MANAGEMENT INFORMATION SYSTEMS FOR URBAN TREES[1]

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Abstract. The concept and applications of computerized information systems for the management of urban trees are reviewed. Among their uses are landscape planning, choosing species to be planted, organizing work on trees, departmental planning and evaluation, and public relations. Five types of data required for these purposes pertain to the location of trees, tree characteristics, site characteristics, actions recommended, and work completed. Methods for handling data are reviewed including collection, processing, storage retrieval, and updating. Computer equipment and software options are discussed, particularly microcomputers. Advice is offered on installing a management information system for urban trees and for using it effectively.

Résumé. Le concept et les applications des systèmes d'information informatisés pour les arbres urbains sont évalués. Parmi leurs utilisations figurent l'aménagement paysager, la sélection des espèces à planter, l'organisation des travaux arboricoles, la planification et l'evaluation des services municipaux et les relations publiques. Cinq types de données requises pour ces usages sont la localisation des arbres, les caractéristiques des arbres, les charactéristiques du site, les actions recommandées et les travaux réalisés. Les méthodes pour analyser les données sont évaluées, incluant la collecte, la traitement, l'emmagasinage, le recouvrement et les mises à jour. Les équipements informatiques et les logiciels sont comparés, particulièrement les micro-ordinateurs. Des conseils sont donnés pour l'établissement d'un système de gestion informatisé des arbres urbains et pour son utilisation effective.

The utility of organized information for the systematic management of urban trees has been recognized in North America since early this century (13). Applications of the management information system (MIS) concept in arboriculture have become common only in the last decade, however. A survey of 172 U.S. cities in 1973 found that only 30% conducted trees inventories and fewer than 3% handled data by computer (2). By 1979 fourteen cities were known to be using computers for processing tree data, and six computerized inventory systems had been developed for general usage (8). In a 1980 survey of 2,861 U.S. cities, 1,534 responded and 767 had systematic tree care programs; 511 provided further information, indicating that 43% kept records on trees and 10% had records computerized (5). The advent of microcomputers subsequently has made it easier and less expensive for towns and cities to adopt this technology in their tree care programs.

Accordingly a general summary of the concept and applications of computerized information systems for the management of urban trees may be useful to those who wish to install a new system. The manager of the municipal tree care agency should be fully involved in its development, as he is in the best position to know what information is needed for planning and making decisions, and how it will be used.

Information Needed for Urban Tree Management

Several categories of information may be included in a comprehensive system (1, 7, 11, 15). Only those pertaining directly to trees and planting sites are considered here, excluding records of equipment, payrolls, and others which can also be handled by computer. It is convenient to group types of information according to their use, for example:

- Landscape planning
- choice of species and cultivars for planting
- maintenance and removal of trees
- departmental planning, budgeting, and evaluation
- inter-agency and public relations

The data needed within each category will depend on the objectives, strategies, and operational procedures of the tree department. These may be documented in the department's management plan, or may exist only in the mind of the municipal arborist. In any case, clearly conceived objectives and strategies should be brought to bear in

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designing an appropriate managment information system.

Landscape planning requires geographically based summaries. These could be organized by districts or features such as transportation corridors, groups of buildings, and parks. Qualitative and quantitative data are needed to make plans for planting or renovation of the landscape. The adequacy of landscaping in the various geographical units can then be evaluated and compared, in order to establish priorities. The planning decisions should also be guided by a philosophy or policy describing the type of landscape desired.

The principal decisions about tree planting involve choice of species and cultivars that are adapted biologically and architecturally, and site modifications that will assure high survival rates and continuing tree health. Thus information about site characteristics and species/cultivar performance become interrelated with each other and the landscape plan. These decisions will have long-lasting consequences, and may be the most important ones to be made. In implementing planting plans, MIS data can expedite the timely procurement of trees.

The largest expenditures of a tree department typically are devoted to maintenance of trees through various cultural techniques, and removal of trees when they become hazardous or die. Because tree care practices are labor intensive, the MIS offers substantial cost-saving possibilities by devising more efficient operations. Analyses of data on tree characteristics and work records are required for this purpose.

