better balance between private and public vehicles in the regional transportation system by reducing freeway loadings in the critical peak periods of the day as well as the demand for parking on highly expensive downtown Milwaukee properties.

SUMMARY AND CONCLUSIONS

Ridership on the freeway flyer service increased from approximately 81,000 revenue passengers on a single route in 1964 to approximately 675,000 revenue passengers on seven routes in 1971, despite the occurrence in the interim of a major strike against the operator, civil disorders in the central city, fare increases, cutbacks in service, a ready-fare requirement plan, and most importantly, the loss of approximately 29 million passengers, or one-third of the riders on the regular bus service of the Transport Corporation.

Two very significant findings of the surveys were: 1) freeway flyer service has attracted a substantial number of new transit riders on each route surveyed, and 2) the service has demonstrated its ability to convert auto-driving commuters to transit-riding commuters in significant numbers on each route.

Comparisons with data obtained in the SEWRPC 1963 regional land use-transportation study show that freeway flyers attracted a different type of rider than those found on regular bus service. Approximately 96 percent of freeway flyer riders were members of auto-owning households, compared to 43 percent of regular bus riders; 47 percent of freeway flyer riders were members of households owning more than one auto, compared to 9 percent of regular bus riders; 84 percent of freeway flyer riders were licensed to drive an automobile, compared to 34 percent of regular bus riders; and 60 percent of freeway flyer riders had an automoble available as an alternative means of making the trip, compared to 14 percent of regular bus riders.

The substantial numbers of patrons who requested that freeway flyer service operate over longer periods of the day, particularly earlier in the afternoon and later in the evening, as well as the considerable numbers who requested operation of service on Saturdays, would appear to warrant experimentation in this respect. The survey finding that more than 40 percent of freeway flyer patrons have increased the amount of their shopping at shopping center terminals since freeway flyer service was established on the routes could well encourage the management of other shopping centers or shopping districts to provide parking space for the service. The rather extraordinary number of patrons making voluntary, enthusiastic comments concerning freeway flyer service would appear to be useful in any promotional advertising for the service.

The pattern of freeway flyer ridership growth and change has varied somewhat by route. In the first year or two of operation, each route except the Capitol Drive route experienced rapid growth. This rapid growth was particularly evident on the Mayfair and Bay Shore routes. Both of these latter routes have shown a general decline in ridership in recent years, however, while ridership on all other routes, although smaller in scale, has continued upward. When the exclusive transitway is put into operation in the east-west corridor of Milwaukee County, ridership on all of the present routes as well as on routes to be established within the influence area of the transitway corridor may be expected to experience rapid growth.

DEVELOPMENT OF EQUATIONS FOR RAINFALL INTENSITY-DURATION-FREQUENCY RELATIONSHIPS

By Stuart G. Walesh, Water Resources Engineer

INTRODUCTION

Rainfall intensity-duration-frequency (I-D-F) relationships are an important element in storm drainage system design. Such relationships facilitate determination of the average rainfall intensity, normally expressed in inches per hour, which is expected to be reached or exceeded for a particular duration, usually expressed in minutes, at a given recurrence interval stated in years. The engineer designing a storm drainage system for an urban area by the rational method selects a design recurrence interval and then utilizes the I-D-F relationships to determine the critical rainfall intensity at successive, selected locations in the storm drainage system. These rainfall intensity values permit computation of hydraulic loadings to be used in sizing system elements such as storm water inlets, storm sewers, and storm water conveyance swales and channels.[1]

Under its comprehensive watershed planning program, the Southeastern Wisconsin Regional Planning Commission developed a set of rainfall I-D-F relationships which, until recently, were available only in graphic form. The Commission recently formulated mathematical equations for these relationships because of the increased use of digital computers in engineering design by governmental units and consulting firms and the corresponding actual and anticipated need for I-D-F equations, as opposed to I-D-F curves, for use in storm drainage design computer programs.

This article describes the analytic techniques used to determine equation coefficients and exponents and presents the resulting I-D-F equations. Two analytic techniques are discussed: a graphical procedure and a mathematical curve fitting method executed by a digital computer program. Whereas the data used and the results obtained are strictly applicable only to the southeastern Wisconsin planning region, the analytic techniques, that is, the graphical procedure and the mathematical curve fitting approach, may be expected to be generally applicable to any rainfall I-D-F data.

ORIGINAL SEWRPC RAINFALL INTENSITY-DURATION-FREQUENCY ANALYSES AND CURVES

The Commission in 1965 developed point rainfall I-D-F relationships using rainfall data collected by the National Weather Service (formerly U. S. Weather Bureau) at the Milwaukee station during the 49-year period from 1903 through 1951. The statistical analysis of that rainfall data was revised under the SEWRPC Fox and Milwaukee River watershed studies to incorporate 15 years of additional rainfall data to determine if the additional historical record would alter the rainfall I-D-F relationships. No significant change occurred, but as a result of that supplemental analysis, point rainfall I-D-F relationships are now available for the 64-year period from 1903 through 1966. There is at this time no need to update the statistical analyses using post 1966 data, since the aforementioned revision using 15 additional years of rainfall data had an insignificant influence on the resulting rainfall I-D-F relationships.

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[1] *For a detailed discussion of the application of the rational method to urban storm water drainage design, including the use of rainfall I-D-F relationships, see "Determination of Runoff for Urban Storm Water Drainage System Design," by K. W. Bauer, SEWRPC Technical Record, Volume 2, No. 4, April-May 1965.*

The data are shown in tabular form in Table 1; and graphic representations, based on the tabular data, are presented in Figures 1 and 2.[2] Figure 1 is a log-log graph of rainfall intensity versus duration for recurrence intervals of 2, 5, 10, 25, 50, and 100 years, and is presented here primarily for use in the subsequent discussion of the graphical procedure and the mathematical curve fitting procedure for determining I-D-F relationship equations. Figure 2 presents the rainfall intensity-duration data on arithmetic paper and is intended for actual use in storm drainage system design, since arithmetic scales are easier to read than logarithmic scales.

Table 1

POINT RAINFALL INTENSITY-DURATION-FREQUENCY DATA FOR MILWAUKEE, WISCONSIN[a]

RECURRENCE INTERVAL (YEARS)	DURATION AND INTENSITY[b]						
	5 MINUTES	10 MINUTES	15 MINUTES	30 MINUTES	1 HOUR	2 HOURS	24 HOURS
2	4.32	3.40	2.89	1.93	1.16	0.70	0.098
5	5.55	4.55	3.79	2.57	1.57	0.95	0.135
10	6.37	5.31	4.38	3.00	1.84	1.12	0.160
25	7.40	6.27	5.13	3.54	2.19	1.33	0.191
50	8.17	6.98	5.69	3.94	2.44	1.48	0.215
100	8.93	7.68	6.23	4.34	2.70	1.64	0.238

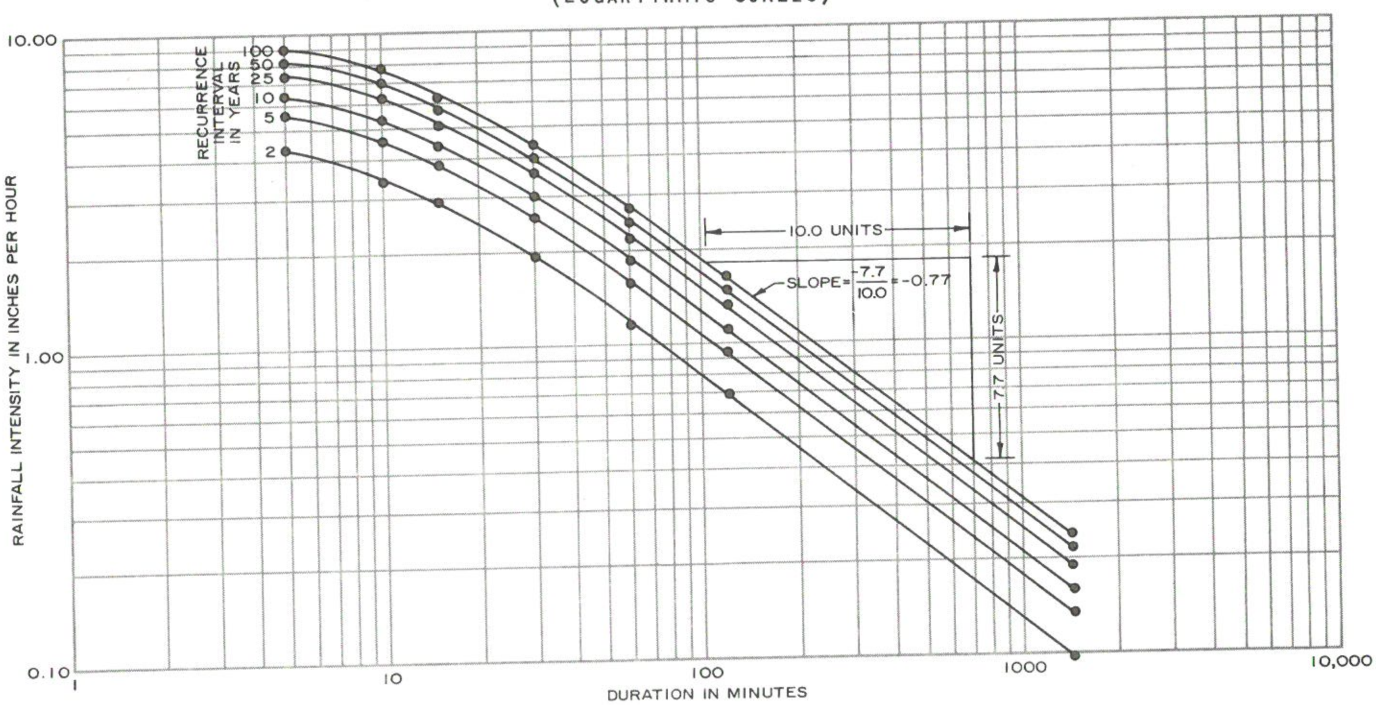
[a]THESE DATA ARE BASED ON A STATISTICAL ANALYSIS OF MILWAUKEE RAINFALL DATA FOR THE 64-YEAR PERIOD OF 1903 TO 1966.

[b]INTENSITY EXPRESSED IN INCHES PER HOUR.

SOURCE- SEWRPC.

Figure 1

POINT RAINFALL INTENSITY-DURATION-FREQUENCY RELATIONSHIPS FOR MILWAUKEE, WISCONSIN--DURATIONS OF 5 MINUTES TO 24 HOURS (LOGARITHMIC SCALES)



Source: SEWRPC.

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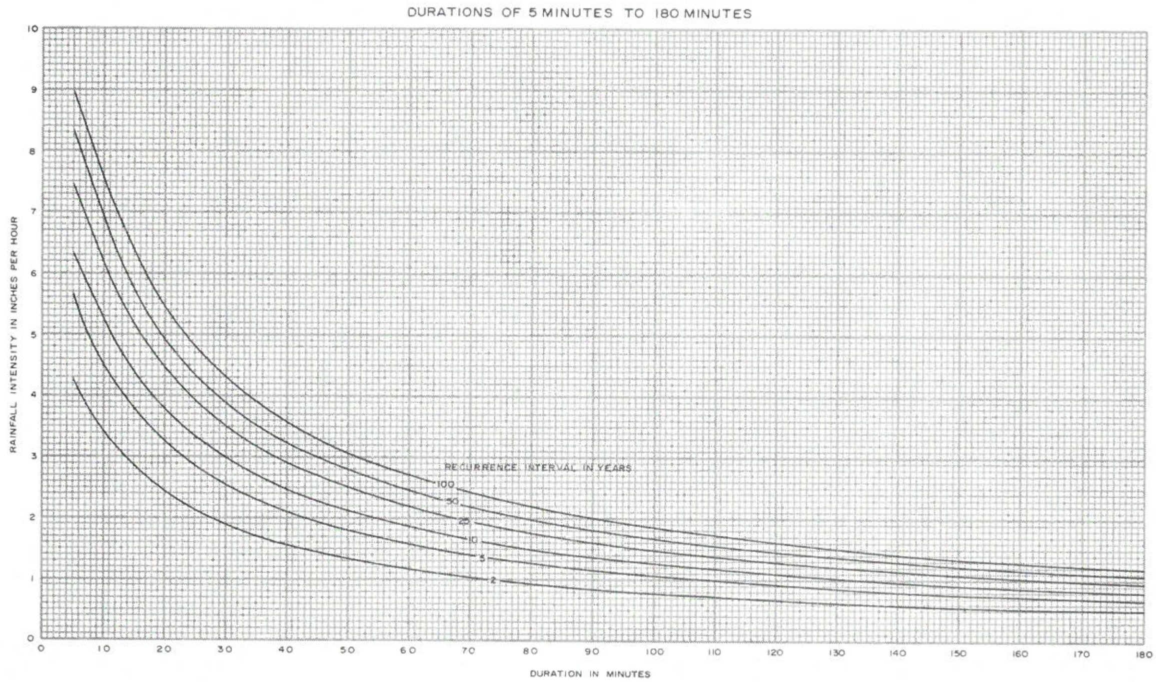
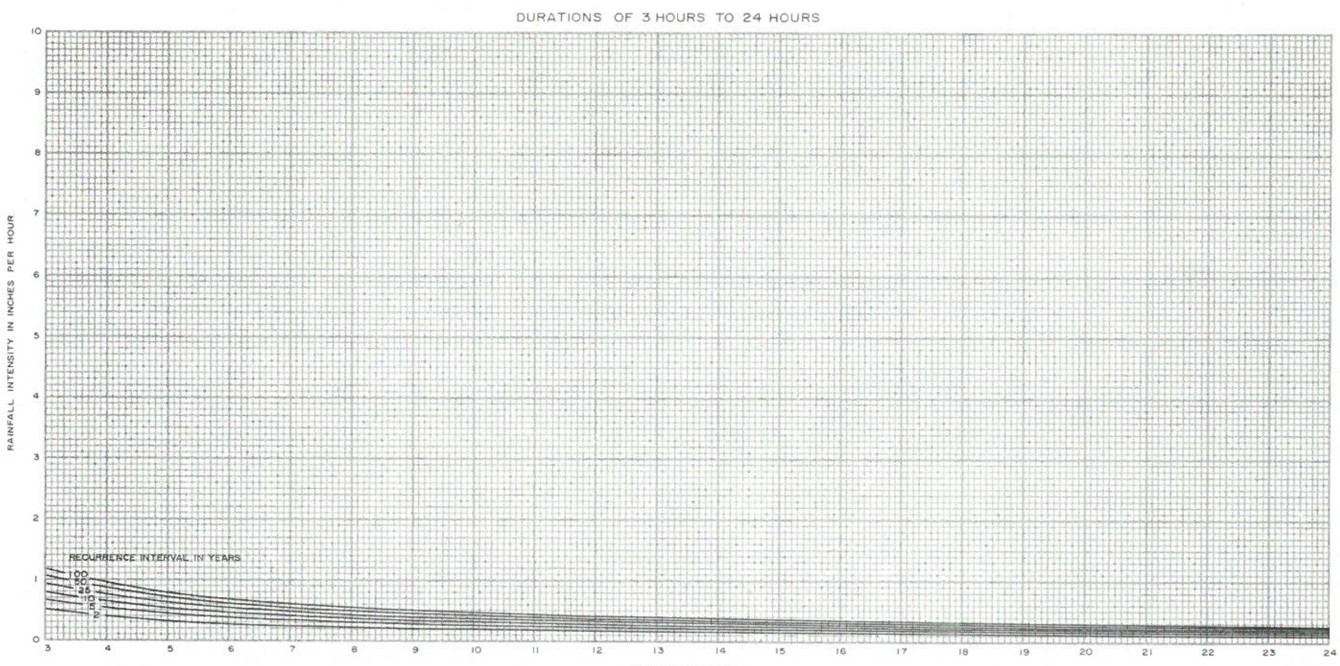
[2] *The rainfall intensity-duration-frequency curves set forth in this Technical Record article are intended to update and replace the curves set forth in Appendix C of SEWRPC Planning Report No. 12, A Comprehensive Plan for the Fox River Watershed, Volume 2, and in Appendix C of SEWRPC Planning Report No. 13, A Comprehensive Plan for the Milwaukee River Watershed, Volume 2. The previously published curves show excessive rainfall intensities for all recurrence intervals in the duration range of approximately two to 24 hours.*

Figure 2

POINT RAINFALL INTENSITY-DURATION-FREQUENCY RELATIONSHIPS FOR MILWAUKEE, WISCONSIN (ARITHMETIC SCALES)





Source: SEWRPC.

