INFRASTRUCTURE SYSTEMS : 1987 SUMMARY STATISTICS

INFRASTRUCTURE SYSTEM	RESPONSIBLE AGENCY(S)	REPLACEMENT COST	PROFILE QUANTITY	PROFILE MEASURE	IMPLIED REPLACEMENT CYCLE Last 10 Year	IMPLIED REPLACEMENT CYCLE 1987	ESTIMATED USEFUL LIFE in YEARS
Br...ges	Bureau of Engineers Bureau of Bridges & Buildings	$517,000,000	225	Units	86 years	56 years	50 to 50 years
Streets	Bureau of Engineers Bureau of Street & Sewer Maintenance	$1,150,000,000	1,292.2 27,799,470.0	Miles Square Yards	51 years	35 years	40 to 50 years (Concre 25 to 35 years (Asphal
Alleys	Same as Streets	$120,000,000	420	Miles	65 years	53 years	40 to 60 years
Sidewalks	Same as Streets	$125,000,000	2,000.0 62,400,000.0	Miles Square Feet	49 years	38 years	50 to 50 years
Street Lighting System	Bureau of Traffic Engineering & Electrical Services	$123,000,000	71,183	Units	88 years	33 years	30 to 45 years
		Lighting Unit	71,183	Units	88 years	33 years	30 years
		Poles	60,384	Units	74 years	71 years	30 to 35 years
		Cable	2,477	Miles	66 years	38 years	45 years
Traffic Control	Bureau of Traffic Engineering & Electrical Services	$31,000,000					10 to 25 years
		Signals	694	Units	22 years	16 years	20 to 25 years
		Signs	98,326	Units	9 years	10 years	10 to 15 years
		Control Cabinet	688	Units	12 years	12 years	to 15 years
Parking Facilities	Bureau of Traffic	$33,000,000			40 years	51 years	20 to 50 years
		Facilities	73	Units			
		Stalls	3,376	Units			
Sewers (all)	Same As Streets	$2,090,000,000	2,446.0	Miles	288 years	306 years	125 to 125 years
		Storm	947.0	Miles	1,578 years	4,510 years	125 to 125 years
		Sanitary	932.0	Miles	236 years	360 years	125 to 125 years
		Combined	567.0	Miles	144 years	109 years	125 to 125 years
Water Distribution	Bureau of Engineers Milwaukee Water Works	$1,135,000,000	1,905.2	Miles	360 years	278 years	125 to 125 years
		6 inch	621.9	Miles	179 years	160 years	125 to 125 years
		8 inch	685.7	Miles	811 years	411 years	125 to 125 years
		12 inch	264.6	Miles	465 years	217 years	125 to 125 years
		16 inch	333.0	Miles	837 years	4,163 years	125 to 125 years
		Hydrants	18,745	Units			
		Valves	43,071	Units			
		Blowoffs	437	Units			
		Meters	160,115	Units	11 years	11 years	10 to 10 years
		Connections	163,500	Units			
Water Purification Storage/Pumping	Same as above	$400,000,000	2 Purification Plants 11 Reservoirs & Tanks 3 Major Pumping Stations 10 Booster Stations 5 Other Facilities Capacity - 375 Million gallons/day		N/A	N/A	10 to 60 years
Underground Conduit	Same as Traffic Control	$85,000,000					110 to 110 years
		$57,000,000 Conduit	523.3	Trench Miles	632 years	969 years	110 to 110 years
		$22,000,000 Manholes	7,225	Units			110 to 110 years
Communications	Bureau of Traffic	$35,000,000					10 to 40 years
	Electromechanical equipment		N/A	N/A			25 to 25 years
	Solid State equipment		N/A	N/A			10 to 15 years
	Cable		968.0	Miles			30 to 40 years
Buildings (B & B)	Bureau of Bridges & Public Buildings ONLY	$130,000,000	129.0	Units	"1986 DATA"		20 to 50 years
		Roofs			42 years	27 years	20 to 20 years
		Buildings			65 years	N/A years	50 to 50 years
		HVACS			43 years	28 years	25 to 35 years
uildings	Various	$280,000,000	101.0	Units	N/A	years	20 to 50 years

CITY OF MILWAUKEE

THE 1988 TO 1993

CAPITAL IMPROVEMENTS

PROGRAM

SECTION FOUR

INFRASTRUCTURE PRESERVATION

INTRODUCTION

MILWAUKEE'S INFRASTRUCTURE

Infrastructure describes the collection of physical systems and facilities that constitute the anatomy of the City. Certain systems and facilities provide for the safe and efficient movement of people and goods to their destinations. Some purify and convey water to meet the demands of the community. Corresponding systems remove waste water, excess rain and snow melt from the community. Another facility cleans the wastewater to the extent that it is no longer a threat to the public health. Still other facilities serve a support role in the provision of public service that protect people or property or that enhance the quality of life, such as garbage collection, fire and police protection, culture, and recreation.

The private sector infrastructure includes facilities and systems that provide a service the benefits of which can be controlled by the provider. In order to ensure that the public interest is protected, the providers of these services are regulated by the Public Service Commission and other governmental agencies.

A characteristic common to most infrastructure systems, whether provided by the public or private sector, is that in order to be most efficient there can be only one system of each kind. For instance, there is only one sewer, street or water main serving a particular property. In other words, because of the nature of the service being provided, these systems are usually operated by a single provider or monopoly.

The anatomy of a city or its infrastructure, like our own bodies, is subjected to the forces of nature. Disease and stress reduce the efficiency of our anatomy as corrosion and stress impair the efficiency of the City's infrastructure. For instance, cancer left unchecked destroys the ability of the body's systems to perform their functions. Rust, like cancer, destroys the support structure of bridges. Water mains corrode to the point where they fail. A portion of our street system is made of Macadam. This material provides a very durable roadway surface but only if it is "oiled" or sealed periodically. If it isn't sealed, it will dry out, crack, develop potholes and eventually break up completely.

Just as it is advisable to have our bodies periodically examined by a physician, the infrastructure should be examined by trained technicians. Physicians want to know the medical history of a patient and the patient's family before making a diagnosis or prescribing treatment. Similarly, the people taking care of infrastructure require similar kinds of information prior to recommending a course of action. Health professionals gather and process enormous quantities of data and conduct experiments with the goal of improving and extending life. Similarly, infrastructure professionals are engaged in many areas of research designed to enhance and extend the life of the infrastructure.

Decisions of infrastructure professionals are subjected to a great deal of scrutiny. For instance, the statement "if it isn't broke, don't fix it!" frequently is made in reference to preventive maintenance activities. While the thought "an ounce of prevention is worth a pound of cure" may come to mind, it is frequently necessary to prove that doing something now will save money in the short run. Unfortunately, sometimes there is not enough information or experience to prove that a given action is appropriate or that its benefits will accrue within a short time frame. If there is proof, it is usually theoretical or that the benefits will accrue over a longer period of time. The need to develop an information system capable of processing existing information about the construction and maintenance histories of the infrastructure goes unmet because of the lack of proof of its benefits compared to the initial expense of starting such a system. However, by reverting to an abstract analysis, it is possible to speculate about potential benefits. Assume that the average life of the infrastructure could be extended as the result of the knowledge that might be gained by an information processing system. Given that the estimated replacement cost of the City's infrastructure is about $6.5 billion, a one percent savings would be worth $65 million. Hopefully funds can be provided to develop and operate an infrastructure information systems capable of providing: accurate and current engineering data; maintenance plans and data; and cost and condition information.

Early in 1987, the Common Council authorized the Department of Public Works to engage a consultant to assist in the development of a long-range Master Plan for its information management needs. An in-house information management systems (IMS) technical committee was formed to provide technical guidance and to evaluate the Department's information needs. In addition to the Committee members, representatives from Central Electronic Data Services (CEDS), City-wide Information Management Committee (CIMC), Comptroller's Office and the Budget Office were present at some meetings to offer their input for the Master Plan. The charge of the IMS Committee was to:

- identify problems and needs;
- provide information on procedures and record-keeping;
- review and advise on proposed computerized implementation;
- establish priorities and evaluation criteria;
- take a lead role in representing each bureau and identifying its needs;
- identify areas of interface with other City systems or applications; and
- establish rehabilitation/replacement needs and costs.

The Information System Master Plan complements the National Council on Public Works Improvements final report entitled "Recommendations to Improve Public Works Decision-Making", which recommends establishment of automated data collection, management, and reporting systems from which cost-effective decisions can be analyzed to present the overall least cost options for public works managers and their policy makers.

The development of the Master Plan was undertaken in three phases as follows:

Phase I - Assess Current Information Systems

During this phase, the IMS Committee undertook a thorough analysis of existing manual and automated information systems.

Phase II - Define Long-Term System Requirements

During this phase of the study, each Bureau identified its long-range information system requirements. The Bureaus evaluated their needs in detail to determine the necessary information resources and functional capabilities that would have to be satisfactorily met. Based upon the evaluation, the Committee identified the various information systems that would need to be developed.

Phase III - Information System Master Plan Design

During this phase, the Committee reviewed the cost effectiveness of each system and, according to evaluation criteria and priorities established by the Committee, developed the implementation schedule and budget.

The Information System Master Plan as developed by the IMS Committee in conjunction with Peer Systems, Inc. and its subconsultant, Burke and Associates, Inc. is a guide to information system development and will be reevaluated each year to reflect changes that may occur based upon changed requirements, more information, or budgeting changes. The final report has been submitted to the Mayor and members of the Common Council. Implementation of this plan will greatly enhance the City's ability to cost effectively manage its infrastructure in the next century.

The need to extend the life of certain infrastructure systems which are approaching the end of their useful life is especially important when large portions were built at the same time. An example of this would be the City's bridges built in the 1920's and 1930's. Given that over 100 of the City's Bridges were built before 1940 and that the State considers the average useful life of a bridge to be about 50 years, many of these bridges will need to be replaced soon. Some will last far longer than 50 years. Perhaps additional useful life can be extracted from these and other facilities by innovative rehabilitation methods, increased preventive maintenance and where appropriate, reduced levels of service.

VALUE OF THE INFRASTRUCTURE

The importance of the infrastructure can be expressed in terms of its function. The urban environment could not exist without the clean water, waste removal, mobility, and protection provided by the infrastructure.

The estimated replacement costs have been developed based on unit costs, professional judgements and information produced for insurance purposes. The following figures do not include facilities owned privately or by other governments.

CITY OF MILWAUKEE

FUNCTION	FACILITY	REPLACEMENT COST (in $1,000,000)
TRANSPORTATION		
	Bridges	$ 517
	Streets	$1,150
	Alleys	$ 120
	Sidewalks	$ 125
	Street Lighting	$ 123
	Traffic Control	$ 31
	Parking	$ 33
	Harbor Facilities	$ 100
TOTAL - TRANSPORTATION		$2,199
PUBLIC HEALTH		
	Sewage Collection	$2,090
	Water Distribution	$1,135
	Water Purification/ Storage/Pumping	$ 400
TOTAL - PUBLIC HEALTH		$3,625
GENERAL GOVERNMENT		
	Public Buildings	$ 410
	Underground Conduit & Manholes	$ 85
	Wired Communication	$ 35
TOTAL - GENERAL GOVERNMENT		$ 530
AESTHETICS & QUALITY OF LIFE		
	Boulevards, etc.	$ 28
	Street Trees *	$ 56
	Recreational Facilities	$ 50
TOTAL - AESTHETICS & QUALITY OF LIFE		$ 134
GRAND TOTAL - CITY OF MILWAUKEE		$6,488

* Assumes trees would be replaced with 2 1/2 inch diameter trees rather than in kind. In kind replacement would cost about $385 million.

** Includes City facilities and facilities operated by the Division of Municipal Recreation of the Milwaukee Public Schools.

Replacement costs are one of several factors that should be considered in projecting annual capital needs. As an example, recent experience has shown that it costs about $2 per square foot to replace sidewalks. This includes removal of existing walk, its replacement and inspection costs. The replacement cost of the 62,400,000 square feet of sidewalk at $2 a square foot would be about $125 million. The estimated useful life of a sidewalk stone is 60 years, therefore, the estimated annual replacement expense for sidewalks would be about $2,000,000. Of course, the actual capital budget for any given year for sidewalks would vary from this amount. Other factors that would influence how much is budgeted for sidewalks would include condition surveys, citizen demand, competing capital needs and available financial resources.

These replacement costs should be adjusted to derive an estimate of their actual value. Ideally, consideration would be given to physical deterioration as well as functional obsolescence due to technological advances and changes in design, when deriving a value of the infrastructure in place.

In addition to the infrastructure owned by the City of Milwaukee, other governmental agencies and the private sector own and operate a vast complex of facilities. The following is a partial listing of some of the public and private infrastructure that are not operated by the City.

PUBLIC	PRIVATE
Freeways and Major Highways	Railroads
Public Transit System	Parking Structures
Airports	Wisconsin Electric (Including Downtown Steam Heating System)
Sewage Treatment Plants	Wisconsin Bell
Interceptor Sewers	Gasoline Pipelines and Storage Terminals
University of Wisconsin-Milwaukee	Schools
Milwaukee Public Schools	Colleges
Milwaukee Area Technical College	Hospitals
County Institutions	Wisconsin Natural Gas Co.
Park System (Zoo, Domes)	Western Union Telegraph
County Stadium	Telephone & Telegraph
Public Museum	
Performing Art Center	
Public Housing	

While specific information about the replacement costs of the above listed infrastructure has never been collected, the Land Use Report from the GOALS 2000 report indicated that the replacement cost of the region's public infrastructure was $12.63 billion. It can be reasonably assumed that the replacement cost of the private infrastructure is about one half of this or another $6 billion.

THE REGIONAL INFRASTRUCTURE

THE STATE

In February of 1985, the Department of Development of the State of Wisconsin published a report entitled: " Public Infrastructure in Wisconsin: A Strategic Analysis." This report focussed on the condition and outstanding needs of wastewater facilities, public roads and bridges in Wisconsin. In relation to Milwaukee the report concludes:

1) Seventy percent of outstanding state wastewater facility needs are associated with the Milwaukee area. The report concludes that if Wisconsin and the federal construction grants programs continue, all the outstanding wastewater treatment needs in the state could be funded by the end of fiscal year 1989.

2) The Interstate system in the Milwaukee area is expected to develop serious capacity needs over the next 15 years. Because of severe physical constraints, creative traffic system management solutions will be required. An extensive study of freeway management techniques is currently underway for the Milwaukee area. Despite this, the Department of Transportation expects many of the major Milwaukee travel corridors to be congested by the year 2000.

3) The miles of urban State Trunk Highway (STH) arterials improved are planned to be increased to twice the current level according to the State Highway Plan. Presumably this would benefit Milwaukee.

THE COUNTY

The County annually prepares a five year capital program document. The focus of this report is the capital budget section in which cost details, project description, project justification, and operating cost/revenue reports are presented for each requested capital improvement. The capital program contains a planning component reflecting the County's longer term physical development needs, objectives, concerns, and issues. This incorporates concepts developed in individual facility or functional master plans. A line item listing of individual projects requested in the budget year and remaining four out-years is summarized in the five year program along with a financing analysis.

The majority of the County's infrastructure responsibilities are concentrated in four areas; Health and Human Services, Parks and Recreation, Public Works and Transportation, and General Government/Public Safety.

HEALTH AND HUMAN SERVICES

The Milwaukee County Medical Complex (MCMC) has a bed capacity of 338 and provides acute and rehabilitative inpatient care. In 1987, there were 12,144 patient admissions and 95,976 days of care provided. Additional, the Medical Complex provides a broad spectrum of outpatient preventive, diagnostic and treatment services. The Medical Complex administers the County's paramedic program and is associated with the "Flight for Life" emergency helicopter transport service. Comprehensive 24-hour emergency services and various educational programs are also offered. An extensive facility renovation and expansion program is currently underway, and is expected to enhance many of the Medical Complex's state-of-the-art programs.

The Milwaukee County Mental Health Complex provides care and treatment to emotionally and mentally ill adults, children and adolescents on an outpatient, partial hospitalization, and inpatient basis. Services include intensive short-term treatment as well as extended care. The Mental Health Complex has a total setup capacity of 884 beds. In 1987, there were 5,880 admissions to the inpatient facility and 287,292 inpatient days of care provided; there were also 26,860 admissions and 572,966 appointments for the outpatient programs.

PARKS AND RECREATION

The County Park System, comprised of 137 parks and parkways consisting of 14,754 acres, contains senior, youth and community centers, and provides facilities for golf, swimming, skiing and other sports. Operating revenues support approximately 37% of the cost of this function.

Major facilities include:

County Stadium - 188 acres devoted to major sports events (Milwaukee Brewers, Green Bay Packers) with seating for 55,000.

Horticultural Conservatory - Three conoidal glass domes each 87 feet high and 140 feet wide feature separate, artificially controlled climates. One is a desert, another a tropical rain forest, and the third houses spectacular seasonal displays.

McKinley Marina - This 655-slip facility is located near the downtown area on Lake Michigan. The marina can accommodate vessels up to 60 feet long. A launching site and community sailing center are also available.

Zoo - The Milwaukee County Zoo will begin the third year of its comprehensive $25 million capital expansion program in 1988. The expansion program is the result of a joint fund raising effort with the private sector to provide a year round zoo facility. An important enhancement in the program will be the construction of a core zoo which will serve as a "zoo for all seasons." This will consist of the addition of three new buildings (Caribbean Cove, Valley of the Apes and the Visitor/Welcome Center) which will be connected to existing facilities. The new enclosed zoo will allow visitors to enjoy a variety of animal exhibits without having to contend with adverse weather. This expansion program is expected to result in more winter use and increased zoo operating revenues. Another major component of the expansion program is the Heritage Farm, an exhibit featuring a working farm and dairy complex.

Museum - The fifth largest natural history museum in the country literally places the viewer within exhibits. Milwaukee's cultural heritage is captured in the European Village and Streets of Old Milwaukee exhibits, and the Third Planet Earth exhibit contains the largest open dinosaur diorama in the world. The Wizard Wing provides an interactive learning center for the entire family. A new exhibit in 1988 will be a tropical rain forest as part of the museum's Biology Hall.

Performing Arts Center - This cultural center is host to the Milwaukee Symphony Orchestra, the Pennsylvania and Milwaukee Ballet Company and special events entertainment.

PUBLIC WORKS AND TRANSPORTATION

Airports - Milwaukee County operates two airports. General Mitchell Field is a modern air transportation center of 2,090 acres located six miles south of the City of Milwaukee's central downtown. Seven major carriers and six regional carriers provide over 140 daily departures from GMIA. Nearly every major United States city is served nonstop or direct, and connections are available to cities throughout the world. Over 3.5 million passengers utilized GMIA in 1987. Timmerman Airport is a 420 acre general aviation facility serving business and privately owned aircraft. Both airports are self-supporting; all maintenance and operational expenses are guaranteed through contractual agreements with the major carriers serving GMIA.

Mass Transit - The Milwaukee County Transit System has an active bus fleet of 530 vehicles serving 64 routes and over 55 million annual revenue passengers. Fare revenue and Federal and State aid account for approximately 82% of operating costs.

Public Works - The County maintains 68 miles of State freeways, 94 miles of State trunk highways and over 85 miles of County trunk highways. Maintenance costs are offset 92% by State and Federal aid. Other typical public works functions such as buildings and grounds maintenance and professional services are performed.

GENERAL GOVERNMENT/PUBLIC SAFETY

Courts and Judiciary - Milwaukee County, the first judicial administrative district of the State system, has 37 judges, with two additional positions authorized for August, 1988, and 17 court commissioners. State and other revenues support approximately 44% of the cost of this function.

Public Safety - This function includes a District Attorney's office, Medical Examiner, an 830-bed House of Correction, and Sheriff's department which operates a 459-bed County Jail. The Sheriff's department also patrols State freeways within the County and receives State aid for this service.

General Governmental Services - This function includes a County Treasurer, County Clerk, Register of Deeds, Election Commissioner and Law and Reference Library. As a group, these services are supported approximately 71% by operating revenues.

MILWAUKEE METROPOLITAN SEWERAGE DISTRICT

The District is a special purpose municipal corporation organized under the laws of Wisconsin. The District was created in 1982 by the reorganization of its predecessor body pursuant to the Enabling Act. The predecessor body to the District was known as the Metropolitan Sewerage District of the County of Milwaukee.

Sewage treatment is provided at two District-owned treatment plants. One is the Jones Island Wastewater Treatment Plant located along Lake Michigan at the Milwaukee Harbor. The other is the South Shore Wastewater Treatment Plant also located along Lake Michigan about 9 miles to the south of the Jones Island plant.

The Jones Island Wastewater Treatment Plant began operations in 1925. Its current design capacity is 200 million gallons per day (MGD) of sewage. Nearly all sludge from the treatment process is dried and made into Milorganite, a commercial fertilizer sold throughout the United States and Canada.

The South Shore Wastewater Treatment Plant began operations as a primary treatment facility in 1968. Subsequent additions and expansions have been made to provide secondary wastewater treatment. Its design capacity is 120 MGD. Approximately 80% of the sludge derived from the treatment process is processed through anaerobic detesters which stabilize the sludge and collect methane gas produced during the stabilization process. The remainder is transported to the Jones Island Wastewater Treatment Plant to be dried and made into Milorganite. The methane gas is used to generate electricity to power most of the treatment plants' needs. After digestion, the sludge is pumped into lagoons and hauled to farm lands where it is spread as a low grade soil conditioner known as Agri-Life at no charge to the landowner.

Wastewater is conveyed to the treatment plants by a 2,200-mile system of collector sewers which are owned and maintained by the local municipalities, and by a 235-mile system of intercepting and main sewers which are owned and maintained by the District and which carry wastewater from the collection system to the treatment plants.

The District's sewerage system must comply with federal and state water pollution control laws, which require that wastewater be treated to secondary treatment standards. The local- and District-owned sewer systems and the two District-owned treatment plants consistently collect and treat wastewater to the necessary standards during dry weather. During periods of wet weather, however, the sewerage systems become overloaded by clear water. In June 1980, the District adopted the Master Facilities Plan. The Facilities Plan and its accompanying Environmental Impact Statement were formally approved by the EPA and the DNR approximately one year later. The planning process assessed the District service area wastewater treatment needs to the year 2005.

The Facilities Plan provides for the following improvements:

Rehabilitation of sewer lines to reduce excess clear water pursuant to recommendations reached in the District's completed Sewer System Evaluation Survey;

Construction of relief sewers to abate overflows and bypassing of untreated wastewater into the rivers and Lake Michigan from the existing separated sewer systems during wet weather. A major component of this element is the inline storage system which is comprised of approximately 17 miles of large diameter sewers, constructed in bedrock, which will correct the overflowing and bypassing of untreated wastewater from the separated areas;

Reduction in the frequency of overflows from the combined sanitary and storm sewer system through dual use of the inline storage system, separation of some existing combined sanitary and storm sewers, construction of storage facilities and construction of an intercepting sewer system (near-surface collectors) to carry overflows from the local municipal combined sanitary and storm sewer system to the inline storage system and storage facilities;

Rehabilitation and expansion of the Jones Island Wastewater Treatment Plant to enable secondary treatment of all wastewater flowing to the plant;

Expansion of the South Shore Wastewater Treatment Plant to enable secondary treatment of all wastewater flowing to the plant;

Improvements of methods to process and utilize waste solids; and

Extension of District-owned sewers, to serve areas within the District's service area currently served by local treatment plants or not now served by a publicly owned sewerage system.

MILWAUKEE PUBLIC SCHOOLS

The physical plant of the Milwaukee Public Schools is comprised of over 160 school buildings, warehouses, and office buildings. Currently there are 103 elementary schools, 18 middle schools and 15 high schools. Additionally, the School Board owns a number of other undeveloped properties (sites), as well as some facilities which are utilized by other agencies. Until the 1970-1975 School Building and Sites Plan, little detailed information on individual schools existed. Since that time, much improvement in both the quality and the quantity of the data base has been made. This improvement is due to the computerization of the data, thus enabling easy storage, retrieval, and great flexibility in utilization.

This data includes certain key descriptive characteristics about each facility -- such as date built, additions, annexations, site size, number of teaching stations. The data is contained in six categories - elementary (pre-1910), elementary (1910-1945), elementary (1945-present), middle, high school and other buildings. This data is not all that is known about a particular building.

There are numerous other files which are available. Some of the more important files which are available are:

1. Building construction type
2. Design capacity
3. Use capacity
4. Distance to the nearest school
5. Enrollment by race on an annual basis
6. Areas of buildings, roof, and site
7. School standards criteria
8. Cost/pupil on an annual basis since 1973
9. Five-year average cost/pupil
10. Energy cost by type of fuel on an annual or monthly basis
11. Energy cost/square foot or cost/pupil
12. Types of hot lunch facilities.

The buildings in the school plant have been maintained very well based on high standards. This maintenance has included the completion of repairs when necessary, provision of certain preventive maintenance procedures on a systematic basis, annual inspections by the City Building Inspector, Fire Department, and Milwaukee Public Schools staff, and the correction of all needed safety items on an immediate basis. The cost of this maintenance will increase in the future and as the school plant continues to increase in age, some major repairs and structural changes will be required for both maintenance and educational purposes.

MILWAUKEE AREA TECHNICAL COLLEGE

The Milwaukee Area Technical College (MATC) District operates under provisions of Chapter 38 of the Wisconsin Statutes. The MATC District considered to be a unit of local government with statutory authority to issue general obligation debt and levy local property taxes.

The MATC District is composed of the entire population of Milwaukee County (964,988), approximately 96% of the population of Ozaukee County (64,302), 18% of the population of Washington County (15,273), and 0.8% of the population of Waukesha County (2,243). The total District population as of the 1980 census was 1,046,806. That total has been updated and revised to an estimated 1,028,535 in 1985.

Remodeling and renovation projects are implemented yearly to modernize instructional facilities, to provide facilities for new educational programs, and to renovate the aging physical plant. Numerous requests for remodeling and renovation are reviewed each year and the top priority projects are identified in an annual project series. The Board reviews the annual remodeling/renovation projects and submits a preliminary list of projects to the State VTAE Board each year. This preliminary list must be approved by the State VTAE Board and is finalized by the MATC Board during the annual budget review and approval process. Financing for these projects is normally provided on an annual basis from grants, interest earnings, borrowing and operating levy allocations. MATC updates a five-year remodeling and renovation plan each year. Plans for 1988 to 1993 indicate an expenditure of at least $1.5 million each year for remodeling and renovation of facilities.

The Student Center, completed in January 1988, at 7th and State Streets, consolidates student service area and provides a new main entrance to the Milwaukee Campus. The facility fills a critical need identified in the master facility plan of 1973 to provide an appropriate space for student activities and services. The building adds approximately 86,000 square feet to the Milwaukee Campus and cost $7.6 million.

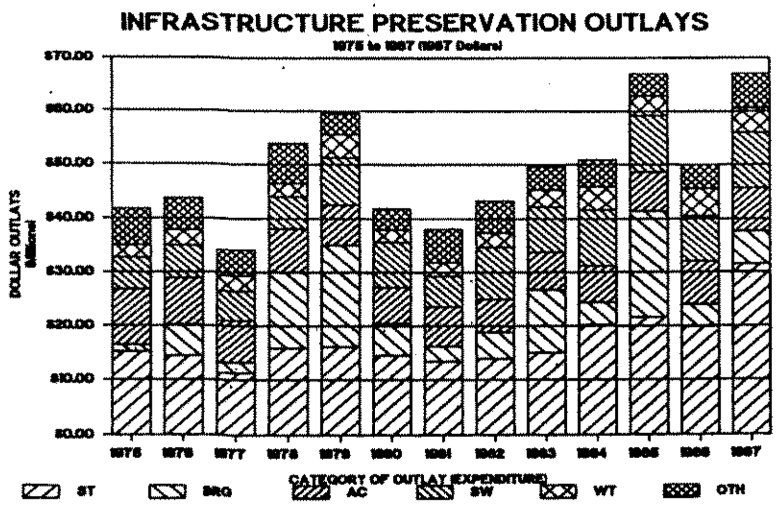
Two additional projects related to the Student Center construction are the development of a mall on 7th Street and a parking area to the west of the Center. The mall project is estimated to cost about $300,000. Parking development to the west of the Center, estimated to cost about $200,000, requires demolition of the "X", "M", and "G" Buildings on 8th Street and is, therefore, dependent upon relocating programs through remodeling projects.

MILWAUKEE'S INFRASTRUCTURE

A great deal of local and national media attention has recently been focussed on the need to restore the nation's "crumbling" public infrastructure. This issue is not new to the City of Milwaukee. The following excerpt from the City's 1975-1980 Capital Improvement Program prepared over a decade ago demonstrates the Committee's awareness and commitment to preserve the physical plant.

> "In preparing this Six Year program, a constant consideration has been the projected ability of the City to support this program financially. In the struggle to assign resources properly to all budgetary requirements, the Capital program has traditionally been the competitor which may most easily be deferred. Unfortunately, such deferrals have far reaching effects which may not surface for a number of years, but which eventually must surface as a deteriorated City plant, reduced services, and a lowered level of urban living. The Capital Improvements Committee's recommendations seek to forestall this situation."

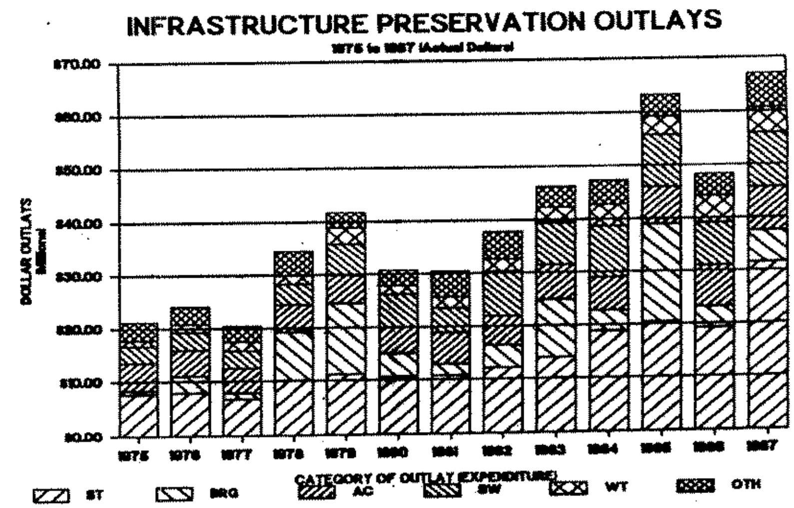
It is, of course, the allocation of the City's financial resources that transforms recommendations into reality. In Milwaukee, the responsibility to allocate these increasingly scarce financial resources rests solely with the Mayor and the Common Council. It is through their support that the Committee's recommendations reach fruition. The graph below depicts the infrastructure preservation expenditures made on City facilities during the period 1975-1987.



Legend:

STR - Streets & Alleys	SEW - Sewers
BRG - Bridges	WAT - Water Works
ACC - Sidewalks, Traffic Control, Street Lighting, Trees, etc.	OTH - Public Buildings, Harbor, Parking, etc.

These outlays include state and federal aid. The relatively large expenditures in 1978 and 1979 were the result of the State constructing the 27the Street Viaduct, a project estimated to cost $15 million. In order to compare these yearly expenditures they have been inflated to 1987 dollars in the graph below. The inflation factor used to adjust these expenditures was based on the Engineering News Records Construction Cost Index from Minneapolis, Minnesota and Chicago, Illinois. With the exception of the years 1978 and 1979 explained above, this graph shows that inflation adjusted infrastructure preservation expenditures on City facilities have increased.



While it appears that most public facilities operated by the City of Milwaukee have been well maintained, these facilities do have finite service lives. The Capital Improvements Committee evaluated the condition of some of the City's infrastructure in 1983. A considerable amount of information had existed on streets, bridges, sewers, water distribution and water purification/storage/pumping system, so they were selected for the initial study. In 1984, the study was expanded to include alleys, sidewalks, and street lights. In 1986, the study was expanded to include traffic control, parking, underground conduit, boulevards, and trees.

REPORT SUMMARY

Each infrastructure report is organized into eight sections. They include:

PROFILE

Description of the system to include: Data base - what is in it, how good is it and should it be improved and why. Summarize the available information such as how many, how large, how old or latest condition information.