Budget planning requires predictions of the various activities in the next year and their costs. Basic data for calculating general trends and specific needs should be extractable from the MIS. Complete tracking of all costs is not necessary for planning purposes, and could make the MIS too cumbersome. Sufficient precision may be achieved by sampling costs or through separate studies. To support budget requests, summaries of accomplishments and some details that dramatize a few meaningful examples are very useful. Evaluations derived from MIS data can demonstrate effective use of funds, and also can be used to improve productivity of operations.

Public relations of a tree department may involve exchanges of information with individual property owners, various city agencies, and the public at large via news media. Usually information is needed quickly for these purposes, and may be difficult to anticipate. Data may pertain to individual trees, to certain streets or subdivisions, to problems associated with particular species, or to accomplishments or needs of the tree department. By remaining sensitive to public interests, a manager can prepare information periodically for public relations. But in addition, ready access to a well-orgainzed record system is required for rapid responses in urgent situations. Thorough documentation may also be needed for legal purposes, for example in defense against lawsuits.

Structure of Data Base

When the kinds of information needed have been defined, logical choices can be made among the types of data that are to be collected and the specifications for each. Data elements can be divided into five groups:

location of tree(s) or site
tree characteristics
site characteristics
actions recommended
work completed

Most larger cities have subdivisions that are convenient for organizing the work of a tree department. Data should be arranged in accord with such management districts when the data base is constructed.

Location. There are at least four approaches to designating tree locations: property address, distance and direction from a street intersection, map coordinates, and a geographical unit system named GBF/DIME (Geographical Base File/Dual Independent Map Encoding) (Silver 1978, U.S. Dept. Commerce 1977). Property addresses are convenient for finding trees quickly, for summarizing data by street blocks, and for responding to telephone inquiries; trees at the same address can be numbered to give them unique identities. Greater precision is possible by referencing trees to intersections, but this consumes more time and may not be necessary. Map coordinates, referenced to street maps or aerial photos, are most useful in parks, were permanent reference points are scarce. The more complex GBF/DIME system, which was developed for several types of census data, has been employed in Kansas City, Missouri (8) and Charlotte, North Carolina (14). Each block has three sets of coordinates, which permit computer mapping and merging of tree data with other data bases.

Tree Characteristics. Variables describing the species, size, and condition of trees are commonly used for purposes which are obvious. Letter codes may be assigned to species for brevity, e.g. TICOGR designating *Tilia cordata* cv. 'Greenspire' may be easier to remember than a number. Tree diameter, height, and crown spread can be measured or estimated, and recorded as absolute values or in classes. Codes for vigor, health, and injuries caused by diseases, insects, or other agents should be clearly defined in a practical manner, to standardize their use. Monetary values of individual trees can be calculated from these variables if they are appropriately defined (3).

Site Characteristics. A description of the environment in which a tree is placed may be brief or extensive. The most common uses are in choosing suitable species or cultivars, in analyzing their performance in relation to site variables, and in planning work such as planting, trimming, or removal of trees. Examples of variables include:

- site class or land use
- planting space dimensions, above- and below-ground
- type of ground cover or pavement
- presence of utility wires or pipes
- condition of paved walkways
- street width, or amount of traffic
- quality of landscaping

Actions Recommended. Work that needs to be done typically is decided on the site. The date and person making the recommendation should always be recorded. Information may be needed on:

- planting
- watering
- fertilizing
- spraying
- trimming
- removal
- repair of pavement
- priority of the work (N.B. avoid designations of hazards that might imply liability)

Some of these actions may be conducted routinely, in which case it may be sufficient to note only when each has been completed. The particular data will depend on how the tree department conducts its operations.

Work Completed. A decision to undertake a particular job usually is implemented through a work order or a contract. By entering such data in the MIS, a link is provided with the Actions Recommended category. The details may be brief or elaborate, depending on the availability of related records and how they will be used. Accumulated data can provide a complete history of work done on each tree.