EXPECTED FORMS OF INTENSITY-DURATION-FREQUENCY EQUATIONS

For short durations, that is, up to one or two hours, equations for I-D-F relationships for a given recurrence interval are normally[3] of the form

$$i = \frac{A}{B + t} \qquad (1)$$

where
- i = average rainfall intensity in inches per hour,
- t = duration or period of interest in minutes, and
- A, B = coefficients varying with geographic location and reflecting local climatic and topographic conditions.

Equation 1 may be rearranged into the linear form

$$\frac{1}{i} = \frac{B}{A} + \frac{t}{A} \qquad (2)$$

The linear form is useful for determining the numerical values of the coefficients A and B when tabular I-D-F data, like that presented in Table 1, are available. If the mathematical equation relating i and t data for a given recurrence interval is of the form indicated by Equation 1 and if 1/i values are computed and plotted as a function of t values on ordinary arithmetic graph paper, it follows from an examination of Equation 2 that the graph will be linear and have a slope of 1/A and will intercept the ordinate or vertical axis at B/A.

For long durations, that is, in excess of one or two hours, equations for I-D-F relationships are normally[4] of the form

$$i = C\,t^{-n} \qquad (3)$$

where i and t are as previously defined and C and n are a coefficient and an exponent, respectively, each of which varies with geographic location, reflecting differing local climatic and topographic conditions. Equation 3 may be transformed into a linear form by the use of natural (base e) or common (base 10) logarithms so as to obtain:

$$\log i = \log C - n \log t \qquad (4)$$

This linear form facilitates evaluation of the numerical values of the coefficient C and the exponent n when tabular I-D-F data are available. If the mathematical equation expressing i as a function of t is of the form given by Equation 3 and if the log i is plotted versus the log t on arithmetic graph paper, it follows from an examination of Equation 4 that the graph will be linear with a slope of -n and an ordinate intercept of log C. Instead of computing and graphing the logarithms of i and t, it is, of course, easier to obtain the linear graph by plotting i versus t on log-log graph paper.

FORMS OF INTENSITY-DURATION-FREQUENCY EQUATIONS FOR MILWAUKEE

Figure 1 is a log-log graph of Milwaukee rainfall intensity as a function of recurrence interval and duration and is seen to be approximately linear for all recurrence intervals when the duration is in excess of one hour. Therefore, for durations of 60 minutes through 24 hours, I-D-F relationships for the Milwaukee area may be described by equations having a form like Equation 4 or its equivalent, Equation 3.

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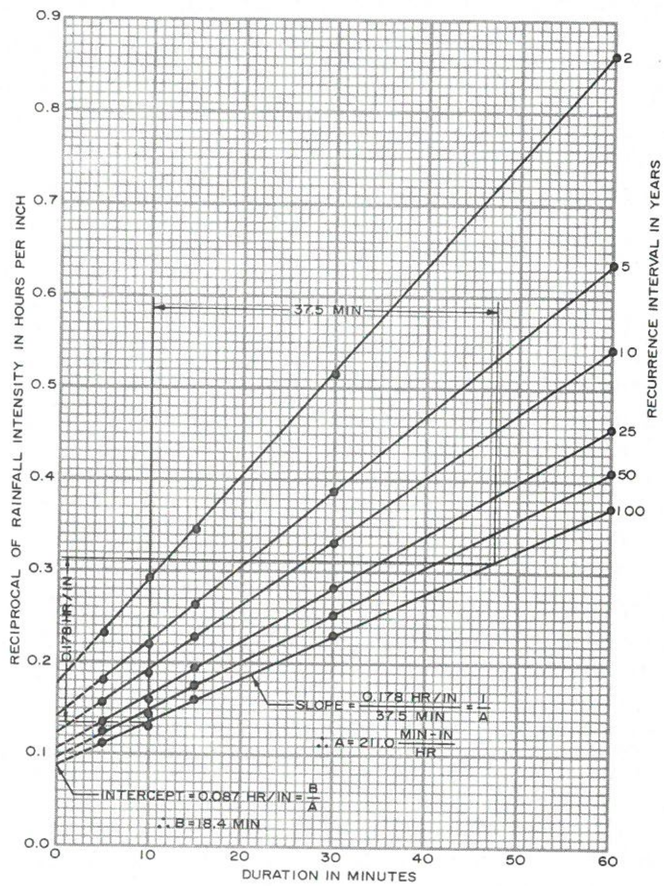
[3] *R. K. Linsley, M. A. Kohler, and J. L. H. Paulhus, Applied Hydrology, McGraw-Hill, New York, 1949, p. 91.*

[4] *Ibid.*

The I-D-F curves in Figure 1 are obviously not linear for shorter durations, that is, for durations of 5 minutes to one hour. However, a graph on arithmetic graph paper of 1/i versus t data for durations of 5 minutes to one hour, as shown in Figure 3, is seen to be linear for all recurrence intervals. Therefore, in this duration range I-D-F relationships for the planning region may be described by equations having a form like Equation 2 or its equivalent, Equation 1.

Figure 3

RECIPROCAL OF POINT RAINFALL INTENSITY AS A FUNCTION OF RECURRENCE INTERVAL AND DURATION FOR MILWAUKEE, WISCONSIN-- DURATIONS OF 5 MINUTES TO 60 MINUTES



DETERMINATION OF COEFFICIENTS AND EXPONENTS IN INTENSITY-DURATION-FREQUENCY EQUATIONS

Once the functional forms of the regional I-D-F relationships were determined by graphing the data as discussed above, the next step was to determine the numerical values of the three coefficients A, B, and C and the exponent n. Two analytic techniques were used, one being a graphical method and the other a mathematical curve fitting procedure utilizing the least squares method and accomplished with the aid of a digital computer program.

Graphical Method

Under the graphical method, Figure 1 was utilized to determine the coefficient C and the exponent n in the I-D-F equations for durations from 60 minutes to 24 hours. The slope of each of six linear intensity-duration relationships was determined directly from the graph, thereby providing numerical values for the exponent n. For example, as shown in Figure 1, the 100-year recurrence interval intensity-duration relationship for durations of 60 minutes to 24 hours has a slope of -0.77; and, therefore, $n = 0.77$.

With n determined for each of the six equations, the coefficient C was then determined for each equation by substituting an arbitrarily selected pair of intensity-duration values into Equation 1 and solving for C. For example, consider again the 100-year recurrence interval intensity-duration relationship shown in Figure 1 for durations of 60 minutes to 24 hours. The aforementioned value of $n = 0.77$ was substituted into Equation 3 along with an arbitrarily selected point on the curve having coordinates of $t = 100$ minutes and $i = 1.85$ inches per hour, and the coefficient C was computed as 64.3. In summary, Figure 1 was used to graphically determine the exponent n and coefficient C in the six I-D-F equations for durations of 60 minutes to 24 hours and recurrence intervals of 2, 5, 10, 25, 50, and 100 years.

Figure 3 was used to graphically evaluate the coefficients A and B in the I-D-F equations for durations from 5 minutes to 60 minutes. The slope of each of the six linear intensity-duration relationships was measured directly from the graph, thereby giving the numerical values for 1/A which facilitated computation of the coefficient A for each equation. In order to illustrate this procedure, consider 100-year recurrence interval data for durations of 5 minutes to 60 minutes as shown in Figure 3. The linear graph of the reciprocal of rainfall intensity versus duration has a slope of 0.178 hours per inch divided by 37.5 minutes. The reciprocal of this is 211.0 minute-inches per hour and is equal to the coefficient A.

The numerical value of A for each equation, in combination with the intercept of the curve with the ordinate or vertical axis of Figure 3, yields the numerical value of the coefficient B. Consider again the 100-year recurrence interval intensity-duration relationship shown in Figure 1 for durations of 5 minutes to 60 minutes. If the linear relationship is extrapolated to the ordinate, it intercepts that axis at a value of 0.087 hours per inch, which value is, according to Equation 2, equivalent to B/A. Since the coefficient A was determined above to be 211 minute-inches per hour, B is computed to be 18.4 minutes.

In summary, Figure 3 was used to graphically evaluate the coefficients A and B in the six I-D-F equations for durations of 5 minutes to 60 minutes and recurrence intervals of 2, 5, 10, 25, 50, and 100 years. The I-D-F equations developed with the graphical method, as discussed above, are not included in this article. Instead, the article presents the complete set of equations obtained from application of the more precise least squares method which is described in a subsequent section.

Least Squares Method

The method of least squares is a statistical procedure that may be used to determine an equation expressing the relationship between two variables that are related in an approximately linear fashion. This method fits the equation of a straight line to the set of sample points such that the sum of the squares of the deviations of the sample points from the fitted line is a minimum. A detailed discussion of the least squares method is beyond the scope of this paper, and the interested reader is referred to statistics textbooks for additional information.[5]

The method of least squares may be used to determine coefficients and exponents in the equations for Milwaukee rainfall I-D-F data since, as demonstrated above, that data may be transformed so as to graph linearly. Intensity-duration data for durations of 60 minutes to 24 hours graph linearly if the logarithm of intensity is plotted versus the logarithm of duration as shown in Figure 1, whereas intensity-duration data for durations of 5 minutes to 60 minutes graph linearly on arithmetic graph paper if the reciprocal of intensity is plotted versus duration as shown in Figure 3. Another way of stating this is that the least squares method may be used to determine coefficients and exponents for rainfall I-D-F equations because the rainfall intensity-duration data may be transformed to a linear form corresponding either to Equation 2 or Equation 4.

A digital computer program was written for the purpose of applying the method of least squares to the I-D-F data presented in Table 1. The program performs the following functions and computations:

1. Reads a set of pairs of intensity duration data preceded by the recurrence interval of the data, the number of data pairs, and the type of equation which describes the functional relationship between rainfall intensity and duration.

   a. An intensity-duration relationship is defined as Type 1 if the mathematical relationship is approximately given by Equation 1 or its equivalent, Equation 2.

   b. An intensity-duration relationship is defined as Type 2 if the mathematical relationship is approximately given by Equation 3 or its equivalent, Equation 4.

2. Converts each set of intensity-duration data into an equivalent linear form.

   a. If a Type 1 intensity-duration relationship exists, the data are linearized by computing the reciprocal of the rainfall intensity values and analyzing them as a function of duration.

   b. If a Type 2 intensity-duration relationship exists, the data are linearized by computing the natural logarithm of intensity values and analyzing them as a function of the computed natural logarithms of the duration values.

[5] See A. J. Duncan, *Quality Control and Industrial Statistics*, R. D. Irwin, Inc., Homewood, Ill., 1959, Chapter 32.

3. Applies the method of least squares to each set of linearized intensity-duration data resulting in the determination of coefficients and exponents for the corresponding I-D-F equation.

   a. If a Type 1 intensity-duration relationship exists, the method of least squares yields the coefficients A and B in Equation 1 or Equation 2.

   b. If a Type 2 intensity-duration relationship exists, the method of least squares yields the coefficient C and the exponent n in Equation 3 or Equation 4.

   Application of the method of least squares includes calculation of the coefficient of correlation which has a maximum absolute value of 1.0 and measures the degree of correlation between the linearized intensity-duration data. The square of the coefficient of correlation is the fraction of the variation in the dependent variable (the reciprocal of rainfall intensity or the natural logarithm of rainfall intensity depending on the type of intensity-duration relationship) that is accounted for by the linear equation relating that dependent variable to the independent variable (the duration or the natural logarithm of duration depending on the form of the intensity-duration relationship).

4. Prints results of the least squares analysis for the set of intensity-duration data pairs.

5. Repeats the above four steps for each successive set of intensity-duration data.

A list of the computer program is included in Appendix A. Numerous comment statements are included in the program to assist a potential user in understanding computation details. The Milwaukee I-D-F data set forth in Table 1 were input to the computer program. A list of that input data is attached as Appendix B, which exhibit also includes notations describing the necessary input and the format in which they must be arranged. Computer program output corresponding to the Milwaukee I-D-F data is shown in Appendix C.

The I-D-F equations resulting from the least squares method of analysis of the Milwaukee data are presented in Table 2. The short duration equation and the long duration equation for a given recurrence interval will not yield identical rainfall intensities at the common duration of 60 minutes. A slight discontinuity exists such that the short duration equations for the six recurrence intervals will yield 60-minute duration intensities less than, but within about two percent of, the corresponding long duration equations. In order to avoid complications for a 60-minute duration, it is recommended, as noted in Table 2, that the short duration equation be used for durations up to, but not including, 60 minutes and that the long duration equation be used for durations beginning with 60 minutes.

Table 2

POINT RAINFALL INTENSITY-DURATION-FREQUENCY EQUATIONS FOR MILWAUKEE, WISCONSIN[a]

RECURRENCE INTERVAL (YEARS)	EQUATION[b]	
	DURATION OF 5 MINUTES OR MORE BUT LESS THAN 60 MINUTES	DURATION OF 60 MINUTES OR MORE THROUGH 24 HOURS
2	$I = \frac{87.5}{15.4 + T}$	$I = 28.9\ T^{-0.781}$
5	$I = \frac{120.2}{16.6 + T}$	$I = 38.2\ T^{-0.776}$
10	$I = \frac{141.8}{17.1 + T}$	$I = 44.2\ T^{-0.772}$
25	$I = \frac{170.1}{17.8 + T}$	$I = 52.3\ T^{-0.771}$
50	$I = \frac{190.1}{18.0 + T}$	$I = 57.3\ T^{-0.768}$
100	$I = \frac{211.4}{18.4 + T}$	$I = 63.5\ T^{-0.768}$

[a]THE EQUATIONS ARE BASED ON MILWAUKEE RAINFALL DATA FOR THE 64-YEAR PERIOD OF 1903 TO 1966. THESE EQUATIONS ARE APPLICABLE, WITHIN AN ACCURACY OF ±10 PERCENT, TO THE ENTIRE SOUTHEASTERN WISCONSIN PLANNING REGION.

[b]I = RAINFALL INTENSITY IN INCHES PER HOUR.
T = DURATION IN MINUTES.

SOURCE- SEWRPC.

Discussion of Methods

If rainfall I-D-F data are being examined for the first time with the idea of ultimately determining equations for the I-D-F relationships, a preliminary analysis could be conducted using the graphical method. Such an analysis would reveal the nature of the mathematical relationship between intensity and duration for a given frequency, and more specifically, would indicate the duration range described by Equation 1 or its equivalent, Equation 2, and the duration range described by Equation 3 or its equivalent, Equation 4.

Once the duration value separating the Type 1 equation from the Type 2 equation has been determined graphically, the sets of intensity-duration data could be input to the computer program for computation of coefficients and exponents. If additional years of intensity-duration data are obtained at a later date, the computer program could be used directly to calculate refined values of I-D-F equation coefficients and exponents.

The principle advantage of the computer method relative to the graphical method is that once the demarcation between Type 1 and Type 2 relationships has been determined, the former method is completely objective whereas the latter method is partly subjective in that a line must be fitted by eye to the plotted intensity-duration data. Furthermore, the computer program provides, by virtue of the correlation coefficient, an objective statistical measure of how well the resulting equation expressing intensity as a function of duration fits the sample data. Finally, once the critical duration separating Type 1 and Type 2 I-D-F equations has been determined, the least squares method computer program facilitates, relative to the graphical procedure, a rapid determination of equation coefficients and exponents.