CONDITION MEASUREMENT AND PROJECT SELECTION

Describe the process used to determine the condition of the facilities and how needs are prioritized. Identify the costs and benefits associated with the current condition assessment effort. Identify the costs and benefits associated with improving the condition assessment effort. That is, describe the technologies or processes currently used or that should be added if better information was required.

HISTORICAL EFFORT

Measure quantitatively the capital activity over the last ten years that restores or replaces existing infrastructure. What are the consequences of decreasing, increasing or maintaining the current effort? What should be done and on what basis?

ESTIMATED USEFUL LIFE

Description of the estimated useful life in years, hours of use or other quantitative measure of the various components of the infrastructure system. This section should also include a discussion of the validity and source of this measure. Where appropriate, describe the importance that changes in technology, changes in demand or standards and environmental conditions have on system life expectancy.

IMPLIED REPLACEMENT CYCLES

Based on the historical effort, identify the number of years between complete replacement or refurbishment of the system at the replacement rate that actually was accomplished over the last ten years, three years, and the latest year available. If appropriate, explain why there is a difference between this and the estimated useful life. For example, the current rate of replacement is inadequate and additional funding is being requested; the system is too new to be experiencing major replacement needs; or condition measurement activity appears to indicate that the estimated useful life is too conservative or too optimistic and the current rate of replacement could be reduced, should be adequate or needs to be increased.

PREVENTIVE MAINTENANCE

Describe and measure quantitatively and in dollars the maintenance activities that prolong the life of the system. Estimate the cost to replace the entire system and describe how the estimate was calculated. Identify the percentage the above maintenance activity is compared to the total replacement cost. If preventative maintenance goals exist, identify them and compare the current effort to the goals. Also, identify new or existing technologies that are being used, tested or implemented, which have not been described previously, that will extend system life, reduce costs or provide better information.

SYSTEM PERFORMANCE

Describe the function(s) the system performs. That is, what it does and who benefits and how they benefit. Describe how system performance is currently measured and how it could or should be measured.

CONCLUSION

Describe the adequacy of current replacement and maintenance efforts. Identify recommended policy changes or the need for increased or decreased funding. Briefly highlight the most important points described in the other sections of the report.

The following is a summary of the major conclusion of each of the eight reports. The detailed reports follow these brief summaries.

TRANSPORTATION

Bridges -
Based on the most recent bridge sufficiency ratings, the City had 51 bridges which were rated 50 or less on a scale of 100, making them eligible for Federal Bridge Replacement Funds.

Streets -
While the City's streets are in reasonably good condition, the City's preservation efforts have not, until recently, kept pace with goals. A Department of Public Works task force has recently completed an evaluation of current pavement maintenance practices and efforts.

Alleys -
About 180 miles of alleys were built over 50 years ago. The rate of alley reconstruction has increased dramatically since 1978. Alley maintenance programs should be increased in order to preserve existing pavements over 50 years old until they can be replaced.

Sidewalks -
About one in five sidewalk stones in the City is defective. This situation is being monitored to determine whether the current rate of sidewalk replacement is adequate.

Street Lighting -
The street lighting system is in good condition. However certain areas do not have adequate lighting (if any) and 2,299 lights are inefficient incandescent type lights. A new street lighting policy has been approved by the Common Council.

Traffic Control -
The System of traffic control devices throughout the City's roadway network contribute to the safe, efficient and predictable movement of traffic. While the system is in general being well maintained, there are a significant number of signs which have been in service beyond their estimated useful life.

Parking -
The City owns four parking structures and 73 surface parking lots, which provide 6,461 parking spaces. While the surface lots are in relatively good condition, two of the parking structures require extensive repairs to the structural floor slabs and another requires upgrading of equipment and improvements to the facade.

PUBLIC HEALTH

Sewers -
The City's sewer system is relatively new. The current rate of replacement should be adequate for the next 20 to 50 years.

Water Distribution -
The rate of water main breaks, which has been increasing since the 1960's, appears to be stabilizing. This is probably the result of increased replacement efforts. The level of replacement recommended in the Capital Improvements Program should be adequate to stabilize the water main break rate.

Water Purification/Storage/Pumping -
The available evidence indicates this system is in good condition. The systems capacity is adequate to meet current and anticipated future demands.

GENERAL GOVERNMENT AND SUPPORT SERVICES

Underground Conduit on Manholes -
This system consists of a network of conduits and manholes under the roadway providing a reliable, safe and aesthetic carrier for communication, lighting, traffic control, and other cable systems. More information is needed on the condition of this system and an inspection program is being developed.

AESTHETICS AND QUALITY OF LIFE

Boulevards -
About 70 percent of the boulevards in the City were constructed between 1950 and 1970. The average construction rate for this period was about eight acres per year compared to the average replacement over the last 10 years of 4.3 acres per year. As most of the components of the boulevard systems have an estimated useful life of 30 to 35 years, the current boulevard replacement rate is inadequate.

Trees -
There are about 328,000 trees lining streets contributing to the quality of life in Milwaukee. The trees are well maintained and in good condition.

B R I D G E S

The table below displays the level of government responsible for the bridges located in the City of Milwaukee. It counts each bridge structure that the City has some responsibility for only once.

Bridges in Milwaukee in 1987

Level of Government	Number	Percent
City (including Railroads)	223*	31.0
County	32	4.5
State (Excluding signs)	463	64.5
TOTAL	718	100.0

*15 were on the Federal Aid Primary System and 85 were on the Federal Aid Urban System

The Wisconsin Department of Transportation (DOT) defines a bridge as a structure having an opening or "clear span" measured along the centerline of the roadway of more than 20 feet between the face of the abutments, or between the extreme ends of openings for multiple pipe culverts where the distance between pipes is less than half the size of the pipe opening. According to the March 4, 1983 report of the Wisconsin DOT (P05S05), All Bridges - By County and Sufficiency Rating, there were 1,155 bridges in the County of which 786 were located in the City of Milwaukee. The actual number of bridges may differ from these figures because the State counts bridges somewhat differently.

Included within the 223 bridges that the City has some responsibility for are 54 structures that carry railroad tracks over City streets and 33 structures carrying City streets over railroad tracks. In general, there exists an agreement between the railroad and the City outlining responsibility for the bridge, wholly or by its specific parts, and the facilities beneath the bridge. Each of these agreements relate to a specific bridge and have provisions unique to the particular bridge. However, a very limited review of these agreements revealed several generalities, as follows:

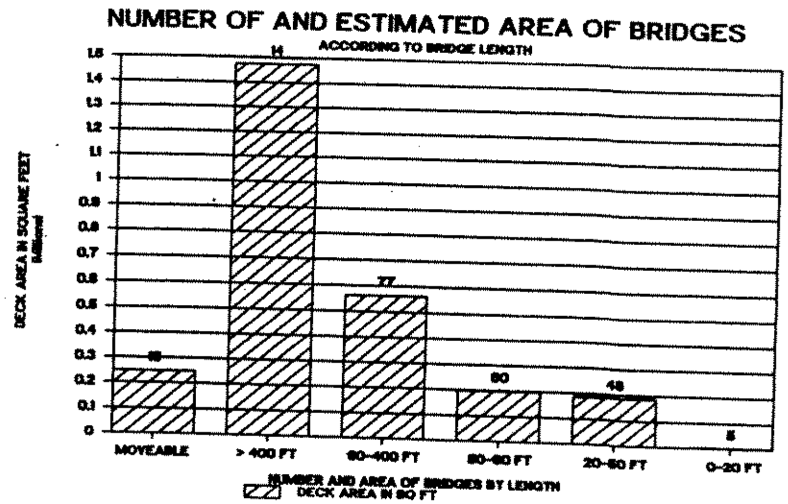
1. For bridges supporting railroads crossing over City streets, the railroad company is usually responsible for the structure. The City may have responsibility for the retaining walls and/or abutments. The City has responsibility for the roadway and related facilities.

2. For bridges supporting City streets crossing over railroads the City has responsibility for the deck, the roadway and related facilities. Responsibility for the remainder of the bridge may be with the railroad or with the City. The railroad has responsibility for its tracks and related facilities.

3. Bridges built in recent years, whether railroad underpasses or overpasses, have generally been built to benefit vehicular traffic. This, perhaps, explains why the agreements between the railroad and the City have tended to place more construction and maintenance responsibility on the City.

Unfortunately, the railroads have not been fulfilling their responsibilities and the City has been faced with the dilemma of allowing bridge structures to deteriorate until collapse occurs, maintaining and reinforcing deteriorated structures or replacing deteriorated structures. One of the railroads, the Milwaukee Road, was bankrupt and the Bankruptcy Court would not allow the railroad to spend money on facilities that do not produce revenue. Therefore, the bridges carrying City streets over the railroads were presumably not being maintained. The Milwaukee Road has now been acquired by the SOO Line, which, hopefully, will act more responsibly.

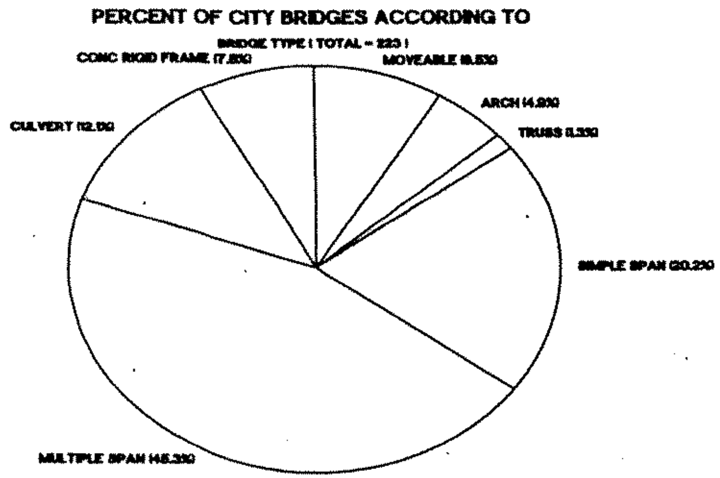
According to current information, the City has some responsibility for 223 bridges. The graph below displays the estimated deck area of these bridges by various categories of span length.



FOOTNOTES:

(1) There are three bascule bridges which are part of viaducts. The City actually has 220 bridges if these bascules are counted as part of the viaducts of which they are a part.
(2) There are only two bridges between 300 and 400 feet and three between 200 and 300 feet.

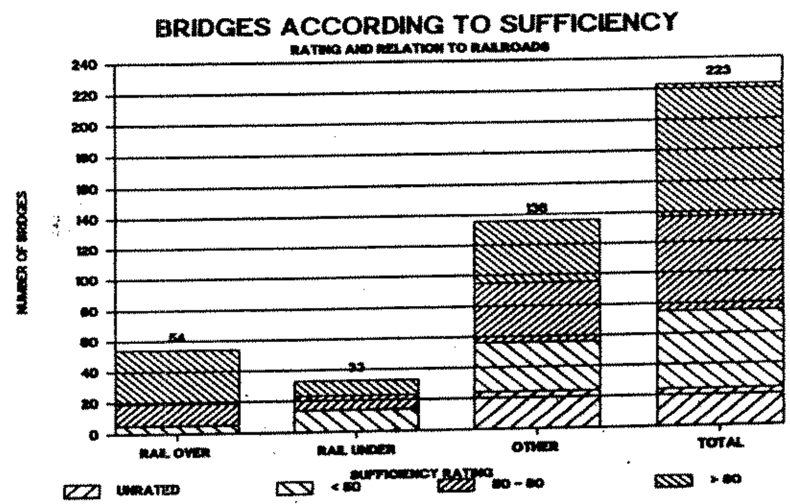
The following graph depicts the City's bridges according to the type of support structure or substructure of the bridge.



CONDITION MEASUREMENT AND PROJECT SELECTION

The Bureau of Bridges and Public Buildings established its Bridge Safety Inspection Program in 1968. All bridges under its jurisdiction are inspected and rated in accordance with National Bridge Inspection Standards on a two-year cycle. Each bridge is inspected by two professional engineers using the State's Bridge Inspection Report. This rating is based on factors which are indicative of the bridge's sufficiency to remain in service. The sufficiency rating of a bridge is based on the following four categories: (1) Structural adequacy and safety; (2) Serviceability and functional obsolescence; (3) Essentiality for public use; and (4) Special reductions pertaining to detour lengths and structure type. Emphasis is placed on the first category, the structural adequacy and safety, with lesser importance on the remaining three categories. Each bridge is originally assigned a total of 100 points with points subsequently deducted for deficiencies in the above listed areas. State and locally owned bridges with sufficiency ratings ranging from 0 to 50 are eligible for Federal Bridge Replacement Funds. These funds are provided on an 80/20 Federal/Local or State/Local matching basis, providing funds are available. State and locally owned bridges with a sufficiency rating ranging from 50 to 80 are eligible for Federal Bridge Rehabilitation Funds to retard further structural deterioration. The Wisconsin Department of Transportation, however, requires a structure to have a sufficiency number less than 40 to qualify for bridge replacement, rehabilitation or removal funding. Municipally owned bridges are eligible for Federal Bridge Replacement and Rehabilitation funds through the County and State in which they are located. Each county develops its own priority listing of eligible county and municipally owned bridges and submits this list to the Wisconsin Department of Transportation. Therefore, since all requests must pass through the State Department of Transportation, City of Milwaukee bridges must have a sufficiency rating of less than 40 to qualify for Federal or State funding.

Based on the 1984 sufficiency ratings, the City had 46 bridges rated 50 or less, of which 18 were not on the Federal Aid System. Based on the most recent Sufficiency Ratings, the City had 51 bridges rated 50.0 or less. This does not include railroads over City streets. The following graph portrays the most recent Sufficiency Ratings by various types of bridges.



Note: Based on 1987 Bridge Sufficiency Ratings

Annually the Bureau prepares a budget and six year program for bridge maintenance, repair and replacement. The potential projects are ranked on the basis of several factors:

1. The State's sufficiency rating for each bridge and the corresponding inspection reports.
2. The Bureau's perception of the importance of each bridge to traffic, commerce or other purposes.

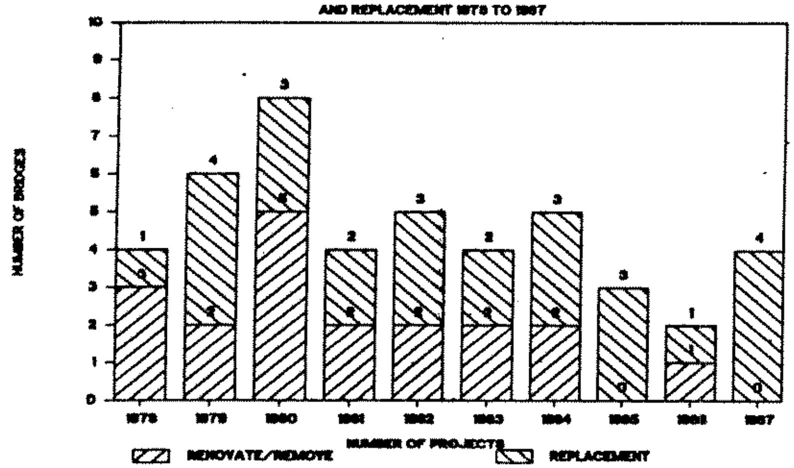
3. Funding availability.
4. Other information - such as reports from bridge maintenance personnel.

The selection of projects for each of the next six years is heavily influenced by the availability of funding, particularly if the projects are eligible for State or Federal funds. The Bureau does not recommend complete bridge replacement if their analysis determines that rehabilitation is feasible. The State Department of Transportation, however, considers it uneconomic to perform major repairs on bridges with a sufficiency rating lower than 38 to 40 that were constructed before 1948.

HISTORICAL EFFORT

In the period 1978 to 1987, the City replaced 26 bridges. The City also renovated or removed 19 bridges. This includes viaducts, moveable bridges and other bridges. The following graph displays the bridge renovation, removal and replacement effort over the last ten years.

BRIDGE RENOVATION, REMOVAL
AND REPLACEMENT 1978 TO 1987



* Note: This graph includes only bridge renovation, removal and replacement projects funded in the capital budget or by grants. It excludes the numerous repair projects funded in the operation and maintenance budget.

Bridge Renovation/Removal/Replacement*

Average	Renovation/Removal	Replaced	Total
Last 10 Years	1.90	2.60	4.50
Last 3 Years	0.33	2.67	3.00
Last Year	0.00	4.00	4.00

In addition to the bridges replaced or renovated during the period 1978-1987, there are two bridges for which funding has already been provided. These bridges are not included in the 1988-1993 Capital Improvements Program. The total cost of these bridges is estimated to be $9,422,000 of which the City's share is about $3,822,000.

The 1988-1993 Capital Improvements Program requests funding for the renovation or replacement of 28 bridges. The City's share is $12,413,000 out of a total estimated cost of $50,747,000.

During the period 1978 to 1987, 746,931 square feet of bridge deck surface was replaced. Of this, 213,120 square feet was as a result of the replacement of the 27th Street Viaduct.

ESTIMATED USEFUL LIFE

The estimated useful life of a bridge structure is about 50 years and for a bridge deck 40 years. The effects of age, however, vary widely for different bridges. The major factors associated with bridge condition are environment, design, capacity versus traffic usage, levels of maintenances and materials composition.

IMPLIED REPLACEMENT CYCLE

Sometimes the adequacy of an infrastructure preservation program is measured by the "implied replacement cycle". The following table shows the implied replacement cycle for bridges for the last ten years, the last three years and last year.

Bridge Replacement Cycle*

Last 10 Years	Last 3 Years	Last Year
86 Years	84 Years	56 Years

*Excludes renovation, removal and repair projects

It should be noted that "implied replacement cycles" can be misleading. They falsely assume that facilities were built uniformly over time, and that they are uniform in size and construction.

As mentioned above the City replaced about 746,931 square feet of bridge deck during the period 1978 through 1987. This is an annual average of 74,693 square feet. The City has about 2.7 million square feet of bridge deck. Therefore, the "implied replacement cycle" for bridge decks would be 34.8 years. It is generally assumed that the life of a bridge deck is 40 years, depending on traffic loadings, salt usage and other factors.

PREVENTIVE MAINTENANCE

The Bureau's annual operating budget for bridges includes funding for preventive maintenance, rehabilitation and repair projects and administration. The preventive maintenance program includes painting, concrete sealing, asphalt patching, machinery maintenance, routine cleaning, gear and cable greasing and snow shoveling. The Bureau's maintenance expenditures for bridges for the last six years are shown on the following table.

Bridge Maintenance Expenditures

Year	Expenditures	Year	Expenditures
1982	$3,800,000	1985	$3,900,000
1983	$4,000,000	1986	$3,600,000
1984	$3,800,000	1987	$3,800,000

Considering that the estimated replacement cost of the City's bridges is $516,816,720, maintenance costs of eight-tenths of one percent of the replacement cost are very low. The largest bridge maintenance expenses were painting, machinery maintenance, concrete sealing and asphalt patching. One of the major bridge problems in areas with severe winter climates is the deterioration of concrete bridge decks. This problem of spalling and delamination of concrete decks is directly related to the extensive use of road salt. The addition of chlorides destroys the high alkalinity of concrete deck surfaces that would normally protect steel reinforcing rods from corrosion. The use of salt and other chemical deicing agents can also cause the deterioration of structural members. Annually, the City uses approximately 35 thousand tons of salt on roads and bridges. Based on the information available, there does not appear to be any major changes in salt usage over the last decade, though there is substantial variation in the annual usage, depending on weather conditions. There has been a major increase in the use of calcium chloride in the last several years, but its use is small compared with total salt (sodium chloride) usage. In 1982, funding was provided to the Bureau of Sanitation to install liquid calcium chloride tanks at all sanitation districts. The use of calcium chloride enhances the effectiveness of the salt operation which should reduce the total salt usage.

Since 1981, the Bureau of Bridges and Public Buildings has applied a protective coating to 608,124 square feet of bridge deck. This was a relatively new practice, as only minimal amounts were applied prior to that. In 1987, approximately 240,867 square feet of bridge deck received this protective coating. This protective coating is expected to be effective for a minimum of five years.

There have also been several changes instituted for the design of replacement bridges and bridge decks that should minimize the corrosive action of salt. These include a thicker cover of concrete over the deck reinforcing steel and the use of epoxy coated reinforcing steel. In addition, new decks are designed with elastomeric expansion joints rather than sliding plates or finger joints to protect the underlying structure of bridges from salt laden water dripping from the decks.

The fixed bridges and viaducts in the City are painted on a ten year cycle. The painting process involves a commercial number six sandblasting with a three coat rust retardant paint system. Moveable bridges are painted on an eight year cycle. These bridges receive a white metal sandblasting with a four coat vinyl paint system.

SYSTEM PERFORMANCE

Bridges are a critical part of the street system. They are also the most expensive part of the street system. The cost per square foot of a fixed bridge, not a culvert, is about $100 and for a moveable bridge it might be $500 or more, compared to less than $5 for street reconstruction.

The primary purpose of a bridge is to connect two segments of a transportation network which are separated by an obstruction, such as a valley, water, a railway or highway. Therefore the performance of a bridge should be measured by the degree to which it does this in a safe and efficient manner. That is, if a bridge cannot carry the weight and/or volume of traffic at the appropriate speed safely, it detracts from the efficiency of the transportation system.

While sufficiency ratings do indicate the condition of the City's bridges, they are a compilation of several factors that are not directly related to the ability of a bridge to carry traffic. Various factors that are included in the sufficiency rating give a more precise indication of a bridge's performance. The most important of these measures structural deficiency and functional obsolescence. A bridge is defined as functionally obsolete if the deck geometry, under-clearance or approach road alignment is rated three or less out of a possible nine. A structurally deficient bridge is defined as one for which the condition rating of the deck, substructure, superstructure or the culvert is four or less out of nine; or if the water adequacy rating is less than two. The report "Flood Control Plan for Lincoln Creek" prepared by the Southeastern Wisconsin Regional Planning Commission stated that the waterway for several of our Lincoln Creek Bridges was inadequate. This report caused an increase in the number of structurally deficient bridges.

CONCLUSION

There are 223 bridges in the City of Milwaukee for which the City has some responsibility. The City shares responsibility for 93 of these bridges with the railroads, including seven pedestrian bridges. While the railroad bridges over City streets are in relatively good condition, the bridges carrying City streets over railroads are generally in very poor condition. The railroads have not fulfilled their responsibilities to repair and replace these bridges. The requested 1988-1993 Capital Improvements Program includes $12,413,000 for the City's share of the replacement cost of bridges. The State and Federal share will be about $38,334,000.

Considering the limited funds that the City has available and the large number of bridges that the City needs to replace, it will be necessary to delay replacement of bridges that are the responsibility of the City in order to replace bridges that are in part the responsibility of the railroads.

The City's Capital Improvements Program and the allocations of the State's Bridge Replacement Program will help reduce the existing backlog of deteriorated bridge projects. If the City continues to get a reasonable portion of future Bridge Replacement funds, it will be able to continue to reduce the backlog of bridge projects that are the responsibility of the City.

STREETS

There are 1,413.8 miles of streets and highways in the City which are open to traffic. The table below indicates the mileage of highways and roads in the City which are under the jurisdiction of other governmental units.

Type	Mileage 12-31-87
Freeways	40.29
State Highways	25.88
State Maintained Roads	7.46
County Trunk Highways	25.44
County Park Roads	21.58
Harbor Commission and Water Dept. Roads	.98
TOTAL	121.63

Source: Bureau of Engineers

In 1942, the City began the development of a systematic method of inventorying its streets. In 1944 this project was broadened, in a City sponsored Public Roads Administration project, to include a complete historical record of street improvements. The system now called the "Road Life Study" contains information on individual blocks, block segments and intersections. The information contained in the system includes location, identification, length, width, area and type of pavement, paving history, curb-gutter, and other information. This record system enables the City to study pavement life characteristics and to project future pavement replacement needs.

As can be seen from the following graph, most of the City's streets are concrete or asphalt. This is especially true for those streets in the higher classifications (which carry more traffic). The table below identifies the percent based on mileage and area of the City's streets according to the State Functional Classification.

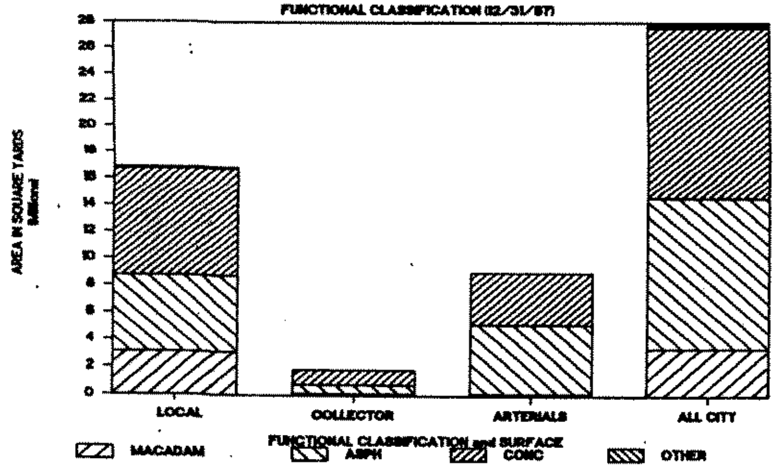
City Streets 12-31-87

Classification	Length	Area
Arterials	22.0%	32.6%
Collectors	6.0%	6.7%
Local Access	72.0%	60.7%
TOTAL	100.0%	100.0%

Source: Bureau of Engineers

The following graph based on area shows the relative proportion of the City's streets that have a surface of macadam, asphalt, concrete or other material according to functional classification.

AREA OF PAVEMENT TYPE ACCORDING TO



Source: Bureau of Engineers

CONDITION MEASUREMENT AND PROJECT SELECTION

The Bureau of Street and Sewer Maintenance annually inspects each street in the City to determine its maintenance needs and to recommend streets for the annual paving program. Their reports are integrated by the Commissioner of Public Works' Special Layout Office with citizen complaints, aldermanic requests, and inspections by the staff of the Bureau of Engineers. The Layout Office maintains a file on street segments which are likely candidates for the paving program based on the above information and their own inspections. In addition, a color coded map depicting the paving projects under consideration for each of the next six years is maintained. Each year those streets that have been coded for that year are again inspected to verify that an improvement is warranted. The above procedure is essentially the process used to select some arterials, residential streets and alleys for the annual paving program. The Special Layout Office has developed a six year paving program for residential streets. Major street six year program is developed each year by a committee consisting of representatives from various City agencies.

Each year a Committee reviews and updates the Long Range Major Street Improvement Program. This program listing includes all major street projects and most bridges scheduled for resurfacing, reconstruction, widening and new construction required over the next six years. It also lists projects which are contemplated in the more distant future. At these meetings, the concerns of the City's planners and economic development specialists, those of traffic, paving, bridge and maintenance engineers and those of the Commissioner of Public Works are discussed. The revised program evolving from this meeting provides the basis for those major projects scheduled for the upcoming budget. The projects identified for the upcoming year in the Long Range Major Street Improvement Program along with the minor arterials and residential streets program are, if appropriate, subject to non-destructive pavement testing. The pavement rehabilitation strategy selected for each street on the annual paving program is determined on the basis of the following factors:

- Field evaluations
- The pavement condition report
- Evaluation of proposed improvements to underground utilities, such as sewer and water
- Location of the pavement and private improvements abutting the street

This determination is made by the Pavement Type Committee which consists of representatives of the Commissioner of Public Works and the City Engineer. On State and Federal Aid Projects, the rehabilitation strategy is determined by the City Engineer, subject to State approval.

HISTORICAL EFFORT

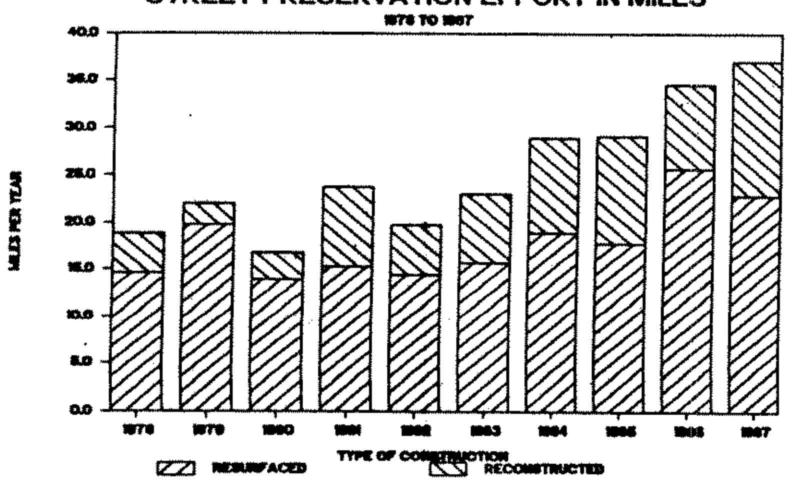
In 1972, the Bureau of Budget and Management Analysis in conjunction with the Bureau of Engineers, developed a formula based on survivor curves and the data contained in the inventory of the street system. The purpose of this formula was to project the level of funding for street resurfacing and reconstruction necessary to preserve the street system. In 1979, this report was updated by the Bureau of Engineers and now serves as an annual funding goal for the City's paving program. The 1979 report found that the weighted average age of pavements had increased since 1971. The report also found that more pavements were resurfaced rather than reconstructed, and that the type of survivor curve which fit the retirement data for some pavement types indicated longer average lives than originally estimated. The report concluded that the average annual funding for street reconstruction and resurfacing should be approximately $14,000,000 (based on 1979 costs) per year for the first ten years and approximately $15,000,000 per year for the succeeding twenty years. This would provide for the resurfacing of about 450,000 square yards and the reconstruction of approximately 200,000 square yards of pavement annually. It should be noted that the expected life of a street resurfacing is substantially less than that for a street reconstruction. Based on the costs developed for the 1979 study, it would cost 2.4 times more to reconstruct streets than to resurface.

The following graph depicts the miles of streets that were resurfaced or reconstructed over the last ten years, including State and Federal Aid Projects and capital projects undertaken by the Bureau of Engineers and the Bureau of Street and Sewer Maintenance. The level of accomplishment in recent years is substantially greater than in prior years.

Street Preservation

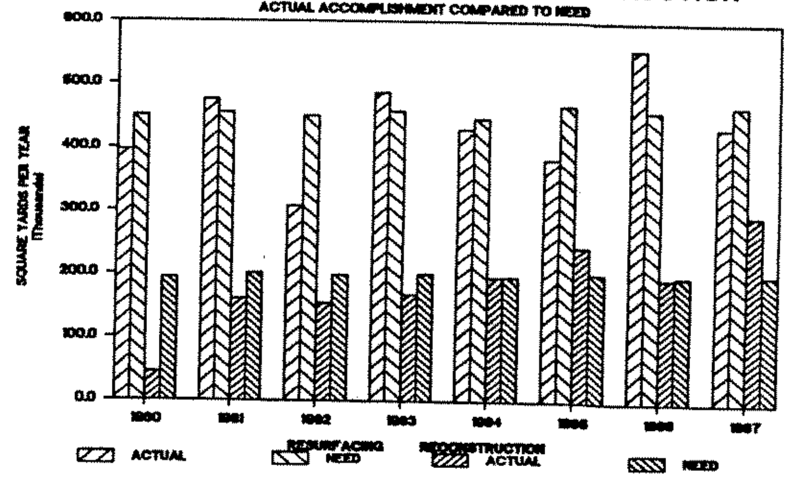
Average	Resurfaced	Reconstructed	Total
Last 10 Years	17.9 miles	7.5 miles	25.4 miles
Last 3 Years	22.2 miles	11.4 miles	33.6 miles
Last Year	23.0 miles	14.1 miles	37.1 miles

STREET PRESERVATION EFFORT IN MILES



The following graph depicts the square yards of streets that were resurfaced and reconstructed over the last eight years, including State and Federal Aid projects, capital projects undertaken by the Bureau of Engineers and the Bureau of Street and Sewer Maintenance compared to the goals identified in the above paving study.