Data Base. The design of the data base for a management information system should follow certain principles that are common to many different applications. In our research MIS (10), we have found that it is absolutely necessary to think through the logical relationships among data elements and how the information will ultimately be used. When this is not done, it is almost inevitable that time will be spent collecting and recording data that is later unused or, worse, even unusable.

Computerized systems, which depend upon pattern recognition, require consistency from tree to tree in the manner in which each data element is measured and coded, as well as parsimonious coding of data in order to conserve storage space. In general, each field (variable) must be filled in for each record (tree) and in the same manner, especially for numeric data. If the data can be scaled, as for example tree height or tree health rating, then a numeric code is appropriate. If the data fall into unscaled categories, as for example injury code or type of ground cover, it should probably be coded alphabetically. The reason for this is that alphanumeric characters require less storage space (1 byte each, as opposed to usually 2 for integers and 8 for decimal numbers).

Provisions must be made for exceptions, such as odd location designations. Data irregularities that are normally handled with explanatory notes in paper filing systems must be avoided. Although computerized systems can accomodate character fields containing "miscellaneous notes", such fields are very wasteful of disk storage space in most systems. An 80-character field for such notes would require 800,000 bytes of storage space for a 10,000-tree inventory, even though for most trees this field may be empty. Since computers can do little more than retrieve such information (as opposed to combining and summarizing it with other data), it is best kept in notebook form anyway.

Methods of Handling Data

When data elements have been specified, methods can be designed for collecting, storing, retrieving, and processing data. A systematic way of updating information also should be incorporated. In some cities the process may begin with a complete inventory of all trees and potential planting sites. In other cases a sample or partial inventory may be conducted, or an existing data system may be converted to a new one.

Inventories. Several alternatives may be considered in defining the scope of an inventory. An urban forest may consist of municipal trees along streets or in parks, private trees around buildings or in woodlots, and other kinds of vegetation which usually are not inventoried. It may be impractical or unnecessary to collect data about every tree, so the populations of interest must be defined. If potential planting sites are to be included, criteria should specify space and other requirements. The data to be collected from street trees may be more extensive than those in parks, which may be managed as groups rather than individuals. There may be questions about what constitutes a street tree, as defined by local ordinances or regulations. Sometimes all trees within a specified distance from the street edge are included, because even privately owned trees affect public landscape plans.

An inventory may be conducted at one time or in stages. High-priority districts may be surveyed first, with the intention of expanding to others when funds permit. However, summaries of partial inventories can not be extended to estimates pertaining to the entire city tree population unless sampling is truly representative.

The validity of estimates derived from partial inventories is dependent on an appropriate sampling scheme, several of which have been devised. In Jersey City, New Jersey 10% of the linear street distance was sampled using a street map, grid coordinates, and a random number table to select locations of plots 200 feet in length (6). In Chicago aerial photographs were used to stratify 10-acre sample units by tree frequency categories within management units; 172 samples were needed to achieve 5% error in volume estimates (4). A combination of systematic and cluster sampling was employed by Valentine *et al.* (12).

Updating. Because some data are subject to change, such as tree size or condition, provisions must be made for updating information. One approach is to repeat the inventory process periodically, covering the entire city, or one district at a time, or randomly selected portions of all districts. An alternative is to update information in those blocks where crews are working, perhaps supplemented with a more comprehensive scheme for certain variables. The updating method will have implications for the recording and storage of data.

Recording Data. Data about urban trees may be obtained in several ways. There are severe limitations on the types of data that may be derived from aerial photographs or by observers in moving vehicles, though these do have appropriate applications. The kind of information needed for a comprehensive management information system can best be obtained by observers on foot. These may be people specially trained to conduct a tree inventory, or tree department employees who collect data while engaged in other duties. Unskilled or semi-skilled people have been used successfully with proper training and periodic checking. However, problems have occurred in other places where personnel did not have the necessary skills, motivation, or careful supervision.