In lieu of using the graphical method prior to applying the least squares method computer program, it is also possible to directly apply the computer program with an assumed value of the critical duration, that is, the duration separating the Type 1 equations from the Type 2 equations. Upon examination of correlation coefficients calculated by the computer program, the critical duration could be altered and the I-D-F data reanalyzed with the computer program. This iterative, trial and error process could be repeated until the most favorable overall set of correlation coefficients was obtained.

REGIONAL APPLICABILITY OF MILWAUKEE INTENSITY-DURATION-FREQUENCY DATA, GRAPHS, AND EQUATIONS

The I-D-F data set forth in Table 1 are, as noted earlier, based on a frequency analysis of Milwaukee rainfall data for the 64-year period from 1903 through 1966 and are, therefore, along with the I-D-F curves in Figures 1 and 2 and the I-D-F equations in Table 2, strictly applicable to the immediate Milwaukee area. Spatial variations of I-D-F relationships occur in the planning region, with those variations being characterized, for a given recurrence interval and duration, by slightly increasing intensities in a southwesterly direction across the Region.

An earlier comparison[6] of rainfall I-D-F data for Milwaukee, Madison, and Chicago revealed relatively small rainfall intensity differences between these three locations and concluded that the Milwaukee I-D-F relationships would be adequate for use anywhere in the planning region. A recent independent examination of regional I-D-F data, conducted in conjunction with the development of I-D-F equations, confirmed that conclusion.

This examination utilized isohyetal maps[7] to develop I-D-F relationships for the northeast corner of Ozaukee County and the southwest corner of Walworth County. These relationships, which encompassed regional extremes, were then compared to Milwaukee I-D-F relationships with the conclusion that I-D-F curves and equations developed by SEWRPC using Milwaukee rainfall data are applicable anywhere within the seven-county planning region with an accuracy of plus or minus 10 percent.

A rainfall intensity error of 10 percent or less would be reflected in a 10 percent or less error in storm water design flow if a procedure like the rational method of storm drainage is used. A 10 percent error in design flow would have a negligible effect on the design size of storm water system components such as storm water inlets, storm sewers, storm water conveyance swales, and channels, since the required

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[6] *K. W. Bauer, "Determination of Runoff for Urban Storm Water Drainage System Design," SEWRPC Technical Record, Volume 2, No. 4, April-May 1965.*

[7] *U. S. Weather Bureau, "Rainfall Frequency Atlas of the United States," Technical Paper No. 40, Washington, D. C., May 1961.*

size of these components does not normally increase in direct proportion to the design discharges. If, for example, the Manning equation is used for the hydraulics computations, it can be demonstrated that a 10 percent error in the design discharge of a storm sewer designed to flow full would result in about only a 4 percent error in the required sewer diameter. A 4 percent error in required sewer diameter is small relative to the roughly 15 percent or more error needed to effect the selection of the next smaller or larger standard pipe size. Therefore, the SEWRPC I-D-F curves and equations are of sufficient accuracy for use anywhere in the Region and there is no practical need to develop other criteria for use in southeastern Wisconsin.

It is important to note that the I-D-F data of Table 1, the curves in Figures 1 and 2, and the equations in Table 2 pertain to point rainfall intensity. If rainfall intensity estimates are required for areas in excess of 5 to 10 square miles, the intensity values obtained from I-D-F curves and equations presented herein should be reduced through application of a factor obtained from area reduction curves. Such curves, which are readily available,[8,9] give the percent of point rainfall for a given area as a function of area and duration.

SUMMARY

The Southeastern Wisconsin Regional Planning Commission, under its program of comprehensive watershed studies, developed point rainfall intensity-duration-frequency relationships intended for use in storm drainage system design. These relationships, which are applicable within acceptable tolerances to the entire seven-county planning region, were until recently available only in graphic form.

In response to the increased use of digital computers in engineering design by governmental units and consulting firms in the Region and the corresponding actual and anticipated need for I-D-F equations to use in storm drainage design computer programs, the Commission recently developed I-D-F equations to supplement the earlier I-D-F curves. This article describes and discusses two analytic techniques—a graphical method and a computer-assisted mathematical curve fitting method—used to develop equations expressing point rainfall intensity as a function of recurrence interval and duration. Although specifically applied to southeastern Wisconsin I-D-F data, the methodology discussed herein is general and may, therefore, be useful for water resources engineering work in other geographic areas.

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[8] *Bauer, op. cit.*

[9] *U. S. Weather Bureau, op. cit.*

Appendix A

COMPUTER PROGRAM FOR DETERMINATION OF EQUATIONS FOR RAINFALL INTENSITY-DURATION-FREQUENCY RELATIONSHIPS

(Potential users are urged to contact the Southeastern Wisconsin Regional Planning Commission for the most recent version of the computer program.)

```
C     *******************************************************************
C     *******************************************************************
C             COMPUTER PROGRAM FOR DETERMINATION OF EQUATIONS
C             FOR RAINFALL INTENSITY-DURATION-FREQUENCY
C             RELATIONSHIPS
C
C     THIS PROGRAM COMPUTES THE COEFFICIENTS AND EXPONENTS IN INTENSITY-
C     DURATION-FREQUENCY EQUATIONS BY APPLYING THE METHOD OF LEAST
C     SQUARES TO LINEAR FORMS OF THOSE EQUATIONS
C
C     SOURCE OF PROGRAM--
C         SOUTHEASTERN WISCCNSIN REGIONAL PLANNING COMMISSION,
C         OLD COURTHOUSE, WAUKESHA,WIS., FEB. 1973
C
C     REFERENCE FOR STATISTICAL ANALYSES--
C         CUNCAN,A.J., QUALITY CONTROL AND INCUSTRIAL STATISTICS,
C         CHAPTER 32, R.D. IRWIN,INC., 1959.
C
C     *******************************************************************
C     *******************      SELECTED DEFINITIONS     *****************
C
C     REC = RECURRENCE INTERVAL   (YEARS)
C
C     PAIRS OR NPAIRS = NUMBER OF PAIRS OF INTENSITY-DURATION VALUES
C
C     I = COUNTER,  I = 1,2....NPAIRS
C
C     DURAT(I) = TIME PERIOC CR DURATION   (MINUTES)
C
C     R(I) = AVERAGE RAINFALL INTENSITY   (INCHES/HOUR)
C
C     RECIP(I) = RECIPROCAL OF AVERAGE RAINFALL INTENSITY   (HOURS/INCH)
C
C     A,B,C = COEFFICIENTS
C
C     XN OR N = EXPCNENT
C
C     TYPE = TYPE OF INTENSITY-DURATION EQUATION
C
C         TYPE 1 EC. IS OF THE FORM  R = A/(B+DURAT)  WHICH GRAPHS
C         LINEARLY CN ORDINARY RECTANGULAR GRAPH PAPER WHEN WRITTEN IN
C         THE FORM  1/R = (B/A)+(DURAT/A)
C
C         TYPE 2 EQ. IS OF THE FORM  R = C*(DURAT**(-N))  WHICH GRAPHS
C         LINEARLY AS LOG(R) = LOG(C)-(N*LOG(CURAT))
C
C     *******************************************************************
C     ***********    ESTABLISH T DISTRIBUTION C.050 POINTS    ***********
C                    FOR SAMPLE SIZES RANGING FROM 3 TO 20
      CIMENSION DURAT(20),R(20),RECIP(20),CLYL(20),CLYL(20),CLRU(20),
     1CLRL(20),CR(20),T(20)
      T(3)=6.314
      T(4)=2.920
      T(5)=2.353
      T(6)=2.132
      T(7)=2.015
      T(8)=1.943
      T(9)=1.895
      T(10)=1.860
      T(11)=1.833
      T(12)=1.812
      T(13)=1.796
      T(14)=1.782
      T(15)=1.771
      T(16)=1.761
      T(17)=1.753
      T(18)=1.746
      T(19)=1.740
      T(20)=1.734
C
C     *******************************************************************
C     ***********************   READ  DATA   ****************************
C
C     READ RECURRENCE INTERVAL (OR TERMINATE COMPUTATIONS), EQUATION
C     TYPE AND NUMBER OF CATA PAIRS
      COUNT=0.0
    1 READ(1,5) REC,TYPE,PAIRS
    5 FORMAT(3F10.0)
      IF(REC)1000,1000,10
   10 NPAIRS=PAIRS
C     READ INTENSITY - DURATICN VALUES IN ORDER OF INCREASING DURATION
      READ(1,15) (R(I),DURAT(I),I=1,NPAIRS)
   15 FORMAT(8F10.0)
C
C     *******************************************************************
C     *********   CCMPUTE SQUARES, CROSS PRODUCTS, SUMS, MEANS   *******
C
C     SET INITIAL ZERCS
      SUMY=0.0
      SUMX=0.0
      SUMXY=0.0
      SUMXSQ=0.0
      SUMYSQ=0.0
      DO 60 I=1,NPAIRS
      IF(TYPE-2.0)30,40,1000
C     TYPE 1 EQUATION
   30 RECIP(I)=1.0/R(I)
      Y=RECIP(I)
      X=DURAT(I)
      GO TO 50
C     TYPE 2 EQUATICN
   40 Y=ALOG(R(I))
      X=ALOG(DURAT(I))
   50 SUMX=SUMX + X
      SUMY=SUMY + Y
      SUMXY=SUMXY + (X*Y)
      SUMXSQ=SUMXSQ + (X*X)
      SUMYSQ=SUMYSQ + (Y*Y)
   60 CONTINUE
      XMEAN=SUMX/PAIRS
      YMEAN=SUMY/PAIRS
C
C     *******************************************************************
C     ******   COMPUTE SLOPE AND INTERCEPT OF LINEAR EQUATICN   ********
C
      SLOPE=(SUMXY-(PAIRS*XMEAN*YMEAN))/(SUMXSQ-(PAIRS*(XMEAN**2.0)))
      CEPT=YMEAN-(SLOPE*XMEAN)
C
C     *******************************************************************
C     ***   CCMPUTE COEFFICIENT OF CORRELATICN OF LINEAR REGRESSION   **
C
C     SAMPLE VARIANCE (SQUARE OF STANDARD DEVIATION OF Y)
      VARISY=(SUMYSQ-(PAIRS*(YMEAN*YMEAN)))/(PAIRS)
C     ESTIMATE OF UNIVERSE VARIANCE
      VARIUY=(PAIRS/(PAIRS-1.0))*VARISY
C     SAMPLE VARIANCE (SQUARE OF STANCARD DEVIATION OF X)
      VARISX=(SUMXSQ-(PAIRS*(XMEAN*XMEAN)))/(PAIRS)
C     SQUARE OF STANCARD ERROR OF ESTIMATE ( SQUARE OF STANDARD
C     DEVIATION OF CEVIATIONS FROM LINE OF REGRESSION)
      SQSTER=(SUMYSQ-(CEPT*SUMY)-(SLOPE*SUMXY))/(PAIRS-2.0)
C     FRACTION OF TOTAL VARIANCE UNACCOUNTED FOR BY REGRESSION
      FRACTU=SQSTER/VARIUY
C     CORRELATION CCEFFICIENT
      IF(TYPE-2.0)61,62,1000
C     TYPE 1 EQUATICN
   61 CORCO=(1.0-FRACTU)**0.5
      GO TO 63
C     TYPE 2 EQUATICN
   62 CORCC=-((1.0-FRACTU)**0.5)
C     FRACTION OF TCTAL VARIANCE ACCOUNTED FOR BY REGRESSICN
   63 FRACTA=CORCO*CORCO
C
C     *******************************************************************
C     *********   CCNVERT SLOPE AND INTERCEPT IN LINEAR FORM   **********
C                 OF EQUATION TO COEFFICIENTS AND EXPONENT
C                       IN NON-LINEAR FORM OF EQUATION
C
      IF(TYPE-2)65,70,1000
C     TYPE 1 EQUATION
   65 A=1.0/SLOPE
      B=A*CEPT
      GO TO 80
C     TYPE 2 EQUATICN
   70 C=2.71828**CEPT
      XN=-SLOPE
   80 CONTINUE
C
C     *******************************************************************
C     ************   COMPUTE 90 PERCENT CONFICENCE LIMITS   ************
C                                FOR EQUATIONS
      DO 600 I=1,NPAIRS
      IF(TYPE-2.0)505,510,1000
C     TYPE 1 EQUATICN
  505 SX=DURAT(I)-XMEAN
      GO TO 515
C     TYPE 2 EQUATICN
  510 SX=ALOG(DURAT(I))-XMEAN
C     HALF OF 90 PERCENT CONFIDENCE LIMIT RANGE FOR Y
  515 HALF=T(NPAIRS)*(SQSTER**0.5)*(((1.0/PAIRS)+((SX*SX)/(VARISX*PAIRS)
     1))**0.5)
C     UPPER AND LOWER 90 PERCENT CCNFIDENCE LIMITS FOR Y
      CLYU(I)=YMEAN+(SLOPE*SX)+HALF
      CLYL(I)=YMEAN+(SLOPE*SX)-HALF
C     RAINFALL INTENSITIES EQUIVALENT TO CONFIDENCE LIMITS FOR Y
      IF(TYPE-2.0)520,525,1000
C     TYPE 1 ECUATION
  520 CLRU(I)=1.0/CLYL(I)
      CLRL(I)=1.0/CLYU(I)
      GO TO 600
C     TYPE 2 EQUATICN
  525 CLRU(I)=2.71828**CLYU(I)
      CLRL(I)=2.71828**CLYL(I)
  600 CONTINUE
C
C     *******************************************************************
C     *****   COMPUTE RAINFALL INTENSITY FOR SELECTED DURATIONS   ******
C                   USING DERIVED INTENSITY-DURATION EQUATIONS
C
      DC 700 I=1,NPAIRS
      IF(TYPE-2.0)605,610,1000
C     TYPE 1 ECUATICN
  605 CR(I)=A/(B+DURAT(I))
      GC TO 700
C     TYPE 2 EQUATICN
  610 CR(I)=C*(DURAT(I)**(-XN))
  7C0 CONTINUE
C
C     *******************************************************************
C     ***********   SUMMARIZE INPUT DATA AND RESULTS OF ANALYSIS   *****
C
      IF(COUNT)1000,85,105
   85 WRITE(3,90)
   90 FORMAT(55H1******************************************************)
      WRITE(3,100)
```

```
  100 FORMAT(46HOSUMMARY OF INPUT DATA AND RESULTS OF ANALYSIS)
      COUNT=COUNT+1.0
  105 WRITE(3,110)
  110 FORMAT(55HO******************************************************)
      WRITE(3,115) REC
  115 FORMAT(23HORECURRENCE INTERVAL = ,F5.1,6H YEARS)
      WRITE(3,120) DURAT(1),DURAT(NPAIRS)
  120 FORMAT(15H DURATION FROM ,F6.1,12H MINUTES TO ,F6.1,8H MINUTES)
      IF(TYPE-2.0)130,150,1000
C     TYPE 1 EQUATION
  130 WRITE(3,140)
  140 FORMAT(50H INTENSITY - DURATION EQ. OF FORM--  R=A/(B+DURAT))
      GO TO 170
C     TYPE 2 EQUATION
  150 WRITE(3,160)
  160 FORMAT(54H INTENSITY - DURATION EQ. OF FORM--  R=C*(DURAT**(-N)))
  170 WRITE(3,180)
  180 FORMAT(52HORAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS)
      IF(TYPE-2.0)190,260,1000
C     TYPE 1 EQUATION
  190 WRITE(3,200)
  200 FORMAT(48HO   DURATION          INTENSITY       RECIPROCAL    )
      WRITE(3,210)
  210 FORMAT(48H                                          OF          )
      WRITE(3,220)
  220 FORMAT(48H                                      INTENSITY     )
      WRITE(3,230)
  230 FORMAT(48H   (MINUTES)         (INCH/HOUR)     (HOUR/INCH)    )
      DO 250  I=1,NPAIRS
      WRITE(3,240) DURAT(I),R(I),RECIP(I)
  240 FORMAT(F10.1,F17.3,F16.3)
  250 CONTINUE
      GO TO 310
C     TYPE 2 EQUATION
  260 WRITE(3,270)
  270 FORMAT(30HO   DURATION          INTENSITY )
      WRITE(3,280)
  280 FORMAT(30H   (MINUTES)         (INCH/HOUR))
      DO 300  I=1,NPAIRS
      WRITE(3,290) DURAT(I),R(I)
  290 FORMAT(F10.1,F17.3)
  300 CONTINUE
  310 WRITE(3,320)
  320 FORMAT(20HORESULTS OF ANALYSIS)
      IF(TYPE-2.0)330,350,1000
C     TYPE 1 EQUATION
  330 WRITE(3,340) A,B
  340 FORMAT( 6H  A = ,F6.2,8H    B = ,F6.2)
      GO TO 365
C     TYPE 2 EQUATION
  350 WRITE(3,360) C,XN
  360 FORMAT( 6H  C = ,F6.2,8H    N = ,F7.4)
  365 WRITE(3,370) CORCO
  370 FORMAT(48HOCORRELATION COEFFICIENT OF LINEAR REGRESSION = ,F8.6)
      WRITE(3,375) FRACTA
  375 FORMAT(52H FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = ,F8.
     16)
      WRITE(3,400)
  400 FORMAT(51HOREGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS)
      WRITE(3,405)
  405 FORMAT(51HO   DURATION                  I  N  T  E  N  S  I  T  Y)
      WRITE(3,410)
  410 FORMAT(51H   (MINUTES)                         (INCH/HOUR)       )
      WRITE(3,415)
  415 FORMAT(61H                        REGRESSION           LOWER
     1UPPER)
      WRITE(3,420)
  420 FORMAT(61H                          VALUE              LIMIT
     1LIMIT)
      DO 430 I=1,NPAIRS
      WRITE(3,425) DURAT(I),CR(I),CLRL(I),CLRU(I)
  425 FORMAT(F10.1,3F17.3)
  430 CONTINUE
      GO TO 1
 1000 CONTINUE
      WRITE(3,110)
      STOP
      END
```