STREET RESURFACING AND RECONSTRUCTION



Since 1980, the City has accomplished about 95% of the street resurfacing and 91.5% of the street reconstruction called for in that study. Based on the needs identified in the study, at the end of 1987, the accumulated shortage of street resurfacing would be 177,253 square yards and of street reconstruction would be 134,364 square yards. It should be noted that the square yards of pavement actually constructed vary from year to year because of carryover projects. Because of increases in the paving budget, the square yards of pavement constructed have come closer to the goals established in the Paving Study.

ESTIMATED USEFUL LIFE

The estimated useful life of a pavement is defined as the average number of years after construction that the pavement remains in service prior to its removal, resurfacing or reconstruction. The City has 32 different types of pavement. The Bureau of Engineers' 1979 paving study estimated the expected average pavement life using Iowa survivor curves. Based on those estimates, the surface of a concrete pavement has an estimated service life of 40 to 50 years, asphalt 25 to 35 years. These estimates are used for long range planning purposes but are not used directly in determining which streets need work. In addition, original street pavements are resurfaced where conditions and grades permit, thereby extending the useful life of the original pavement as a base for a new surface.

IMPLIED REPLACEMENT CYCLE

The effectiveness of infrastructure preservation programs is sometimes measured by "implied replacement cycles." This measure does not directly account for such important variables as stress factors (traffic loadings), materials, and changes in purpose or need. Pavement studies have found that pavements deteriorate in geometric patterns, very little in the beginning and rapid and accelerating deterioration in the latter part of pavement life. The impact of these factors formed the historical basis for the survivor curve projections found in the above mentioned paving study.

The "implied replacement cycle" of the street system may be calculated by dividing the total miles in the system by the average number of miles resurfaced or reconstructed annually, or by dividing the total square yards in the system by the total square yards resurfaced or reconstructed annually.

The table below depicts the "implied replacement cycle" for the street system.

Implied Replacement Cycle

	Last 10 Years*	Last 3 Years*	Last Year*
Resurface or Reconstruct	50.8 Years	38.4 Years	34.8 Years

* Based on miles accomplished

About 13 percent of the City's street system is constructed of material called macadam or penetration tar macadam. This classification describes pavements consisting of layers of stone and tar or asphalt. This type of pavement is thought to have a very long service life provided it is seal coated regularly. The seal coating process does, however, present problems for the abutting property owners and vehicle users. The stones used in the seal coating process are dusty, damage vehicles, and gravitate onto the lawns and driveways. A seal coat also does not correct a high crown or substantially improve the rideability or correct drainage problems. To reconstruct a street with a new concrete pavement, curb and gutter, sidewalk, and drainage would cost $550,000 per mile. The Bureau of Street and Sewer Maintenance estimates that it cost $13,500 in 1986 to seal coat a mile of macadam pavement. This does not include the cost of other maintenance operations, such as patching, required for this pavement type. The seal coating process can only be used on macadam pavements with normal crowns, good curb and gutter, and adequate drainage. If these criteria do not exist, reconstruction may be necessary. The average useful life of a seal coat is six years.

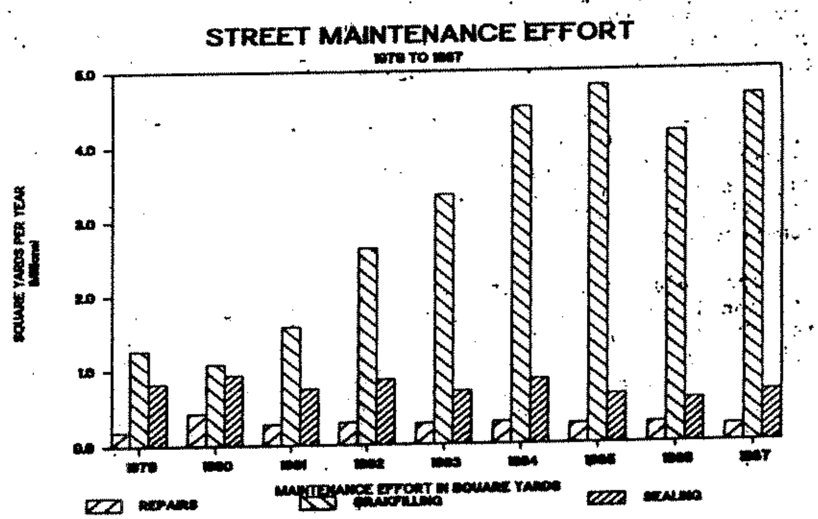
Because the cost of seal coating is less expensive than reconstruction it may be appropriate to continue preserving macadam pavements that meet the criteria. Some of these pavements may be extended beyond their normal service life at a relatively small cost. This would allow more paving funds to be concentrated on other pavement types.

PREVENTIVE MAINTENANCE

The Bureau of Street and Sewer Maintenance is responsible for preventive and emergency maintenance of the City's streets. The major preventive maintenance activities include seal coating and crackfilling.

In 1988 the City will begin the development of a computerized pavement maintenance management system. This system will include all the information in the "Road Life File" along with the pavements surface and structural condition. It is intended that this information will provide the data for a computer program which will aid in the preparing of the paving program and estimating future needs. The program will be able to provide estimates of cost for future needs and help in the development of the most cost effective maintenance and construction strategies.

The following graph shows the preventive maintenance activity during the period 1980 to 1987.



The Bureau spent about $6,065,200 on maintenance activity in 1987, which is less than one percent of the estimated $1.15 billion cost to replace the entire street system. The crackfilling program is the primary preventive maintenance activity of the Bureau. The sealing program is also a preventive maintenance activity but it is applicable to only 14 percent of the City's street system and mostly on local residential streets. According to the Bureau's recommended practice for preserving the street system, arterial asphalt streets should be crackfilled every four years, asphalt residential streets and concrete streets every six years. Therefore, to protect the concrete and asphalt pavements (about 85% of the system), it would be necessary to crackfill 4,300,000 square yards of pavement annually. This has been accomplished since 1984.

SYSTEM PERFORMANCE

System performance may be defined as the degree to which it meets certain criteria or achieves measurable objectives. In analyzing a complex system such as the City's streets, the appropriate performance criteria for the system as a whole may not be appropriate for the component subsystems. For instance, appropriate criteria for the primary street system might be to minimize the stopping time of vehicles and congestion in order to facilitate the movement of large volumes of traffic at relatively high speeds between different areas of the City. These criteria would be inappropriate for local access streets, particularly in residential areas. Through trips are to be discouraged if not prohibited and speeds should be kept at a minimum in order to maximize the safety of pedestrians and allow the maximum access to property. These two purposes, at opposite ends of the spectrum, highlight the complexity involved in evaluating the performance of the street system. Further complicating the evaluation is the necessity of concurrently evaluating the traffic control and lighting system, which play an integral role in the above described functions.

In addition to its role of providing a route for vehicles to transport people and products safely and efficiently while minimizing adverse impacts on the environment, the street system right-of-way also provides a location for public utility facilities, such as water, sewer, gas, electric and communication.

The relationship between composition of the street system, its condition and its function may result in separate standards for different parts of the street system. The Commissioner of Public Works has created a committee of top management personnel in the Department of Public Works to review and evaluate current practices, and develop a comprehensive pavement maintenance strategy. The results of this study will guide the development of appropriate system performance measures.

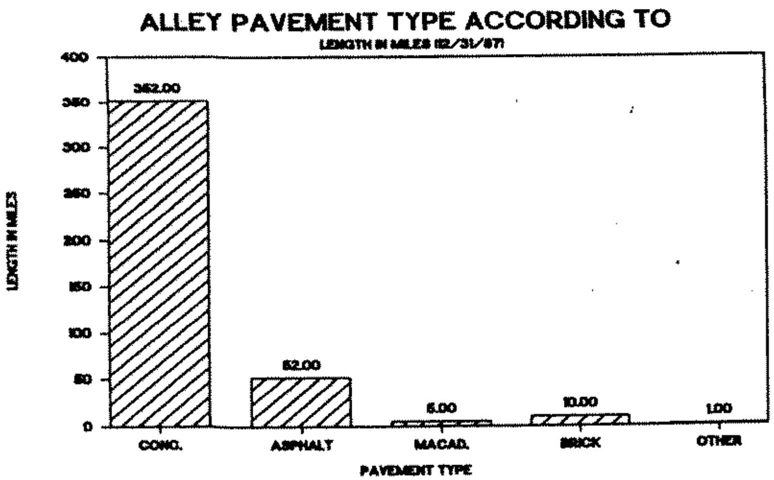
CONCLUSION

The condition of the City of Milwaukee's street system compares favorably with its peer cities, primarily due to the quality construction and extensive maintenance effort by the City over the years. But as was previously mentioned, since street maintenance and replacement goals were established in 1979, the City has fallen below the established goals. The City has achieved about 95 percent of the street resurfacing goal and about 91 percent of the reconstruction goal since 1980. The crackfilling effort has met the "recommended practice" level since 1984. In the last three years, the City's street preservation effort has been much nearer to that called for in the 1979 paving study.

The requested 1988-1993 Capital Improvements Program includes funding of an average annual effort of approximately 650,000 square yards of street reconstruction and resurfacing. Given the constraints of limited transportation aids and the property tax base, the Capital Improvements Program reflects a fiscally responsible level of effort in our City's commitment to preserve our street system.

A L L E Y S

There were 420 miles of alleys in the City of Milwaukee as of December 31, 1987. The graph below identifies the materials composition of these alleys.



Source: Bureau of Engineers

In 1963, the Road Life Study card file system was created which combined the records of a WPA (Works Progress Administration) project with those maintained by the Estimating Section of the Bureau of Engineers. There are approximately 4,500 alley cards in this system. These cards are filed in alphabetical order based on the streets surrounding the alley. Information contained on these cards includes pavement type, date of construction, alley width and block dimensions, pavement plan identification number, established grades and ordinance numbers. These records are being incorporated into an electronic data base, which when completed will facilitate the study of alley pavement life characteristics and the projection of future retirement needs, similar to the method used for streets.

In 1982, the Bureau of Engineers prepared a preliminary report regarding the age of the alley pavements in the City of Milwaukee. The data used for this study is being updated by the Bureau to reflect the latest information. The data indicates that 45 percent of the alleys are over 40 years of age, 31 percent are 20 - 40 years of age and 24 percent are under 20 years of age. There are about 150 miles of alleys currently in service that were built between 1920 and 1930. It should be noted that very few alleys were constructed during the Depression and World War II.

CONDITION MEASUREMENT AND PROJECT SELECTION

At least once every four years, each alley in the City is inspected by the Bureau of Street and Sewer Maintenance. The purpose of the survey is to: 1) provide a realistic appraisal of the condition of alleys; 2) prepare maintenance programs such as crackfilling and pavement repair on an efficient basis; and 3) recommend alleys that require resurfacing or reconstruction to the Department of Public Works Special Layout Office. These reports are integrated with citizen complaints, aldermanic requests and inspections by the Bureau of Engineers. The Special Layout Office maintains a history card on alleys which are likely projects for the annual paving program based on the above information and their own inspections. In addition, a color coded map depicting the alley projects under consideration for each of the next six years is maintained by the Special Layout Office. Each year those alleys that have been coded for that year are again inspected to verify that an improvement is warranted for that year's annual paving program. The Special Layout Office is in the process of developing a Three Year Alley Paving Program.

Recently a study was made of the alleys that were refurbished from 1981 to 1985. It was found that the average age of alleys being retired was about 55 years. The ages of these alleys ranged from 11 (for a portion of an alley) to 89 years. Over 56 percent of the alley pavements retired were between 40 and 60 years old and 36 percent retired were greater than 60 years old. It has been estimated that there are 162 miles of alleys 40 to 60 years old and another 28 miles over 60 years old. Considering that few alleys were built in the 1930's, almost 200 miles of alleys or about one-half of the system is approaching the age where experience has shown that their condition requires replacement.

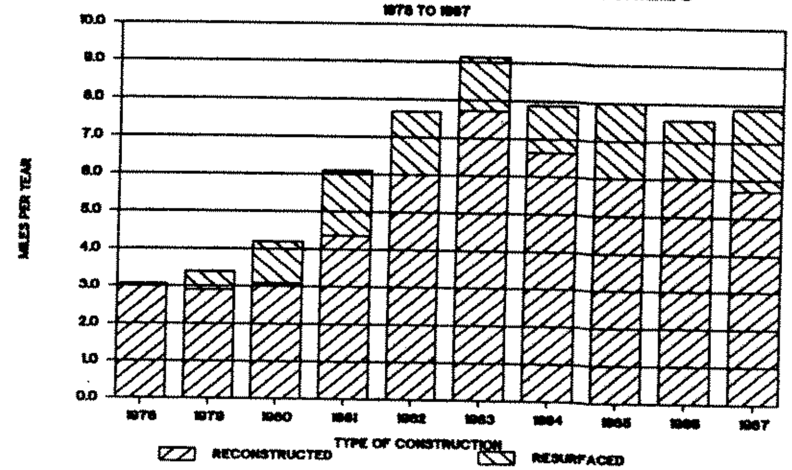
Precisely what level of pavement deterioration is tolerable and for how long will be determined by the City policymakers with the appropriate engineering and public input. Alleys, however, have functions that do permit significantly more deterioration than would be acceptable for streets. For instance, the primary purpose of alleys is to provide access to the rear of residential and commercial properties, while the primary purpose of streets is to provide an efficient and safe means of transportation, including access to property. While the quality of the street pavement surface is of critical importance to the safe and efficient movement of vehicles, a lower quality pavement surface of alleys can still provide acceptable access. Vehicles normally travel at much lower speeds in alleys than in streets. However, drainage of an alley can be just as important a consideration as its physical condition. The City's public hearing process which occurs prior to any assessable improvement to alleys or streets enables neighborhood residents to register their support or opposition to a project. If in the opinion of the Alderman representing the area where the proposed improvement is to take place, there is major opposition to a project, at his or her discretion, the project can be cancelled.

While a street is generally perceived as a barrier separating neighbors, an alley is less of a barrier because there is less traffic. The result is that alleys can be a focal point of a neighborhood. While a deteriorated alley tends to detract from a neighborhood's appearance, a refurbished alley will tend to be self-cleaning and contribute to neighborhood attractiveness. In some instances, the refurbishment of an alley has stimulated the repair and clean up of the rear of properties, such as fences, garages and refuse storage areas, thereby increasing property values.

HISTORICAL EFFORT

For several years now the City has been increasing the annual budgetary allocation for Alley Reconstruction and Resurfacing. Since 1978, the budget allocation has increased from $650,000 to $2,500,000 in 1988. The pace of reconstruction and resurfacing of alleys has also steadily increased, although not quite as rapidly as budget allocations. In part, this is the result of inflation, but it can also be attributed to the fact that a greater proportion of the alleys were reconstructed in recent years at greater expense than being resurfaced. The alley program requires proportionately more reconstruction than the street program, because an alley resurfacing may not provide the necessary minimum slope in the flow line and could result in the alley line being higher in elevation than some of the abutting garage floors and yard areas, creating drainage problems for property owners. Also, the pavement deterioration that occurs before an alley project is approved for rehabilitation may prevent its use as a base for resurfacing. The graph below depicts the miles of alleys that were resurfaced or reconstructed over the last ten years. The dramatic improvement that has occurred in the City's effort to preserve the alley system is demonstrated by the difference between the averages for the period 1978-1984 compared with the 1985-1987 period and in the following graph.

ALLEY PRESERVATION EFFORT IN MILES



Source: Bureau of Engineers

Average	Reconstruction	Resurfacing	Total
Last 10 Years	5.15 Miles	1.34 Miles	6.49 Miles
Last 3 Years	5.91 Miles	1.89 Miles	7.81 Miles
Last Year	5.70 Miles	2.17 Miles	7.87 Miles

ESTIMATED USEFUL LIFE

The estimated useful life of alley pavement is defined as the time between original construction and reconstruction, resurfacing or removal. The estimated useful life of a reconstructed concrete alley is 50 to 60 years and for asphalt resurfacing is 25 to 35 years. This estimate is used only for planning and is not used as a factor to program specific projects.

IMPLIED REPLACEMENT CYCLE

Sometimes the effectiveness of infrastructure preservation programs is measured by "implied replacement cycles". This is calculated by dividing the total mileage of an infrastructure system by the average mileage rehabilitated or refurbished annually during a given cycle. The table below shows the "implied replacement cycle" for alleys over the last ten years, the last three years and last year.

Alley Replacement Cycle*

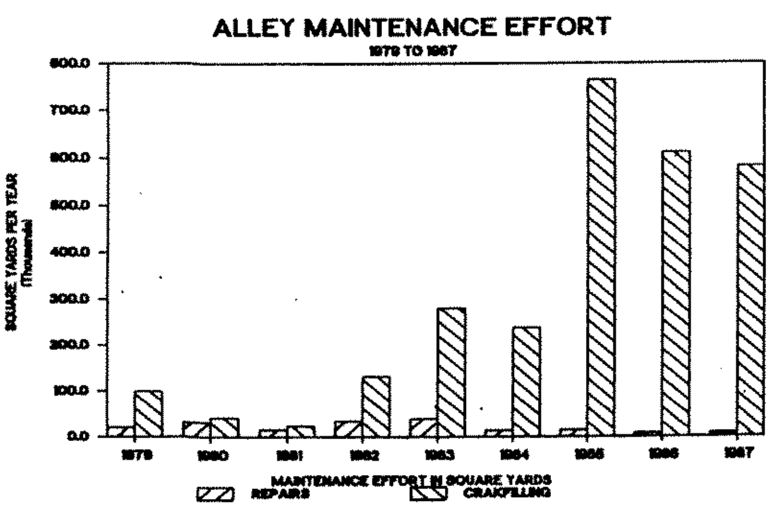
	Last 10 Years	Last 3 Years	Last Year
Replacement Cycle	65 Years	54 Years	53 Years

*Assuming 420 miles of alleys

The "implied replacement cycle" has improved dramatically in recent years. Based on this, the 1987 cycle appears to be adequate. However, one of the problems with "implied replacement cycles" is that they do not take into consideration that public facilities, like the real estate they serve, are not built up uniformly over time.

PREVENTIVE MAINTENANCE

The Bureau of Street and Sewer Maintenance is responsible for preventive and emergency maintenance of the City's alleys. The primary preventive maintenance activity of alley pavements is crackfilling. The graph below shows the maintenance activities during the last six years.



The Bureau reports that the ideal crackfilling cycle for alley pavements is six years. To achieve this cycle it would be necessary to crackfill approximately 600,000 square yards of alleys per year. The Bureau achieved this crackfilling goal since 1985 and should be able to maintain it in the future unless funding is reduced. In addition to crackfilling, the Bureau patches potholes and makes permanent repairs to alleys.

When these maintenance expenditures are viewed in the context of the estimated $120,000,000 replacement cost of the alley system, they appear to be quite low. In fact, 1987 maintenance expenditures were less than one-half of one percent of the estimated replacement cost of the City's alley system. The pothole patching occurs primarily in the fall, winter and spring when emergency repairs are required. The permanent repairs involve area wide patching or spot patching with hot-mix asphalt concrete during warmer months.

SYSTEM PERFORMANCE

At the present time, there does not exist a precise, objective measure to evaluate the performance of the City's alleys as a system. In large part, alleys are not a system at all because each one exists independently of other alleys. Other systems, such as streets, sewers, watermains, etc., are characterized by interdependencies; that is, being continuous or connected in some way which is essential to serve their function. While it may not be feasible to measure system performance, there are other ways to evaluate the City's alleys. Perhaps one of the best indicators that the City's alleys are in a deteriorated condition is the relative lack of opposition to the resurfacing and reconstruction of alleys proposed at public hearings. In general, the abutting property owner pays about 46 percent of the cost of an alley project compared to 23 percent for street improvements. In 1987, 37 percent of street projects were cancelled at public hearings compared to 14 percent for alleys.

CONCLUSION

The City has increased the annual capital budget allocations for alley resurfacing and reconstruction from $650,000 in 1978 to $2,500,000 in 1988. The 1988 allocation will provide for the resurfacing and reconstruction of 9.25 miles of alleys. Currently there are about 190 miles of alleys that are at least 40 years old. Given the existing construction rate of 7.9 miles per year, it would take about 24 years to reconstruct or resurface the alleys that are now 40 years old. It is, therefore, recommended that the current rate of construction be maintained or slightly increased. At the present construction rate, some of the alleys will be over 70 years old before they are reconstructed. As a result, it is likely that increased funding for alley maintenance programs will be necessary, in order to hold together some of the oldest alleys, until they are scheduled for replacement.

S I D E W A L K S

At the present time, it is estimated that there are 2,000 miles of sidewalk in the City or about 62,400,000 square feet. In areas of the City where public improvements were originally installed prior to 1958, most of the sidewalk is six feet wide and five inches thick. Since then the standard width has been reduced to five feet. Exceptions to these generalizations, include full walk (lot line to curb) in commercial areas, six foot width required around schools, bus stop paving, and variations at corners, alleys, driveways, etc. Prior to 1960, the City required that sidewalks be constructed on both sides of the street whenever permanent pavement was constructed. Since then, many streets have been constructed with no sidewalks or sidewalks on only one side. In addition to the sidewalks on streets, there also are more than 150 pedestrian ways and malls which contain public sidewalks.

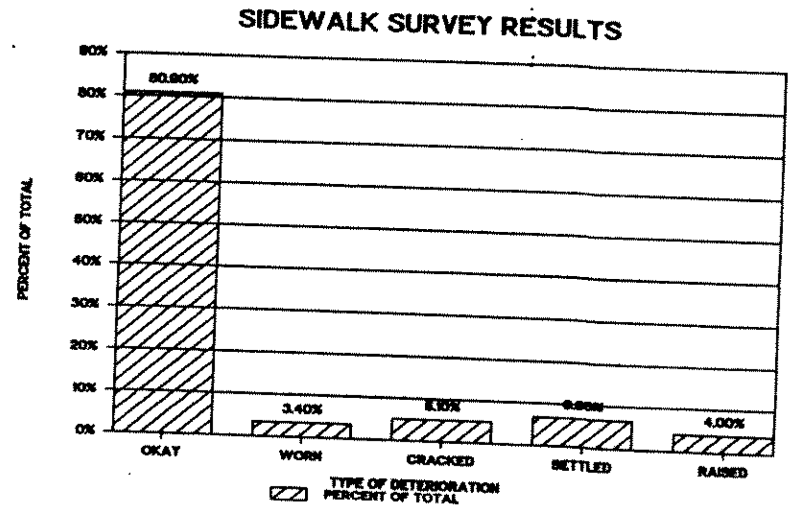
The Bureau of Engineers is in the process of accumulating and entering data in the Road Life computer file which will show which streets do not have walk or have walk on only one side of the street. This project will not be completed for many years. It will provide only the miles of walk and not the total area, because of the many variations in walk width.

CONDITION MEASUREMENT AND PROJECT SELECTION

Unlike other infrastructure systems, the City does not have a detailed inventory of the sidewalks. This type of inventory has not been kept because the maintenance of such an inventory would be very expensive. While it may be possible to compile the original construction of sidewalks, it would be difficult to keep information up to date because sidewalks are replaced for several reasons by different City agencies and private contractors. It would be necessary to keep records identifying each sidewalk stone. There are approximately two million sidewalk stones in the City. It is doubtful whether or not the extensive amount of record searching and field investigation required to develop and maintain a detailed profile of the sidewalk system would be worthwhile.

In the fall of 1983, the Bureau of Engineers, with field assistance provided by the Bureau of Street and Sewer Maintenance, undertook a survey to develop an estimate of the overall condition of the City's sidewalk system. For the survey, 961 block faces were selected out of a total of approximately 32,000 block faces. This sample size provided a reasonably accurate profile of the condition of the City's sidewalk system. Another survey is planned for 1988. If such a survey were done every four or five years, changes in the overall condition of the City's sidewalk system could be monitored. This would be one method of determining whether or not the current rate of replacement is adequate. The results of the 1983 survey indicate that approximately 19% of the City's sidewalk have one or more defective conditions. The sidewalk survey indicated that on average slightly less than one in five sidewalk stones were defective, although in some samples as many as every other stone was defective and in others virtually none. This wide variation can be explained by the fact that in some areas there has not been a walk replacement contract for at least 20 years and in others the defective walk was replaced recently. If a defective condition is hazardous, the City eliminates the hazard by temporary patching immediately after it becomes aware of it.

The following graph shows the proportion of various defective conditions found by the survey.



Source: Bureau of Engineers

The construction and replacement of sidewalk is accomplished through a number of different agencies and procedures. This makes it difficult to determine the location and total quantities constructed or replaced each year and the reason for its replacement. At the present time, the Bureau of Street and Sewer Maintenance hires contractors to replace sidewalks, driveway, curb and gutter on an area wide basis. This accounts for about 47 percent of total walk replacement. The Bureau's crews replace about 12 percent of the total on an individual basis, and about 41 percent is replaced in connection with street, sewer and water construction projects. The following is a list of the ways by which walk replacement is accomplished.

1. Bureau of Engineers street and alley construction contracts
2. State of Wisconsin Department of Transportation contracts
3. Bureau of Street and Sewer Maintenance walk repair contracts
4. Bureau of Street and Sewer Maintenance force account work
5. Bureau of Engineers sewer construction contracts
6. Bureau of Engineers water construction contracts
7. Permit construction by utility companies
8. Permit construction by private owners
9. Construction of handicap ramps

Sidewalk replacement is the result of many factors, some of which are independent of age or condition. The situations which cause walk replacement can be divided into two categories, those which require replacement because of defective condition and those which are replaced as a result of abutting or other improvements. The following table lists those reasons.

Defective Condition	Other Improvements
1. Deterioration	1. New building construction
2. Cracking	2. Replacement of curb and gutters
3. Settlement	3. Utility construction
4. Heaving	4. Construction of pedestrian ways
	5. Construction/widening of driveways

Of these, the only items which can be related to the age of the walk are the deterioration and a portion of those which are cracked, the remainder of the cracked walk, and the settlement and heaving are independent of age. Inspectors from the Bureau of Street and Sewer Maintenance determine what walk should be replaced in the area sidewalk replacement program. This program is currently on a 20-25 year cycle. Statutory authority to replace sidewalks allows the levying of special assessments without a public hearing because it corrects defective conditions. Property owners are notified of defective conditions and given an opportunity to correct them on their own. After a certain period of time, a private contractor will replace all the defective sidewalks that the City has indicated is appropriate.

The Bureau's operation and maintenance budget funds walk replacement that is done by Bureau personnel. The work done by Bureau forces is generally in response to a complaint or request to remove a defective condition. It is not part of the area-wide sidewalk replacement program.

The replacement of sidewalk as part of a paving, sewer or water project is under the direction of the Bureau of Engineers. On paving projects, the replacement of walk is sometimes based on paving needs, not walk deterioration. For instance when existing land improvements permit changing the grade, all of the sidewalk might be replaced rather than just that which is defective, thereby allowing the use of the existing street pavement as a base for resurfacing. This results in a reduction in the overall cost of the project.

In 1963, the City began a capital program to replace a backlog of raised, cracked and broken sidewalks in some of the older sections of the City. Except for a program in the early 1950's sidewalk replacement was done when streets were rehabilitated or on an as needed basis by crews of the Bureau of Street and Sewer Maintenance. The Capital program enabled the Bureau of Street and Sewer Maintenance to hire private contractors to correct defective sidewalk conditions on an area-wide basis. City crews were still needed to correct defective walk conditions in an expeditious manner in order to protect citizens from injury and avoid liability.

HISTORICAL EFFORT

As mentioned previously, sidewalks are replaced by several different agencies. The determination of the total amount of public sidewalk constructed each year requires a search of the records in several locations. In some instances, the information is readily available and annual quantities have been tabulated. The graph below provides the data from records which are available for the past ten years. The walk constructed by street paving contracts includes new construction and carriage walks. In addition, on some street construction contracts all of the sidewalk is replaced not because it is defective but because the paving plans require a change of grade. It is reasonable to assume that on the average over 1,000,000 square feet of sidewalk per year has been replaced during the past ten years. A more detailed study to determine the quantities placed would not seem to be warranted, because of the time required to review plans and records. Also considered is the fact that there is only an estimated inventory quantity.

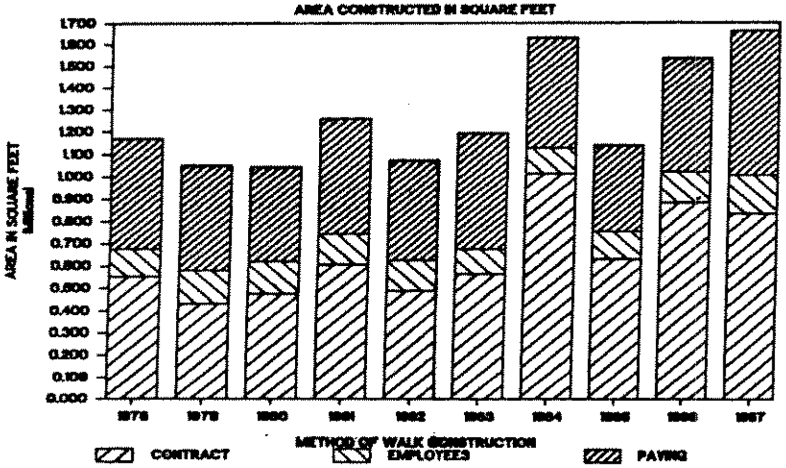
Concrete Walk Construction in Square Feet *

Averages	Contracts	City Forces	Paving Contracts	Total
Last 10 Years	650,894	135,053	492,650	1,278,597
Last 3 Years	787,065	146,950	514,719	1,448,734
Last Year	837,913	176,720	645,216	1,659,849

Source: Bureau of Street and Sewer Maintenance & Bureau of Engineers

The following graph displays the sidewalk construction over the last ten years from City sidewalk contracts, work done by City employees and that done as part of paving contracts.

SIDEWALK CONSTRUCTION 1978-1987



ESTIMATED USEFUL LIFE

The estimated useful life of sidewalk stones is about 50 years. As evidenced in the 1983 sidewalk condition survey, deterioration constitutes a relatively minor proportion of total defective conditions.

IMPLIED REPLACEMENT CYCLE

The following table shows the implied replacement cycle for sidewalks, over the last 10 years, the last three years and the last year.

Sidewalk Replacement Cycle*

Last 10 Years	Last 3 Years	Last Year
48.8 Years	43.1 Years	37.6 Years

* Assuming 62,400,000 square feet of sidewalk

The survey, mentioned in the condition measurement section, indicated that about 19% of the City's sidewalks were defective. This would be about 11,900,000 square feet of the estimated 62,400,000 square feet of sidewalk. If sidewalk replacement continued at 1,200,000 square feet a year, it would take 10 years to replace that much defective sidewalk.

PREVENTIVE MAINTENANCE

The only maintenance activity required on sidewalks is patching or ramping to eliminate or reduce hazardous conditions.

SYSTEM PERFORMANCE

Conceptually, infrastructure systems, such as, streets, sewers and water mains, have two distinguishing characteristics. Components of each system are interdependent. That is, each segment of street, sewer or water main must be part of a network or connected to the rest of the system to serve its primary function. The other distinguishing characteristic is that components can be functionally classified within a hierarchical order. For instance, the streets within the transportation system have been given a functional classification by the State Department of Transportation based upon land use and/or traffic volume. The highest classification or most volume would be the Principal Arterials, then Minor Arterials, Collectors and Local Access streets. Viewed in this context, alleys would be included within the local access classification. Sidewalks do not provide vehicular access to property, but they do provide pedestrian access and may, therefore, be considered part of the Transportation System. This is especially true when the public transit system is considered because passengers are dependent on sidewalks to provide access from their residence to the limited number of bus stops. Sidewalks might also be considered part of a pedestrian system separate from the transportation system.

An important function of sidewalks and pedestrian paths is to reduce intermodal transportation conflicts by separating pedestrian from vehicular traffic. The pedestrian system might be construed to have a hierarchical order. Facilities such as skywalks, elevators, and escalators might be considered specialized components of the pedestrian system similar to bridges in that they provide a connecting link between pedestrian paths. Sidewalks or other pedestrian paths in or around commercial, office, government, educational and entertainment facilities might be the highest order in the pedestrian system carrying the greatest volumes of pedestrian traffic. Sidewalks in residential areas provide a relatively safe route between destinations for children going to school, to link residences to neighborhood shopping facilities and public transit points and are also part of children and adult recreational space particularly tricyclers and joggers. Based on the 1980 Census, 19,827 people use public transit to get to work in the City of Milwaukee. The Census Bureau estimated that 58,349 households or 24.1 percent of total households in the City of Milwaukee did not have a vehicle. There are approximately 165,000 students enrolled in public or private schools, including advanced education. It seems likely that most of these students walk to school or at least to the bus stop.