Various kinds of equipment and supplies have been used for recording data. Choices depend on the complexity of the inventory, and should be compatible with methods of data collection and data storage. For the simplest inventories, tally sheets may be used for rapid recording of trees by species and condition within streets or districts. More detailed methods employ forms specially designed for efficient recording and processing of data on each tree or planting space.

There are several ways of expediting data collection, including "op-scan" or "mark-sense" forms, voice tape recorders, portable calculators, and portable data collectors which can be linked with computers. Some portable microcomputers are now powerful enough that they could be carried in trucks for data entry and retrieval; these could replace or supplement office computers in appropriate circumstances.

Computer Options

For any tree maintenance program handling more than a few thousand trees, a computerized MIS will ultimately be cheaper, even though the initial investments in equipment, advice, and software are significant costs that can be avoided with manually maintained record systems. Computerized systems save costs whenever information has to be retrieved, summarized, combined, or revised. Their advantage in scheduling work activities can be appreciable when the size of the operation exceeds what one person can reliably keep in his head.

As recently as two or three years ago, sophisticated computer implementations of urban tree management information systems required expensive hardware and, usually, expensive assistance from consultants. This has changed with the advent of microcomputers that address more than 64K-bytes of memory, large capacity diskettes or fixed disks for storing information, and database management software that can exploit these hardware capabilities. Hardware and software prices and performance are now attractive enough that new MIS implementations in small and medium-sized cities, and major revisions of existing ones, should be designed for microcomputers. If any necessary equipment purchases cannot be justified on the basis of the MIS alone, they may be justifiable by the versatility of microcomputers in handling word processing and other office tasks.

Nevertheless, microcomputers have limitations which can be easily exceeded unless foresight is exercised. A typical, rather thorough street tree inventory might have 30 data elements per tree or planting location. If 15 of these are stored in numeric fields at an average of 4 bytes per field, and 15 in character fields with an average of 4 characters each, a total of 120 bytes of computer storage would be required for each record. If the data storage media are 360 K-byte (K = 1024) diskettes, the largest file could hold information for only about 3,000 trees. Larger inventories could be divided among two or more files, by management district of the city for example, but any data queries across files would require that the system have one diskette drive for each file plus at least one for the database management software.

Alternative solutions for larger inventories are to reduce the number of fields per record (or field sizes), or to purchase a fixed disk storage unit. Fixed disks are becoming very attractively priced and typically hold 10,000 K-bytes or more of information, enough for over 80,000 trees using the example above. Depending upon the particular software, actual capacities may be lower than these estimates because of the need for overhead information on each file and the need for the computer to create scratch files during data manipulation. Urban tree management information systems for very large cities require minicomputer or mainframe hardware.

Advancements in microcomputer hardware precede advancements in software, and database management programs capable of handling a medium-sized street tree inventory are a very recent development. In fact, it is probably advisable in planning a MIS implementation to select a suitable program first, and then purchase the hardware necessary to run it.

Software choices for urban tree management information systems range from: 1) special-purpose programs written in one of the basic computer languages, to 2) general-purpose database management programs, to 3) special-purpose programs written in the procedural language of a general-purpose program and designed to run in conjunction with it. Of the three, general-purpose database management programs are likely to be the best documented, most sophisticated, and least error-prone because the market for them warrants large investments in product development. Ultimately, general-purpose database management programs offer the most flexible solution to managing street tree data but are also the most difficult to learn. Adapting one to a particular municipality's purposes requires a significant personal commitment from someone on the staff and very possibly some outside assistance. To a degree, this adaptation is already accomplished in the case of the third alternative mentioned above, but the user may be limited to the design features (e.g., query choices) deemed important by the developer.

There are many dozens of general-purpose database management programs for microcomputers available on the market. The good ones are very good, the results of literally man-years of effort; the poor ones are hardly worth the diskettes they are on. For the purpose of managing street tree information, a good program should have the following features:

1. Capability of adding, deleting, revising, and retrieving information by record (tree or planting space) and by field (data element).