Appendix B

COMPUTER PROGRAM INPUT:
MILWAUKEE INTENSITY-DURATION-FREQUENCY DATA

Input data must be placed in 10-column fields with each value entered as a floating point number, that is, with a decimal point. It is suggested that each input number be right justified in its respective field for ease of reading and checking the computer program input.

The following list of input data includes notations intended to describe the necessary input data. Note that any number of intensity-duration-frequency data sets may be input to the computer program. It would be necessary to change the DIMENSION statement in the computer program (Appendix A) if any one data set contains more than 20 pairs of rainfall intensity-duration values.

DATA SET 1	2.0 RECURRENCE INTERVAL IN YEARS	1.0 TYPE OF EQUATION	5.0 NO OF PAIRS OF INTENSITY-DURATION VALUES					
	4.32	5.0	3.40	10.0	2.89	15.0	1.93	30.0
	INTENSITY IN INCHES/HOUR	DURATION IN MINUTES	INTENSITY	DURATION	INTENSITY	DURATION	INTENSITY	DURATION
	1.16	60.0						
	INTENSITY	DURATION						
DATA SET 2	5.0	1.0	5.0					
	5.55	5.0	4.55	10.0	3.79	15.0	2.57	30.0
	1.57	60.0						
DATA SET 3	10.0	1.0	5.0					
	6.37	5.0	5.31	10.0	4.38	15.0	3.00	30.0
	1.84	60.0						
ETC.	25.0	1.0	5.0					
	7.40	5.0	6.27	10.0	5.13	15.0	3.54	30.0
	2.19	60.0						
	50.0	1.0	5.0					
	8.17	5.0	6.98	10.0	5.69	15.0	3.94	30.0
	2.44	60.0						
	100.0	1.0	5.0					
	8.93	5.0	7.68	10.0	6.23	15.0	4.34	30.0
	2.70	60.0						
	2.0	2.0	3.0					
	1.16	60.0	0.70	120.0	0.098	1440.0		
	5.0	2.0	3.0					
	1.57	60.0	0.95	120.0	0.135	1440.0		
	10.0	2.0	3.0					
	1.84	60.0	1.12	120.0	0.160	1440.0		
	25.0	2.0	3.0					
	2.19	60.0	1.33	120.0	0.191	1440.0		
	50.0	2.0	3.0					
	2.44	60.0	1.48	120.0	0.215	1440.0		
LAST DATA SET	100.0	2.0	3.0					
	2.70	60.0	1.64	120.0	0.238	1440.0		
	-1.0 INDICATOR TO TERMINATE COMPUTATIONS							

Appendix C

COMPUTER PROGRAM OUTPUT:
COEFFICIENTS AND EXPONENTS FOR MILWAUKEE INTENSITY DURATION FREQUENCY EQUATIONS

****

SUMMARY OF INPUT DATA AND RESULTS OF ANALYSIS

****

RECURRENCE INTERVAL = 2.0 YEARS
DURATION FROM 5.0 MINUTES TO 60.0 MINUTES
INTENSITY - DURATION EQ. OF FORM-- R=A/(B+DURAT)

RAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS

DURATION (MINUTES)	INTENSITY (INCH/HOUR)	RECIPROCAL OF INTENSITY (HOUR/INCH)
5.0	4.320	0.231
10.0	3.400	0.294
15.0	2.890	0.346
30.0	1.930	0.518
60.0	1.160	0.862

RESULTS OF ANALYSIS
A = 87.50 B = 15.41

CORRELATION COEFFICIENT OF LINEAR REGRESSION = 0.999948
FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = 0.999895

REGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS

DURATION (MINUTES)	I N T E N S I T Y (INCH/HOUR)		
	REGRESSION VALUE	LOWER LIMIT	UPPER LIMIT
5.0	4.288	4.219	4.358
10.0	3.444	3.405	3.484
15.0	2.878	2.853	2.903
30.0	1.927	1.916	1.938
60.0	1.160	1.153	1.168

****

RECURRENCE INTERVAL = 5.0 YEARS
DURATION FROM 5.0 MINUTES TO 60.0 MINUTES
INTENSITY - DURATION EQ. OF FORM-- R=A/(B+DURAT)

RAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS

DURATION (MINUTES)	INTENSITY (INCH/HOUR)	RECIPROCAL OF INTENSITY (HOUR/INCH)
5.0	5.550	0.180
10.0	4.550	0.220
15.0	3.790	0.264
30.0	2.570	0.389
60.0	1.570	0.637

RESULTS OF ANALYSIS
A = 120.20 B = 16.62

CORRELATION COEFFICIENT OF LINEAR REGRESSION = 0.999971
FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = 0.999942

REGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS

DURATION (MINUTES)	I N T E N S I T Y (INCH/HOUR)		
	REGRESSION VALUE	LOWER LIMIT	UPPER LIMIT
5.0	5.559	5.496	5.622
10.0	4.515	4.478	4.552
15.0	3.801	3.778	3.824
30.0	2.578	2.568	2.588
60.0	1.569	1.561	1.576

****

RECURRENCE INTERVAL = 10.0 YEARS
DURATION FROM 5.0 MINUTES TO 60.0 MINUTES
INTENSITY - DURATION EQ. OF FORM-- R=A/(B+DURAT)

RAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS

DURATION (MINUTES)	INTENSITY (INCH/HOUR)	RECIPROCAL OF INTENSITY (HOUR/INCH)
5.0	6.370	0.157
10.0	5.310	0.188
15.0	4.380	0.228
30.0	3.000	0.333
60.0	1.840	0.543

RESULTS OF ANALYSIS
A = 141.82 B = 17.14

CORRELATION COEFFICIENT OF LINEAR REGRESSION = 0.999904
FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = 0.999809

REGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS

DURATION (MINUTES)	I N T E N S I T Y (INCH/HOUR)		
	REGRESSION VALUE	LOWER LIMIT	UPPER LIMIT
5.0	6.406	6.279	6.538
10.0	5.226	5.151	5.303
15.0	4.413	4.364	4.462
30.0	3.008	2.987	3.030
60.0	1.838	1.823	1.855

****

RECURRENCE INTERVAL = 25.0 YEARS
DURATION FROM 5.0 MINUTES TO 60.0 MINUTES
INTENSITY - DURATION EQ. OF FORM-- R=A/(B+DURAT)

RAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS

DURATION (MINUTES)	INTENSITY (INCH/HOUR)	RECIPROCAL OF INTENSITY (HOUR/INCH)
5.0	7.400	0.135
10.0	6.270	0.159
15.0	5.130	0.195
30.0	3.540	0.282
60.0	2.190	0.457

RESULTS OF ANALYSIS
A = 170.14 B = 17.81

CORRELATION COEFFICIENT OF LINEAR REGRESSION = 0.999765
FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = 0.999529

REGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS

DURATION (MINUTES)	I N T E N S I T Y (INCH/HOUR)		
	REGRESSION VALUE	LOWER LIMIT	UPPER LIMIT
5.0	7.459	7.237	7.696
10.0	6.118	5.985	6.258
15.0	5.186	5.099	5.275
30.0	3.559	3.520	3.599
60.0	2.187	2.158	2.217

****

RECURRENCE INTERVAL = 50.0 YEARS
DURATION FROM 5.0 MINUTES TO 60.0 MINUTES
INTENSITY - DURATION EQ. OF FORM-- R=A/(B+DURAT)

RAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS

DURATION (MINUTES)	INTENSITY (INCH/HOUR)	RECIPROCAL OF INTENSITY (HOUR/INCH)
5.0	8.170	0.122
10.0	6.980	0.143
15.0	5.690	0.176
30.0	3.940	0.254
60.0	2.440	0.410

RESULTS OF ANALYSIS
A = 190.08 B = 18.01

CORRELATION COEFFICIENT OF LINEAR REGRESSION = 0.999697
FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = 0.999394

REGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS

DURATION (MINUTES)	I N T E N S I T Y (INCH/HOUR)		
	REGRESSION VALUE	LOWER LIMIT	UPPER LIMIT
5.0	8.261	7.985	8.557
10.0	6.786	6.620	6.961
15.0	5.758	5.650	5.871
30.0	3.959	3.910	4.009
60.0	2.437	2.400	2.474

****

RECURRENCE INTERVAL = 100.0 YEARS
DURATION FROM 5.0 MINUTES TO 60.0 MINUTES
INTENSITY - DURATION EQ. OF FORM-- R=A/(B+DURAT)

RAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS

DURATION (MINUTES)	INTENSITY (INCH/HOUR)	RECIPROCAL OF INTENSITY (HOUR/INCH)
5.0	8.930	0.112
10.0	7.680	0.130
15.0	6.230	0.161
30.0	4.340	0.230
60.0	2.700	0.370

RESULTS OF ANALYSIS
A = 211.36 B = 18.42

CORRELATION COEFFICIENT OF LINEAR REGRESSION = 0.999581
FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = 0.999163

REGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS

DURATION (MINUTES)	I N T E N S I T Y (INCH/HOUR)		
	REGRESSION VALUE	LOWER LIMIT	UPPER LIMIT
5.0	9.025	8.678	9.401
10.0	7.437	7.227	7.660

15.0	6.324	6.187	6.468
30.0	4.365	4.302	4.430
60.0	2.695	2.648	2.744

****

RECURRENCE INTERVAL = 2.0 YEARS
DURATION FROM 60.0 MINUTES TO 1440.0 MINUTES
INTENSITY - DURATION EQ. OF FORM-- R=C*(DURAT**(-N))

RAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS

DURATION (MINUTES)	INTENSITY (INCH/HOUR)
60.0	1.160
120.0	0.700
1440.0	0.098

RESULTS OF ANALYSIS
C = 28.87 N = 0.7812

CORRELATION COEFFICIENT OF LINEAR REGRESSION = -.999774
FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = 0.999547

REGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS

DURATION (MINUTES)	I N T E N S I T Y (INCH/HOUR)		
	REGRESSION VALUE	LOWER LIMIT	UPPER LIMIT
60.0	1.179	1.025	1.355
120.0	0.686	0.614	0.766
1440.0	0.098	0.083	0.117

****

RECURRENCE INTERVAL = 5.0 YEARS
DURATION FROM 60.0 MINUTES TO 1440.0 MINUTES
INTENSITY - DURATION EQ. OF FORM-- R=C*(DURAT**(-N))

RAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS

DURATION (MINUTES)	INTENSITY (INCH/HOUR)
60.0	1.570
120.0	0.950
1440.0	0.135

RESULTS OF ANALYSIS
C = 38.16 N = 0.7755

CORRELATION COEFFICIENT OF LINEAR REGRESSION = -.999789
FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = 0.999578

REGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS

DURATION (MINUTES)	I N T E N S I T Y (INCH/HOUR)		
	REGRESSION VALUE	LOWER LIMIT	UPPER LIMIT
60.0	1.594	1.395	1.822
120.0	0.931	0.838	1.036
1440.0	0.136	0.115	0.160

****

RECURRENCE INTERVAL = 10.0 YEARS
DURATION FROM 60.0 MINUTES TO 1440.0 MINUTES
INTENSITY - DURATION EQ. OF FORM-- R=C*(DURAT**(-N))

RAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS

DURATION (MINUTES)	INTENSITY (INCH/HOUR)
60.0	1.840
120.0	1.120
1440.0	0.160

RESULTS OF ANALYSIS
C = 44.22 N = 0.7724

CORRELATION COEFFICIENT OF LINEAR REGRESSION = -.999743
FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = 0.999485

REGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS

DURATION (MINUTES)	I N T E N S I T Y (INCH/HOUR)		
	REGRESSION VALUE	LOWER LIMIT	UPPER LIMIT
60.0	1.872	1.616	2.168
120.0	1.096	0.975	1.231
1440.0	0.161	0.134	0.193

****

RECURRENCE INTERVAL = 25.0 YEARS
DURATION FROM 60.0 MINUTES TO 1440.0 MINUTES
INTENSITY - DURATION EQ. OF FORM-- R=C*(DURAT**(-N))

RAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS

DURATION (MINUTES)	INTENSITY (INCH/HOUR)
60.0	2.190
120.0	1.330
1440.0	0.191

RESULTS OF ANALYSIS
C = 52.29 N = 0.7711

CORRELATION COEFFICIENT OF LINEAR REGRESSION = -.999776
FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = 0.999552

REGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS

DURATION (MINUTES)	I N T E N S I T Y (INCH/HOUR)		
	REGRESSION VALUE	LOWER LIMIT	UPPER LIMIT
60.0	2.225	1.940	2.551
120.0	1.304	1.169	1.453
1440.0	0.192	0.162	0.227

****

RECURRENCE INTERVAL = 50.0 YEARS
DURATION FROM 60.0 MINUTES TO 1440.0 MINUTES
INTENSITY - DURATION EQ. OF FORM-- R=C*(DURAT**(-N))

RAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS

DURATION (MINUTES)	INTENSITY (INCH/HOUR)
60.0	2.440
120.0	1.480
1440.0	0.215

RESULTS OF ANALYSIS
C = 57.31 N = 0.7675

CORRELATION COEFFICIENT OF LINEAR REGRESSION = -.999812
FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = 0.999624

REGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS

DURATION (MINUTES)	I N T E N S I T Y (INCH/HOUR)		
	REGRESSION VALUE	LOWER LIMIT	UPPER LIMIT
60.0	2.474	2.184	2.803
120.0	1.454	1.317	1.605
1440.0	0.216	0.185	0.252

****

RECURRENCE INTERVAL = 100.0 YEARS
DURATION FROM 60.0 MINUTES TO 1440.0 MINUTES
INTENSITY - DURATION EQ. OF FORM-- R=C*(DURAT**(-N))

RAINFALL INTENSITY - DURATION DATA USED IN ANALYSIS

DURATION (MINUTES)	INTENSITY (INCH/HOUR)
60.0	2.700
120.0	1.640
1440.0	0.238

RESULTS OF ANALYSIS
C = 63.46 N = 0.7675

CORRELATION COEFFICIENT OF LINEAR REGRESSION = -.999797
FRACTION OF VARIANCE ACCOUNTED FOR BY REGRESSION = 0.999594

REGRESSION VALUES AND 90 PERCENT CONFIDENCE LIMITS

DURATION (MINUTES)	I N T E N S I T Y (INCH/HOUR)		
	REGRESSION VALUE	LOWER LIMIT	UPPER LIMIT
60.0	2.740	2.407	3.119
120.0	1.609	1.452	1.784
1440.0	0.239	0.203	0.281

****

A BACKWARD GLANCE

by Sheldon W. Sullivan, Chief of Data Collection

THE AMERICAN AUTOMOBILE: A BRIEF HISTORY OF THE DEVELOPMENT OF THE AMERICAN AUTOMOBILE AND THE GROWTH OF AUTOMOBILE REGISTRATIONS IN THE UNITED STATES, WISCONSIN, AND THE SOUTHEASTERN WISCONSIN REGION: 1896-1970

INTRODUCTION

The purpose of this article is two-fold: to relate a brief history of the development of the automobile in America, including highlights and remembrances of an auto age long past, and to present the remarkable historical growth in automobile registrations in the United States, the State of Wisconsin, the Southeastern Wisconsin Region, and in each of the seven counties which together comprise the Region.