It is obvious that sidewalks are an important means of transportation to the citizens of Milwaukee. The importance of sidewalks and their condition is, however, not uniform throughout the City. Areas such as, the East side of Milwaukee, the Downtown, West of Downtown, and areas near schools, shopping districts, elderly and low income housing projects etc. receive the greatest amount of pedestrian traffic and, therefore, should be in the best condition. Residential areas that are densely populated, having 40 foot wide lots or smaller for single family and areas with duplexes or multifamily units may require that sidewalks be in the best condition. Areas that are less densely populated, may require sidewalks on only one side of the street and the condition may be somewhat less critical. Areas that are primarily industrial or that have only three or four single family homes per acre may not require sidewalks.

One method to evaluate whether the present overall condition of sidewalks is adequate is to examine the frequency and cost of accident or injury claims filed against the City because of defective sidewalks. According to the City Attorney, there are approximately 30-50 claims filed against the City each year because of defective sidewalks. It is estimated that the annual payout due to defective sidewalks is less than $20,000. Another method of determining whether or not the current rate of replacement is sufficient would be to periodically survey the overall condition of sidewalks as was done in the Fall of 1983. This is planned for 1988. These surveys would then be compared to identify trends.

CONCLUSION

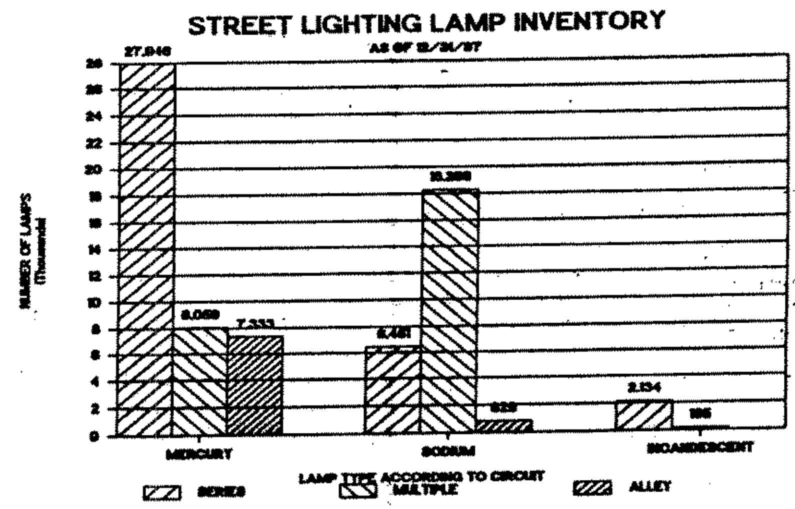
At the present time, the City is replacing about 1,200,000 square feet of sidewalk annually. It would take about fifty years to replace the existing sidewalk at this replacement rate. Whether or not this rate is adequate depends on two questions. First, is the amount of defective sidewalk, approximately one out of five stones, acceptable to the citizens of this community and their representatives? Second, will the current rate of replacement increase, decrease or maintain the current overall condition of the City's sidewalk system? These questions should be addressed before changing the current replacement effort. This is being carefully monitored.

STREET LIGHTING

The City's street lighting system is constructed, maintained and operated by the Bureau of Traffic Engineering and Electrical Services. The City of Milwaukee purchases electricity wholesale from the Wisconsin Electric Power Company. The Electric Company provides various primary voltages to the City's 232 substations. Power from these substations is distributed through the City's underground and overhead cables to the City's street lighting units. The lighting units are connected in either series or multiple circuits. Each lighting unit consists of a pole, bracket fixture and luminaire (light fixture). Power is provided to ballasts which start and operate the light source contained in the fixture.

The Bureau of Traffic Engineering and Electrical Services began development of a data base of its street lighting system in 1977. Data is being collected in conjunction with the Bureau's lamp replacement program. It will include the type, manufacturer and age of poles, the type and manufacturer of luminaire lamp and the type of circuit. This data base and associated software will enhance the Bureau's maintenance programs and provide detailed profiles of the lighting system for use in developing the annual capital budget and long range capital improvements program, as well as generate the annual washing and group lamp replacement programs.

The following graph and inventory information portray the City's street and alley lighting system as of December 31, 1987.



Substations		Cable Plant	
Permanent Type	52	Underground	2,392 miles
Temporary Type	6	Overhead	85 miles
Street Enclosures	174	Total	2,477 miles
Total	232		

Light Poles 60,384

The City purchased the alley lighting system from the Wisconsin Electric Power Company in October, 1983. That system included 8,103 alley lighting units and the associated brackets, fixtures, and other equipment. The City purchased the original system for $590,000. In 1987, the Wisconsin Electric Power Company established a Grant and Loan Program to promote the conservation of electrical energy.

The conversion of existing alley lights from 100 watt mercury vapor to 70 watt high pressure sodium vapor lights qualifies for a grant under the terms and conditions of that program. Therefore, during the summer of 1987, the City of Milwaukee entered into an agreement with the Wisconsin Electric Co. to convert all alley lights from 100 watt mercury vapor to 70 watt high pressure sodium vapor. It is estimated that the conversion of the alley lights will result in a 55% increase in lighting levels with a 30% decrease in electrical energy consumption. The conversions were started in fall of 1987 and are tentatively scheduled to be completed in 1989.

Unlike most other infrastructure systems, street lighting systems have experienced rapid technological advancements in the last several decades. Milwaukee, like other communities, has embarked on street lighting programs, which before they have been completed, become obsolete because of advanced technology. In terms of lighting effectiveness and energy efficiency, the current recommended technology of high and low pressure sodium vapor are at least two and one half times more efficient than the previously recommended mercury vapor, which was twice as efficient as the old incandescent lights. In addition to the functional obsolescence resulting from rapid technological change, the minimum street lighting standards appropriate for different purposes have increased. As a result, it has been necessary to continuously upgrade the street lighting system. These standards are established by the American National Standards Institute after review of the recommendations by the Illuminating Engineering Society (IES). The IES's recommendations are based on the need for improved lighting (to improve traffic safety and reduce crime) modified by economics, technology and the results of research.

When changed, these minimum standards for street lighting do not necessitate the immediate replacement of all existing below standard street lights. It is, however, necessary to install lighting that meets current standards when streets are reconstructed and the previously existing lighting is removed.

Adequate street lighting is an essential ingredient in the City's effort to reduce crime and improve traffic safety. It is intuitively obvious that poorly lighted streets, alleys, parks and other public areas provide an environment more conducive to crime than such areas would if they were adequately lighted. The City's traffic safety record, which is, and has been one of the best in the country, is in part, the result of an adequate street lighting system that has kept pace with technology and changing needs.

CONDITION MEASUREMENT AND PROJECT SELECTION

Several years ago the City began a group replacement program of street light lamps (bulbs). This maintenance program involves the replacement of lamps on a four year schedule. This provides an opportunity to inspect the street lighting system on a four year cycle. Occasionally, in response to an observed system problem, a system survey is performed to evaluate the problem. An example of this is the recent City-wide survey of concrete poles (street lighting). As a result of the survey, a three year capital program was initiated in 1983 to replace several hundred defective concrete poles. That program was completed early in 1987.

The function of the street lighting system is to maintain adequate lighting on all Milwaukee streets in a cost effective and aesthetically pleasing manner. The latest published American Standard Practice of Roadway Lighting is used as a design guide. These standards are recommendations for the minimum amount of light required.

There are a number of other factors considered when selecting projects for the annual street lighting program, including information from maintenance personnel, historical major and minor circuit troubles, Aldermanic and citizen requests, traffic and pedestrian safety, crime reports and coordination with the paving program. Recently the annual street lighting program priorities have been dictated by the capital budget in the following proportions.

1988 CAPITAL BUDGET

Purpose	Percent	Amount
1. Paving connected work	96.7	$2,960,000
2. Installation of permanent lighting where no lighting exists or replacement of Wisconsin Electric Co. or interim lighting.	0	0
3. Replacement of incandescent lighting.	0	0
4. Replacement of defective concrete poles.	0	0
5. Replacement of large wattage mercury vapor	0	0
6. Miscellaneous.	3.3	100,000
TOTAL	100.0%	$3,060,000

The street lighting policy emphasizes lighting alterations in coordination with the paving program and lighting areas presently without permanent lighting. Energy conservation, rather than lighting standards should receive priority.

With the development of ballasts to operate both the high and low pressure sodium vapor lights on the existing series system, the "old style" incandescent and the now standardized mercury vapor lamps should no longer be installed. Any new circuits in the outlying areas should continue to be multiple as well as areas within but only when large major recabling projects are required for other than light source changes. This is because of the inherent efficiencies of the sodium vapor light sources as shown below:

Lumen Output Per Watt Consumed

Type of Lamp	Lumens
Incandescent	17 - 25
Mercury Vapor	50 - 60
Sodium Vapor-High Pressure	120-130
Sodium Vapor-Low Pressure	180-190

In recognition of the City's street lighting goals, past practices, and new technologies, the City's adopted policy for the street lighting program is as follows:

The more efficient light sources should be utilized, such as high or low pressure sodium vapor, and the large wattage incandescent and/or mercury vapor lighting be replaced with the more efficient light sources as funds allow.

Underground street lighting cable be replaced only due to being defective, for paving construction, if necessary; or for circuit cutovers.

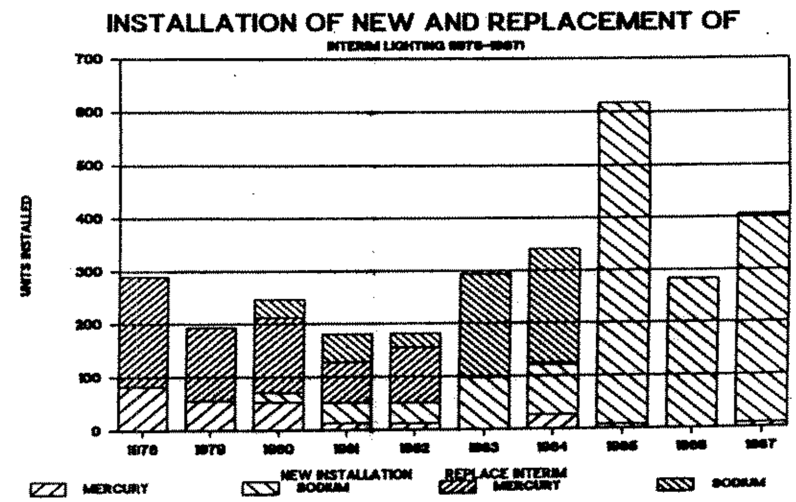
Street lighting pole replacement and/or relocation should be kept at a minimum on all relighting projects.

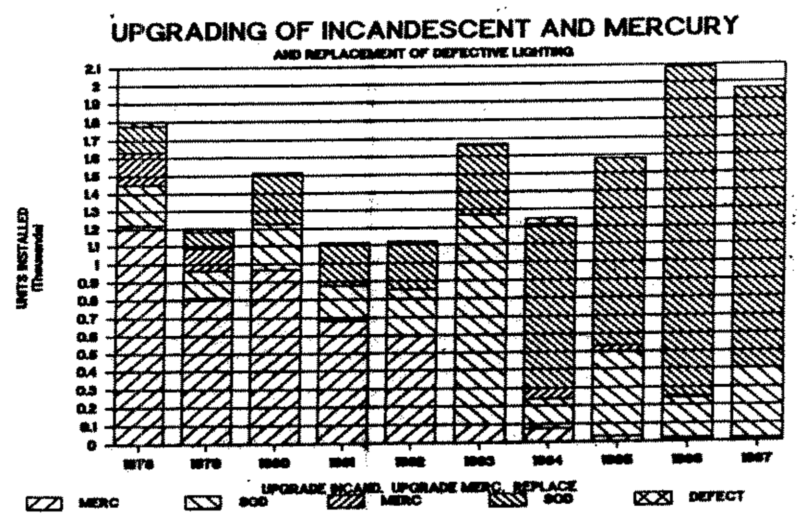
No more incandescent or mercury vapor lighting shall be installed except in historic districts so designated by the Common Council; and that the latest state-of-the-art be monitored and, if applicable, and with the approval of the Common Council, integrated into the system in the future as funds allow.

The final selection of proposed projects to be undertaken in a given year is determined by the Superintendent of the Bureau along with the Engineer in charge of street lighting.

HISTORICAL EFFORT

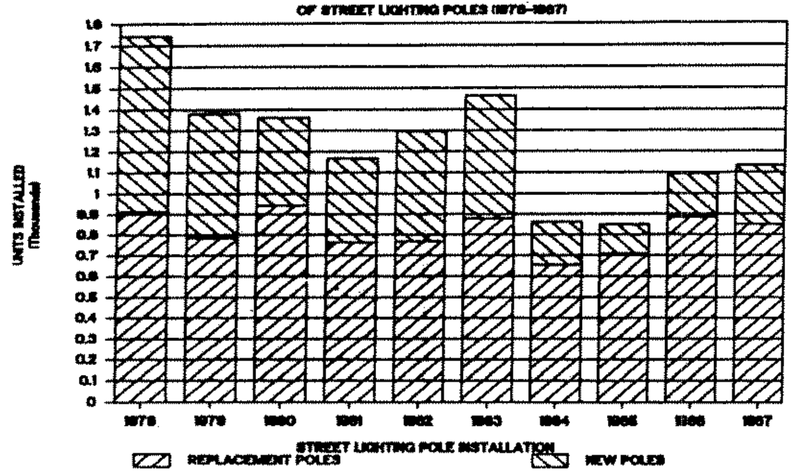
The following graphs depict the number of street lighting units that have been installed new or as replacement in the last ten years. This includes work paid for with State and Federal Aid, Community Development Block Grant funds and various redevelopment projects.



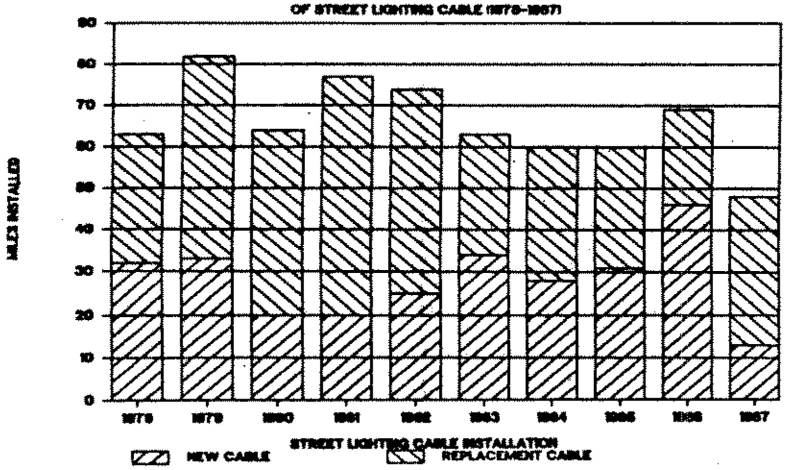


Of the 18,347 street lighting units installed in the past ten years, 15,317 or 83.5% were for the replacement or upgrading of existing facilities. The following graphs depict the number of street light poles and the length of cable that have been installed in the last 10 years, for new installation, or the removal and replacement of existing facilities.

INSTALLATION OF NEW AND REPLACEMENT



INSTALLATION OF NEW AND REPLACEMENT



Street Lighting Installations

Average	Street Lighting Poles Installation New	Replace	Total	Street Lighting Cable Installation in Miles New	Replace	Total
Last 10 Years	421.0	814.6	1,235.6	28.2	37.8	66.0
Last 3 Years	212.3	814.3	1,026.7	30.0	29.0	59.0
Last Year	285.0	849.0	1,134.0	13.0	35.0	48.0

Each year approximately 2% of the cable plant is replaced in conjunction with the paving program or the programmed replacement of aged and defective cable. During the mid 1970's, all street lighting cable between the East/West Expressway, West North Avenue, the Milwaukee River and the Milwaukee Road Railroad (C.M.ST. P.+ P. RR) right-of-way was replaced, primarily as a result of a Model Cities relighting project.

ESTIMATED USEFUL LIFE

The estimated useful life of the major components of the street lighting system are as follows:

Component	Estimated Useful Life
Street Lighting Fixtures	30 years
Street Lighting Pole	30-35 years
Street Lighting Cable	45 years
Substation	40 years
Substation mounted on wood poles	15-20 years

As indicated elsewhere, technological and functional obsolescence as well as alterations to other infrastructure systems frequently determine street lighting replacement needs rather than deterioration.

IMPLIED REPLACEMENT CYCLE

One measure of the effectiveness of an infrastructure preservation program is the "implied replacement cycle". This is calculated by dividing the total number of units in the system by the quantity replaced or refurbished in a year. This yields the cycle or number of years that would pass before the entire system would be replaced, refurbished, or upgraded. The table below shows the "implied replacement cycle" for street lighting units, poles and cable for the last 10 years, the last three years, and last year.

Implied Replacement Cycle

Facility	Last 10 Years	Last 3 Years	Last Year
Street Lighting Units	88.2 Years	33.6 Years	32.6 Years
Street Light Poles	74.1 Years	74.1 Years	71.1 Years
Street Light Cable	65.5 Years	76.7 Years	37.8 Years

PREVENTIVE MAINTENANCE

The major preventative maintenance activities of the Bureau include: lamp replacement, lens cleaning and substation maintenance. Some of the maintenance on substations is of a preventive nature such as sealing the roofs and tuckpointing the bricks, etc. As mentioned previously, vapor type street lamps are replaced on a four year cycle, and incandescent lamps on a six month cycle. Although lamps might last considerably longer, the rate of lamp mortality increases rapidly after these replacement frequencies. It is more than twice as expensive to replace lamps individually compared to group replacement. Therefore, this group replacement program is preventive in nature.

SYSTEM PERFORMANCE

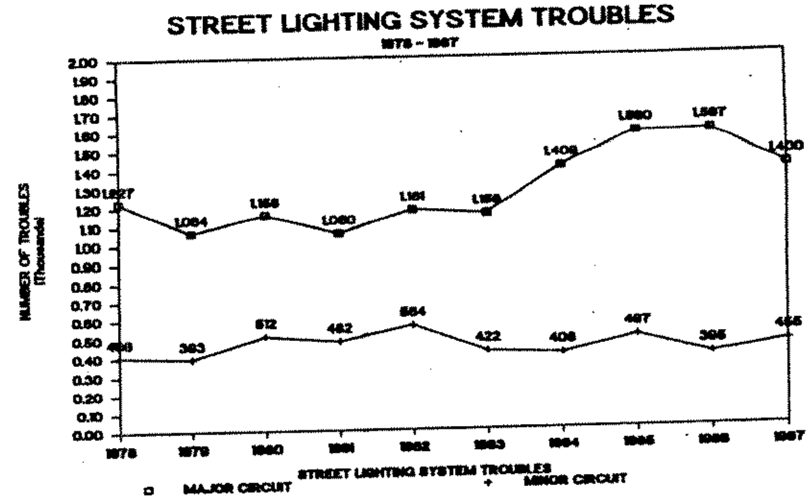
The Bureau has estimated that about 74 percent of the City's street lighting system is in general conformance with the latest recommended minimum levels of lighting. A significant accomplishment, considering that in 1972, almost none of the City's lighting system met the standards that were newly published at that time. There is, however, a backlog of areas without permanent lighting of approximately 3,000 fixtures or $7.1 million in current construction costs.

The Bureau of Traffic Engineering & Electrical Services maintains a record of two types of system problems. These are defined as:

Major Circuit Troubles include any faults or failures that cause a circuit or substation to go off during the night which could not be relighted and which required a daytime crew to repair. The fault could have been caused by natural deterioration, damages, and/or vandalism. Most major troubles are repaired within 24 hours.

Minor Circuit Troubles include transformer or cable failure which put out only one or two lights on the block with the remainder functioning. These include brief Wisconsin Electric Power Company outages, circuit troubles which cure themselves or are corrected by night crews, breakers tripped or fuses blown for no apparent cause, poles knocked down, etc. Most minor troubles are repaired within 30 days.

The following graph displays the system experience during the last 10 years. The frequency of troubles is often dependent on winter ground conditions such as depth of frost and snow cover.



Note: Large amounts of rainfall in 1984 resulted in more major circuit troubles.

Source: Bureau of Traffic Engineering & Electrical Services

While there appears to be a general increase in the frequency of street lighting system failures, the rate of failure has stabilized or slightly decreased because of the increased facilities exposed to potential fault. This seems to indicate that the rate of cable replacement may be adequate for now, but these performance measures must be monitored annually for trends.

Although the anticipated average useful life of a street lighting fixture is about 30 years, lighting technology has been evolving at a rapid rate resulting in technological obsolescence occurring prior to physical deterioration. In addition, the minimum acceptable level of lighting has also increased resulting in functional obsolescence.

The anticipated average useful life of a street light pole is between 30 and 35 years. In the section on Condition Measurement, it was mentioned that in 1983 an accelerated street light pole replacement program was initiated. This improved the replacement cycle, but may still be short of the average life cycle. When the current computerized record system is complete, survivor curves can be developed to guide the replacement program.

While the Bureau of Traffic Engineering and Electrical Services estimates that an undisturbed street lighting cable would last 45 years, it is often necessary to replace cable earlier because the street is reconstructed. More computerized information is required to develop future survivor curves for cable replacement. Technological changes in the last 20 years have resulted in approximately 75% of the cable system being less than 20 years old, but only 40% of the poles are less than 20 years old. The development of meaningful survivor curves for cable may not be practical within the next 10 years, but is appropriate and should be available for poles. The cable plant records should also be computerized.

CONCLUSION

While the City's street lighting system is in good condition, there are a number of areas of the City which either do not have street lights (about 47 miles) or have temporary lights. In addition, at the end of 1987 there were still 2,299 incandescent lights in the system. These incandescent lights do not produce enough light to meet the minimum standards and are becoming impossible to purchase. They also use about twice as much electricity to produce light as the sodium vapor lights that would replace them.

The rate of street light fixture installation in the last ten years has not kept pace with the estimated life cycle of 30 years. However, some of these installations provide an increased level of services as the number of street lights serving a street are increased when lighting on the street is upgraded to current national standards. Therefore, the installation rate includes both the replacement and enhancement of the existing street lighting system. Replacements must be separated from additions to increase the usefulness of the data in examining the City's preservation effort.

The rate of pole replacement has not kept pace with the estimated life cycle of 30-35 years. The 1985 budget increased the rate of pole replacement. However, further increases may be necessary. The rate of cable replacement is probably adequate considering the the relative newness of a large part of the system, but a better computerized record system must be developed in the near future to develop survivor curves. The current computerized system covers only poles and fixtures and is incomplete. The rate of cable replacement should be reviewed periodically to assure adequate replacement.

The Six Year Program is in the process of being revised in keeping with the new street lighting policy and the above recommendations. Current levels of funding, with revised priorities from the new street lighting policy seem adequate for replacement lighting. Funding for new lighting to provide uniformity of service and for replacement of incandescent lighting should be increased. It may also be necessary to increase the rate of replacement of cable and poles.

TRAFFIC CONTROL

The Bureau of Traffic Engineering and Electrical Services is responsible for the installation, operation, and maintenance of all traffic signals, signs and pavement markings on nearly 1,300 miles of City streets and highways and participates in providing traffic control on facilities of other jurisdictions within the City. The traffic control devices described in the table below were operated and maintained by the City of Milwaukee as of December 31, 1987.

Standards for the use of traffic control devices are set forth in the Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), published by the U.S. Department of Transportation, Federal Highway Administration, to provide uniformity of traffic control devices throughout the nation. This manual sets forth the basic principles that govern the design and usage of traffic control devices and provides the framework for their installation, operation and maintenance. Traffic patterns and roadway geometries govern the appropriate combinations of traffic control devices installed.

In 1977, the Bureau completed implementation of a computerized sign inventory system to assist in the management of traffic signs. Information includes size and type, location, method of mounting, sign messages where applicable, date of initial installation and date of the most recent replacement. The inventory provides information to identify replacement needs, to locate missing signs, and to provide information on signs currently in service.

Traffic Control Devices as of December 31, 1987

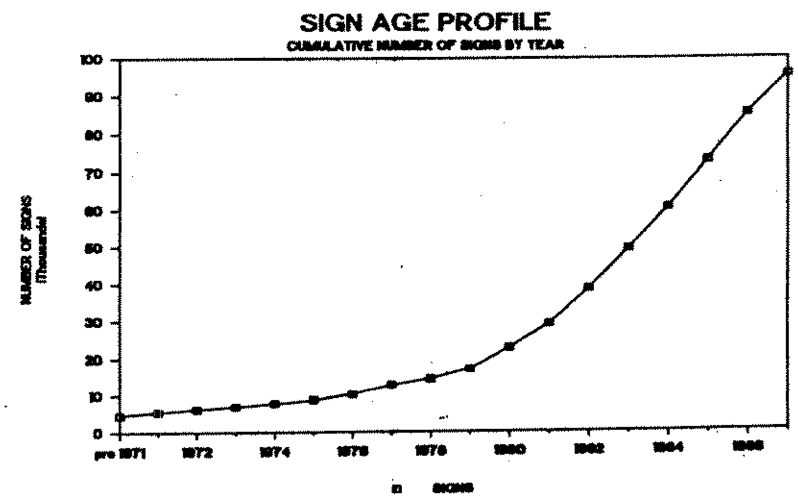
Traffic Control Type	Quantity
Traffic Signals	
Signalized Intersections	685 Intersections
Traffic Control Beacons	9 Locations
Pavement Markings	
Center Lines and Lane Lines	
Painted	207.8 Miles
Semipermanent	101.4 Miles
Total Center & Lane Lines	309.2 Miles
Crosswalks	1,650 Intersections

Signs

Stop and Stop Related	11,559
Yield	822
Parking	35,232
Other Regulatory	16,411
Warning	6,128
Street Names	21,354
Reflectors	5,738
Miscellaneous	1,082
Total Signs	98,326

Source: Bureau of Traffic Engineering & Electrical Services

The following graph portrays the number of signs in the field which were installed in the identified year or earlier.



It should be noted that the above graph excludes alley signs and black and white street name signs. The graph shows that while overall the majority of signs are relatively new, there are more than 6,000 signs which are over 15 years old which should be replaced. However, their replacement is funded in the Operation and Maintenance Budget which has not been sufficient to reduce this backlog.

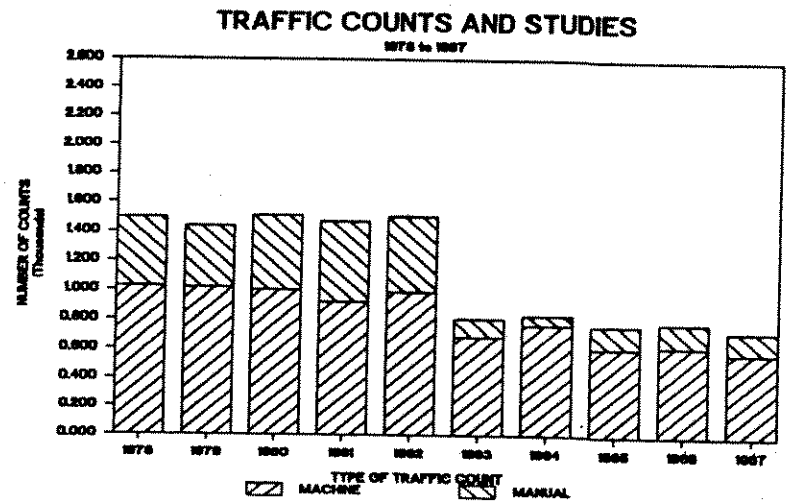
Computerization of the traffic signal inventory began in 1983. These data files include the type of controller and latest date of replacement, interconnect cable, program clocks, and number of signal lamps and controlled visibility lenses. In addition, specific intersection signal phasing and timing information can be stored on the computer for solid state controllers. This information can be transferred directly from the computer to the traffic signal controller, simplifying the programming or reprogramming of a controller and reducing the potential for error. Location, type, signal timing and phasing data, are also maintained in a series of engineering drawings for each individual installation. Individual maintenance and trouble reports are kept in a non-computerized file.

Pavement markings are used to provide guidance for motorists and pedestrians at intersections or on roadway segments. Records are maintained on engineering drawings and on computerized records. Files are maintained on the annual painting program, as well as on age and type of semipermanent pavement markings in service.

CONDITION MEASUREMENT AND PROJECT SELECTION

Traffic control devices must be continually reevaluated and adjusted to reflect changes in traffic patterns. Information on travel patterns and overall performance of the City's street system, is derived from data on traffic volume and accidents which are collected and evaluated on a continuous basis, and from data on speed, vehicular delay and pedestrian volumes which are collected as needed.

The performance of existing traffic control devices, as well as the assessment of additional needs, are evaluated through a variety of traffic checks and studies. Twenty-four hour machine traffic volume counts are performed on a continuing basis, ranging from once monthly at 23 key counting stations to once every five years on all arterial roadway segments under City jurisdiction, and as needed on other non-arterial roadways and for specific traffic movements. These counts are used to determine levels of facility usage and to analyze citywide travel habits and patterns. Additional manual counts and studies are performed as needed to evaluate system performance and effectiveness, and to provide necessary design information. A historical summary of traffic studies completed is presented in the following graph.



Source: Bureau of Traffic Engineering and Electrical Services

Since 1970, accidents reported in the City have been entered into a computer. Reports generated from this data identify intersections or roadway segments having high accident frequencies. Accident patterns found at these high accident locations, are studied to identify deficiencies in traffic operations and suitable countermeasures. In many cases, accidents have been reduced through improvements or additions to traffic control devices. Due to a change in Police Department accident reporting procedures, 1987 accident records cannot currently be accessed by computer and a new computerized method of retrieving accident information is being developed.

Traffic control devices currently are maintained through several group replacement programs. These programs are based on normal useful life and serve as a preventive maintenance measure to ensure continuing operation of these facilities. All signs in service for fifteen years or more are identified and subsequently replaced on a group basis.

Group replacement of traffic signal lamps is done at all traffic signal installations as a preventive maintenance measure. All signal lamps are replaced annually, as well as all electromechanical controller mechanisms and associated major electronic components.

Complex traffic signal operations are being upgraded to microprocessor based traffic signal controllers to allow greater flexibility in traffic signal operation. The number of solid state controllers installed annually is constrained primarily by budgetary limitations. Traffic signal projects are also initiated due to reports of trouble, changing traffic patterns, and deterioration of equipment.