2. A query language by which information can be retrieved and displayed on the screen or printer. Among other things, the language should permit sorting by field, automatic calculation of summary statistics, and conditional phrases ("less than", "equal to", etc.) that can be linked with Boolean operators ("and", "or", etc.) to retrieve information with certain combinations of characteristics.

3. A fairly rich procedural language that permits frequent queries or other procedures to be linked and programmed for automatic execution by clerical personnel. Procedural languages include such things as looping and "go to" commands, provision for keyboard input in response to screen forms and prompts, and the capability of performing complicated arithmetic operations on field values.

4. Capability of indexing key fields for faster retrieval of information.

5. Provisions for editing of data entries (default values, range tests, entry masks that allow only certain characters, etc.) to reduce the possibility of input errors.

6. Capability of manipulating two or more files at once if related data are stored in more than one file.

7. Upper limits on the permissible number of fields per record, records per file, bytes per field, etc. that exceed the anticipated needs.

8. Data security provisions to avoid unauthorized access or modifications to files, and data encryption for extra security if some data are confidential.

A further desirable feature of general-purpose database management systems is that data be exportable in a data format readable by the computer's operating system for later transport to another program. With this provision, one can be sure of never being locked into an unsatisfactory software and hardware system. In fact, the greatest advantage of using a good general-purpose program is the flexibility that it permits. We have found that one never remains completely happy with the present system, and so development and refinement of the MIS is a continuing process.

System Design and Operations

Developing and using an MIS for urban trees obviously is a complex task for any tree department that has more than a few employees. A multitude of interrelated questions must be addressed about what information is needed and why, which data variables should be chosen, how data will be collected and processed, and which computer hardware and software are most suitable. The effectiveness of the MIS will depend first on how well a tree department has dealt with these questions, and subsequently on how well the MIS is utliized in improving the efficiency of tree care operations.

It is worth re-emphasizing that the manager of the city tree department has a key role in developing and using the MIS. In addition, a specialist may need to be consulted for advice on equipment, software, data collection and processing, and installing the system. The undertaking may be costly in time and money, but the potential savings within a few years are likely to be much greater.

The design of the MIS should be based on an analysis of the decisionmaking process in the tree department (15). In larger organizations this will involve several managerial and supervisory positions, from crew foreman to department head. For each position the functions, decisions, and information needs should be analyzed in relation to the existing process and the proposed MIS. The analysis should consider what tree-related information is needed, by whom, when, where, and why. It will be helpful to examine all types of departmental forms and reports, to interview people in the various positions, and to construct a flowchart of the existing information system.

The ultimate success of the MIS will be determined by the qualifications of the people involved in its operation. Those engaged in routine tasks must be trained and checked occassionally to assure accuracy and timeliness in handling data. It is also important that they understand their roles in the system. One person must have responsibility for the complete MIS, and for evaluating its effectiveness. A creative systems manager will continually develop new applications. With imagination, good judgement, and cost/benefit considerations, the manager can find ways to overcome barriers to higher productivity and thus to improve the efficiency of the tree department.

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Abstract

Davis, S. H. Jr. 1986. **Use the formula for tree appraisal.** Am. Nurseryman 163 (12): 70-73.

A tree's value is relatively simple to determine when the tree in question is of moveable size—that is, when its diameter is less than 12 inches at 4½ feet above the soil line, which is the diameter at breast height. A nurseryman or landscape designer who is asked to place a retail price on a tree quotes a price that is approximately 2½ times the wholesale price. This price includes transporting and planting the tree and usually a 1-year guarantee. But how do nurserymen, landscapers or arborists determine the values of trees that they consider too large to move? And how do they determine the value of trees whose locations make transplanting impossible? Many years ago, a few individuals tried to address the issue of placing a value on large trees. CTLA, representatives from several green industry organizations, concluded that the best method for determining the value of a tree that is too large to transplant hinges on four factors: size-square inches in dbh; kind—the genus, species variety or clone; location—whether the tree is in a historic area, golf course, front or rear of a home, etc.; and condition—age, mechanical damage, insect or disease problems, etc.