BRIEF HISTORY OF THE DEVELOPMENT OF THE AMERICAN AUTOMOBILE

THE EARLY YEARS

Any attempt to precisely fix the birth date of the American automobile is very likely to be a fruitless enterprise, since the automobile as we know it today is unquestionably the product of experimentation and evolutionary development by many persons over many scores of years, and is still in the process of change. For many years after the invention of the steam engine, experiments were undertaken, first in Europe and later in America, to build, through application of the steam engine, self-propelled road vehicles. One, if not the very first, experimenter was Captain Nicholas Cugnot, a French artillery officer who before 1770 had constructed a huge, lumbering, three-wheeled contraption which was to be used as a steam-powered gun tractor.

The first successful American self-powered road vehicle may have been the crude amphibious steam dredge built about 1805 by Oliver Evans of Philadelphia, Pennsylvania, which could travel on its own power but at an exceedingly slow rate over the road or in shallow water. About 20 years later a steam vehicle was constructed by Thomas Blanchard of Springfield, Massachusetts, which could carry passengers, run forwards and backwards, and even climb hills at a fair rate of speed. In the early 1860s a light steam motor wagon constructed by Sylvester Roper of Roxbury, Massachusetts, was featured at circuses and fairs in the eastern United States, sometimes carrying stouthearted passengers, sometimes racing and usually winning against trotting horses, and sometimes not able to be run at all. Some claim the Roper vehicle to be America's first automobile. But these and many other experiments conducted in the United States and in Europe from the early 1800s through the next 80 years did not produce a single vehicle which could be considered a true prototype of the modern auto.

A great many of the early vehicles could be generally described as flat-bodied, four-wheeled wagons upon which a steam boiler was anchored, usually at the rear, with a raised bench for driver and passenger and a tiller for steering. In many types there was no roof, windshield, or fenders, and in some there were no headlights. In the first 80 years of the 19th century, both in America and abroad, emphasis was placed on the development of steam railroad locomotives and not on road vehicles. In the United States, vast extensions of railway systems used for military purposes during the Civil War further advanced the development of steam locomotives, and undoubtedly retarded the development of steam road vehicles and common roads. Contrary to what is probably commonly believed in the United States, the Europeans and not the Americans were in the end acclaimed for having perfected a true prototype of the modern automobile. Working independently in the mid-1880s, two German inventors, Gottfried Daimler and Karl Benz, each produced practical motor cars powered by an internal combustion engine several years before the first such successful American cars appeared.

The first successful inventors of American-made motor cars propelled by internal combustion engines are generally considered to be the brothers Charles and Frank Duryea of Springfield, Massachusetts, who built the "Duryea" car about 1893, and Elwood Haynes, who designed the "Haynes" which was built by the brothers Edgar and Elmer Apperson of Kokomo, Indiana, in about 1894. Both of these vehicles are now on exhibit in the Smithsonian Institute in Washington, D. C.

There appears to be considerable evidence, however, that a number of American gasoline-powered machines of the same or even earlier vintage were being driven at the time on America's streets and roads. One of the latter, for example, is said to have been driven in Milwaukee, Wisconsin, at least as early as 1892 by a local inventor, Gottfried Schloemer. This original Schloemer car is now on exhibit at the Milwaukee Public Museum. According to the records, there were also practical electric-powered and steam-powered motor cars in use prior to the advent of the Duryea and the Haynes. One such electric car is said to have been built in 1891 in Des Moines, Iowa, by William Morrison. Of the many early steam cars listed, one made by Dr. J. W. Carhart of Racine, Wisconsin, was constructed as early as 1871 to 1872. Other motor cars built in Wisconsin in this early period are said to be the Pennington, made in Racine in the early 1890s, and another said to be the first automobile sold in the United States, built by A. W. Ballard, an Oshkosh bicycle repairman, and sold in 1895.

An auto race from Chicago to Evanston, Illinois, was held in 1895 under the sponsorship of the Chicago Times-Herald newspaper. J. Frank Duryea, the winner, averaged about 7 m.p.h. over the distance. It is believed that this race was the first in the United States in which various makes of autos were entered.

THE BEGINNING OF THE INDUSTRY: 1896-1900

The beginning of the American automobile industry dates back, according to the automotive industry, a little over three-quarters of a century to 1896, when for the first time in America, multiple motor cars of the same design were built by a single manufacturer, the Duryea brothers. By that time, it is estimated that upwards of 80 one-of-a-kind motor cars had been constructed, although it is possible that as many more have escaped the notice of automobile historians as wagon builders, carriage makers, machine shop operators, bicycle manufacturers, farm implement makers, and innumerable home mechanics began to tinker with this marvelous new form of transportation which represented, according to one historian, "the only improvement in road transportation since Moses."[1] In the first years of the new industry, designs of the wagon and carriage makers prevailed. Holding to established forms, their new products strongly resembled the old, and indeed were called horseless carriages and wagons or horseless buggies as the terms might apply.

The chief reliance at the turn of the century was still by far on electric and steam-driven cars. This gradually changed and the gasoline car became dominant in the industry, with the decline of the electric car beginning after 1905 and that of the steam car after 1910, with both kinds, however, remaining in substantial use for a decade or two. The decline of these two kinds of automobiles was brought about principally, in the case of the electric auto, by the limit of its range before recharge of batteries was necessary and by its lack of speed, and in the case of the steam auto, by problems of water storage and excessive water weight.

It is estimated that by 1900 at least 400 different makes of American cars had been built. For a large majority of these, manufacture ceased within a year and consisted almost entirely of experimental cars and "homemade" machines. But a number of makes in this era remained in production for many years, such as the Stanley Steamer, the Waverley Electric, and the Winton, all of which were produced for more than 20 years; the Haynes, Locomobile, Peerless, and the Stearns, each in production for more than 30 years; the Packard, remaining in production for nearly 60 years; and the Ford and Oldsmobile, which are still in production after more than 70 years.

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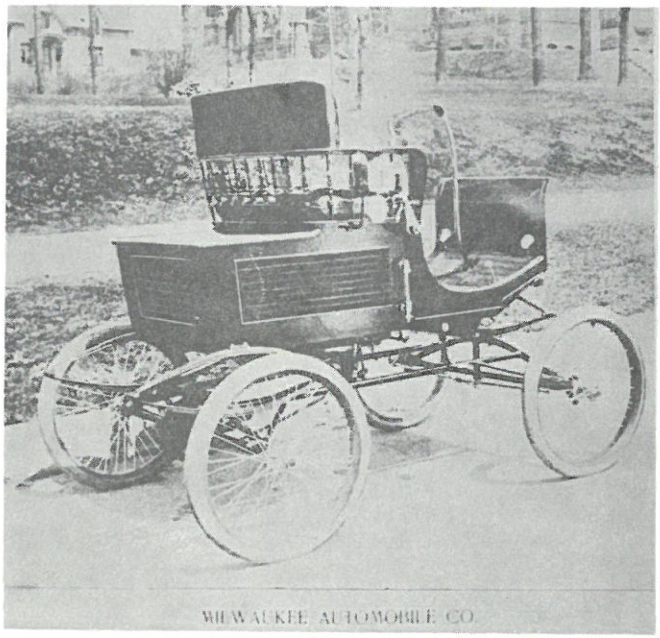
[1] *James R. Doolittle, The Romance of the American Automobile Industry, Klebold Press, 1916.*

In 1897 the Milwaukee Steamer, built by the Milwaukee Automobile Company, made its first appearance. The manufacturers gave the following description of it: "Our carriage is a light, well-constructed four-wheeled vehicle with one seat, and contains within itself a complete automatic steam power plant with storage tanks for water and the fuel, which is gasoline. This is burned in a strong, standard boiler, thereby generating steam, which operates a small but powerful engine. This engine transmits its motion by a chain to the rear axle and rear wheels, which propel the carriage. Both front and rear wheels are 28 inches in diameter and have 2-1/2" pneumatic puncture-proof tires. The wheels have wire spokes and metal rims. The carriage weighs 700 pounds and the price is $750."



In 1897, Emil Estberg of Waukesha drove this Milwaukee Steamer, manufactured by the Milwaukee Automobile Company, from Milwaukee to Waukesha. His two-passenger steam-powered auto was reportedly the first automobile to be operated on the streets of Waukesha. Mrs. Estberg learned to drive her husband's Milwaukee Steamer, and reportedly became the first woman to drive an auto in the State of Wisconsin.

Photo Courtesy of the Waukesha County Historical Society.

In 1900, factory sales of American-made passenger cars totaled about 4,200; the first national auto show opened November 3 in New York City; and the first use of the French term "automobile" was being heard in America. The automobile boom had now begun, but only just begun.

THE BOOM YEARS: 1901-1930

The Europeans may have won the race to build the automobile prototype, but it was the Americans who rapidly improved and produced it in huge numbers. Wagons and carriage makers and especially farm machinery manufacturers, sensing or recognizing the commercial possibilities in this revolutionary vehicle and therein a serious threat of unwanted competition to their industries, quickly turned to its manufacture. Still others, such as machinists, home and farm amateur mechanics, and would-be inventors became part of the development of the automobile, less for financial reasons than simply for the satisfaction and delight of building their own machines.

During the first decade of the new century more than 1,000 new makes of American cars were constructed, and perhaps even more remarkably, another approximately 1,000 new makes were to appear in the decade to follow. To place these numbers in perspective, it is estimated that less than 400 new makes of cars were built in the decade ending in 1930, and only a few more than 100 new makes have been built in all the years since then. The large majority of new makes constructed from 1901 to 1920 was short-lived, for it is estimated that only about 35 percent survived the first year of manufacture and that less than 10 percent survived five years of manufacture. As in the earliest periods, many of the makes were also one-of-a-kind consisting for the most part of experimental makes or the homemade variety.

Soon after the turn of the century, the lines and styling of the horseless carriages and buggies were replaced by a design borrowed from the French, including its name, "tonneau," in which a back seat was added to the open carriage, entered directly by side doors. Canvas or leather folding tops were now being used on roadsters and touring cars, oil cloth or leather side curtains with isinglass windows could be attached in stormy weather, and a steering wheel still on the right side had replaced the tiller.

Within the first decade of the 20th century, Henry Ford, after the manufacture of eight previous models, on October 1, 1908, introduced the Model T, soon to be affectionately known as the "Tin Lizzie" and to become and remain the most famous of all American automobiles. Indeed, a greater number of this car were produced in essentially the original design than any other car of record except the German Volkswagen. In the approximately 19 years of production ending in 1927, 15,007,033 Ford Model T passenger cars were produced. In comparison, Volkswagen number 15,007,034 was produced in February 1972 after approximately 26 years of production. The 15 millionth Volkswagen car was sent to the Smithsonian Institute in Washington, D. C. in June 1972. Other famous makes appearing in that first decade included Auburn, Buick, Cadillac, Chalmers, Detroit Electric, Franklin, Hupmobile, Wisconsin's Kissel, Marmon, Maxwell, Mercer, Metz, Wisconsin's Mitchell, Moon, Oakland, Pierce-Arrow, Premier, Reo, Willys-Overland, Wisconsin's Rambler, and Studebaker, among others.

Two brothers, Harry and Edward Smart, owned this garage, the first in the Village of Eagle shortly after the turn of the century.

Photo Courtesy of the Waukesha County Historical Society.

Other Wisconsin-made automobiles in addition to the Kissel, Mitchell, and Rambler built during this period were the Badger auto built by Four Wheel Drive Auto Company in Clintonville; another Badger auto made in Columbus; the Burdick auto made in Eau Claire; the Clark-Hatfield and the T-M-F autos both made in Oshkosh; the Monitor and the Owen-Thomas autos both built in Janesville; the Petrel and the Earl autos built by the same firm, first in Milwaukee and later in Kenosha; the Piggins and the Pierce-Racine autos both made in Racine; the Fawick auto body made by Charles Abresch Company of Milwaukee, the frame built by A. O. Smith Company in Milwaukee and the engine built by Waukesha Motor Company, Waukesha; and the Earl, Eclipse, F-S, Haase, Hay Berg, Ideal, Johnson, Krueger, Kunz, and Merkel autos and another Milwaukee auto (this one a gasoline-powered auto) all built in Milwaukee.

By 1910, traffic laws were being enacted and licensing of motor vehicles and auto drivers was required in most states. A number of seemingly impossible transcontinental trips by auto had been completed as early as 1903 despite the lack of roads, bridges, filling stations, garages, and other essentials. One auto named the Old Pacific, which made the trip as early as 1903, is preserved today in the Greenfield Museum in Dearborn, Michigan. The popularity of auto racing was rapidly spreading, with one racer attaining an average speed of more than 2 miles per minute in a Stanley Steamer "Rocket" as early as 1906. Annual endurance trips called Glidden Tours were begun in 1905, the first of which was an 870-mile round trip from New York City to Bretton Woods, New Hampshire via Hartford and Boston, which provided a severe test for both driver and vehicle. The automobile provided inspiration for songwriters almost from the beginning of the industry. One of dozens of such compositions, entitled "In My Merry Oldsmobile," was written in 1905 and has retained its popularity to this day. Also in this decade, in 1908, General Motors Corporation was founded. In 1910, factory sales of American passenger cars reached approximately 181,000 for the year compared to about 4,200 cars produced in 1900. The boom would continue.

In the second decade of the century, mass production of automobiles, barely begun in the previous decade, exploded throughout the industry. The number of automobiles built exceeded 10 million, 20 times the number built in the first decade, despite the disruptive influence on production of America's entry into World War I in 1917. Despite the very large increase in the number of autos produced, the number of new auto makes produced decreased slightly, particularly in the last half of the decade, influenced to some degree by the exigencies of war.