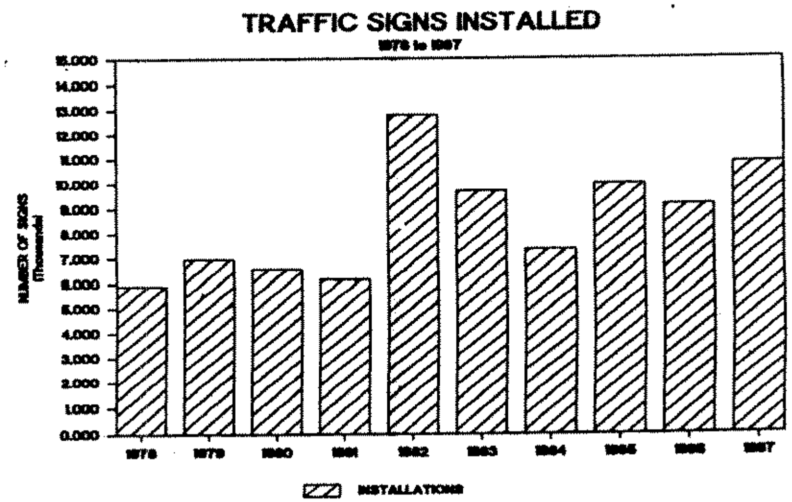
Projects to reconstruct, upgrade and install new traffic control devices are prioritized based on the following needs and fund availability:

1. Paving program
2. Accident countermeasures and safety improvements
3. Urban development
4. Citizen complaints and requests
5. Changes in travel demand and patterns
6. New technological advancements
7. Changes in minimum standards

HISTORICAL EFFORT

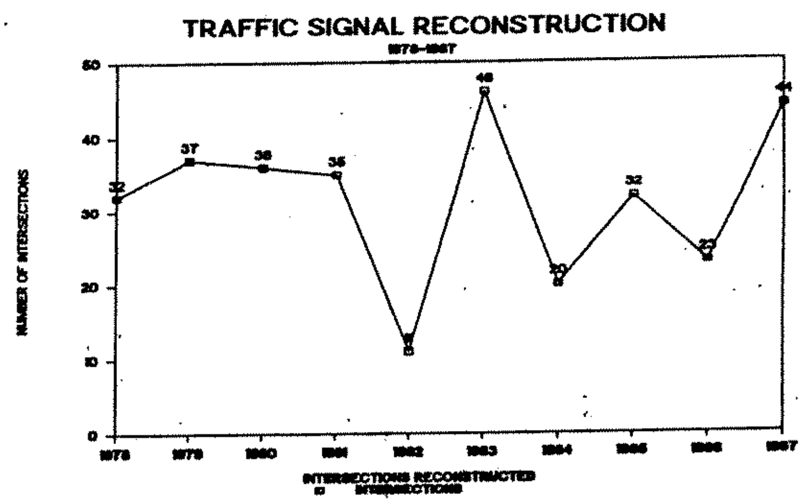
Traffic signs are replaced because of age, damage, vandalism, theft, and in conjunction with paving. Several group replacement projects have also been completed that brought signs up to standards set forth in the MUTCD. Since the early 1970's, the City has replaced all "No Left Turn", "No Right Turn", "No U-Turn" and "Do Not Enter" signs, "One-Way" signs, "Yield" signs, and warning signs to meet these standards.

Sign installation for the period from 1978 through 1987 is shown in the graph below. Of the 120,520 signs installed from 1978 through 1987, approximately 80,674 signs or 67 percent were new sign installations. Reflected in this total is the installation of parking restriction signing in the Fall of 1979 to implement the winter parking program in the third Aldermanic district and an expansion to the remainder of the City in the Fall of 1982.



Source: Bureau of Traffic Engineering and Electrical Services

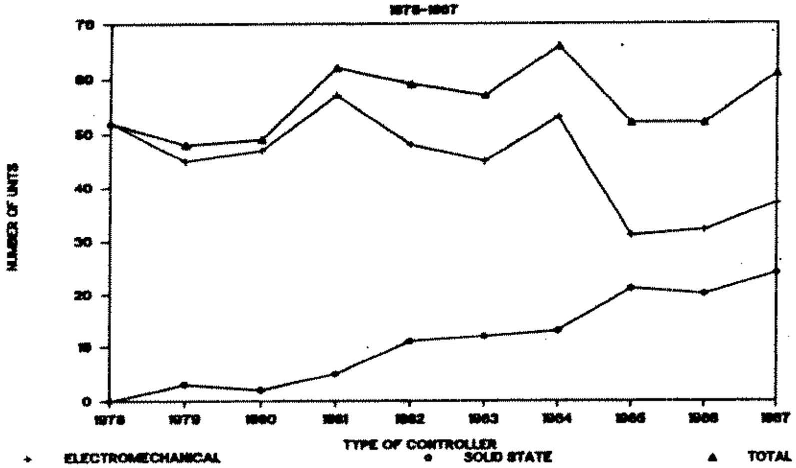
The reconstruction of traffic signal installations is completed primarily as a function of paving activity, hazard elimination and urban redevelopment. The number of installations reconstructed by year during the last ten years is detailed in the graph below.



Source: Bureau of Traffic Engineering and Electrical Services

New traffic signal control cabinets are installed to replace deteriorated or damaged cabinets and electrical components, or to upgrade signal operation to meet the changing needs of both vehicular and pedestrian traffic. Replacement activity for the last ten years is also shown in the following graph. A total of 558 control cabinets were installed during this period.

CONTROL CABINET REPLACEMENTS
1978-1987



Source: Bureau of Traffic Engineering and Electrical Services

Traffic Control System Installations

Average	Signs	Signals	Control Cabinets
Last 10 Years	12,052	32	58
Last 3 Years	13,145	33	55
Last Year	10,801	44	61

The City installed its first solid state controller in 1977. These controllers provide the flexibility required to accommodate the most complex traffic control situations, and provide an added measure of safety through the use of a conflict monitor which prevents the display of conflicting signal indications. As of December 31, 1987, solid state controllers have been installed at 93 locations, and are being used primarily to replace complex electromechanical controllers and upgrade signal operations to be more responsive to fluctuations in traffic volumes.

ESTIMATED USEFUL LIFE

The useful life of the different types of traffic control devices varies considerably. Signs typically have a useful life of approximately ten to fifteen years. Changes in national standards for size, shape and message of traffic signs have resulted in group replacement programs, whereby signs were replaced prior to reaching the end of their useful life.

The components of a traffic signal installation have varying useful lives. Signal standards are replaced predominantly as a result of damage and roadway improvement projects. The useful life of an individual signal lamp is approximately one year. Although lamps may last longer, mortality increases rapidly after this period, and to eliminate replacement of individual lamps as they fail, bulbs are group replaced annually. Control cabinets have an average life of approximately fifteen years and are replaced as they physically deteriorate.

Electromechanical controller mechanisms last almost indefinitely because of current maintenance procedures. Rapid technological advancements have,however, led to the obsolescence of several of the initially installed solid state controllers. As these were only installed very recently, the physical useful life of solid state controllers is unknown. The estimated useful life of the major components of the traffic control system for planning purposes are as follows:

Component	Estimated Useful Life
Reflectorized signs (Pre 1976)	10 years
Reflectorized signs (Post 1976)	15 years
Signal standards	25 years
Signal controllers	20 years
Control cabinets	15 years
Cable	50 years

IMPLIED REPLACEMENT CYCLE

To assess the adequacy of existing replacement efforts in preserving the present levels of traffic control, the implied replacement cycle for traffic control devices was determined by expanding current replacement efforts to determine the period of time over which the entire existing traffic control system would be replaced. These values are then compared to the estimated useful life of the various components. The results of this analysis are shown in the following table.

Implied Replacement Cycle

Traffic Control Device	Current Number of Installations	Last 10 Years	Last 3 Years	Last Year
Signs	98,326	9	8	10
Signals and Beacons	694	22	21	16
Control Cabinets	688	12	13	12

Source: Bureau of Traffic Engineering and Electrical Services

Signs typically are replaced as the end of their useful life is reached. It should be noted that this analysis does not take into account annual fluctuations in the number of signs in service due to installation of new signs, signs removed from service, signing alterations due to changes in legislation, or replacement of signs due to changes in traffic patterns.

The implied replacement cycle for traffic controllers would indicate more frequent controller replacements than necessary to maintain the existing system. However, since traffic flow does not remain static and with recent advances in solid state controller technology, many controllers have been replaced to improve the quality of traffic signal operation and enhance the performance of both individual intersections and systems of traffic signals, providing safer and more efficient traffic operation. In addition, 122 control cabinets or approximately 22 percent of all control cabinets replaced during the past 10 years were replaced due to knock down or other type of damage. Reconstruction of a traffic signal installation also does not necessitate the complete replacement of all equipment.

PREVENTIVE MAINTENANCE

Several major preventive maintenance programs are operated by the City to preserve effective operation of traffic control devices. The most extensive maintenance is performed at traffic signal installations. To ensure proper visibility and function of all signal indications each individual lens is cleaned and all bulbs are replaced annually. Special programmed visibility lenses are cleaned twice annually to preserve proper focus and visibility. All mast arm installations are inspected annually and following any severe wind conditions for any indication of structural damage or failure. These lamp cleaning and replacement programs also ensure the annual visual inspection of all equipment and proper operation of each signal installation.

All electromechanical controller mechanisms and associated electronic components in a control cabinet, are returned to the City's signal shop each year for cleaning and to rebuild or replace any worn or damaged parts. This annual replacement and rebuilding of controllers and electrical components increases the life of a control cabinet and reduces the probability of signal failure or loss of service. At the present time, no general maintenance is performed on solid state controllers. However, a systematic inspection and maintenance program is being developed for these devices. Under this program, conflict monitors and controllers will be checked for proper operation, and all equipment will be visually inspected and replaced as needed.

To maintain sign reflectiveness; approximately 2,400 low level signs, reflectors, hazard markers and "Keep Right" signs are washed annually. No maintenance is performed on other traffic signs.

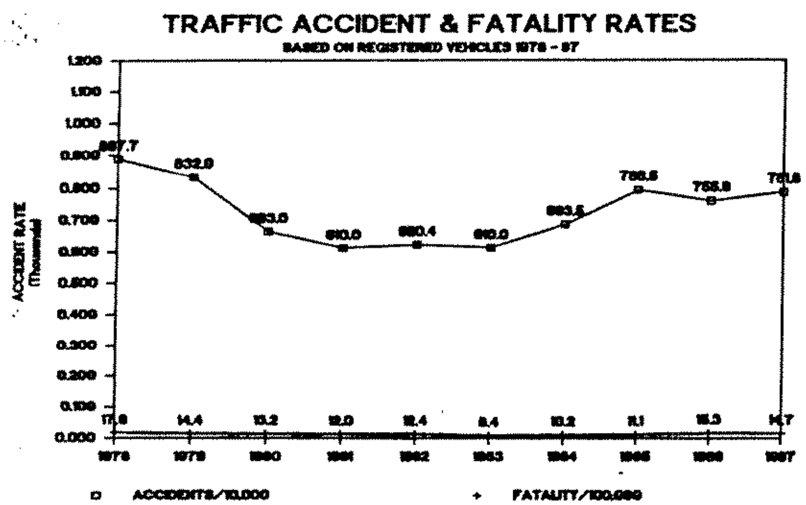
SYSTEM PERFORMANCE

Traffic control devices regulate, warn, or guide traffic in order to provide safe, efficient and predictable movement of all traffic throughout the City's street and highway network. These devices must be designed and situated in such a manner as to gain the attention of all drivers and pedestrians, while conveying a clear and simple meaning and providing sufficient time for a proper response. To be effective, traffic control devices must command the respect of all roadway users.

Traffic control devices are installed and operated to meet the varying needs of traffic throughout the City. They are installed in a uniform manner to assure that vehicle operators and pedestrians alike recognize and understand the meaning of these devices, and properly respond to them based on previous exposure to similar traffic control situations. Uniformity simplifies the task of the road user by treating similar situations in the same manner, and by aiding in the recognition and meaning of these devices. However, traffic control devices used where inappropriate may result in disrespect for these devices at locations where they are needed. As such, it is the responsibility of the City not only to install traffic control devices in a uniform fashion only at appropriate locations, but to remove devices no longer required when changes in traffic patterns occur.

One indicator of the overall performance of the City's traffic control system is trends in accidents experienced on City streets. The total number of accidents and fatalities which occurred in the City of Milwaukee for the last ten years is displayed in the following graph. The data indicates that both accident frequency and accident rate have declined substantially during this period. Some of this decline may also be due to changes in reporting. When compared to the number of registered vehicles in the City, the accident rate of 888 accidents per 10,000 registered vehicles in 1978 has declined to a rate of 782 accidents per 10,000 registered vehicles in 1987. The fatality rate was 1.47 deaths per 10,000 registered vehicles in 1987.

Several other measures of effectiveness are used to assess traffic control operation, such as level of service, congestion, delay and travel time. These measures are currently used to evaluate subsystems of the street network but could be expanded to system-wide evaluation of traffic to improve planning activities and assess deficiencies in traffic operation.



Source: Wisconsin Department of Transportation and Bureau of Traffic Engineering and Electrical Services.

CONCLUSION

Changes in national standards, technology and standard practices, have resulted in significant improvements in traffic control operations. Uniform signing throughout the country, has made messages conveyed by signs more easily recognizable and therefore more effective. The Capital Improvements Program should provide sufficient funding for the installation and replacement of traffic control signs, signals, and control cabinets thereby maintaining safe and orderly movement of traffic throughout the City. There is, however, a need for increased funding in the Operations and Maintenance Budget for the replacement of aging signs. Also, solid state traffic signals are more responsive to changing traffic demands and expansion of these systems would provide more efficient movement of traffic and reductions in delay.

The life of signal equipment has been extended and equipment failures have been minimized through effective maintenance programs. Existing replacement programs preserve the effectiveness of all types of traffic control devices, and thereby maintain safe operation of traffic. With solid state technology, further improvements in traffic signal operation can be achieved.

P A R K I N G

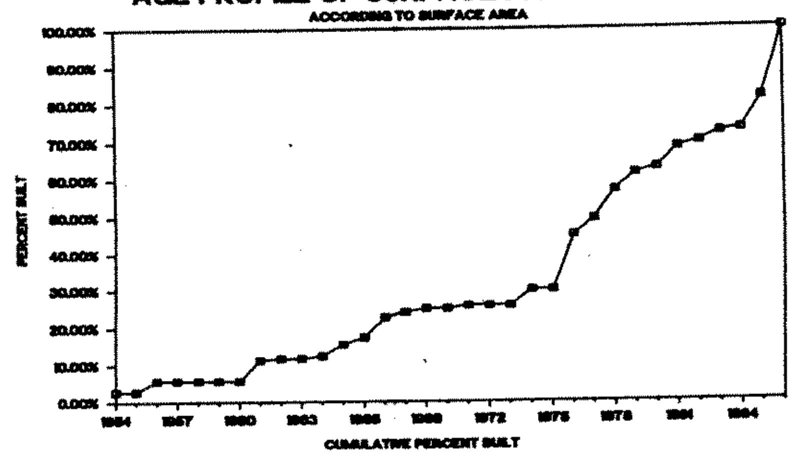
The City of Milwaukee's Parking Division is responsible for the operation and maintenance of 73 off-street parking lots and four parking structures. In addition, the Division administers the City's metered parking program which utilizes over 5,100 meters in its operations. Operation of the off-street facilities may be categorized as follows:

Type	Number	Stalls
Structures	4	3,085
Surface Lots		
Temporary	6	200
Permanent	64	3,091
Employee	3	85
TOTAL	73	3,376
Meters		
On-Street	4,252	
Off-Street	765	
TOTAL	5,017	

The four municipally owned parking structures are operated under lease arrangements with private operators or managed under a management contract. These four structures provide for 3,085 downtown parking spaces to the general public in a variety of forms, such as short term and long term hourly parking; unreserved/reserved monthly parking; and special event parking. Maintenance of these facilities is undertaken jointly by the lessee or manager, responsible for general "housekeeping" duties; and the City, responsible for the structural integrity and mechanical systems upkeep.

The temporary lots, available for public use, and the Municipal employee/visitor lots are made available through obtaining a specific type of permit. The permanent lots available for public use may be further categorized by method of operation. This includes permit parking lots, either municipally administered or through lease arrangement with private operators, metered parking or free parking or any combination of operations on a single lot, dependent on the localized user characteristics. The majority of lots in the permanent lot inventory have relatively new surfaces. Of the 64 lots, 70% have surfaces newer than 11 years and only 11% have surfaces older than 25 years. These older lots will be scheduled in the future as part of the Parking Division's renovation program. Maintenance of the facilities is accomplished through a combination of in-house force account work and by private contract work. The following graph portrays the age profile of permanent surface lots based on surface area.

AGE PROFILE OF SURFACE PARKING LOTS



The City's metered parking program was developed to aid in the control of parking in the heavily used downtown and satellite business districts throughout the City. The main function of meters is to discourage long-term parking by employees and area residents and assure space for area patrons. The actual number of meters in operation on any given day is variable due to a number of factors such as, but not limited to, temporary repairs or removals associated with private or public construction work. Generally, there are approximately 5,100 to 5,300 meters throughout the City. Maintenance, removal and replacement of the meters is handled in house. Revenue collection and winding is done by contract. This task is performed an average of approximately once per meter per week.

CONDITION MEASUREMENT AND PROJECT SELECTION

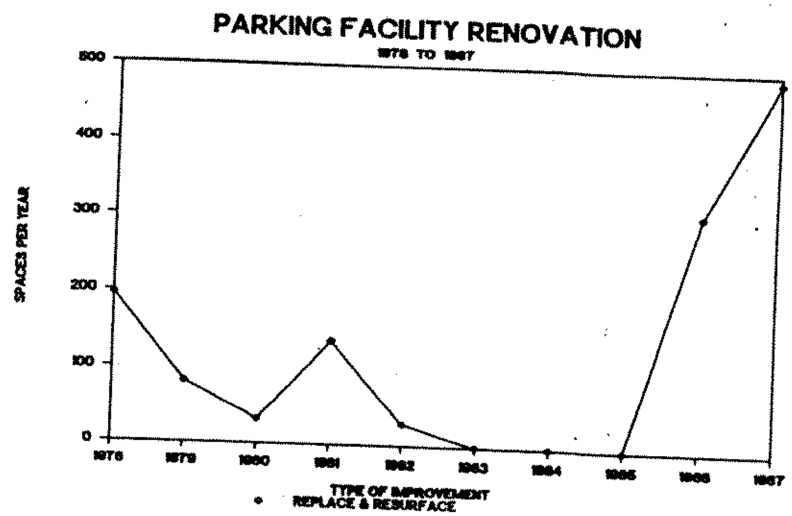
Parking Division engineers inspect all surface lots and parking structures at least each spring and fall. Structural engineers from the Bureau of Bridges and Public Buildings are called upon as needed to evaluate structural problems. Personnel have also been trained and are instructed to check facilities in the area and on routes to and from specific job locations. Parking staff make four meter checks per year between the hours of 5:00 a.m. and 8:00 a.m. to determine if meters are not functioning or are missing. Parking patrons provide information regarding maintenance needs or missing items. On those facilities that are leased, maintenance information is provided by the operators.

Annually, the Division prepares a budget and a six-year program for facilities upgrading. Two structures, MacArthur Square and Milwaukee/ Michigan, 20 and 30 years old respectively, need major floor repairs. The deterioration of these floor slabs can be attributed to lack of floor sealing upon completion of original construction and the relatively flat floor grades. Lack of positive floor drainage caused ponding of salt water, which accelerates corrosion of the structural steel. Repairs for the MacArthur Square Garage began in 1987 with deck replacement on the N. 7th Street East Level. Further repair needs include removal of the entire unsupported deck spans from the N. 9th and N. 7th Street West level, structural modifications to the column capitals, construction of new decks and application of a protective coating. Due to the total removal of the decks, the integral conduit system will also be removed requiring new conduit. This presents an opportune time to update several important systems in the structure which have become obsolete due to technological advances. A few of the systems are the carbon monoxide monitoring system, the structure alarm system, and the traffic and audit control equipment. Although not programmed at this time, the structure at Milwaukee/Michigan will also be in need of similar work in the near future.

The structure at 724 N. 2nd St., although 26 years old, shows little deterioration of the slabs in comparison with the previously named structures. This can be attributed primarily to the design of the structure in that all floors are sloped thus eliminating ponding on the slabs. There is, however, other work required at the structure. Renovations completed in 1987 included new vertical louvres in the helix, new pipe railing and a new lighting system. Plans to further renovate the structure at 724 n. 2nd Street include improvements to the north face of the structure, cleaning the east and west facades, rehabilitating the lobby, and updating the existing elevators. This work is scheduled to take place in 1988. The structure at N. 6th St. and W. Highland Avenue is only five years old and in condition.

HISTORICAL EFFORT

In the period 1977 to 1987 the City resurfaced or repaved 20 surface lots and constructed or acquired 19 new surface lots. In addition, one new parking structure was opened for public use in 1982. The following graphic representation indicates the facility renovation over the last ten years based on the number of spaces.



Parking Facility Construction According to Number of Spaces

Average	New	Replace or Resurface	Total
Last 10 Years	125	128	253
Last 3 Years	66	267	333
Last Year	125	491	616

ESTIMATED USEFUL LIFE

The estimated useful life of a surface parking facility is approximately 20 to 25 years. This figure can, however, vary significantly as a result of weather, salt usage, level of maintenance and vehicle usage. The more extreme the weather variations and/or vehicle usage, the shorter the life span. The estimated useful life of a structure is 30 to 50 years. This too, however, may vary considerably due to design, construction materials, sealing, level of maintenance, drainage and to a lesser extent usage.

IMPLIED REPLACEMENT CYCLE

The implied replacement cycle is a measure of infrastructure preservation. The following table indicates the implied replacement cycle for the last ten years, three years and 1987 for surface parking facilities based on the number of spaces.

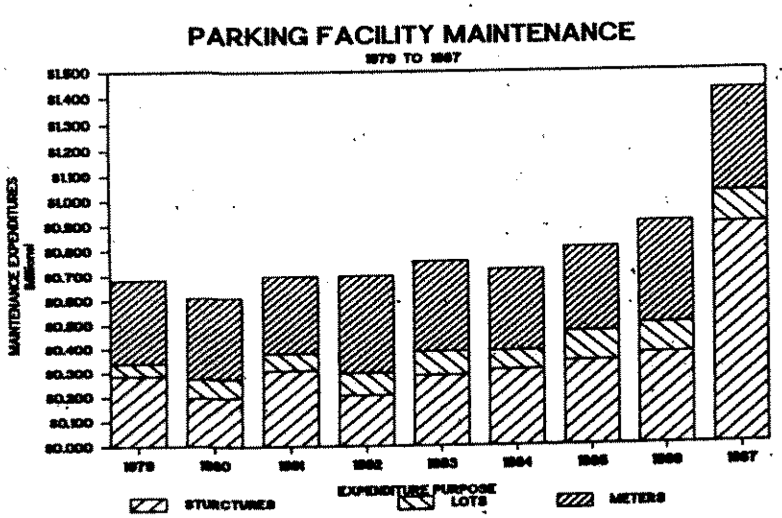
Implied Replacement Cycle

	Last 10 years	Last Three Years	Last Year
Spaces	40 Years	27 Years	51 Years

Implied Replacement Cycle can vary, depending on the method of calculation. Major work on parking facilities is dependent on more factors than facility conditions, such as: other budget items, location of the facility, use of the facility and need of the facility. The best Implied Replacement Cycle would be that calculated over the long range or the ten year figure of 40. Considering that the accepted average useful life of a facility is about 25 years, the renovation program needs to be improved.

PREVENTIVE MAINTENANCE

The Parking Division's annual operating budget for parking facilities includes funding for administration of the parking program, maintenance of the surface lots, and structures and meters, as well as their support facilities such as lighting, wheel stops, fencing, guard rail, paint lines and graphics. Capital work includes rehabilitation of existing facilities and acquisition of new facilities. The preventive maintenance program includes painting, pavement sealing, patching, mechanical system maintenance and cleaning, flushing and snow removal and meter maintenance. Expenditures for maintenance activities over the past nine years are shown in the following graph.



The replacement cost of the entire parking program, including lots, structures, meters, fencing, guard rail, wheel stops and mechanical equipment has been estimated to be approximately $33,000,000. The average maintenance cost of the system is, therefore, approximately 2%. A maintenance cost in this range is relatively low considering the high frequency of use received by the parking facilities and the fact that none of the facilities are protected from the environment. In addition, the human element interaction with the facilities can cause great physical stress especially as it relates to parking meters. The largest maintenance expenses associated with the parking program were for meter mechanism cleaning and repairing, electrical energy and maintenance, painting, surface patching and sealing and mechanical maintenance.

A lighting replacement program at MacArthur Square Garage began in 1985. The original system employed the use of fluorescent lighting and conduit buried in the concrete slabs. The new system will be installed with exposed conduit and sodium vapor lighting. This alteration is expected to reduce energy consumption by 66% and to ease maintenance of the system.

With respect to painting, there are two operations to consider. These operations include corrosion preventive painting, and aesthetic painting. The corrosion preventive painting is done on a need basis with the latest in corrosion inhibitive paints. Aesthetic painting is done on a need basis. Frequency of painting is related to weather conditions, ambient moisture levels (in the structures), and vandalism. There have been a number of advances in "graffiti proof" paint.

The Division patches spalled concrete within the parking structures and pot holes in the surface lots and seals both surfaces. The sealing program is designed to minimize the occurrence of spalling and pot holes by keeping moisture and salt out. It is important that the surfaces be kept clean since the abrasive action of dirt and grit can accelerate deterioration of the sealing compound. Regular flushing and sweeping of the facilities is used to accomplish this task.

Maintenance of the mechanical systems includes oiling of motors, greasing of elevator cables, cleaning of filters and servicing of cash registers and ticket dispensers.

The Meter Shop has a program of regular cleaning as it relates to the internal meter mechanism. This procedure should prolong the useful life of the meter as well as minimize down time and emergency maintenance.

SYSTEM PERFORMANCE

The Municipal Parking Facilities including lots, structures and meters, are a vital part of the urban environment. The availability of parking is a major concern in patronage of a complex or business area, especially downtown. The Parking Division strives to implement measures to assure that municipal parking is provided and used to the benefit of area development. These measures include acquisition and disposal of land for parking lots to the extent possible, as the situation and area requires, placement of and time limit regulation of meters as necessary to achieve desired parking turn over levels and availability, and regulation of parking structure lease requirements to assure their operation in the public's best interest. Residential lots play an important part in snow removal from the street system in that they provide residents an alternate to on-street parking. With adequate police enforcement of the facilities, the Parking operation will continue to function in an efficient, acceptable manner in providing space and turnover for the City's residents and visitors.

CONCLUSION

In general, the surface parking facilities and the metered parking facilities are in relatively good shape. Two of the parking structures, MacArthur Square and Milwaukee/Michigan, are in need of major rehabilitation work on the structural floor slabs. MacArthur Square is tentatively scheduled for further floor and joist renovation over the next four years (1988-91) at a cost of approximately $6.0 million dollars.

A number of developments will affect the operation of the parking program. The new Bradley Sports Center and the Theater District will involve the Parking Division in as many as four new parking structures. The debts for these structures, to be paid for by the Parking Division, may require increased revenues from other parking facilities in order to meet this responsibility.

S E W E R S

The City of Milwaukee is responsible for a sewage collection system comprised of combined, storm and sanitary sewers, drainage channels, storm sewer inlets, catch basins, pumps and manholes. There are 2,446 miles of public sewers, excluding building sewer laterals and catch basin and storm inlet connections. The intercepting sewers as mentioned above, are owned by the Sewerage District. The City's sewers range in size from 8 to 156 inches in diameter. Most of the sanitary sewers are 18 inches or less in diameter; storm and combined sewers range from 12 to 156 inches, and include large box sewers.

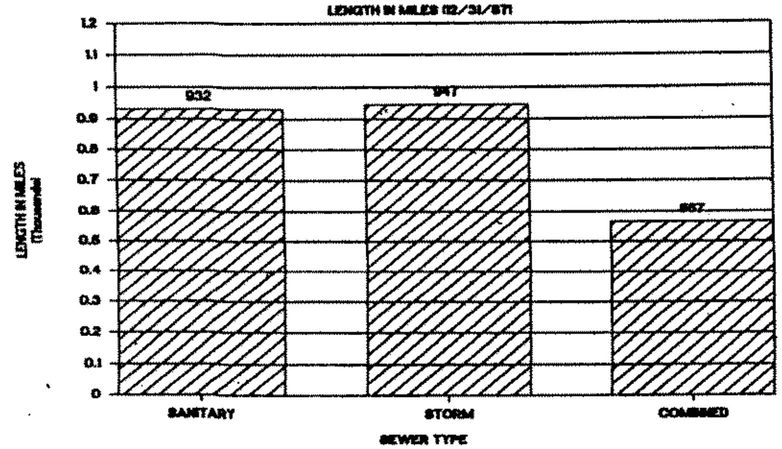
Sewage treatment is the responsibility of the Milwaukee Metropolitan Sewerage District (MMSD). It owns two treatment plants and the interceptors that convey sewage from the City, 17 other Milwaukee County communities and several areas outside of the County. The operating costs of the district are financed by user charges and its capital program is financed by property tax levies. The City accounts for slightly more than one half of the District as measured by property value.

In 1976, the Bureau of Engineers completed an inventory of the sewage collection system. The information contained in this inventory for each segment of sewer includes location, type, length, diameter, age, appurtenances and estimated replacement costs. Most of these records have been coded and can be analyzed by a computer program. This information system should be operational in the early 1990's and will enable the City to study pipe life characteristics and to project future replacement needs. At this point, however, only about eight percent of the total sewer system has been replaced. This, plus the fact that there is insufficient data on the construction material of sewers and that sewers have frequently been replaced for hydraulic rather than structural reasons, makes it difficult to project future needs for sewers. In order to project future needs, at least 20 percent of the system must have been replaced. Some preliminary survivor curves have been developed for combined sewers constructed prior to 1900. They indicate an average life of about 100 years. Since separate sanitary and storm sewers have only been constructed from 1916 and onward, it might be another 50 years before sufficient retirement data on these sewers becomes available. In the interim, it is being assumed that the average useful life for sewers is approximately 125 years. The following table and graph describe the major components of the sewerage system.

Facility	Quantity	Facility	Quantity
Sanitary Sewers	932 Miles	Storm Inlets	31,700
Storm Sewers	947 Miles*	Catch Basins	24,000
Combined Sewers	567 Miles	Manholes	73,000
Total Sewers	2,446 Miles		

*Excludes approximately 55.5 miles of drainage channels, most of which are the responsibility of MMSD.

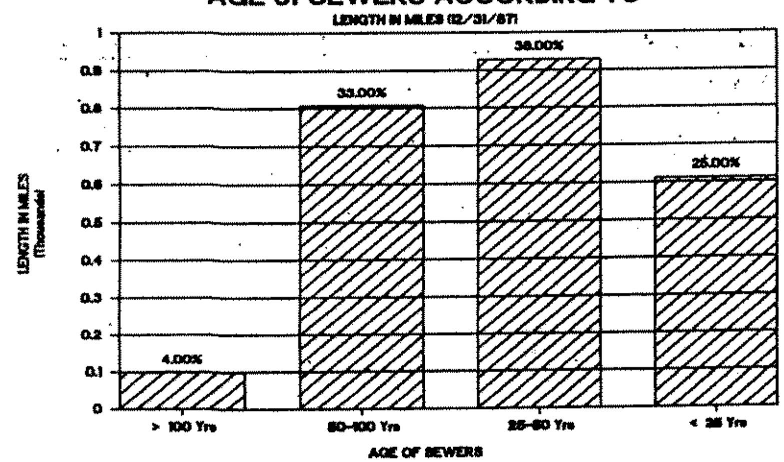
TYPE OF SEWER ACCORDING TO



Source: Bureau of Engineers & Bureau of Street & Sewer Maintenance.

According to the Bureau of Engineers records, the City's oldest existing sewer was constructed in 1869. The few sewers older than that have already been replaced. The following graph portrays the age composition of the City's sewers.

AGE of SEWERS ACCORDING TO



Source: Bureau of Engineers

Sewers are typically constructed of concrete, clay, brick or polyvinyl chloride. Because there is a potential of corrosive discharge, sanitary sewers which serve industrial areas are constructed of clay pipe or coal-tar epoxy-coated concrete.

CONDITION MEASUREMENT AND PROJECT SELECTION

In 1982, MMSD began a $1.5 billion water pollution abatement program to comply with the applicable Federal and State Water Quality Regulations. Prior to this, the District was engaged in numerous planning studies to determine the most cost effective means of eliminating sewage bypasses. Two of these studies are related to the collection system. They are an Infiltration/Inflow Analysis (I/I) and a Sewer System Evaluation Survey (SSES). The District conducted an I/I Study including data from the City's I/I analysis of the sanitary sewers in the metropolitan area. This analysis identified those areas of the separated sanitary sewer system where the elimination of excessive I/I would be cost effective. A Sewer System Evaluation Survey (SSES) was undertaken for these areas. The SSES was completed in 1981. This study involved physically inspecting manholes, smoke testing, storm sewer flooding, televising sewers and inspecting plumbing systems to identify specific sources and quantities of infiltration and inflow of clearwater into the sanitary sewers. The cost of eliminating the identified I/I was compared with the cost of conveying, storing and treating the flow. Based on this analysis, a detailed sewer system rehabilitation program and implementation schedule was developed. The SSES indicated rehabilitation work in the City of Milwaukee cost approximately $12 million. The work included manhole rehabilitation, sewer relays, and spot repair and sealing of sanitary sewers.