In the first years of the decade, the first Indianapolis 500-mile race was held on Memorial Day, 1911, and was won by a Marmon driven by Ray Harroun, averaging about 75 m.p.h.; electric headlights were introduced; self-starters had come into more common use although hand cranking on many makes was still necessary; purchase of autos on the installment plan began; an oil company became the first to distribute free road maps; a number of manufacturers turned to the use of metal disc wheels and wire wheels; the steering wheel was moved to the left side on most autos; and a new federal law called for the establishment of an integrated nationwide highway system. As America entered World War I the automobile industry pledged full cooperation to the government, and began to convert its factories to the production of shells, tanks, guns, gun carriages, aircraft engines, and naval craft. Auto production, although not halted in the war, was reduced by nearly one-half in 1918 from the previous year. A statewide system of identifying highway routes by marking numbers on routes and on maps was developed in Wisconsin in 1918 and was soon adopted by all other states and many foreign countries as well.

By the end of the decade the number of "closed" cars was estimated at about 10 percent of total auto production. New makes of autos introduced in the decade which were to become successful and remain in manufacture for a considerable length of time included the Chandler, Chevrolet, Doble Steam Car, Dodge, Duesenberg, Elcar, Essex, Jordan, Nash, the elegant Rolls-Royce, Scripps-Booth, Stutz, and Willys-Knight, among others.

In Wisconsin during this period a number of small, light cars called cyclecars were built, including the Flagler cyclecar made in Sheboygan, the True cyclecar made in Kenosha, the Ziebel cyclecar built in Oshkosh, and the Billiken, Vixen, and Ward cyclecars, all built in Milwaukee. In 1914, the Jeffery Company dropped the name Rambler and replaced it with the name Jeffery. Two years later the Jeffery firm was purchased by Charles W. Nash, who in 1917 manufactured an auto bearing his name and which was to remain in manufacture for nearly 40 years. Other makes built in this period included the Case, Lewis, and Maibohm autos, all built in Racine; the AEC, Ogren, and the Smith Flyer auto, the latter built by A. O. Smith Company and all built in Milwaukee; the Superior made in Superior; the Ritter and the Cruiser autos, both made in Madison; and the Wisco auto built in Janesville. In 1920, factory sales of American passenger cars reached an all-time record of 1,905,000 compared to 181,000 a decade earlier.

In the century's third decade ending in 1930, the number of new auto makes in the industry decreased sharply to less than 40 percent of each of the two previous decades, and as before, probably as many as 80 percent of those produced were to remain in production for less than one year. In the decade, safety glass, balloon tires, and hot water heaters were first introduced; gasoline gauges began to appear on instrument panels; closed cars rose from 10 percent of total auto production at the beginning of the decade to 90 percent at the end; straight-eight engines became a trend in several auto makes, while in one make V-12 and V-16 engines were also offered; and four-wheeled brakes became standard equipment on nearly all new makes and models. In May 1927 the last Model T Ford left the assembly line, ending 19 consecutive years of production of a single model and setting a record which was to endure for more than 40 years. In November 1927 a second edition of the Model A Ford was introduced. The original Model A, a far more primitive design, had appeared in 1903. This new Model A has been acclaimed by many in recent years as one of the best of America's "classic" automobiles.

In the decade, new makes which were to gain considerable popularity included Ambassador, Chrysler, Cord, DeSoto, Durant, Erskine, Graham, Imperial, LaSalle, Plymouth, Pontiac, Rickenbacker, and Willys, among others. In Wisconsin in the decade the sporty Jay-Eye-See auto was produced by the J. I. Case Company of Racine, the auto borrowing its name from the initials of the firm; the Winther auto was built in Kenosha; the Ambassador, Lafayette, and Ajax autos were produced by the Nash Motor Company of Kenosha, the last named built in Racine; the Harris auto was made in Menasha; the nine-passenger Samson was built in Janesville; the Ruxton auto was manufactured in Hartford briefly by the Kissel Motor Car Co.; and the experimental Briggs and Stratton Flyer was built in Milwaukee.

Factory sales of American automobiles, after dipping from about 1.9 million in 1920 to less than 1.5 million in the post-war Depression year of 1921, climbed rapidly, if erratically, to an astonishing 4.6 million in 1929, a figure not to be equaled again for 20 years. In 1930, factory auto sales plummeted to approximately 2.8 million, a decrease of 1.8 million, or about 40 percent in a single year, as the Great Depression began. The boom years in new makes of autos were ended, and the boom in the number of autos produced annually was over, at least for a time. Notwithstanding, nearly 32 million American automobiles were produced in the decade, nearly three times the total number produced in America up to that decade.

THE YEARS OF THE GREAT DEPRESSION AND OF WORLD WAR II AND ITS AFTERMATH: 1931-1950

In the Depression years of the 1930s, the number of new American auto makes dropped abruptly to little more than a score, reflecting the great severity of business decline throughout the nation. During the decade, hand brakes were moved to the driver's left side, automatic transmission was introduced, and streamline design was a feature on several makes of autos. Power brakes, the automatic choke, a steering column gearshift, a windshield washer, sealed beam headlight, and an early version of an air-conditioning unit were among other innovations in the industry. Also in the decade, the first of the true freeways in the United States, the Pennsylvania Turnpike, was opened to traffic.

Among the new auto makes produced in the 1930s, Lincoln Continental and Mercury were probably the most successful. Other popular new makes of cars included American Bantam, Crosley, Rockne, Terraplane, and Ford's Zephyr, but of these, only the Crosley was to remain in production for more than a few years. During the decade, factory auto sales ranged from a low of about 1.1 million in 1931 in the depth of the Depression to a high of 3.9 million in 1937 as the nation's business climate improved. A sharp recession in 1938 dropped factory sales to about 2.0 million for that year, but by the end of the decade in 1940 sales had rebounded to approximately 3.7 million, an improvement which was to be short-lived, however. Total factory sales for the decade amounted to about 26.3 million, down about 5.5 million from the total of the previous decade.

As America's entry into World War II appeared inevitable in the late 1930s, the production of war material by the American automobile industry began, and was accelerated greatly with the approach and actuality of war. Within about two months after the attack on Pearl Harbor, all production of civilian automobiles ceased, and the full force of the automobile industry was directed to the production of material for the armed forces.

According to the records, there were no new makes of autos produced during the war years, but after the war, in the remaining years of the decade, there were about 40 new makes listed. The best known of these were Frazer, Kaiser, Tucker Torpedo, and the Henry J., all of which were to remain in production for a relatively few years, and none more than seven years. One Wisconsin-made auto was built in this decade. It was a small two-passenger car called the "Pup," manufactured in Spencer but which appears to have failed to survive beyond its first year of manufacture. One military vehicle developed during the war, however, the "Jeep," was modified and manufactured in substantial numbers immediately after the war for civilian use by Willys-Overland. During the 1940s, radio telephones were in use in some autos, and power-operated windows, tubeless tires, seat belts, and hardtop roofs were also in use in many auto makes.

In 1950, factory sales of American automobiles were nearly 6.7 million, an all-time high. The total factory sales for the decade were about 25.5 million, and the total sales of the industry from its beginning stood at 94.4 million.

THE LATE YEARS: 1951-1970

The coming of the Korean War in the early 1950s again brought material shortages and government restrictions relating to the production of automobiles for civilian use, and brought military contracts to most major automobile manufacturers as well. Among the approximately 20 new auto makes introduced in the decade, the better known were the Allstate produced by Kaiser-Frazer Corporation for Sears, Roebuck and Company, and the ill-fated Edsel and the glamorous Thunderbird, both built by the Ford Motor Company.

It was a decade of freeway construction for a number of states, including Connecticut, Indiana, Kansas, Ohio, New Jersey, New York, West Virginia, and Wisconsin. The Highway Act of 1956 called for the construction of a nationwide interstate highway system of 41,000 miles for which the federal government pledged to pay 90 percent of construction costs. The first portion of the Wisconsin interstate system was opened to traffic in September 1958. By the end of the decade more than 9,000 miles of interstate highways of the system had been completed within the United States. The first section of freeway within the Region was open to traffic in September 1958. It was a 2.6-mile section of IH 94 in Waukesha County. Additional sections of IH 94 were open to traffic in Kenosha and Racine Counties in 1960. The first section of freeway in Milwaukee County, however, was not opened to traffic until 1962.

In 1954, following the amalgamation of the Hudson Motor Car Company of Detroit and the Nash Motor Company of Kenosha to form the American Motors Corporation, the production of Hudson autos was transferred from Detroit to Kenosha.

Innovations during the decade included power steering, safety padding on dashes, unit body construction, sliding roofs, and swing-away steering wheels. During the decade, factory auto sales ranged from a low of 4.3 million in the war year of 1952 to a new all-time high of 7.9 million in 1955. Following an economic recession in the late 1950s, the industry ended the decade in 1960 with sales of 6.7 million. Total factory sales for the decade were 57.7 million, also a new all-time high for a decade, and the total sales of the industry from its beginning reached 152 million.

In the 1960s, the number of new auto makes dwindled to scarcely a score, of which the best known were the Avanti II, made by Avanti Motor Corporation, South Bend; AMX, Gremlin, Hornet, Javelin, and Rebel, all built by American Motors; Excalibur SS, made in Milwaukee; the Mustang and the Maverick built by the Ford Motor Company; and the Cobra, built by Shelby American, Inc., of Los Angeles, although the chassis and body of the Cobra were imported from England. Also in Wisconsin in this period, the unusual and expensive Mohs auto, built in Madison, made its appearance. There were numerous experimental cars built mainly by the four major American manufacturers, as well as numerous changes in the names and designs of models within various makes.

In the decade, dual brake systems, dual tail lights, rear seat belts, and disc brakes become standard equipment on many makes. General Motors Corporation and Ford Motor Company each began experimentation with electric automobiles, collapsible steering columns were being installed on most makes, air-conditioning units were contained in about 40 percent of the total cars produced by the end of the 1960s, and Congress was proposing experimentation with steam cars.

During the decade, factory auto sales ranged from a low of about 5.5 million in 1961 to an all-time high of 9.3 million in 1965; averaging for the decade about 7.7 million autos per year. The total number of factory auto sales in the decade amounted to about 76.7 million, a new record, and the total number of factory auto sales since the beginning of the industry stood at about 228 million, nearly 60 percent of which were made since 1950.

SUMMARY

It is estimated that since the first successful automobile was constructed in the United States, from 1,250 to 1,500 American automobile manufacturers have produced to date approximately 2,500 to 3.000 different makes of automobiles. Many of the early manufacturers built only a few autos of a single make, some of them experimental, some homemade. Other manufacturers built hundreds or thousands of automobiles of a single make; and some manufacturers such as Ford, Buick, and Chevrolet built millions of the same make. Henry Ford, for example, produced more than 15 million Model T cars by 1927.

Today, the number of American automobile manufacturers can be counted on the fingers of both hands, with major manufacturers on one hand. Mergers, consolidations, and most importantly the Great Depression exacted their toll as famous makes dropped from the roster, including Auburn, Cord, Duesenberg, Essex, Franklin, Hudson, Kissel, Nash, Packard, Pierce-Arrow, LaSalle, Rambler, Reo, Rolls-Royce, Studebaker, Stutz and many, many more. The number of factory sales of American-made automobiles grew from an average of 50,000 per year for the decade ending in 1910 to an average of nearly 3.2 million per year for the decade ending in 1930, and from an average of nearly 5.8 million per year for the decade ending in 1950 to an average of nearly 7.7 million per year for the decade ending in 1970. The enchantment of the American man and woman with the automobile is obvious from these figures.

It is interesting to note that while the automobile industry is presently engaged in the development of gas turbine engine automobiles, it is presently engaged, after a 50-year lapse, in the experimental development of steam-powered and electric-powered automobiles.

AUTOMOBILE REGISTRATIONS IN THE UNITED STATES, WISCONSIN, AND THE SOUTHEASTERN WISCONSIN REGION: 1896-1970

INTRODUCTION

The growth in the number of automobile registrations in the United States, Wisconsin, the Southeastern Wisconsin Region, and each of the seven constituent counties of the Region has been almost continuous since auto registration data were first recorded, checked principally only in the years of the Great Depression of the 1930s and in the years of World War II in the following decade. In the first few years of the new industry and for many years in certain states, automobile registration was strictly a voluntary matter. New York in 1901 became the first state to require registration of all motor vehicles, and by 1905, 24 other states and the District of Columbia had made similar requirements, including the State of Wisconsin in 1905. By 1915, all states and the District of Columbia had enacted registration laws, but four states had perennial registration requirements only. It was not until 1921 that annual registration was a requirement of every state. Hawaii and Alaska, both U. S. territories at the time, enacted annual registration laws in 1906 and 1932, respectively (see Table 1).

Automobile registration data presented in this article for the years 1896 to 1899 represent estimates of the number of automobiles in use in the entire United States for each of those years, since automobile registration was not required in any state until 1901. Data for the years 1901 to 1914 represent registrations for those states which enacted motor vehicle registration laws and estimates of automobiles in

Table I

YEAR IN WHICH MOTOR VEHICLES WERE FIRST REGISTERED BY STATE: 1901-1932

STATE	1901	1902	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1932
ALABAMA			PERENNIAL								ANNUAL											
ALASKA																						ANNUAL
ARIZONA												ANNUAL										
ARKANSAS											ANNUAL											
CALIFORNIA					PERENNIAL									ANNUAL								
COLORADO													ANNUAL									
CONNECTICUT			PERENNIAL							ANNUAL												
DELAWARE					PERENNIAL		ANNUAL															
FLORIDA					PERENNIAL						COUNTY ANNUAL							STATE ANNUAL				
GEORGIA										ANNUAL												
HAWAII						ANNUAL																
IDAHO													ANNUAL									
ILLINOIS							PERENNIAL		ANNUAL													
INDIANA					PERENNIAL								ANNUAL									
IOWA				PERENNIAL							ANNUAL											
KANSAS													ANNUAL									
KENTUCKY										ANNUAL												
LOUISIANA															ANNUAL							
MAINE					PERENNIAL							ANNUAL										
MARYLAND				PERENNIAL						ANNUAL												
MASSACHUSETTS			PERENNIAL					ANNUAL														
MICHIGAN					PERENNIAL					ANNUAL												
MINNESOTA			PERENNIAL			ANNUAL						TRIENNIAL									ANNUAL	
MISSISSIPPI												ANNUAL										
MISSOURI			PERENNIAL								ANNUAL											
MONTANA													PERENNIAL		ANNUAL							
NEBRASKA					PERENNIAL		ANNUAL															
NEVADA													ANNUAL									
NEW HAMPSHIRE					ANNUAL																	
NEW JERSEY			PERENNIAL			ANNUAL																
NEW MEXICO												ANNUAL										
NEW YORK	PERENNIAL									ANNUAL												
NORTH CAROLINA							PERENNIAL		ANNUAL													
NORTH DAKOTA											ANNUAL											
OHIO						PERENNIAL		ANNUAL														
OKLAHOMA											ANNUAL											
OREGON					PERENNIAL						ANNUAL											
PENNSYLVANIA			LOCAL PERENNIAL			ANNUAL																
RHODE ISLAND				PERENNIAL				ANNUAL														
SOUTH CAROLINA						COUNTY PERENNIAL											ANNUAL					
SOUTH DAKOTA					PERENNIAL								ANNUAL									
TENNESSEE						PERENNIAL									ANNUAL							
TEXAS							COUNTY PERENNIAL										ANNUAL					
UTAH									PERENNIAL						ANNUAL							
VERMONT				PERENNIAL					ANNUAL													
VIRGINIA						PERENNIAL				ANNUAL												
WASHINGTON					ANNUAL																	
WEST VIRGINIA					ANNUAL																	
WISCONSIN					PERENNIAL						ANNUAL											
WYOMING													ANNUAL									
DISTRICT OF COLUMBIA			PERENNIAL															ANNUAL				

LEGEND

AUTOMOBILE REGISTRATION REQUIREMETS

NONE — PERENNIAL — ANNUAL — TRIENNIAL

use for those states not having enacted such laws. For the years 1915 to 1970, all numbers were obtained from actual auto registration data.[2]

REGISTRATIONS FOR THE PERIOD 1896-1915

In 1896, the year that reportedly marked the beginning of the automobile industry in America, a total of 16 automobiles were reported to have been registered in the entire United States (see Table 2). By 1900 the number of automobiles registered in the United States had increased sharply to 8,000, and grew rapidly from 77,400 in 1905 to 458,000 in 1910 to 2.3 million in 1915 as mass production techniques were applied to the industry to meet the enormous demand of an obviously delighted public. Wisconsin's share of the nation's automobiles was estimated at 200 in 1900, 1,500 in 1905, 6,000 in 1910, and about 80,000 in 1915.