The Bureau of Street and Sewer Maintenance collects most of the information about the condition of the sewers. Since 1968, the Bureau's primary source of information about sewer condition has been the videotapes made when sewers are televised. Annually, the Bureau televises over 400,000 feet of combined, storm and sanitary sewers. Storm sewers are examined when they are under streets on the paving program. The selection of sewers to examine is determined by back water complaints, other evidence of a sewer problem, by their location under the streets which are scheduled to be paved the next year and by request from the Bureau of Engineers to examine particular sewers, such as the oldest sewers. In 1985 a systematic program to examine all sewers was initiated at the direction of the Commissioner of Public Works. This program has evaluated almost 160 miles of sewers over 50 years old, 27 percent of those over 100 years old were found to be in poor condition and 27 percent of those between 50 and 100 years old were found to be in poor condition. The videotapes and correlated Sewer Examination Reports are combined with records of problems or service requests and the actions taken.

The Sewer Engineering Division prepares the annual capital budget for sewers based on an evaluation of the information described above and hydraulic analyses as needed. A number of general sewer rehabilitation criteria have evolved over the years to guide the formulation of the sewer program. These practices include:

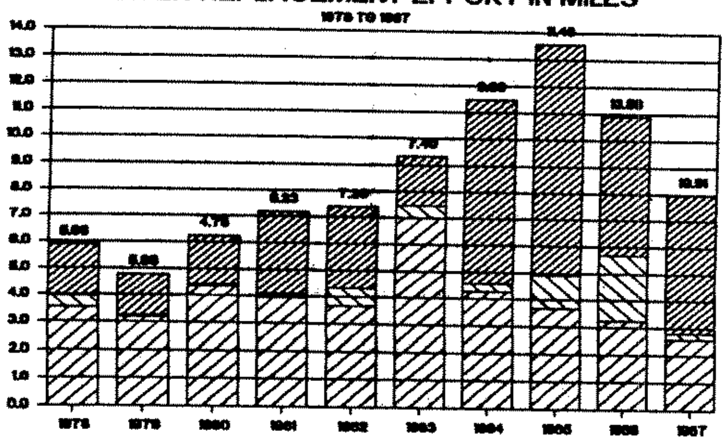
- Relay sewers that are hydraulically inadequate or show decided signs of structural distress, such as loss of shape or excessive cracking.
- Seal structurally and hydraulically sound sewers having circular cracks.
- Perform spot repairs on sewers having a limited number of structural defects, if the sewers are hydraulically adequate.
- Reline sewers where it is cost effective and hydraulic capacity is adequate.

HISTORICAL EFFORT

The following graph depicts the miles of sewers that were relaid by contract over the last ten years. It does not include sewer repairs made by the Bureau of Street and Sewer Maintenance.

SEWER REPLACEMENT EFFORT IN MILES

1978 TO 1987



Miles of Sewer Relays

Average	Sanitary	Storm	Combined	Total
Last 10 Years	4.0	.6	3.9	8.5
Last 3 Years	3.2	1.3	6.4	10.8
Last Year	2.6	.2	5.2	8.0

Source: Bureau of Engineers

ESTIMATED USEFUL LIFE

The estimated useful life of sewers is defined as the expected average age a sewer should remain in service prior to its replacement necessitated by deterioration. For planning purposes this has been estimated at 125 years. It has been noted elsewhere that insufficient capacity rather than deterioration has frequently resulted in sewer replacement, therefore, age is not a reliable indicator of sewer replacement needs. European experience indicates that large diameter sewers may last longer than 125 years.

IMPLIED REPLACEMENT CYCLE

The adequacy of an infrastructure preservation program is sometimes measured by the "implied replacement cycle". The following table shows the implied replacement cycle of sewers over the last ten years, the last three years and the last year.

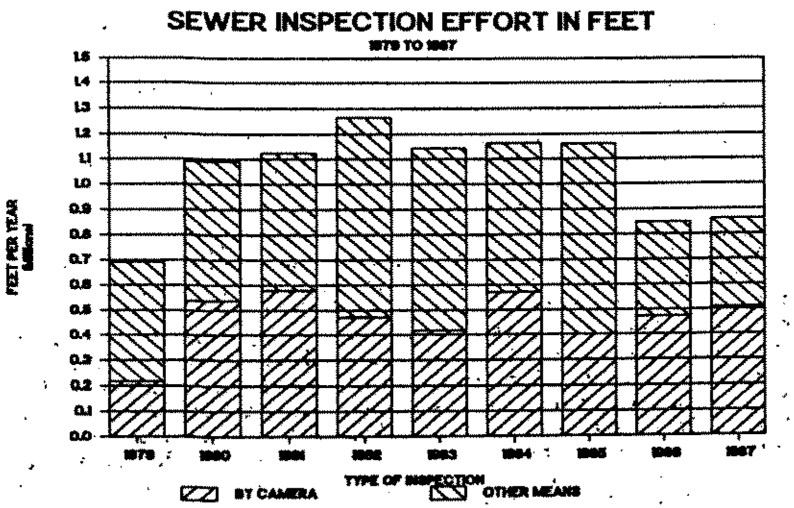
Type of Sewer	Last 10 Years	Last 3 Years	Last Year
Sanitary	236 Years	293 Years	360 Years
Storm	1,578 Years	734 Years	4,510 Years
Combined	144 Years	89 Years	109 Years
All Sewers	288 Years	226 Years	306 Years

"Implied replacement cycles" ignore such variables as the age, stress factors, size, composition, break pattern and soil conditions of sewers, technological changes and changes in standards. While no comparable study for sewers exist, paving studies have found that pavement life deteriorates in a geometric pattern, that is, very little in the beginning and rapid and accelerating deterioration in the last part of the pavement's life. Presumably sewers would follow a similar pattern except extended over a much longer period of time. An example that illustrates the fallacy of replacement cycles, is that, if 100 miles of sewer are constructed and in the first 20 years two miles were replaced, a replacement cycle of 1,000 years is implied. If sewers have an average useful life of 125 years, presumably there would be virtually no replacement needs in the first 20 years.

It can be misleading to rely on miles of sewer replaced as measure of accomplishment. Measuring sewer replacement by miles of sewer replaced ignores the diameter of pipe. (For instance, although relaying one mile of eight inch sewer costs much less than relaying one mile of 60 inch storm sewer, they would both be equal to one mile of sewer relay.) The cost of relaying one mile of eight inch sewer is about $436,000 and the cost for one mile of 60 inch is about $2,322,000.

PREVENTIVE MAINTENANCE

The Bureau of Street and Sewer Maintenance performs all preventive and emergency maintenance and most inspections to the City's sewer system. The following graph shows the Bureau's inspection activities for the years 1980 to 1987.



Source: Bureau of Street and Sewer Maintenance

The Bureau's maintenance activities extend the useful life of the sewer system, provide a high level of system performance, and provide information on sewer condition and performance. Annually, the Bureau inspects about eight percent of the sewer mains, either visually or by televising; makes repairs to about 1.5 percent of the sewer structures and cleans about one-fourth of the sewer mains and structures. The Bureau's maintenance expenditures for the last eight years were as follows:

Maintenance Expenditures

1980	$3,900,961	1984	$5,272,613
1981	$3,637,175	1985	$4,968,482
1982	$4,877,175	1986	$4,323,695
1983	$5,102,629	1987	$4,271,000*

Source: Bureau of Street and Sewer Maintenance
*Estimated

When these maintenance expenditures are viewed in the context of the estimated $2,090,000,000 replacement cost of the sewerage system, they appear to be quite low. In fact, 1987 maintenance expenditures were only three-tenths of one percent of the estimated replacement cost of the sewerage system. For this reason, the Commissioner of Public Works asked the Bureau to develop a preventive maintenance and inspection program.

SYSTEM PERFORMANCE

Ideally, the sewerage system consists of a network of pipes that follows the contours of the land such that sewage flows with the force of gravity at a sufficient pace to keep the sewers clean. The sewage is collected from many sources and flows through an ever concentrating network of pipes to the sewage treatment plant. Unlike the street system with its multiple and conflicting purposes, the purpose of the sewerage system is quite simple. It conveys sewage away from its source to the treatment plant. It also conveys storm water away from properties and pavement to the nearest water course.

Criteria to evaluate how well the City's system is performing might include the frequency of sewer backup, sewer main failures, and the proportion of total sewage flow reaching the treatment plant. It should be noted that the City is not responsible for the interceptor sewers, which are under the direction of the Milwaukee Metropolitan Sewerage District. They convey sewage to the treatment plant itself.

In 1987, there were 49 instances of sewer backups reported due to clogged pipes. Most of these occurred in eight inch sanitary sewers - the smallest in the system. The known causes of these backups were grease, rags and roots. There was an annual average of 56 reported backup incidents during the period 1979-1987. The majority of backups, where known, occurred in small sanitary or combined sewers. The problem of sewer backups does not appear to be increasing. It has been estimated that approximately two sewer main breaks a year occur and these are generally in the smaller diameter sewers. This compares with national statistics of 53.5 breaks per 1,000 miles of sewer pipe per year.

CONCLUSION

The City's sewerage system is relatively new compared to its estimated useful life. Considering this, the City's sewers are still too "young" to be experiencing major replacement needs. However, during 1986 the City experienced unusually high levels of rainfall. Consequently numerous incidents of backwater were reported. This situation is being monitored to determine whether or not the current rate of sewer replacement funded in the 1988-1993 Capital Improvements Program is adequate. At present, it is projected that between the year 2000 and 2030, a gradual increase in the annual replacement rate of sewers will be necessary to achieve a 25 mile per year rate. The City will continue to document and analyze the reasons for sewer failure so that it can more accurately project sewer replacement requirements in the middle and long term future.

WATER DISTRIBUTION

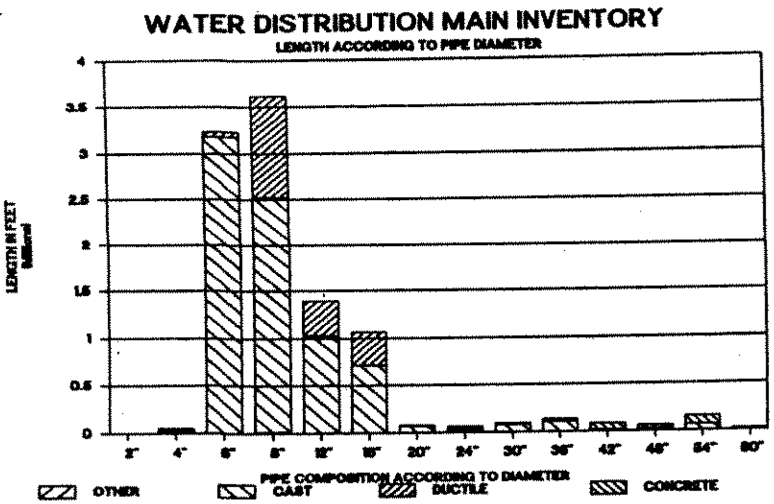
The City of Milwaukee had 1,905.2 miles of transmission (feeder) and distribution mains in its system at the end of 1987. This includes the suburban retail service area in which the mains are maintained by the Milwaukee Water Works. It does not include water mains in communities which purchase wholesale water service from the City. The oldest water mains in the City were installed in 1873. All of the distribution mains installed prior to 1963 are made of gray cast iron. The majority of the distribution mains, 16 inches in diameter or smaller, installed since 1963 are made of ductile iron. All of the transmission mains installed prior to 1957 are made of cast iron. The majority of the transmission mains, 20 inches in diameter or larger, installed since 1957 have been constructed of prestressed concrete.

In 1977, the City began the development of a computerized profile of the water distribution system. The first phase of this project is nearing completion. The second phase of the project will involve the addition of information to the data base on main failures, other main repairs and replacement. The third phase involves the preparation of survivor curves for the various types of material, sizes of pipe and periods of installation.

The basic descriptive data that is being collected for each water main segment includes: location, size, year of construction, pipe material, joint material, pressure district, and appurtenances such as valves, hydrants, etc. The work on the first phase of this project is nearing completion. Work on the second phase of the project will continue in 1988. This project was undertaken initially by CETA personnel and is now being done by existing staff as time becomes available from their other duties. The third phase of the project will be completed when sufficient data becomes available to formulate reliable survivor curves. The project is scheduled to be in operation by the early 1990's.

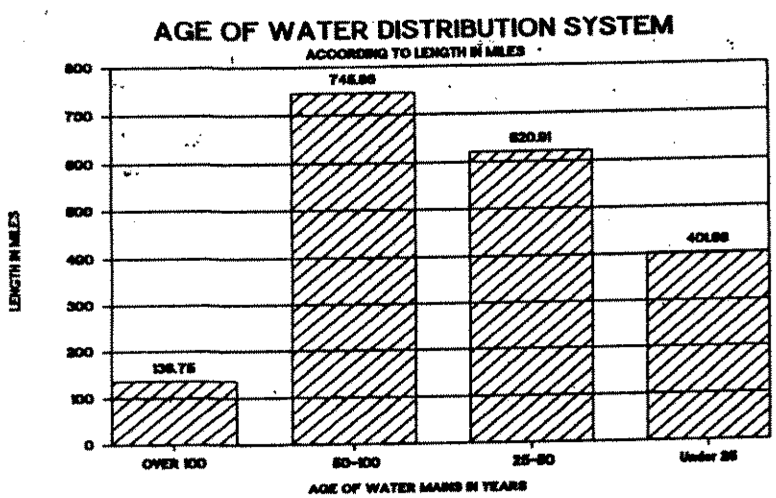
Since the inventory will identify when a main was installed and when it was repaired or replaced, it will be possible to plot a "life history curve" for those water mains that have been retired by type of material, size and period of installation. When sufficient data is available, these plotted curves can be compared with standard survivor curves to project probable future replacement needs. It will also be possible to identify problem areas and ascertain probable causes. At this point, however, only about nine percent of the water distribution mains have been replaced. In order to project a credible survivor curve, at least 20 percent of the mains should have been replaced.

The following graph lists the water mains in the distribution system by material and size:



Source: Milwaukee Water Works

The following graph shows the age of the water distribution system's pipes.



Source: Bureau of Engineers

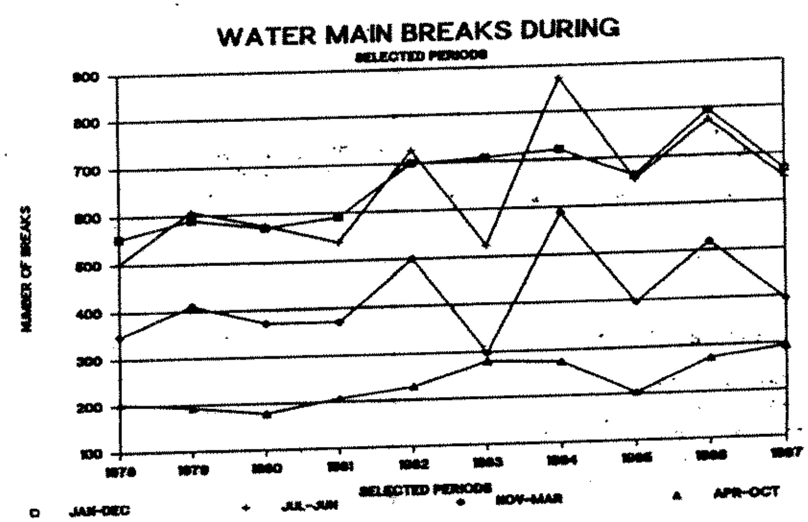
Components of the distribution system other than distribution mains include:

Item	Quantity
Hydrants	18,745
Valves	43,071
Blowoffs	437
Meters	160,115
Service Connections	163,500

Source: Milwaukee Water Works

CONDITION MEASUREMENT AND PROJECT SELECTION

The following graph displays the water main break record over the last ten years. This graph appears to indicate that the rate of water main breaks is clearly associated with winter temperature. It is assumed that the depth of frost penetration rather than low temperatures cause water mains to break. The high rate of main breaks in 1981-1982, 1983-1984, and 1985-1986 can be attributed to the unusually cold winter season. Although the previous period is not shown in the above table, the number of main breaks annually increased steadily from 1965 to 1974, with only 182 breaks in 1965 compared with 379 in 1974. The number of main breaks more than doubled in this 10 year period.



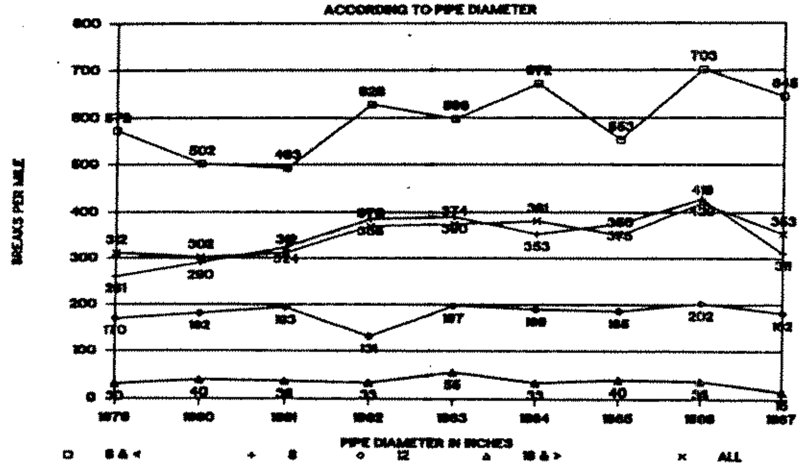
Source: Milwaukee Water Works and Bureau of Engineers

LEGEND		
	Jan-Dec	The calendar year
	Jul-Jun	July of prior year thru June of current year
	Nov-Mar	Nov. of prior year thru March of current year
	Apr-Oct	April thru Oct. of the calendar year

It is apparent that severe winter weather as it relates to frost penetration results in an increase in water main breaks. It is not likely, however, that winters in Milwaukee have been getting worse. Therefore, frost penetration alone does not explain the steady increase in the annual water main breaks. The graph above shows the water main break record for the months of April through October, which would exclude any frost penetration. This data indicates that there is an underlying increase in the number of water main breaks independent of severe weather. The Bureau of Engineers and the Milwaukee Water Works have identified a number of factors associated with water main breaks including pipe material, length of pipe and the presence of chlorides.

The graph below shows the water main breaks by size of pipe during 1979-1987.

MAIN BREAK RATES PER 1,000 MILES
ACCORDING TO PIPE DIAMETER



Source: Milwaukee Water Works and Bureau of Engineers

The six inch mains experienced 56 percent of the breaks and yet they comprise only about 32 percent of system mileage. The eight inch mains comprise about 36 percent of the system and experience about 35 percent of the breaks. The twelve inch mains comprise about 14 percent of system mileage and experience about 7 percent of the breaks. The majority of the breaks in the 12" mains and almost all the breaks in the 16" mains occurred in the original Town of Lake system.

The Bureau of Engineers has prepared a number of studies on the incidence of main breaks for selected areas and for mains installed in certain periods. About 50 miles of water mains were acquired when the Town of Lake was annexed to the City. These acquired mains and 560 miles installed between 1946 and 1963, were made of centrifugally cast iron pipe in 18 foot lengths in accordance with industry standards at that time. These mains have been experiencing a break rate greater than mains installed earlier. About 53 percent of the original Town of Lake system has been replaced or abandoned. This has resulted in a lower incidence of breaks.

The City uses about 35,000 tons of salt during the winter months to de-ice the streets and bridges. A substantial increase in the amount of chlorides present at the location of water main breaks has been observed. Presumably, this is due to the leaching of deicing salts into the gravel bed surrounding water mains. The corrosive effect of these chlorides on cast iron mains is being monitored. Since 1970, mains have been installed in crushed limestone bedding and wrapped with polyethylene which is designed to provide protection from corrosion.

The Water Engineering Division maintains a Water Main Break Experience Record of every segment of water main which has a significant history of breaks. These records contain the following information:

- Pipe description (diameter, length, material, age, joint material)
- Break description (location, date, type, repair material)
- Frequency of past breaks
- Special reports

These records form the basis for the development of a Water Main Break Experience Index which ranks water main replacement projects on the basis of break frequency.

The selection of water mains for replacement for the annual capital budget begins with the Water Engineering Division reviewing the projects listed in the Water Main Break Experience Index. This initial list is then modified on the basis of the following factors:

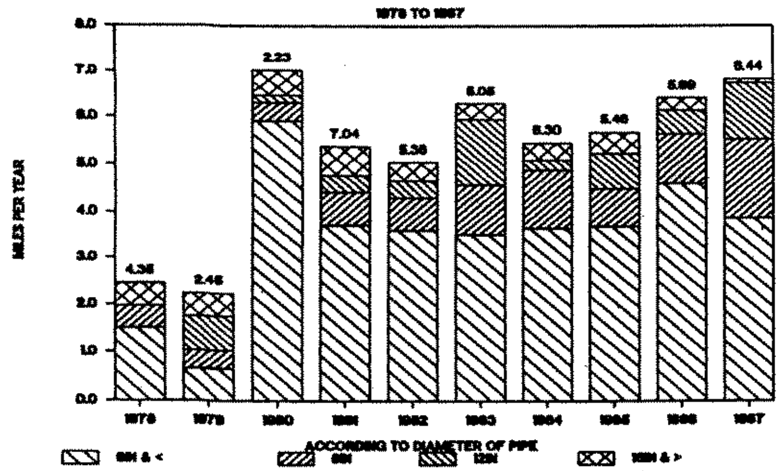
- History of breaks of each main compared to others
- Type of breaks - from corrosion or other causes
- Potential damage from future breaks
- Customer and traffic inconvenience
- Adequacy of existing mains to serve existing and future land uses
- Plans to pave the street

The resulting list of projects and their estimated costs along with other capital needs of the Water Works are compared with the estimated funds available. This stage in the formulation of the annual budget is conducted jointly by the City Engineer and the Water Works Superintendent.

HISTORICAL EFFORT

The following graph depicts the miles of water mains that were retired over the last ten years. It does not include repairs made to water mains.

WATER MAINS RETIRED IN MILES

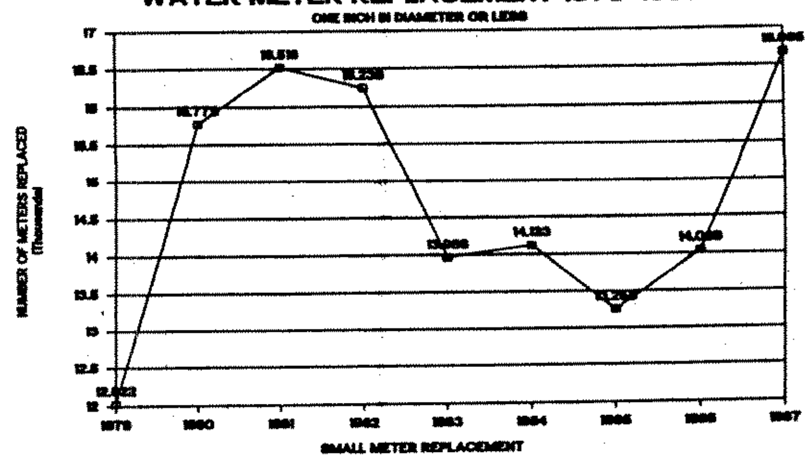


The preceding graph shows that the annual retirement of water mains has increased substantially from what it was earlier. It should be noted that some work recorded as being completed in 1980 was physically completed in 1979. It also shows that retirements were concentrated in the six inch and eight inch water mains, which were identified previously as experiencing the most breaks. It should be noted that the preceding graph shows the number of miles of water mains taken out of the system (retired) and not the actual miles replaced.

The length of water main replaced annually has increased gradually over the last several years. The average annual level of retirement for the last 10 years was approximately five miles. It should be noted that until the late 1950's, the six inch diameter water main was utilized in most residential applications. Since that time, the eight inch diameter main has become the mainstay of the distribution system. Therefore most of the six inch water mains are being replaced with mains that are eight inches in diameter or larger. The existing cast iron pipes are being replaced with ductile iron except sizes 20" and larger which are generally replaced with prestressed concrete.

The following graph shows the number of small water meters that were exchanged for new or repaired meters. Small meters, one inch in diameter or less, comprise over 96% of all meters in service.

WATER METER REPLACEMENT 1979-1987



The staff of the Water Works repair, install and inspect meters. The Water Works saves approximately $130,000 per year by rebuilding water meters compared to the cost of purchasing new meters.

ESTIMATED USEFUL LIFE

The Wisconsin Public Service Commission has established a 125 year depreciable life for water mains. Until more definitive information becomes available, it will be assumed for long range planning purposes that the estimated useful life of a water main is also 125 years. As noted elsewhere in this report, age alone was not found to be a primary factor correlated with water main breaks. The frequency of breaks is closely associated with the length and material of pipes, joint material, size of mains, location of mains and soil conditions.

IMPLIED REPLACEMENT CYCLE

One measure used to gauge infrastructure preservation programs is the "implied replacement cycle." The table shows the implied replacement cycle of water mains of various sizes over the last 10 years, the last three years and last year.

IMPLIED RETIREMENT CYCLE

Size of Main	Last 10 Years	Last 3 Years	Last Year
6 Inch & <	178.86 Years	153.05 Years	160.28 Years
8 Inch	811.47 Years	584.40 Years	410.60 Years
12 Inch	465.01 Years	320.07 Years	216.88 Years
16 Inch & >	836.77 Years	1,264.70 Years	4,162.95 Years
All Mains	360.22 Years	301.14 Years	278.13 Years

The preceding table shows that the average annual retirement of water mains has increased substantially in the last several years. The table also shows that during both of these periods, retirements were concentrated in the six inch size which was identified previously as experiencing the most breaks.

"Implied replacement cycle" or in this case, retirement, is an approximate measure of an infrastructure preservation program. A more reliable measure of the adequacy of the water main preservation program will be the projected future retirement patterns for water mains that are being developed from the inventory. These projections do consider most variables either directly or indirectly, through the historical replacement patterns.

As mentioned earlier a number of studies have been conducted of the City's water main breaks. It has been found that frequency of main breaks is closely associated with the period of installation and certain pipe and soil characteristics. Age was not found to be a primary factor as indicated by the fact that pre-World War II pipe experienced a break rate of one-half the rate experienced by pipes laid after the war.

The Public Service Commission has established a rule that water meters (one inch in diameter or less) be replaced on an eight year cycle. It appears, however, that Milwaukee water meters could be replaced on a ten year cycle without sacrificing accuracy, because of the high quality of the treated Lake Michigan water. The graph in the previous section shows the recent small meter replacement effort. The average for this period was 14,734 per year. There were 154,728 small meters in service at the end of 1987 implying a replacement cycle of 10.5 years. About 30 percent of the replacements are from purchasing new meters and the remainder are from rebuilding.

PREVENTIVE MAINTENANCE

The Distribution Division of the Milwaukee Water Works performs preventive maintenance and emergency repairs to the water transmission and distribution system and the related appurtenances. Their work insures the continuous delivery of potable and palatable water at adequate pressure in the City of Milwaukee and several suburbs. The Distribution Division's expenditures for operation and maintenance over the last ten years are listed in the following table.

Distribution Division Expenditures (in $1,000)

Year	Operation	Maintenance	Total
1978	852	2,245	3,097
1979	945	2,570	3,515
1980	1,090	2,944	4,034
1981	1,194	3,530	4,724
1982	1,372	4,150	5,522
1983	1,394	3,816	5,210
1984	1,543	4,704	6,247
1985	1,638	4,818	6,456
1986	1,808	4,985	6,793
1987	1,829	4,784	6,613

Source: Milwaukee Water Works

These annual maintenance expenditures are relatively moderate when viewed in the context of the estimated $1.135 billion cost to replace the water distribution system. The 1987 maintenance expenses were less than one percent of the estimated replacement value. The preceding table portrays a steady increase in the annual expenditures for the operation and maintenance of the distribution system. The following table lists the most costly activities funded in the maintenance budget and the corresponding 1987 activity.

Activity	Quantity
Broken Mains Repaired	668
Leaks in Main Joints Repaired	97
Leaks in Laterals Repaired	218
Hydrants Replaced	153
Hydrants Repaired	554
Main Gate Valves Replaced	41
Main Gate Valves Repaired	307
Hydrant Gate Valves Replaced	3
Hydrant Gate Valves Repaired	101

Source: Milwaukee Water Works

This maintenance activity is essentially the same as in previous years. It is modified as experience dictates. It should be noted, however, that much of the Division's activity is in response to emergency situations which is intensified during severe winter weather. Beginning in 1985, a preventive maintenance program was initiated to exercise and to repair as needed valves on both the feeder mains and distribution mains.

SYSTEM PERFORMANCE

The water distribution system consists of a network of pipes, fittings, valves and hydrants. Pipes with a diameter 20 inches and larger are referred to as feeder mains. They carry large quantities of water from the two water purification plants outward to the distribution system for service to customers, including suburban wholesale customers or to storage facilities to be repumped during periods of maximum demand.

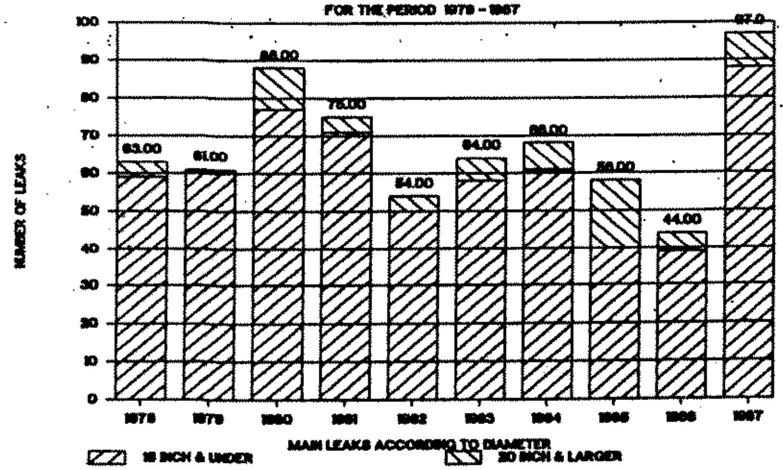
The large distribution mains (12" and 16") are connected to the feeder mains and are cross-connected to similar size mains at intervals of about one-half mile. These mains are connected to the smaller mains (8" and 6") forming a large interconnected grid. This distribution grid furnishes water through service and branch connections for domestic purposes and for fire protection.

Performance criteria for evaluating the water distribution system includes factors related to the ability of the pipe network to deliver water from purification plants to consumers. These factors include conveying water with a minimum of water loss and a minimum of disruption of service to customers. All water consumption is metered except that which is used for municipal service or obtained from fire hydrants. The percent of water pumped into the distribution system annually that is unaccounted for ranges between six and 10 percent. This loss, which is low compared with other large water systems, does not pose a problem. The chemistry of Milwaukee's water is such that tuberculation, a corrosion process which reduces pipe capacity, has not been a significant problem.

The following graph is a record of water main leaks. It does not include leaks in the building service laterals which are more numerous but generally interrupt service to only one customer and are, therefore, not as troublesome.

WATER MAIN LEAKS BY PIPE SIZE

FOR THE PERIOD 1978 - 1987



While the preceding graph indicates there is considerable variation in the number of water main leaks annually, it does not show a significant trend.

The data presented in the section "Condition Measurement and Project Selection" portrayed a water main break record during winter and non-winter conditions. The rate of water main breaks increases dramatically as a result of cold weather frost penetration. The average annual water main break rate for the last ten years was 349 breaks per 1,000 miles. This compares with an estimated average of 272 breaks per 1,000 miles per year for a group of 22 cities similar in size to Milwaukee, based on the years 1976-1978.

CONCLUSION

The underlying upward trend in the annual rate of water main breaks experienced in the 1960's and early 1970's appears to be stabilizing. Presumably, this slowing in the growth of the water main break rate is the result of the accelerated water main replacement program. Between 1977 and 1987, the City increased water main retirements from 4.35 to 6.85 miles per year, an increase of 157 percent. A reduction in the incidence of water main breaks continues to be a major goal of the Milwaukee Water Works and the Department of Public Works. This situation has been and continues to be monitored by the staffs of the Milwaukee Water Works and the Bureau of Engineers, Water Engineering Division. As more data becomes available and better techniques are developed, the water main replacement program will be adjusted.