Automobile registration data by county in Wisconsin first became available for the year 1915. In that year Milwaukee County reportedly had about 13,000 auto registrations of a regional total of 22,000, with Racine, Walworth, and Waukesha Counties following in that order with about 2,000 registrations each. Kenosha and Washington Counties were next with about 1,200 registrations each, and Ozaukee County trailed with about 600 auto registrations.

Table 2

NUMBER OF AUTOMOBILE REGISTRATIONS FOR THE UNITED STATES, WISCONSIN, AND THE REGION BY COUNTY: 1896-1915

GEOGRAPHIC AREA	NUMBER OF AUTOMOBILE REGISTRATIONS (IN THOUSANDS)									
	1896	1897	1898	1899	1900	1901	1902	1903	1904	1905
UNITED STATES	.016	.090	.800	3.2	8.0	14.8	23.0	32.9	54.6	77.4
WISCONSIN	--	--	--	--	0.2	0.3	0.5	0.6	1.0	1.5
SOUTHEASTERN WISCONSIN REGION										
KENOSHA COUNTY....	--	--	--	--	--	--	--	--	--	--
MILWAUKEE COUNTY..	--	--	--	--	--	--	--	--	--	--
OZAUKEE COUNTY....	--	--	--	--	--	--	--	--	--	--
RACINE COUNTY.....	--	--	--	--	--	--	--	--	--	--
WALWORTH COUNTY...	--	--	--	--	--	--	--	--	--	--
WASHINGTON COUNTY.	--	--	--	--	--	--	--	--	--	--
WAUKESHA COUNTY...	--	--	--	--	--	--	--	--	--	--
TOTAL...........	--	--	--	--	--	--	--	--	--	--

GEOGRAPHIC AREA	NUMBER OF AUTOMOBILE REGISTRATIONS (IN THOUSANDS)									
	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915
UNITED STATES	105.9	140.3	194.4	305.9	458.4	618.7	901.6	1,190.3	1,664.0	2,332.4
WISCONSIN	1.2	1.5	2.0	3.0	6.0	6.2	24.6	34.6	53.2	79.8
SOUTHEASTERN WISCONSIN REGION										
KENOSHA COUNTY....	--	--	--	--	--	--	--	--	--	1.2
MILWAUKEE COUNTY..	--	--	--	--	--	--	--	--	--	13.0
OZAUKEE COUNTY....	--	--	--	--	--	--	--	--	--	0.6
RACINE COUNTY.....	--	--	--	--	--	--	--	--	--	2.1
WALWORTH COUNTY...	--	--	--	--	--	--	--	--	--	2.0
WASHINGTON COUNTY.	--	--	--	--	--	--	--	--	--	1.2
WAUKESHA COUNTY...	--	--	--	--	--	--	--	--	--	1.9
TOTAL...........	--	--	--	--	--	--	--	--	--	22.0

[2] *National estimates for the years 1896 to 1899 and for the years 1966 to 1970 were obtained from Automobile Facts and Figures, Automobile Manufacturers Association, 1948 and 1972 editions. National estimates for the years 1900 to 1965 and State of Wisconsin estimates for the years 1900 to 1904 were obtained from Highway Statistics Summary to 1965, U. S. Department of Transportation, Federal Highway Administration, 1967. Estimates for the State of Wisconsin and for the seven counties in the Region from 1905 to 1970 were obtained from calendar year motor vehicle registration reports prepared by the Wisconsin Department of Transportation, Division of Motor Vehicles.*

REGISTRATIONS FOR THE PERIOD 1916-1935

Despite America's entry into World War I in 1917 and the resulting reduction in automobile production by approximately one-half in 1918, when auto factories became arsenals for the armed forces, increases in auto registration were recorded in each succeeding year from 1916 to 1929 for the nation, state, Region, and each county within the Region. National registrations increased from 2 million in 1915 to 8.1 million in 1920, and from 17 million in 1925 to 23 million in 1929, or more than 10 times the number registered in 1915. In Wisconsin, auto registrations increased from about 80,000 in 1915 to 277,000 in 1920, and from 530,000 in 1925 to 689,000 in 1929, more than eight times the 1915 registrations. In the Region, auto registrations increased at a somewhat greater rate than the state, increasing from 22,000 in 1915 to 65,000 in 1920, and from 147,000 in 1925 to 213,000 in 1929, or about 10 times the 1915 total (see Table 2).

By county, auto registration increases in 1929 ranged from more than four to more than 10 times the 1915 figure. From 1915 to 1935, Milwaukee County registrations increased from 13,000 to more than 139,000, Kenosha County registrations increased from 1,000 to 12,000, Racine County registrations increased from 2,000 to 18,000 during the period, and Walworth County registrations increased from 2,000 to 9,000.

The effects of the Great Depression of the 1930s stopped the long, continued, year by year surge in auto registrations in most instances. In 1930, the first full year of the Depression, national, state, regional, and county losses were slight, but the losses deepened in 1931 and 1932, reaching a low point in 1933. In the span from 1929 to 1933, decreases in auto registrations nationally were about 2.5 million, or about 11 percent; in the state they were about 134,000, or nearly 20 percent; and in the Region they were about 34,000, or about 15 percent. By the end of 1935, as the economy improved, auto registrations were slowly climbing back to approximately the 1931 levels.

Table 2 (Continued)
1916-1935

GEOGRAPHIC AREA	NUMBER OF AUTOMOBILE REGISTRATIONS (IN THOUSANDS)									
	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925
UNITED STATES	3,367.9	4,727.5	5,555.0	6,679.1	8,131.5	9,212.2	10,704.1	13,253.0	15,436.1	17,439.7
WISCONSIN	115.6	164.5	190.0	226.1	277.1	319.5	361.1	422.7	476.4	529.9
SOUTHEASTERN WISCONSIN REGION										
KENOSHA COUNTY....	1.8	2.4	2.7	3.4	4.5	4.8	5.7	7.3	8.5	9.8
MILWAUKEE COUNTY..	17.3	23.3	23.7	28.2	36.2	44.3	54.5	68.3	79.7	94.4
OZAUKEE COUNTY....	0.9	1.4	1.6	1.8	2.1	2.4	2.8	3.0	3.4	3.7
RACINE COUNTY.....	2.8	3.6	4.6	5.8	7.4	8.4	9.5	11.9	13.0	14.7
WALWORTH COUNTY...	2.7	3.6	3.8	4.2	4.9	5.6	6.3	7.0	7.5	7.8
WASHINGTON COUNTY.	1.9	2.8	3.1	4.0	4.1	4.5	5.1	5.4	5.7	6.0
WAUKESHA COUNTY...	2.7	3.9	4.4	5.0	5.9	6.7	7.8	8.8	9.8	10.5
TOTAL...........	30.1	41.0	43.9	52.4	65.1	76.7	91.7	111.7	127.6	146.9
GEOGRAPHIC AREA	NUMBER OF AUTOMOBILE REGISTRATIONS (IN THOUSANDS)									
	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
UNITED STATES	19,220.9	20,142.2	21,308.2	23,060.4	22,972.7	22,330.4	20,832.4	20,586.3	21,472.1	22,494.9
WISCONSIN	581.4	610.0	646.2	688.9	676.9	639.9	587.5	555.5	588.7	623.4
SOUTHEASTERN WISCONSIN REGION										
KENOSHA COUNTY....	11.3	11.6	12.7	13.7	12.6	11.6	10.8	10.2	11.3	12.0
MILWAUKEE COUNTY..	109.1	117.9	128.2	142.8	142.6	135.4	125.5	121.6	132.0	139.5
OZAUKEE COUNTY....	3.9	4.1	4.3	4.6	4.6	4.5	4.4	4.2	4.5	4.7
RACINE COUNTY.....	16.2	17.5	18.6	20.9	20.0	18.4	16.2	15.2	16.7	18.5
WALWORTH COUNTY...	8.3	8.6	9.0	9.5	9.5	9.3	8.9	8.5	8.7	9.0
WASHINGTON COUNTY.	6.4	6.8	7.0	7.3	7.3	7.0	6.6	6.6	6.9	7.1
WAUKESHA COUNTY...	11.6	12.3	13.1	14.7	14.8	14.3	13.5	12.9	13.4	14.1
TOTAL...........	166.8	178.8	192.9	213.5	211.4	200.5	185.9	179.2	193.5	204.9

REGISTRATIONS FOR THE PERIOD 1936-1955

As the economy of the country continued to improve in 1936 and 1937, auto registrations again increased, reaching all-time records in the nation, state, Region, and in each of the seven counties in the Region in 1937. The economic recession in 1938 and 1939 caused slight decreases in auto registrations, but in 1940 and 1941 such registrations again established new records in the nation (29.5 million); state (807,000); Region (277,000); and in each of the Region's counties, with Milwaukee County alone totaling about 190,000.

America's entry into World War II decreased auto production drastically in 1942 to 6 percent of the previous year, and virtually stopped production altogether in 1943 and 1944. In the four-year period 1942 through 1945, fewer than 300,000 autos were built, as American auto manufacturing plants converted almost totally to the production of ordnance of a great variety and volume for the armed forces. From 1941 through 1944 auto registrations decreased in the United States by 4 million, from 29.5 million to 25.5 million; in Wisconsin by 120,000, from 808,000 to 688,000; and in the Region by 49,000, from 277,000 to 228,000. Within the Region during this period Milwaukee County registrations decreased by 39,000, from 190,000 to 151,000, while registrations in the other counties also decreased, ranging from as little as 500 in Ozaukee County to as much as 3,500 in Racine County (see Table 2).

In the years immediately following the end of World War II, the numbers of auto registrations increased rapidly throughout the nation, state, Region, and each county within the Region. By 1947, prewar registration records were finally surpassed and new records were established year by year in the nation, state, Region, and counties within the Region, including the years of the Korean conflict in the early 1950s. Registrations increased in the nation from 40 million in 1950 to nearly 52 million in 1955, in the state from 961,000 in 1950 to 1.1 million in 1955, and in the Region from 341,000 to 429,000 in 1955. In 1955, Milwaukee County registrations were more than 280,000; Racine County and Waukesha County registrations were 40,000 and 39,000, respectively; while Walworth, Washington, and Ozaukee County registrations were 17,000, 13,000, and 10,000, respectively.

Table 2 (Continued)
1936-1955

GEOGRAPHIC AREA	NUMBER OF AUTOMOBILE REGISTRATIONS (IN THOUSANDS)									
	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
UNITED STATES	24,108.2	25,390.8	25,167.0	26,139.5	27,372.4	29,524.1	27,868.7	25,912.7	25,466.3	25,694.9
WISCONSIN	690.0	712.5	703.2	705.1	751.0	807.8	688.4	694.5	687.7	693.7
SOUTHEASTERN WISCONSIN REGION										
KENOSHA COUNTY....	13.4	14.1	13.5	13.7	14.7	16.4	14.5	14.4	14.6	14.3
MILWAUKEE COUNTY..	157.6	164.4	159.6	161.1	173.7	189.7	157.2	159.0	150.9	155.1
OZAUKEE COUNTY....	5.1	5.3	5.0	5.0	5.5	5.9	5.2	5.4	5.4	5.5
RACINE COUNTY.....	20.9	22.5	22.0	21.5	23.1	25.1	21.5	21.8	21.6	21.3
WALWORTH COUNTY...	9.7	9.7	9.7	9.6	10.4	10.8	9.0	9.4	9.6	9.8
WASHINGTON COUNTY.	7.4	7.5	7.4	7.4	7.9	8.7	7.6	7.8	7.9	8.1
WAUKESHA COUNTY...	15.5	16.0	16.0	15.9	17.5	20.2	17.2	18.0	18.1	18.4
TOTAL...........	229.6	239.5	233.2	234.2	252.8	276.8	232.2	235.8	228.1	232.5
GEOGRAPHIC AREA	NUMBER OF AUTOMOBILE REGISTRATIONS (IN THOUSANDS)									
	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955
UNITED STATES	28,103.9	30,722.9	33,218.3	36,317.0	40,190.6	42,530.9	43,659.1	46,258.3	48,293.5	51,960.5
WISCONSIN	744.4	792.9	829.1	897.6	961.1	1,000.1	1,003.2	1,056.0	1,092.5	1,135.8
SOUTHEASTERN WISCONSIN REGION										
KENOSHA COUNTY....	14.4	16.6	17.8	19.3	21.7	23.4	24.0	25.7	26.0	28.4
MILWAUKEE COUNTY..	177.7	176.4	187.9	212.6	228.4	239.5	244.4	255.4	266.7	280.6
OZAUKEE COUNTY....	6.2	6.2	6.5	7.0	7.6	8.1	8.2	9.1	9.6	10.4
RACINE COUNTY.....	22.3	24.6	26.5	28.9	31.5	33.8	34.2	36.7	37.9	40.0
WALWORTH COUNTY...	10.5	11.6	12.1	13.0	14.0	14.6	14.6	15.8	16.4	17.3
WASHINGTON COUNTY.	8.7	9.1	9.4	10.1	10.8	11.2	11.3	12.2	12.6	13.3
WAUKESHA COUNTY...	20.1	20.8	22.0	24.3	27.0	29.3	30.0	33.1	35.6	39.2
TOTAL...........	259.9	265.3	282.2	315.2	341.0	359.9	366.7	388.0	404.8	429.2

REGISTRATIONS FOR THE PERIOD 1956-1970

The record of continuous year to year growth in auto registrations in the nation, state, and Region which began in 1945 continued despite the short supply of automobiles in the first years following World War II, the Korean War, the economic depression of 1957 and 1958, the involvement of the country in the Vietnam conflict, and a spiraling economic inflation continuing for throughout most of the period. In the nation, auto registrations rose from 54 million in 1956 to 61 million in 1960, nearly 75 million in 1965, and 89 million in 1970. In Wisconsin, such registrations totaled about 1.2 million in 1956 and rose to 1.3 million in 1960, 1.5 million in 1965, and more than 1.8 million in 1970. In the Region, registrations totaled 456,000 in 1956 and increased to 523,000 in 1960, 610,000 in 1965, and nearly 736,000 in 1970 (see Table 2).

Within the Region from 1956 through 1970, Milwaukee County auto registrations increased from nearly 296,000 in 1956 to 325,000 in 1960, 366,000 in 1965, and 424,000 in 1970. Waukesha County replaced second place Racine County in auto registrations with 44,000 registrations in 1956, nearly 60,000 in 1960, 80,000 in 1965, and nearly 107,000 in 1970. Racine County, which dropped to third in registrations, had nearly 43,000 registrations in 1956, 49,000 in 1960, 60,000 in 1965, and nearly 73,000 in 1970. Kenosha County, fourth in registrations, had 30,000 in 1956, 37,000 in 1960, 42,000 in 1965, and 51,000 in 1970. Walworth County, fifth in registrations, had 18,000 in 1956, 20,000 in 1960, 23,000 in 1965, and nearly 29,000 in 1970. Washington County, sixth in registrations, had 14,000 in 1956, 16,000 in 1960, nearly 21,000 in 1965, and nearly 28,000 in 1970, and gave indications of overtaking Walworth County in the near future. Ozaukee County, seventh and last in registrations, had more than 11,000 in 1956, 14,000 in 1960, 18,000 in 1965, and nearly 25,000 in 1970, gaining on both Walworth and Washington Counties in registrations during the period.