Test results have shown that no significant loss of accuracy exists when small meters remain in service for 10 years. Over the past eight years, the Water Works has improved its rate of exchanges and feels confident that no material amount of water is being lost through inaccurate registration of water meters.

About 90-94 percent of the water generated from the City's water treatment facilities actually reaches its customers. This low loss factor compares favorably to other communities.

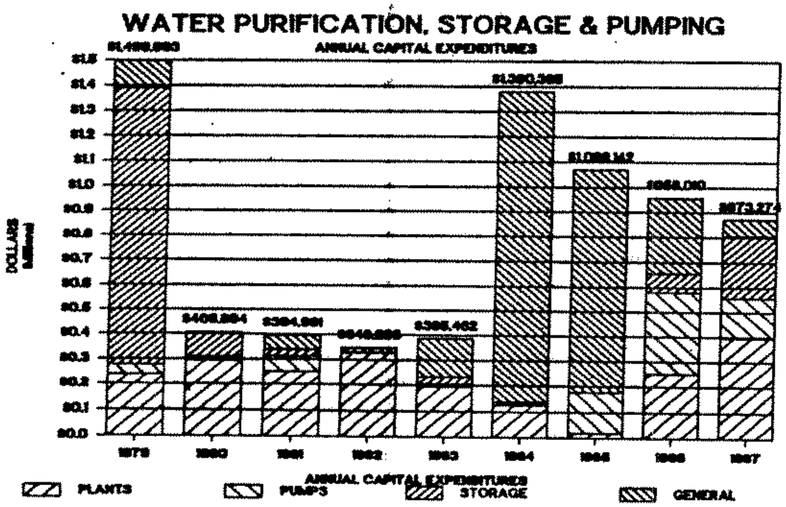
Water mains installed between World War II and the early 1960's were of centrifugally cast gray iron. These mains are experiencing a break rate almost twice that of older mains. This cast gray iron pipe has not been installed since 1963. There were about 560 miles of this type of pipe installed and about 544 miles remain in service. The frequency of main breaks is still quite high and there was a surge in the main breaks in the 1981-1982, 1983-1984 and 1985-1986 winter seasons. The current rate of replacing the mains that experience high rates of breaks should be continued in order to reduce the main break frequency.

The 1988 Capital Improvements Budget provides for the replacement of 8.7 miles of mains. The 1988-1993 Capital Improvements Program should provide sufficient funding for water main replacement to continue to stabilize or reduce the water main break rate.

alternatives, cost impacts and system impacts. Projects related to system reliability and projects that have a payback, such as from reduced energy consumption, receive the highest priority.

HISTORICAL EFFORT

Large capital expenditures were made in 1979 for a cover above the Kilbourn Reservoir (storage) and in 1984-85 for a new meter repair shop (General Plant). Other expenditures in recent years have been for replacement and refurbishment of equipment and buildings. Improvements such as variable speed pump controls improve efficiency and provide greater control over pumping operations. The following graph shows the annual capital expenditures made on various categories of facilities.



ESTIMATED USEFUL LIFE

The Wisconsin Public Service Commission has established various depreciation schedules for utility property based on estimated useful life. They estimate the useful life of buildings and improvements at 50 to 60 years and for machinery and equipment at 10 to 40 years. It should be recognized that the primary purpose of depreciation is to account for, rather than measure the decline in value of a capital investment. In order to identify net income or net loss for the Public Service Commission, actual expenses such as operation and maintenance as well as accounting expenses such as depreciation are deducted from gross income. Depreciation does not recognize the impact of inflation and changes in technology, consumer preferences and service standards. Therefore, it should not be used alone for long range planning. The Linnwood Plant structure, which was completed in 1939, appears to be in excellent condition structurally and is expected to remain so almost indefinitely, making it difficult to project essential useful life. The Howard Avenue Plant structure was completed in 1962 and is also in excellent condition. Almost all the replaceable parts, such as equipment, have been replaced or newly installed in the last 25 years. Equipment, such as electronic control panels, has a very short life, not from wear, but because of technological obsolescence.

IMPLIED REPLACEMENT CYCLE

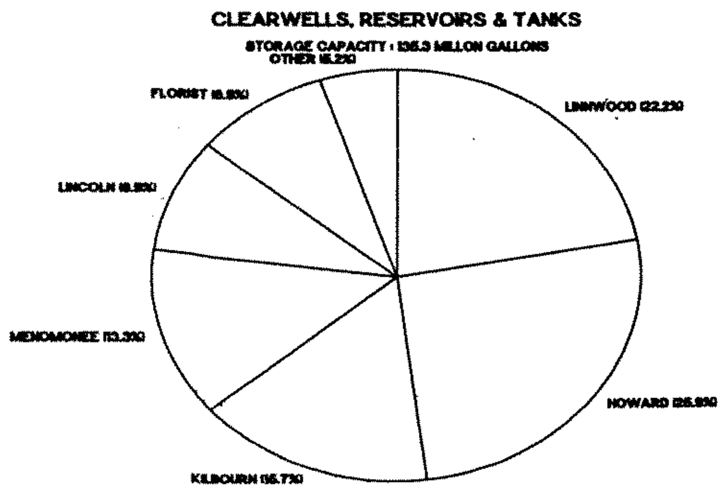
Unlike other infrastructure systems, there is not a simple quantitative measure to determine the City's replacement effort for the Water/Purification/Storage/ Pumping System. That is, there isn't a unit such as square yards of pavement or miles of water mains available to measure replacement effort. In addition, much of the plant replacement cost is in the structure of the purification plants. The parts that are replaceable, such as pumps, chemical feed equipment, pipes, mixing equipment, etc., account for about 40 percent of the replacement cost.

PREVENTIVE MAINTENANCE

The purification plants are highly automated and contain a substantial quantity of chemical feed and other equipment. The purification plants and the Control Center are staffed continuously. All the pumping stations and storage reservoirs are unstaffed and are operated remotely from the load centers at the purification plants or the Control Center. This equipment requires continual maintenance inspection to ensure its operating efficiency and reliability. The graph below shows the annual maintenance expenses in the major categories of Water Works purification, pumping and storage facilities, excluding mains, meters and hydrants.

Facility	Year Constructed	Capacity
Major Pumping Stations (Distribution)		
North Point	1963	165 MGD
Riverside	1924	210 MGD
Howard	1962	269 MGD
Total Design Capacity -		644 MGD
Other Facilities		
Control Center	1960	
Kilbourn Service Bldg.	1966	
Meter Repair Shop	1985	
Lincoln Yard - Maintenance	1963	
Cameron Yard - Maintenance	1966	

The graph below show the capacity of clearwells, reservoirs and tanks and the pumping capacity of the booster stations.



The Control Center for the Water Works contains centralized electronic data telemetering, recording and supervisory equipment for remote control of storage and booster pumps. All pumping stations, purification plants and other major facilities of the Water Works are shown schematically on a semi-circular 50 foot wall panel. The wall panel contains the instrumentation which permits the operators to monitor the individual stations and pumps. It also indicates pressures, flows, and storage level of each tank. The panel includes an electrical line schematic showing the electrical supply and controls for each station. This centralized monitoring and control system enables the efficient operation of the Water Works in meeting widely fluctuating system demands.

CONDITION MEASUREMENT AND PROJECT SELECTION

Unlike other infrastructure systems, the water purification plants and associated pumping and storage facilities are continuously monitored and inspected. The condition information available from the Control Center described above would include whether or not a pump or valve was operating when it was supposed to be. At each of the purification plants there are electronic control panels which will indicate that a pump won't start, that it has stopped, the relative position of essential valves and the relative position of essential circuit breakers. In order to minimize serious damage, pumps are equipped with fail-safe devices preventing the pump from operating when electrically overloaded, bearing temperature exceeds a certain maximum or other conditions occur which might result in damage to the pump. These pumping units are connected to alarms on the control panels of the respective plants.

In addition to equipment monitoring and fail-safe devices, chemical monitoring systems analyze water quality and chemical characteristics continuously. At each purification plant, about 120,000 chemical and bacteriological tests are performed yearly. This includes sampling of the water quality in the distribution system at two points, three times a day, and at 12 points once a week. This high level of monitoring ensures that all water quality standards are not only met but are exceeded.

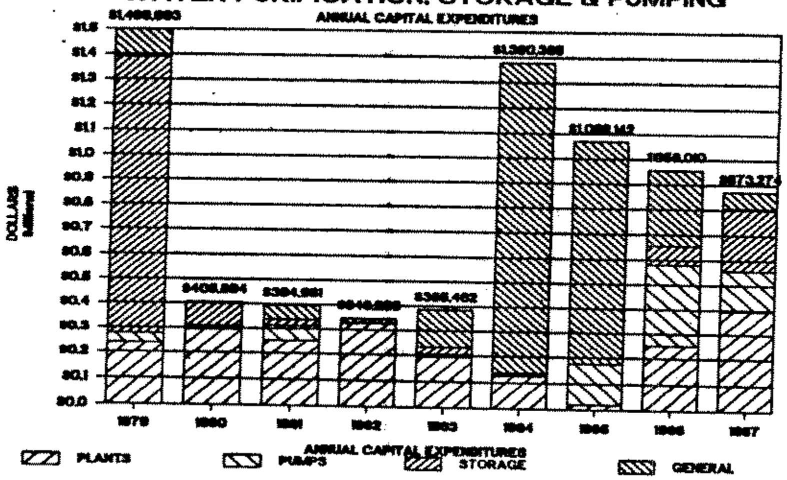
This extensive monitoring and a high degree of preventive maintenance activity enables the Water Works staff to predict the long range replacement needs of the system. The Water Works has developed a detailed six year program of capital needs that ensures the orderly and systematic replacement of inefficient and deteriorated equipment.

Each year, the staff of the Water Works, in conjunction with the staff of the Water Engineering Division of the Bureau of Engineers, review the needs of the Water Works. The process employed for selecting water mains for replacement is described in the report on the Water Distribution System. Currently there is a backlog of projects that would modernize plant and equipment. This backlog of projects is primarily the result of delaying projects because the revenues of the Water Works were not sufficient to meet these needs. This backlog is relatively minor considering the estimated replacement value of the Water Works. This backlog has been reduced by the aggressive modernization effort begun in 1984. The repair or replacement recommendation for most projects originates with the operations and maintenance staff based on existing or anticipated problems. When appropriate, these projects appear in the Water Works Six Year Capital Improvements Program. The selection of specific projects to be undertaken in a budget year is a result of the joint efforts of the Water Works and the Water Engineering Division of the Bureau of Engineers. These projects are prioritized on the basis of the operational need of the Water Works and analysis by the Water Engineering Division of alternatives, cost impacts and system impacts. Projects related to system reliability and projects that have a payback, such as from reduced energy consumption, receive the highest priority.

HISTORICAL EFFORT

Large capital expenditures were made in 1979 for a cover above the Kilbourn Reservoir (storage) and in 1984-85 for a new meter repair shop (General Plant). Other expenditures in recent years have been for replacement and refurbishment of equipment and buildings. Improvements such as variable speed pump controls improve efficiency and provide greater control over pumping operations. The following graph shows the annual capital expenditures made on various categories of facilities.

WATER PURIFICATION, STORAGE & PUMPING



ESTIMATED USEFUL LIFE

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IMPLIED REPLACEMENT CYCLE

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PREVENTIVE MAINTENANCE

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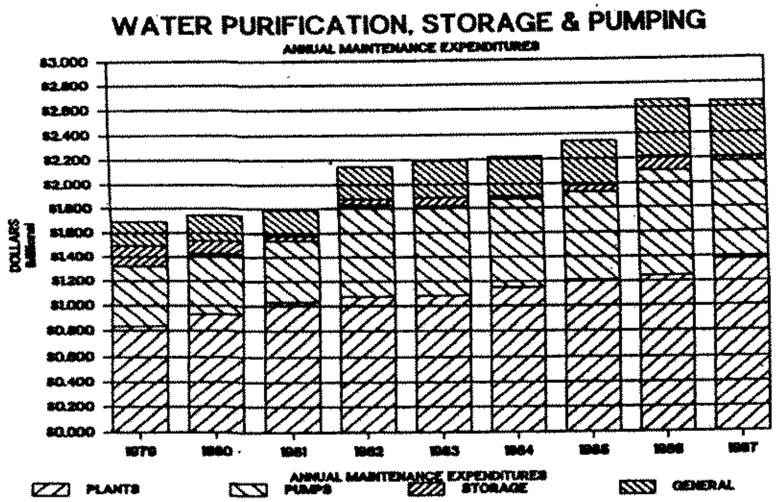


These maintenance expenditures appear to be reasonable when viewed in the context of the estimated $400,000,000 replacement cost of these facilities. In 1987, maintenance costs were less than one percent of replacement cost. These maintenance expenditures include inspection, planning, servicing, repairing, and replacement of existing machinery, equipment and structures. The largest expense categories are service and repair of machinery and equipment, building repair and maintenance of grounds.

SYSTEM PERFORMANCE

In the report on the water distribution system, it was stated that the performance of the water distribution system should be evaluated based on delivering water from the purification plants to customers. Likewise, the performance of the purification plants would be to produce potable and palatable water in sufficient quantity to meet customer needs. The performance of the various pumping and storage facilities would be evaluated on the basis of maintaining adequate water pressure supply throughout the distribution system.

Annually, the Department of Natural Resources inspects the facilities of the Water Works and evaluates the operating methods. Their reviews have found no major discrepancies in the treatment facilities or their operation and that the quality of the finished water was well within the standards established under the Safe Drinking Water Act of 1974 and the Act Amendments of 1986. The treatment process at these facilities produces a finished water that meets or exceeds all of the Environmental Protection Agency's Drinking Water Regulations.

The EPA has proposed a change in the regulation which would lower the allowable level of lead in the water below the present 50 ppb. There is no detectable lead in Lake Michigan water, and average lead levels at most customers' taps are insignificant. A current study will determine the most cost-effective method to achieve a slightly positive Langelier Index with a higher pH of effluent water. This change is then expected to eliminate or substantially reduce the leaching of lead from water services and internal plumbing to assure compliance with the EPA Regulation.

A major concern of water supply and treatment is the adequacy of supply and the systems capacity to meet demand. The supply of raw water from Lake Michigan can meet any foreseeable demand. The treatment system capacity of 375 million gallons per day is more than adequate to meet the highest maximum daily consumption of 293.8 million gallons that occurred July 25, 1966. The maximum daily demand in 1987 was 254.6 million gallons. The system can supplement the maximum daily treatment capacity by drawing from storage capacity enabling the system to provide water at an hourly rate equivalent to 490 million gallons per day for three to four hours. This maximum hourly rate of 490 million gallons per day is adequate to meet the record high maximum hourly rate of 448 million gallons per day that occurred in 1966. The maximum hourly rate in 1987 was 368 million gallons per day. The Water Works has no plans to expand the supply or treatment systems in the near future. The pumping capacity, although adequate to meet current demands, will be supplemented by additional pumps with variable speed motors. These pumps will provide more precise system pressure control and will reduce energy consumption.

CONCLUSION

The capacity of Water Works' purification/storage/pumping system is more than adequate to meet current and foreseeable future demand. Much of the water system requires a high degree of preventive maintenance to ensure the system's reliability. An extensive preventive maintenance program requires that facilities be inspected frequently and that maintenance, repair and replacement needs are anticipated and budgeted in advance. The available evidence indicates that there is no programmed need for major rehabilitation or replacement of the water supply and purification structures, except the replacement of the Hawley Road Storage Tank, which is under construction, and a sludge holding tank at Linnwood. However, there is a continuous need to replace equipment and refurbish facilities. The level of expenditures for these and other purposes had been relatively low in recent years and should be kept at a higher level in the coming years to reduce and eliminate such backlogs.

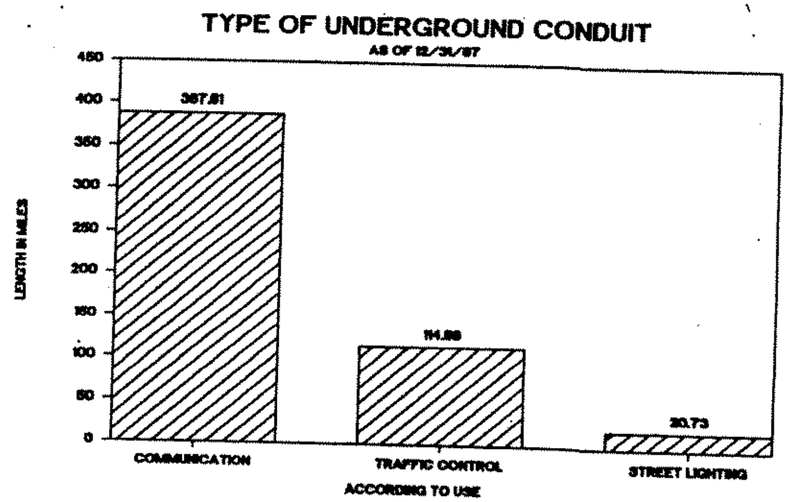
UNDERGROUND CONDUIT

The City of Milwaukee's combined underground conduit and manhole system is engineered, constructed, maintained, and operated by the Bureau of Traffic Engineering and Electrical Services. This system provides a reliable, weatherproof network of underground conduits for Communications, Traffic Control, and Street Lighting. Currently, there are 523.32 trench miles of underground conduit with 7,225 active manholes. Conduit varies from a single hole duct line up to a twenty-four hole duct line. The ducts range in size from two to four inches in diameter and 3-1/4 to 3-1/2 inches square. The conduit lines are installed under roadways and areas between the curb and street line at a depth of approximately 30 to 36 inches. To protect the conduit lines from damage, they are encased in concrete. To enter the conduit system, manhole vaults are strategically located along the conduit line to assure access to the cable for economical splicing and maintenance. The manholes range in size from three to six feet in diameter, four to five feet square, and six feet wide by 12 feet long. The average depth of the manholes range from four to six feet.

Record plans and data that have been compiled reveal that the City's underground conduit and manhole system began in the 1890's. The conduit consisted of square vitrified clay tile and iron pipe. The manholes were constructed of brick with heavy cast iron frames and covers. Plans show that these materials were used until the 1930's. From 1930 until the late 1970's record plans indicate bituminous fibre conduit was used extensively. The manholes in this era were constructed from concrete block or brick with heavy cast iron frames and covers. In the late 1970's technological improvements of plastics caused the use of iron pipe, vitrified clay tile, and bituminous fibre conduit to decline. Iron and vitrified clay pipe are no longer available. Bituminous fibre conduit is rarely available. Plastic conduit known as PVC (Polyvinyl Chloride) is now used extensively for all conduit installations. In 1981, concrete precast manholes became the standard manhole material. Also in 1981 heavy cast iron frames and covers were replaced with light weight cast iron frames and covers.

Conduit systems suspended under bridge decks consist of several different materials. During the 1920's and 1930's record plans indicate transite (concrete) conduit was used. From the 1930's to the late 1970's galvanized steel was used. It also replaced the transite conduit. In 1980 until the present time and for future bridge installations, fiberglass conduit is installed.

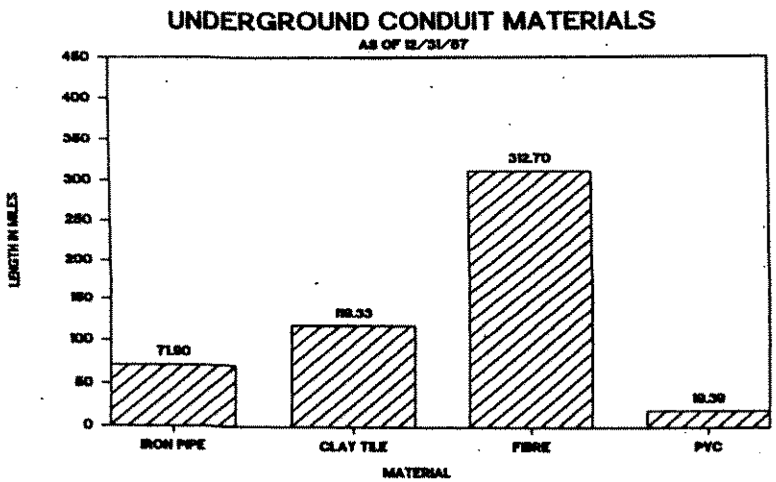
The following graph and table describe the major components of the underground conduit and manhole system.



Manholes

Facility		Quantity
Communication		5,779
Traffic Control		1,373
Street Lighting		73
	TOTAL	7,225

According to the Bureau of Traffic Engineering and Electrical Services records, the City's oldest conduit system was installed in 1890. Conduit systems older than 1890 are not recorded. The following graph portrays the Underground Conduit System in trench miles for iron pipe (1890-1905), clay tile (1905-1930), fibre (1930-1980), and PVC (1980-1987).



Source: Bureau of Traffic Engineering and Electrical Services, Underground Conduit Engineering Section

CONDITION MEASUREMENT AND PROJECT SELECTION

Presently there is no separate program for replacement of manhole frames and covers or a repair program for conduits and manholes. These components, especially the frame and cover, need replacement or maintenance since most of the system is located under roadway surfaces which are subject to deterioration.

Although the conduit and manhole system is a permanent underground installation, certain components need improvement. To prevent damage to installed cable in the conduit system, accumulated water in the conduit is drained into a manhole by gravity flow. Since about 1955, manholes are strategically located in the system so that a drainage system can be installed. This design relieves a possible flooding condition. However, preceding 1955, manholes in the system did not have drains. As a solution to correct this condition, surveys of the manhole locations when flooding occurs should be done by field observation. Proper drainage and cable maintenance could then be accomplished for the entire system.

Factors that are considered when selecting projects for the annual program include: information from shop personnel, aldermanic and citizen requests, private construction projects, contractor damages, cable television requests, and city, county, and state paving programs. The 1987 Capital Budget provided for the following:

Purpose	Percent	Amount
1. Paving related work	56	$ 558,000
2. Protect and Adjust System	24	237,000
3. Non Paving Projects	14	140,000
4. Office and Field Engineering	6	65,000
TOTAL	100%	$1,000,000

To help provide an "accurate picture" for a schedule to restore, replace, or relay the conduit and manhole system, a "Conduit Rodding Program" and a "Manhole Inspection Program" are needed. With the aid of these programs, the increasing demands of the conduit cable capacity, roadway grade and alignment alteration, and continuous downtown redevelopment would be satisfied in an efficient manner. Also, these programs would be an excellent indicator of the conduit and manhole system's condition due to age and environmental activities. However, to implement these programs additional funding, presently not available, would have to be requested.

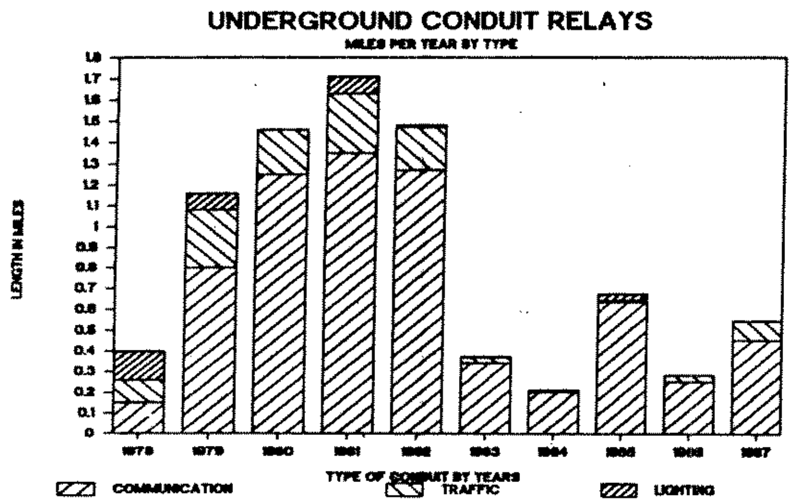
HISTORICAL EFFORT

Over the past ten years several activities have caused existing conduit and manhole systems to be restored or replaced. One of the major activities is conduit cable capacity. In union with the paving program, additional conduit and manhole systems are installed adjacent to existing conduit systems that have reached cable capacity. This procedure is used to keep the existing cable and conduit system in service. Later the existing conduit and cable system is retired. An activity such as roadway grade and alignment alteration is directed by the paving program. It may necessitate the relocation and restoration of the existing conduit facility. Another activity is downtown redevelopment. It can result in street closures and additional property acquisition. In this situation rerouting and relaying the existing conduit and manhole systems restores service that the system provided.

Trench Miles of Underground Conduit Relays

Average	Communications	Traffic Control	Street Lighting	Total
Last 10 Years	0.67	0.13	0.03	0.83
Last 3 Years	0.44	0.04	0.01	0.49
Last Year	0.45	0.09	0.00	0.54

The following graph illustrates the trench miles of underground conduit that was restored or replaced, due to the aforementioned activities, by City forces over the last ten years. It does not show conduit repairs made by the Communications Shop maintenance crews.



ESTIMATED USEFUL LIFE

The estimated useful life of the underground conduit and manhole system is defined as the combined expected average age of the system's components that should remain in service prior to its replacement due to deterioration. For planning purposes this has been estimated at 110 years. Environmental conditions such as the chemical properties of soil, thawing and freezing conditions, and roadway surface conditions have resulted in earlier replacement. Therefore, age is not by itself a reliable indicator of replacement needs.

Preliminary reports of materials used in the conduit and manhole system prior to 1930 indicate an average life of about 90 years. Since the majority of the system (about 63 percent) has been constructed from the 1930's and onward, it might be another 30 years before sufficient data on these materials become available. In the interim, it is being assumed that the average useful life for the conduit and manhole system is approximately 110 years.

IMPLIED REPLACEMENT CYCLE

The rate of replacement of a system is sometimes gaged by the "implied replacement cycle". This is calculated by dividing the total trench miles of underground conduit in the system by the trench miles of underground conduit relayed in a year. This yields the cycle or number of years that would pass before the entire system would be replaced, refurbished, or upgraded. The following table indicates the implied replacement cycle of the underground conduit and manhole system over the last 10 years, the last three years, and last year.

Implied Replacement Cycle

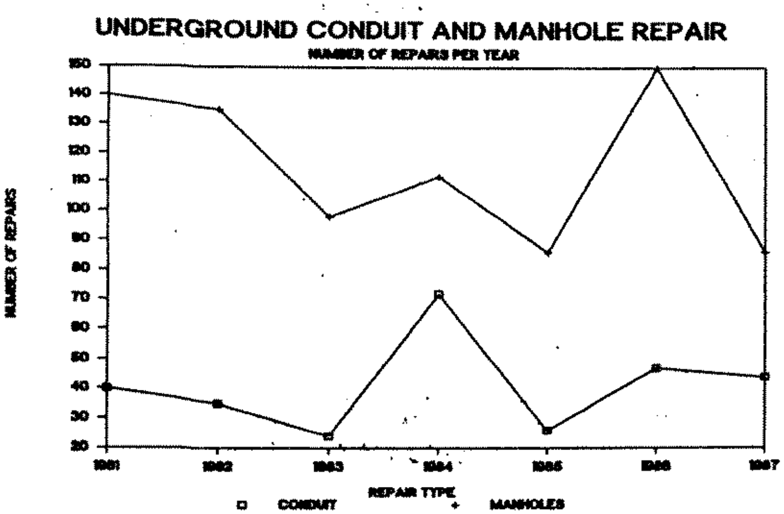
	Last 10 Years	Last 3 Years	Last Year
All Conduit	632 Years	1,047 Years	969 Years

The "implied replacement cycles" do not recognize such factors as size, composition, soil conditions, technological changes, and changes in design or construction methods. While no comparable study of underground conduits and manholes exist, exposed steel or iron conduit studies have shown that there is very little deterioration in the beginning and rapid deterioration in the last part of the conduit life. It is assumed that underground conduit would follow a similar pattern but over a longer period of time due to its location under the ground surface and encasement in concrete. Exposed concrete manhole vault studies also indicate slow deterioration in the beginning and rapid deterioration in the last part of material life. Similarly, it is assumed that underground manholes would last longer due to burial below ground.

Basically, the replacement cycles for this system is not a true picture of replacement or accomplishment. It is based mainly on the activities caused by the paving program and not on an average life cycle. Funding for a replacement cycle is not available at the present time. It would be necessary if the system needs repair or replacement beyond the paving program limits each year.

PREVENTIVE MAINTENANCE

The Communications Shop of the Bureau of Traffic Engineering and Electrical Services performs all preventive and emergency maintenance and inspection to the City's conduit and manhole system. These services are performed on an "As Needed" schedule along with the annual paving program of "Protect and Adjust". The Bureau's maintenance program of "As Needed" service extends the useful life and provides information on the system for future "Protection and Adjustment" of present materials. The following graph displays the underground conduit and manhole repairs over the last several years.



Source: Bureau of Traffic Engineering and Electrical Services

The estimated replacement cost of the entire plant (conduit and manhole system) is defined as the total trench feet of conduit of the system times the current cost per trench foot of conduit plus the total number of active manholes times the current manhole cost. The 1987 maintenance expenditures were less than one percent of the estimated $85 million replacement cost of the Underground Conduit and Manhole System.

SYSTEM PERFORMANCE

The City's underground conduit and manhole system consists of a network of conduits located under roadway right-of-ways. Its purpose is to provide a reliable, weatherproof carrier for municipal telephone systems, fire and police communications andstreet telephone systems, water and sewer manhole alarm controls, and cable television (Warner Cable); and for interconnecting traffic control cable to synchronize signalized intersections; and for above and below ground substation main street lighting cable distribution and recreational special lighting facilities.

Information on how the City's underground conduit and manhole system is performing includes how often manholes fill with water in a particular location, how many times a conduit system is out-of-service, and conduit cable capacity.

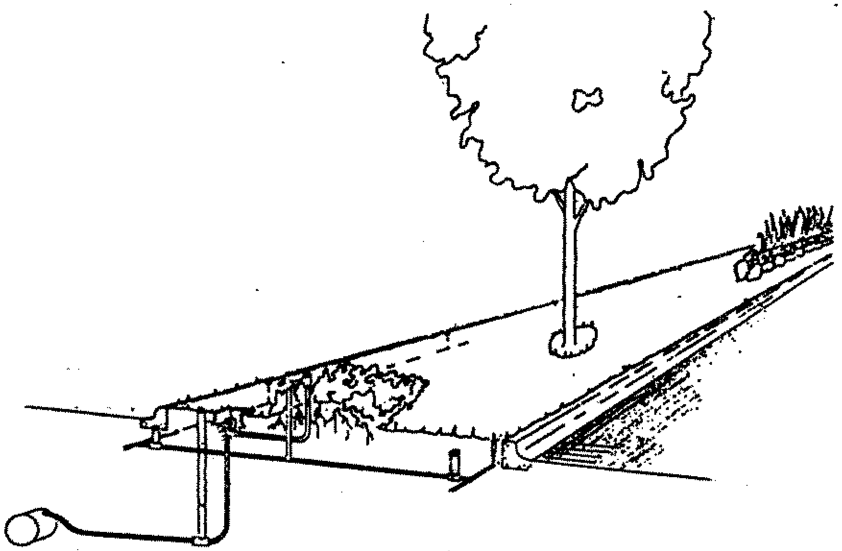
Currently, the Communications Shop maintenance crews pump out manholes as needed or by aldermanic and citizen complaints. If a manhole is pumped out frequently, its location is noted and a suitable drainage system is installed. Since most of the system was built after 1930, it consists of materials that are too new to have many breakdowns. However, shop maintenance crews that perform rodding on a portion of the system for cable installation will notify the office engineering staff of a breakdown. When cable installations are completed in an underground conduit system, the capacity of the system is reported to the office engineering staff for future design information.

CONCLUSION

The City's underground conduit and manhole system is in relatively good condition compared to its estimated useful life. However, there are indications that the older part of the system will be reaching the end of its estimated useful life between the years of 2000 and 2010. At that time, approximately fourteen percent of the system could be replaced. To project for a schedule of this replacement a "Conduit Rodding Program" and a Manhole Inspection Program" will be needed. Particular attention in the "Manhole Inspection Program" should be the condition of the frames and covers of the system's manholes. To meet these goals, funding for a systematic inspection of the underground conduit and manhole system should be initiated.