Table 2 (Continued)
1956-1970

GEOGRAPHIC AREA	NUMBER OF AUTOMOBILE REGISTRATIONS (IN THOUSANDS)							
	1956	1957	1958	1959	1960	1961	1962	1963
UNITED STATES	54,013.8	55,704.6	56,664.4	59,214.0	61,683.9	63,153.4	65,824.9	68,755.8
WISCONSIN	1,190.3	1,221.6	1,249.4	1,281.5	1,328.9	1,350.6	1,355.8	1,434.0
SOUTHEASTERN WISCONSIN REGION								
KENOSHA COUNTY....	30.0	30.5	32.2	34.8	37.3	37.4	37.2	40.2
MILWAUKEE COUNTY..	295.8	303.1	306.7	313.7	325.4	328.1	328.7	343.4
OZAUKEE COUNTY....	11.5	12.3	12.8	13.6	14.3	14.8	15.1	16.3
RACINE COUNTY.....	42.7	43.8	44.9	46.9	49.3	50.1	50.5	54.6
WALWORTH COUNTY...	18.2	18.9	19.4	19.8	20.4	20.6	20.5	22.1
WASHINGTON COUNTY.	14.0	14.5	15.0	15.5	16.4	16.9	17.1	18.5
WAUKESHA COUNTY...	44.2	47.2	51.0	54.8	59.9	63.2	65.6	71.1
TOTAL...........	456.4	470.3	482.0	499.1	523.0	531.1	534.7	566.2

GEOGRAPHIC AREA	NUMBER OF AUTOMOBILE REGISTRATIONS (IN THOUSANDS)							
	1964	1965	1966	1967	1968	1969	1970	
UNITED STATES	71,663.9	74,903.2	77,750.8	80,013.7	83,175.3	86,416.8	89,279.4	
WISCONSIN	1,489.2	1,530.1	1,579.0	1,624.2	1,685.1	1,728.8	1,853.6	
SOUTHEASTERN WISCONSIN REGION								
KENOSHA COUNTY....	41.5	42.3	42.8	43.6	45.4	46.8	51.0	
MILWAUKEE COUNTY..	356.9	366.1	375.8	383.6	394.5	401.7	424.1	
OZAUKEE COUNTY....	17.1	18.0	19.0	20.2	21.6	22.6	24.8	
RACINE COUNTY.....	57.4	60.0	61.7	63.2	65.1	67.3	72.7	
WALWORTH COUNTY...	22.9	23.4	24.2	24.8	26.0	26.7	28.7	
WASHINGTON COUNTY.	19.7	20.6	21.7	22.7	24.3	25.5	27.7	
WAUKESHA COUNTY...	76.0	80.3	85.2	89.6	94.9	98.2	106.7	
TOTAL...........	591.5	610.7	630.4	647.7	671.8	688.8	735.7	

SOURCE- AUTOMOBILE FACTS AND FIGURES, AUTOMOBILE MANUFACTURERS ASSOCIATION, 1948 AND 1972 EDITIONS; HIGHWAY STATISTICS SUMMARY TO 1965, U. S. DEPARTMENT OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION, 1967; AND WISCONSIN DEPARTMENT OF TRANSPORTATION, DIVISION OF MOTOR VEHICLES.

NUMBER OF PERSONS PER REGISTERED AUTOMOBILE

In the 50-year period between 1920 and 1970, the ratio of the number of persons per registered automobile in the United States decreased from 13.0 persons in 1920 to 2.3 persons in 1970. In general, such ratios in the state, Region, and counties within the Region followed the same pattern, decreasing sharply from 1920 to 1930 in the number of persons per auto registered, and more gradually by decade from 1930 to 1970, indicating that the growth in automobile registrations increased at a faster rate than that of the population with each decade (see Table 3). How much longer this relationship can continue to decline is crucial to the forecasts of future numbers of automobiles within the Region. In this respect it is hoped that automobile ownership will reach a saturation level prior to the level at which every person eligible and able to drive an automobile will own one.

GROWTH IN AUTOMOBILE REGISTRATIONS AND IN STREET AND HIGHWAY MILEAGE IN THE REGION: 1930-1970

As indicated in Table 4, the number of automobiles registered within the Region increased from more than 211,000 in 1930 to almost 736,000 in 1970, an increase of approximately 524,000, or about 248 percent during the period. By county, the largest numerical increase in auto registrations was 281,000 in Milwaukee County, where registrations increased from nearly 143,000 in 1930 to 424,000 in 1970. The smallest numerical increase was found in Walworth County, where auto registrations increased from nearly 10,000 in 1930 to nearly 29,000 in 1970. The largest percentage increase by county was about 621 percent in Waukesha County, where registrations increased from more than 14,000 in 1930 to more than 106,000 in 1970. Milwaukee County, although having the largest numerical increase in auto registrations as noted above, had the smallest percentage gain, about 198 percent.

As shown in Table 5, total mileage of streets and highways within the Region increased from 7,258 miles in 1930 to 9,580 miles in 1970, an increase of 2,322 miles or about 32 percent during the period. By county, the largest numerical increase in street and highway mileage occurred in Milwaukee County, where such mileage increased by 796 miles, from 1,779 miles in 1930 to 2,575 miles in 1970. The smallest numerical gain was found in Racine County, where such mileage increased from 939 miles in 1930 to 1,062 miles in 1970, a gain of 123 miles. The largest percentage increase in street and highway mileage was found in burgeoning Waukesha County, where such mileage increased by 59 percent, from 1,220 miles in 1930 to 1,940 miles in 1970. Racine County had the lowest numerical gain and also had the smallest percentage gain, about 13 percent.

Comparing the information contained in Tables 4 and 5, it can be observed that from 1930 to 1970, automobile registrations in the Region increased by 248 percent, while total street and highway mileage increased by only 32 percent. The latter, however, includes local land access and collector streets as well as arterial streets and highways. In urban areas, land access and collector streets—which are required to support urban land use development by providing land access, right-of-way for utilities, storm water drainage, and light and air to building sites regardless of the mode of transportation—comprise approximately 70 percent of the total system.

U. S. AUTOMOBILE REGISTRATIONS AS A PERCENT OF WORLD REGISTRATIONS, AND REGIONAL AUTOMOBILE REGISTRATIONS AS A PERCENT OF U. S. REGISTRATIONS: 1922-1970

The United States' share of the world's automobile registrations has declined almost on a year to year basis since 1922, the first year for which data for both of these universes have been found to be available. In 1922, there were an estimated 12.5 million autos registered throughout the world, of which more than 10.7 million, or about 86 percent, were United States registrations. From 1922 through 1935, the United States' percentage of world registrations declined successively by year from nearly 86 percent in 1922 to 72.6 percent in 1935. The United States' percentage increased slightly in 1936 to 72.8 percent, dipped to nearly 71 percent in 1938, and increased again to nearly 74 percent in 1940 (see Table 6).

Although United States automobile registrations are available for the World War II years, no worldwide registrations were found, and hence calculations of the relationship of U. S. registrations to world registrations are not possible. By the end of the war, with worldwide registrations again available, it was found that the U. S. share of registrations had increased to 78 percent. From 1946 to 1970, however, the U. S. share of world registrations declined successively, from 78 percent in 1946 to 46 percent in 1970. In 1968, U. S. registrations amounted to less than half of world registrations for the first time on record. Thus, despite the remarkable growth in U. S. auto registrations throughout most of the entire age of the automobile to date, the U. S. share of worldwide registration continues to shrink.

The Region's share of U. S. automobile registrations has varied only slightly from 1922 to 1970, ranging by year between 0. 8 and 0. 9 percent of U. S. registrations, as shown in Table 6.

SUMMARY

The growth in the number of automobile registrations in the United States, Wisconsin, the Southeastern Wisconsin Region, and each of the seven counties comprising the Region has been remarkable. In the United States, automobile registrations have increased from 8,000 in 1900 to 2. 3 million in 1915, 22 million in 1935, 52 million in 1955, and 89 million in 1970. In Wisconsin, such registrations have increased from 200 in 1900 to 80,000 in 1915, 623,000 in 1935, 1. 1 million in 1955, and 1. 8 million in 1970. In the

Table 3

NUMBER OF PERSONS PER REGISTERED AUTOMOBILE IN THE UNITED STATES, WISCONSIN, AND THE REGION BY COUNTY: SELECTED YEARS 1920-1970

GEOGRAPHIC AREA	NUMBER OF PERSONS PER REGISTERED AUTOMOBILE					
	1920	1930	1940	1950	1960	1970
UNITED STATES	13.0	5.3	4.8	3.8	2.9	2.3
WISCONSIN	9.5	4.3	4.2	3.6	3.0	2.4
SOUTHEASTERN WISCONSIN REGION						
KENOSHA COUNTY......	11.4	5.0	4.3	3.5	2.7	2.3
MILWAUKEE COUNTY....	14.9	5.1	4.4	3.8	3.2	2.5
OZAUKEE COUNTY......	7.8	3.8	3.5	3.1	2.7	2.2
RACINE COUNTY.......	10.6	4.5	4.1	3.5	2.9	2.4
WALWORTH COUNTY.....	6.0	3.3	3.2	3.0	2.6	2.2
WASHINGTON COUNTY...	6.3	3.6	3.6	3.1	2.8	2.3
WAUKESHA COUNTY.....	7.2	3.5	3.6	3.2	2.6	2.2
TOTAL	12.0	4.8	4.2	3.6	3.0	2.4

SOURCE- SEWRPC.

Table 5

STREET AND HIGHWAY MILEAGE IN THE REGION BY COUNTY: SELECTED YEARS 1930-1970

COUNTY	STREET AND HIGHWAY MILEAGE					PERCENT INCREASE IN STREET, HIGHWAY MILEAGE-1930-1970
	1930	1940	1950	1960	1970	
KENOSHA.....	654	694	712	793	867	32.6
MILWAUKEE...	1,779	1,841	1,989	2,293	2,575	44.1
OZAUKEE.....	536	541	561	620	699	30.4
RACINE......	939	837	862	953	1,062	13.1
WALWORTH....	1,142	1,155	1,167	1,197	1,295	13.4
WASHINGTON..	988	989	1,005	1,069	1,142	15.6
WAUKESHA....	1,220	1,230	1,300	1,670	1,940	59.0
REGION TOTAL	7,258	7,287	7,596	8,595	9,580	32.0

SOURCE- WISCONSIN DEPARTMENT OF TRANSPORTATION, DIVISION OF HIGHWAYS.

Table 4

NUMBER OF AUTOMOBILE REGISTRATIONS IN THE REGION BY COUNTY: SELECTED YEARS 1930-1970

COUNTY	NUMBER OF AUTOMOBILE REGISTRATIONS					PERCENT INCREASE IN AUTO REGISTRATIONS 1930-1970
	1930	1940	1950	1960	1970	
KENOSHA.............	12,647	14,692	21,742	37,332	51,046	303.6
MILWAUKEE...........	142,586	173,713	228,370	325,409	424,060	197.5
OZAUKEE.............	4,598	5,493	7,550	14,331	24,829	418.2
RACINE..............	20,029	23,132	31,549	49,329	72,709	263.0
WALWORTH............	9,536	10,421	14,049	20,418	28,746	201.4
WASHINGTON..........	7,301	7,946	10,872	16,354	27,679	284.4
WAUKESHA............	14,786	17,471	26,972	59,901	106,650	621.3
REGION TOTAL	211,483	252,868	341,104	523,074	735,719	247.9

SOURCE- WISCONSIN DEPARTMENT OF TRANSPORTATION, DIVISION OF MOTOR VEHICLES.

Region, auto registrations have increased from 22,000 in 1915, the first year for which registration data by county are available, to 205,000 in 1935, 429,000 in 1955, and 736,000 in 1970.

Within the Region, the following increases in automobile registrations from 1915 to 1970 were reported: in Kenosha County, from 1,000 to 51,000; in Milwaukee County, from 13,000 to 424,000; in Ozaukee County, from 600 to 25,000; in Racine County, from 2,000 to 73,000; in Walworth County, from 2,000 to 29,000; in Washington County, from 1,000 to 28,000; and in Waukesha County, from 2,000 to 107,000.

In the 50-year period between 1920 and 1970, the ratio of the number of persons per automobile registered decreased in the United States from 13.0 persons in 1920 to 2.3 persons in 1970; in Wisconsin from 9.5 persons in 1920 to 2.4 persons in 1970; and in the Region from 12.0 persons in 1920 to 2.4 persons in 1970, varying slightly by county. These data indicate that automobile growth has continued throughout the period at a faster rate than that of the population as a whole. It is expected that this trend will continue for at least the next decade.

Automobile registrations within the Region increased by approximately 248 percent from 1930 to 1970, varying by county from a low of nearly 198 percent in Milwaukee County to a high of 621 percent in Waukesha County. Street and highway mileage within the Region increased by 32 percent in the same period, varying by county from a low of 13 percent each in Racine and Walworth Counties to a high of 59 percent in Waukesha County. The total street and highway mileage, however, includes local land access and collector streets, as well as arterial streets and highways. In urban areas, land access and collector streets—which are required to support urban land use development by providing land access, right-of-way for utilities, storm water drainage, and light and air to building sites regardless of the mode of transportation—comprise approximately 70 percent of the total system.

Since 1922, when automobile registrations in the United States accounted for nearly 86 percent of total registrations in the world, the U. S. share of world registrations has decreased almost on a year by year basis except in 1936 and in the World War II period, 1939 to 1946. In 1968, U. S. registrations for the first time on record dropped below 50 percent of the world registrations. By 1970, the percentage had decreased further to about 46 percent, and is expected to continue to decrease indefinitely. Throughout the period 1922 to 1970, automobile registrations within the Region remained a little under 1 percent of the total United States registrations.

Table 6

NUMBER OF AUTOMOBILE REGISTRATIONS FOR THE REGION, UNITED STATES, FOREIGN COUNTRIES, AND THE WORLD: SELECTED YEARS 1922-1970

YEAR	NUMBER OF AUTOMOBILE REGISTRATIONS (IN MILLIONS)				REGION TOTAL AS PERCENT OF U. S. TOTAL	U. S. TOTAL AS PERCENT OF WORLD TOTAL
	REGION	UNITED STATES	FOREIGN	WORLD		
1922	0.09	10.7	1.8	12.5	0.8	85.6
1925	0.15	17.4	3.6	21.0	0.8	82.9
1930	0.21	23.0	7.0	30.0	0.9	76.7
1935	0.20	22.5	8.5	31.0	0.9	72.6
1936	0.22	24.1	9.0	33.1	0.9	72.8
1938	0.23	25.2	10.4	35.6	0.9	70.8
1940	0.25	27.4	9.7	37.1	0.9	73.9
1945	0.23	25.7	--[a]	--	0.9	--
1946	0.26	28.1	7.7	35.8	0.9	78.5
1950	0.34	40.2	12.7	52.9	0.8	76.0
1955	0.43	52.0	20.9	72.9	0.8	71.3
1960	0.52	61.4	36.6	98.0	0.8	62.7
1965	0.61	74.9	64.5	139.4	0.8	53.7
1968	0.67	83.2	86.3	169.5	0.8	49.1
1970	0.74	89.2	104.2	193.4	0.8	46.1

[a]WORLDWIDE AUTOMOBILE REGISTRATIONS FOR THE YEAR 1945 WERE NOT AVAILABLE.

SOURCE- WISCONSIN DEPARTMENT OF TRANSPORTATION, DIVISION OF MOTOR VEHICLES; U. S. DEPARTMENT OF TRANSPORTATION, FEDERAL HIGHWAY ADMINISTRATION; AND AUTOMOBILE FACTS AND FIGURES, AMERICAN MANUFACTURERS ASSOCIATION.

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