BOULEVARDS

The City's boulevard system is composed of an estimated 267.2 acres or 117.6 miles of landscaped boulevard medians and triangles. In addition, the City has about 140 sites totaling about 200 acres of landscaped areas, such as totlots, greenspaces, plazas and other public spaces. The drawing below depicts a cross-sectional view of a typical boulevard median.

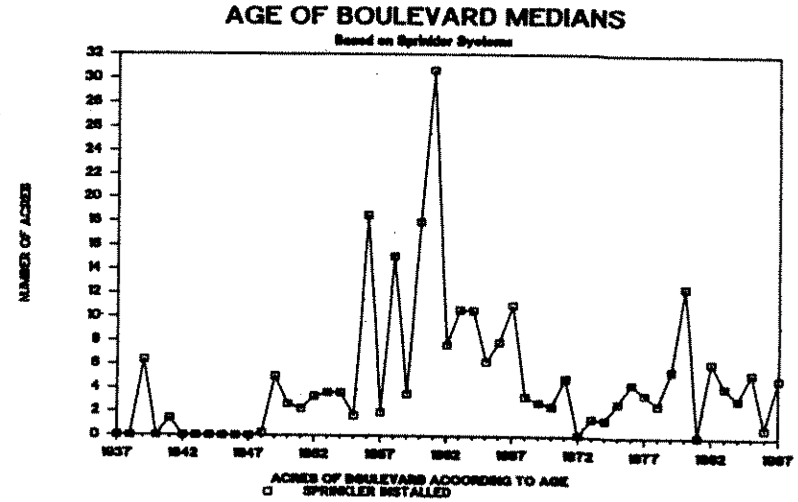


The geometrics of boulevard medians are determined by the Bureau of Engineers at the time of initial construction. The Bureau of Forestry has responsibility for designing the landscaping of the boulevard system and typically uses trees, shrubs, floral beds and turf. Irrigation and drainage systems are incorporated into the design as life support units.

The physical structure within the curb lines varies in width from 2' to 50', depending on the overall right-of-way width and traffic control factors, such as turning lanes. Traffic control factors are the primary determinant of the length of boulevard medians islands, which vary from 80' to 840'.

The boulevard medians not only perform a very important traffic control function, but are also utilized for traffic control signs, light pole placement, easy access to underground utilities, storm runoff drainage and snow storage.

The Bureau of Forestry has a data base in the form of both landscape and irrigation plans that date back prior to 1940. Data is updated on a continual basis, with plans being redrawn as a result of paving projects. In addition, landscape plans are updated each year in order to keep the master plans consistent with field plans that contain the annually changing of plant material. Current records indicate about 2,300 water service taps, 4,700 ornamental and shade trees, 2,700 shrub beds and 1,300 floral beds, consisting of about 450 rose beds and 850 annual flower beds. This data is a result of an annual inventory by Bureau personnel. The graph below depicts the age profile of the City's boulevard system excluding triangles. About 70 percent of the boulevards were constructed between 1950 and 1970.



Source: Bureau of Forestry.

CONDITION MEASUREMENT AND PROJECT SELECTION

All boulevard medians are inspected in the spring and fall, primarily to schedule plant material replacement. All plant material which was lost from car impacts, vandalism and environmental stress is scheduled for replacement. Management personnel identify and evaluate the condition of the profile plant material. This allows for the scheduling of corrective measures, removals and replacement planting to meet the Bureau's goal of making replacements within twelve months.

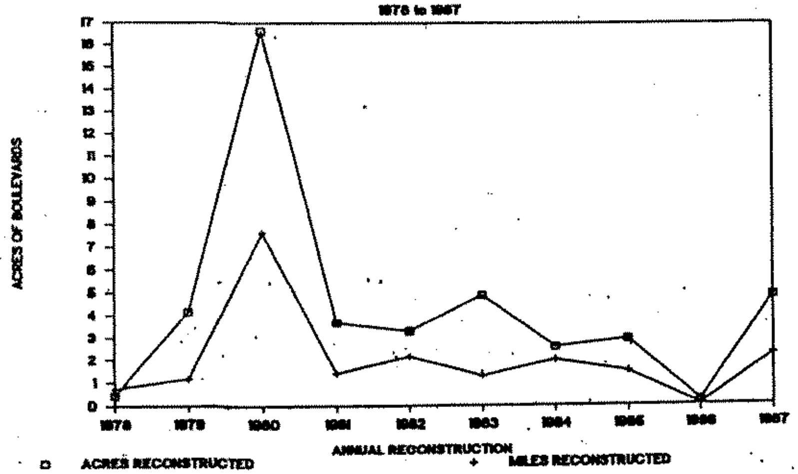
Only 30% of the irrigation system meets current State and City plumbing codes. The Bureau is not required to bring the system into compliance until it is altered as a result of a major repair or reconstruction project. The irrigation system is monitored on a continual basis as it is used. Due to climate, the system must be activated each spring and deactivated each fall. The deep service valves are normally repaired at this time. As the irrigation system is operated, malfunctions are noted and the repairs are prioritized and scheduled. The condition of the landscape and of the irrigation system are not the primary factors used to determine selection of boulevard reconstruction projects. They have been used to request CDA funds and Public Works grants. Boulevard reconstruction is based primarily on paving needs and modification for traffic control.

HISTORICAL EFFORT

The primary source of funds for reconstructing the existing boulevard medians has been the Capital Improvements budget, supplemented through the use of Community Development Agency Block Grant funds. The graph below shows boulevard median reconstruction expenditures over the past 10 years.

BOULEVARD RECONSTRUCTION

1978 to 1987



Boulevard Median Rehabilitation

Average	Acres	Miles
Last 10 Years	4.351	2.009
Last 3 Years	2.639	1.237
Last Year	4.804	2.214

The reconstruction activity during 1980 was abnormally high, due to the reconstruction of Capitol Drive from N. Humboldt to N. 107th Street.

ESTIMATED USEFUL LIFE

The estimated useful life of the major components of the boulevard median system are shown in the table below. The figures are based on the Bureau's experience for optimum conditions.

Component	Estimated Useful Life
Plantings	25 - 40 Years
Turf	25 - 35 Years
Sprinkler Systems	20 - 30 Years

The boulevard turf is affected by debris building up on the soil. The rate of buildup is dependent on volume and speed of traffic and location. Substantial grade differences can cause lawn mowers to slide toward the traffic lanes endangering the operator. It often becomes necessary to raise the sprinkler heads or regrade.

Advances in technology, improved plant varieties and environmental concerns result in the functional obsolescence of some system components before they reach the end of their useful life. The irrigation industry, in particular, has made numerous technological advances. Some of these are shown in the table below.

Technological Improvements

1. Frost-resistant polyethylene pipe replaced galvanized steel pipe.
2. Plastic pop-up heads, offering greater diversity in design, replaced more costly flush-mounted brass heads.
3. Neoprene seals and teflon-coated cores were added to valves to prevent them from seizing up.
4. Use of a single deep valve with a stand pipe was a new code requirement to reduce backflow pollution.
5. The use of vacuum breakers to replace check valves was a code requirement to reduce backflow pollution.

IMPLIED REPLACEMENT CYCLE

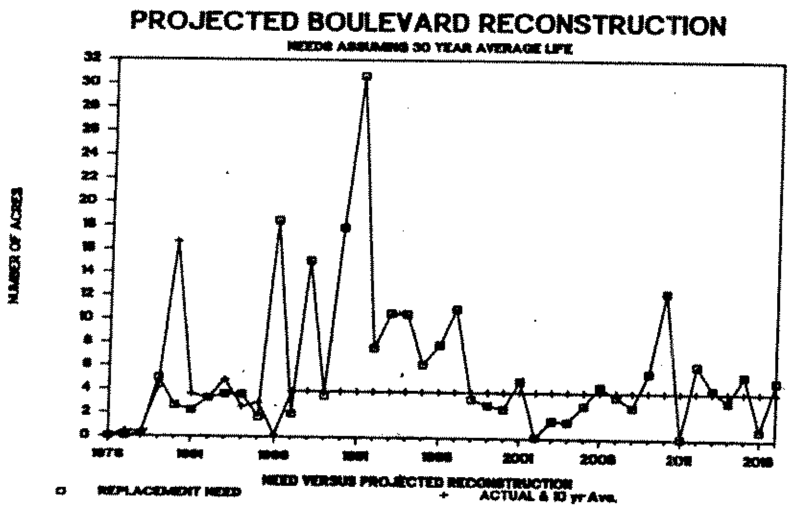
Over the past ten years, the boulevard median system has experienced an average reconstruction rate of 4.3 acres per year. Based on this rate, the current system of 267.2 acres would have an "implied replacement cycle" of over 62 years. This is substantially greater than the estimated useful life that is expected for most of the components of the boulevard system.

Implied Replacement Cycle

	Last 10 Years	Last 3 Years	Last Year
Acres	61	101	56
Miles	59	95	53

This gap between the estimated useful life of the boulevard system and the "implied replacement cycle" is an indication of a deteriorating system. This is supported by the information on the age of the boulevard system identified in the profile section and the operational problems discussed previously. According to the Bureau's records, about 49 acres of boulevards were constructed prior to 1957.

The graph below takes the data from the earlier graph depicting the age profile and adds 30 years to the age of the existing system to graphically present a projected reconstruction need. The historical reconstruction rate of 4.3 acres is also displayed on the graph. The gap between the projected need and the projected historical average reconstruction rate depicts the future backlog of reconstruction needs that would occur even if the historical reconstruction rate were maintained. It should be noted that the rate of boulevard construction during the period 1950 to 1970 was 8 acres per year.



PREVENTIVE MAINTENANCE

The Bureau performs both operational and maintenance activities on the boulevard system. These activities are primarily directed at the care of trees, shrubs, floral beds and turf that comprise the surface of boulevards and the irrigation system which acts as a life support system. All of these activities preserve or prolong the life of plant material in the medians. These activities are, however, more reasonably considered inputs into the operation of the boulevard system, the output of which is the enviable reputation the City has for a beautiful boulevard system.

SYSTEM PERFORMANCE

Boulevard medians function as a form of aesthetically-pleasing, strategically located traffic corridors that connect different areas of the City. The purpose is to provide, at grade, a divided roadway for high-volume traffic through the City, taking into consideration not only traffic requirements, but also the aesthetic compatibility of residential, commercial and industrial land uses. The medians, when they are sufficiently wide, also provide a relatively safe storage area for vehicles that are turning or crossing the roadway, permitting a relatively efficient flow of traffic.

Beyond this traffic control function, boulevards serve an important role in the enhancement of the City as a place to live, to visit and in which to invest. This is a result of several functions performed by the landscape for aesthetic, climatic, architectural and engineering purposes. Technical data has been developed and collected, showing in-depth, the various functions of plants as they relate to solving environmental problems. Landscaped boulevard medians can be found in all areas of the City. The reputation that the City has earned for its attractive boulevard system is a source of pride to its citizens and government officials. The Bureau has relied primarily upon the frequency and nature of both complaints and compliments of the public to evaluate the adequacy and performance of the boulevard system. Another possible measure would be a comparison of the market value of comparable residences in relation to the boulevard median system.

CONCLUSION

The average boulevard median reconstruction rate of 4.3 acres per year over the past ten years is not adequate. The paving program and traffic control island modification are the primary determinants in selecting boulevard median reconstruction projects. The result is an increasing number of boulevard median acres with outdated irrigation systems and depleted landscapes. The previous graph of reconstruction needs compared to the historical construction rate of medians projects a growing backlog of boulevard reconstruction needs.

TREES

In 1987 there were 328,167 trees on City of Milwaukee right-of-ways and property. The majority of the trees are located in the tree border or turf area located between the sidewalk and the curb. Additionally, trees exist on the boulevard system, at municipal properties such as City Hall and the Civic Center, in concrete boxouts in the sidewalk and on other green spaces.

There exists a backlog of 3,486 sites which are ready for planting but as yet do not contain a tree. Major street improvements, such as the reconstruction of curbs and sidewalks, and the construction of new streets, add planting sites to the above totals.

A base inventory of city street trees was conducted in the year 1957. From this data base, the current tree inventory is determined by the subtraction of the number of trees removed and addition of the number of trees planted. Available planting locations are maintained in a computer data base through which annual planting lists are generated. The species of tree designated for a particular street and block is maintained in a Master Planting Plan Plat book.

During 1979-1981 the Bureau of Forestry, in cooperation with the University of Wisconsin-Stevens Point, conducted a sample inventory of the City street trees. Approximately 80,000 trees, 25% of the total, were surveyed, recording the species, size, condition, and vigor class of each tree. Statistics representative of the entire street tree population were generated utilizing the survey data. Over 118 varieties of 65 species are represented in the tree population, six species (Norway Maple, Green Ash, Honeylocust, Sugar Maple, American Elm and Littleleaf Linden) account for 92 % of the City's street trees.

The following table lists the size, distribution and average condition of the tree population based on the sample data. An average condition rating of approximately 70% or better in all size classes indicates a relatively healthy, stable tree population. (a tree in perfect condition is rated 100%)

Stand Size, Distribution and Condition

Size (Diameter Inches)	No. of Trees	% Population	Average Condition %
0 - 1.9	1,969	0.6	58.2
2 - 3.9	103,701	31.6	70.0
4 - 5.9	57,429	17.5	77.3
6 - 7.9	41,349	12.6	78.6
8 - 8.9	35,114	10.7	78.6
10 - 11.9	23,956	7.3	78.1
12 - 13.9	19,690	6.0	76.0
14 - 15.9	8,532	2.6	73.0
16 - 17.9	6,564	2.0	71.2
18 - 19.9	7,221	2.2	70.7
20 - 21.9	6,891	2.1	71.2
22 - 23.9	5,251	1.6	70.6
24 - 25.9	3,938	1.2	70.1
26 - 27.9	2,953	0.9	70.1
28 - 29.9	1,969	0.6	71.9
30 +	1,640	0.5	70.9
TOTAL	328,167	100.0%	74.3

CONDITION MEASUREMENT AND PROJECT SELECTION

Tree condition is assessed to determine necessary corrective maintenance activities or removal needs. Also, condition is assessed to determine the relative success of the management program being employed to support the growth of the tree stand.

Tree condition is assessed in several different ways. The most common method is visual inspection incidental to other routine activities. Evaluations may also be conducted during construction inspections, in response to service requests and during travel between job sites. Additionally, an annual survey is conducted to detect Dutch Elm Disease and to identify dead or hazardous trees requiring removal.

The following factors are used when detailed tree evaluation is required: growth rate, foliage color, foliage density and size, structural integrity, injuries, pests and diseases. Maintenance programs are determined in response to the various assessment criteria. The decision to remove a tree is based on an assessment as to the tree's overall health and safety.

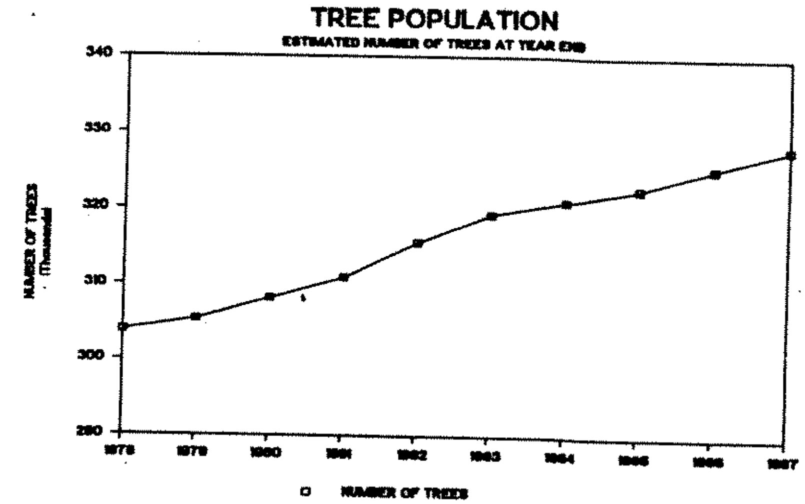
Selection of tree planting projects is based on two factors: replacement of trees previously removed and new street construction. All streets with suitable growing space within the city easements are planted with appropriate species of trees. A minimum of one tree is planted per property where possible. Spacing of these trees is determined by the species site requirements, traffic control signs and street light locations, the presence or absence of utilities, the presence or absence of other permanent structures in the tree border area and by property width. When a tree is removed from an existing street every effort is made to replace it. In some instances, tree replacement may not be done on a one-for-one basis since all new plantings must conform to current spacing standards. All trees which are removed are scheduled for replacement within two years of the removal date.

Improved condition assessment is desirable for better informed management decisions. Currently, management decisions are based on observation of specific problems or on average needs of trees within a specified management unit. However, differences in individual trees, species, microenvironments, resident attitudes and resident involvement all require different management priorities. Additionally, problems handled on a crisis or individual service request basis are less effective and more costly than those performed on a systematic basis. Increasing the frequency and detail of condition assessment efforts would provide information on specific tree needs. This assessment could be used to more promptly remove and replant marginal trees, to reduce plant establishment problems, to reduce storm damage, to minimize insect and disease spread, and to reduce associated complaints.

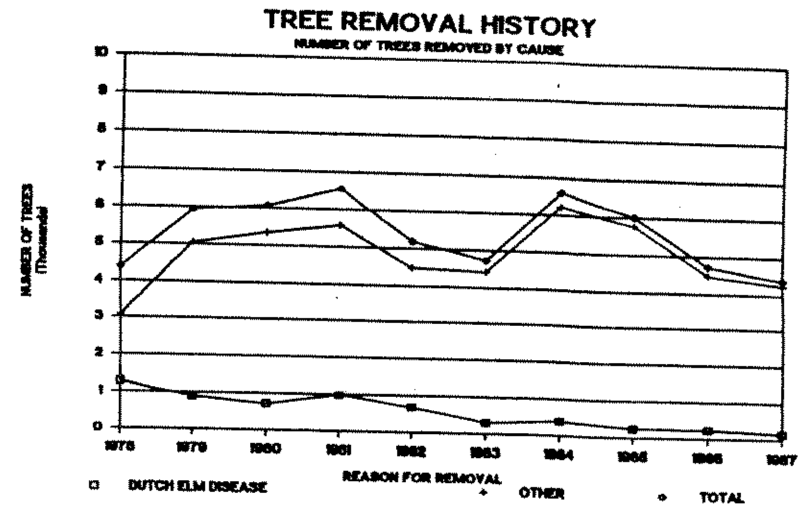
Ideally, an inventory incorporating systematic condition assessment should be performed on each tree on a five year basis, 2 1/2 years out of phase with regular pruning activities. This would allow each tree to be visited once every 2 1/2 years. The first for pruning and the second for visual assessment by management. Current computer technology could be used to organize the data and provide summaries for accurate management decision making. A detailed assessment could be performed at a minimum cost, utilizing summer internships in the position of Urban Tree Evaluators. The annual cost for employing four Urban Tree Evaluators to conduct this survey would be approximately $21,000.

HISTORICAL EFFORT

The population of city street trees has steadily increased over the last ten years. This increase is a function of two factors: 1) federally funded planting to reduce the backlog of open planting locations caused by Dutch Elm Disease, and; 2) street construction projects which created new locations for the planting of trees. The following graph illustrates the tree population increase during the last ten years.

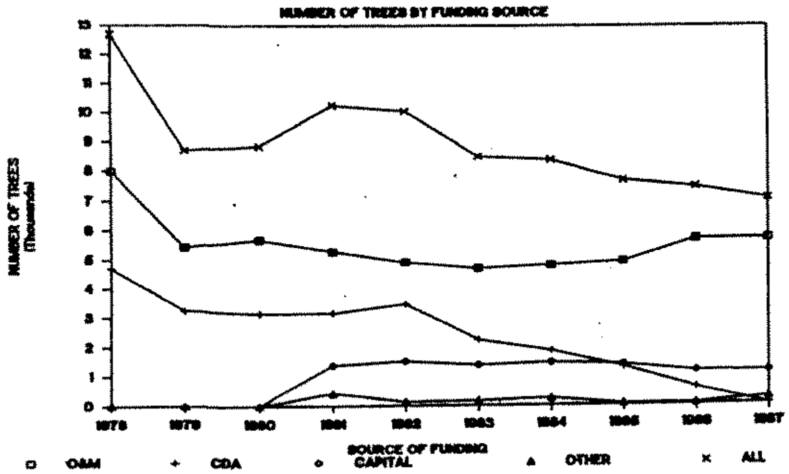


Trees are removed when they die, become infectiously diseased or become hazardous due to structural defect or construction activities. Losses from Dutch Elm Disease have steadily declined over the past ten years. Losses owing to other causes have remained stable, with occasional fluctuations in numbers caused by events such as windstorms, droughts or harsh winters. The graph below portrays the tree removal experience of the City of Milwaukee.



Tree planting is accomplished using various funding sources. Of primary importance is Operations and Maintenance fund replacement planting, whereby trees lost to all causes except construction activities are replaced. Capital Improvements funding, whereby trees are planted either initially on new street construction projects or replaced as a result of street reconstruction activities, accounts for a significant but smaller portion of the tree funding. Community Development Block Grant funding has enabled the bureau to reduce its backlog of planting locations and to compensate for the significant number of trees lost to Dutch Elm Disease in the inner city. While significant in accomplishing the backlog reduction, CDA funding has steadily decreased over the last eight years. The following graph illustrates the Bureau of Forestry's planting activities according to funding source during the last 10 years.

TREE PLANTING HISTORY



The City should continue to reduce its planting backlog to the point where planting is done in the year following loss. Whenever tree replacement is delayed, the resident loses the time of actually enjoying the tree located in front of his residence and more significantly, loses the time and growth that would have occurred had timely replacement taken place. As a result, the City should continue to reduce its planting backlog to the point where planting is done in the year following loss. Replacing the tree in prompt manner communicates a sense of the City's investment in the neighborhood and maximizes the time available for tree growth.

ESTIMATED USEFUL LIFE

Conditions on city streets are far from optimum for tree growth. Restricted space, drought, pollution, salt, mechanical injury, vandalism, insects and disease all contribute to premature mortality in street trees. Under urban conditions, the maximum average life expectancy that can reasonably be achieved is 50-60 years.

IMPLIED REPLACEMENT CYCLE

One measure of the effectiveness of an infrastructure preservation program is the "Implied Replacement Cycle". This is calculated by dividing the total number of units in the system by the quantity replaced in a year. This yields the cycle or number of years that would pass before the entire system would be replaced, refurbished or upgraded. The table below shows the implied replacement cycle for street trees for the last ten years, the last three years and last year.

Implied Total Replacement Cycle

Last 10 Years	Last 3 Years	Last Year
34.0 Years	39.6 Years	42.0 Years

In this instance, implied replacement cycle for the street tree program is projected by dividing the total tree population by the total tree planting program in any given period. It may be observed that the city's implied replacement cycle is shorter than the average life expectancy of the street tree population. This occurs for two reasons. First, the city has been planting at a rapid pace to reduce the backlog of vacant planting locations caused by Dutch Elm Disease; and, secondly, because new street construction and reconstruction has resulted in numerous planting locations being developed. During the past decade, Community Development Block Grant funds have been utilized to help reduce the enormous backlog of tree planting locations owing to Dutch Elm Disease.

PREVENTIVE MAINTENANCE

Preventive maintenance of the tree population consists of six basic activities: pruning, disease and insect control, surgery, fertilization, root control and new tree watering (year following planting only). The following table summarizes maintenance activities and expenses incurred during 1983-1987.

Preventive Tree Maintenance

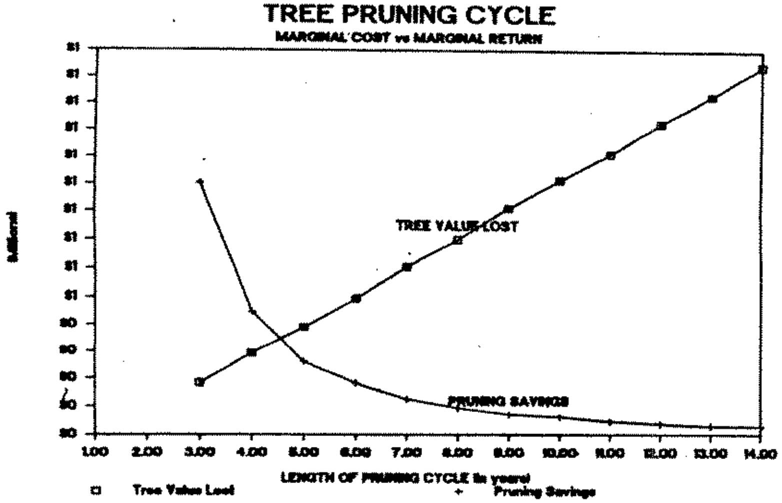
	(Number of Trees) 1984	1985	1986	1987
Pruning	50,142	54,920	59,786	61,552
Post-Planting Maintenance	23,141	27,802	19,987	20,236
Disease & Insect Control	11,420	14,059	14,923	16,039
Surgery	3,299	3,652	5,265	7,154
Fertilization	6,492	8,527	12,162	12,162
Root Control	187	280	189	317
Box-Out Maint.			960	
Total Expenditures	$1,556,995	$1,617,851	$1,934,806	$1,956,515

The overall goals of the maintenance program are to minimize tree mortality and have a healthy, hazard-free tree population. Each maintenance activity has its own purpose and goal.

Pruning is the most important maintenance activity. Its primary purpose is to train tree growth to minimize interference with traffic, utilities, lighting, signs and pedestrians. Additionally, pruning maintains the health of the tree and eliminates the potential hazards of dead wood and poor branch structure. The condition class of a tree and its value is directly related to the frequency with which the tree is pruned.

Approximately 56,000 trees are pruned annually. Therefore, each tree is pruned on 5.8 year cycle. The optimum pruning cycle for the City of Milwaukee is 4.6 years. This cycle has been determined by comparing the loss in tree value against the savings in pruning costs that occur as a result of extending the pruning cycles. The following graph illustrates this concept.

TREE PRUNING CYCLE



The loss in tree value resulting from extending the pruning cycle by one year is the marginal cost attributed to postponing pruning an additional year. The savings associated with extending the pruning cycle by one additional year is the marginal return associated with reduced pruning the next year. The marginal cost and marginal return lines converge at approximately 4.6 years. This indicates that in pruning cycles of less than 4.6 years, more money is expended to decrease the pruning cycle than is justified by increased street tree value. Conversely, extending the pruning cycle beyond 4.6 years results in a loss to the citizenry in that the value of the street trees is lost more rapidly than the pruning savings would justify.

It is unlikely that the bureau can achieve this optimum pruning cycle with current staffing and state-of-the-art technology. However, technological changes in pruning equipment will allow the city to increase pruning efficiencies substantially. It is the goal of the Bureau of Forestry to achieve a five year pruning cycle, through staff and technological changes.

An economic evaluation of the maintenance program in relation to the total value of the street tree stand is appropriate in determining whether preventive maintenance funding is adequate to sustain the system as a whole. The 1987 cost of maintenance of Milwaukee's trees was $1,956,515 or about $5.96 per tree. The total value or reasonable replacement cost for the entire tree population is $384,442,153. This results in a maintenance to replacement ratio of $1,956,515 to $384,442,153 or 0.51%

The removal and replacement of the entire tree population with like-size trees and species cannot actually be accomplished. However, the value of the trees can be calculated utilizing commonly accepted criteria.

The International Society of Arboriculture and the American Council of Tree and Landscape Appraisers have developed tree appraisal formulas which have been widely accepted and have been substantiated by insurance settlements and common law casualty judgements. The evaluation formula utilizes the size, species, location and condition of the tree to determine an individual tree value. The value of Milwaukee's tree stand was determined by extending the sample inventory conducted in 1979-81 to the entire tree population, utilizing the standard appraisal formulas. The average per tree value is $1,171.54. The following table details the net appraisal value for City trees.

Tree Value

Size Diameter In Inches	Number of Trees	Basic Replacement Cost/Value	Average Condition	Appraisal Value
0 - 1.9	1,969	$ 410,805	58.2	$ 239,089
2 - 3.9	103,701	41,362,558	70.0	28,953,791
4 - 5.9	57,429	46,517,490	77.3	35,958,020
6 - 7.9	41,349	58,104,342	78.6	45,690,328
8 - 9.9	35,114	72,398,683	78.6	56,905,365
10 - 11.9	23,956	72,178,339	78.1	56,371,283
12 - 13.9	19,690	41,580,332	76.0	31,601,052
14 - 15.9	8,532	17,587,073	73.0	12,838,563
16 - 17.9	6,564	18,817,801	71.2	13,398,274
18 - 19.9	7,221	24,480,428	70.7	17,307,663
20 - 21.9	6,891	27,862,818	71.2	19,838,327
22 - 23.9	5,251	24,760,586	70.6	17,480,974
24 - 25.9	3,938	21,304,014	70.1	14,934,114
26 - 27.9	2,953	18,341,799	70.1	12,857,601
28 - 29.9	1,969	13,736,978	71.9	9,876,887
30 +	1,640	14,402,170	70.9	10,211,139
Total	328,167	$513,846,216		$384,442,153

SYSTEM PERFORMANCE

Trees add to the quality of life for Milwaukee's residents and businesses in many ways . While trees provide beauty for our pleasure, comfort and well-being, they also help conserve energy and improve the quality of air, water and soil. Trees provide shade, which reduces air conditioning costs, human discomfort and eyestrain. Trees help reduce wind, noise, glare and particulate pollution in the city environment. In addition, trees provide habitat for wildlife. A more tangible function of street trees is the increase in property value they provide, both real and perceived. As detailed previously, the street tree population of the City of Milwaukee is valued at $384,442,153. In addition to the actual value of the trees themselves, studies by the U.S. Forest Service have indicated that street trees increase home property values significantly. The aesthetic, environmental and value enhancement characteristics of street trees all serve to make this community a more attractive, viable place to live and conduct business. The appearance and environmental characteristics of the city help to attract new residents and businesses to the community and to maintain our nationally recognized high quality of life.

The street tree system performance is currently measured by indirect methods such as new requests for commercial plantings, homeowner plantings, and services; and compliments and complaints on the program. Another measure of the performance is reflected in the per tree value or changes in value over time. From 1980 to the present, individual tree values have increased from $497.16 to $1,171.54 per tree. This 135% increase results from increases in tree size, condition, and inflation.

Trees also impact on property values. Studies indicate a sound street tree program may result in property value increases of between five and ten percent. Milwaukee's sound urban forest management system has been recognized by numerous national awards, including an unprecedented seven straight years as National Arbor Day Foundation - Tree City, U.S.A.

CONCLUSION

The City of Milwaukee's tree population has steadily increased to 328,167 trees. These trees represent 118 varieties of 65 species, with a combined current value in excess of 300 million dollars. The street tree system provides environmental, property value, aesthetic, engineering and psychological benefits to city residents.

The street tree system is generally in good condition, owing to a history of sound maintenance programs and extensive tree replacement efforts. In spite of harsh urban conditions, these management efforts have resulted in an average condition rating of 74.3% and a system life expectancy of 50 to 60 years.

Trees are planted and maintained until such time as they are removed. Tree maintenance activities involve condition assessment, post-plant care, pruning, fertilizing, spraying and tree surgery. In Milwaukee's young and vigorously growing urban forest, it is imperative that maintenance programs be conducted at a level which serves to increase tree value. To achieve this goal, the pruning cycle should be reduced from 5.8 to 5 years. Additional efforts should be made to improve the overall condition of the street trees, increase the life expectancy of the stand and increase the value of the trees themselves.

Unlike other infrastructure systems, trees do not become immediately effective upon their replacement or refurbishment. Because of the 15 to 20 year lag time between the planting and the full effectiveness of a tree, it is important that tree replacement occur within one year of removal.

Although information on the condition of the street trees has been gathered informally for years, more detailed information is necessary to effectively manage the street tree system. A more systematic method of condition assessment should be employed by the city. Each tree should be visited not less than once every five years to record growth, condition and maintenance requirement information. To manipulate the vast quantity of data available for management decision making, it will be necessary to utilize computer technology for data storage and summaries.