THE PLUS SYSTEM: WHO NEEDS IT ?

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ABSTRACT

The paper begins with a description of the PLUS system. The use of the system to resolve an intractable problem within the author's own research is then described and, finally, the paper concludes with suggestions for the future use of these computer programs and for possible developments and improvements which might be made in the area of geographical information systems.

LE SYSTEME "PLUS": EST-IL NECESSAIRE?

RESUME

Cette étude commence avec une description du système "PLUS". Une démonstration de l'utilisation de ce système par un auteur qui cherche à résolver un problème obstinée qu'il rencontre dans une de ces recherches. Des suggestions de possibilité d'utiliser ce système afin de développer et améliorer les systèmes d'information géographique.

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HISTORICAL DEVELOPMENT AND FUNCTION OF THE PLUS SYSTEM

In September, 1972 Dr. Jay Beaman (Parks Canada) and Dr. J. H. Ross (formerly of the Lands Directorate) carried out a review of the procedures available for computerised land use planning. This review revealed a need for a system for storing data and for transferring it from one geographical information system to another so that a variety of groups might use it. Secondly, a need was also determined for a system which would allow planners and others with little knowledge of computers to display, manipulate and analyse their data quickly and efficiently. In order to satisfy these perceived needs Dr. M. F. Goodchild (University of Western Ontario) was hired to develop a computer system with these capabilities. This system was fully developed and operational by 1976 and it was dubbed PLUS which is an acronym for Planning Land Use. The rest of this paper describes, briefly, the mechanics of the system and how PLUS was used to solve one particular problem in the author's own research. Finally, there is a discussion of how this package of programs might be used in the future.

THE NUTS AND BOLTS OF PLUS

The raison d'etre of the PLUS system is to allow the transfer of areal data recorded in one geographical information system to a second more useful system. For example, if a researcher has certain information recorded for one set of areal units, such as census tracts, but he is carrying out an analysis using additional information which has been measured for a second set of areas which do not correspond to the first set, such as school districts, then he may find it advantageous to transfer the census tract information to the school district map. The PLUS computer programs will allow him to do this (as will the POLYVRT program produced by the Harvard Laboratory for Spatial Analysis and Computer Graphics). PLUS can also be used to transfer data to a user defined geographical information system. An example will be described later in the paper where information from one geographical system was mapped into a second system comprised of a set of areas known as Thiessen polygons. More commonly, however, researchers will probably use PLUS to transfer data from an inconvenient geographical base to a grid system. A second set of PLUS routines can then be used to manipulate, analyse, tabulate and display this gridded data. The PLUS routines thus fall into two distinct groups. The characteristics and functions of these two groups are described in the two key monographs describing the system (Goodchild 1976 and Goodchild, Ross and Swanson 1977). Here it may simply be noted that PLUS is divided into the PLUSX routines which, among other things, perform all the operations which are required to transform point, line and polygon data to grid cells and, secondly, into the PLUS/2 routines for the display and analysis of the gridded data. The PLUSX program is designed to be run on a large main frame computer by a skilled user while

PLUS/2 may be run on much smaller machines by users who have very little knowledge of computers and simply wish to use the machines as a means to an end.

The Mechanics of PLUSX

The PLUSX routines will accept data which consists of polygons, lines or points. It will then carry out the required scale transformations and coordinate rotations so that the data may be read out in a grid format at the desired scale and orientation. One of the more straightforward operations which PLUSX performs is the co-called point-in-polygon process which allows the user to determine whether a given point falls within a user defined area. A modified example of the use of this procedure in the author's own research is described below. More commonly, perhaps, a user will initially have data in polygon form which has been derived from some geographical information system such as the Canadian Geographical Information System (C.G.I.S.). Such polygon data may be stored in one of two ways. The first method is known as the image/centre (IC) format. Here the sides of each polygon are digitised (this is the image section of the file) together with an arbitrary point from the centre of the polygon (the centre part of the file). If this information is digitised from a map the polygons will in many cases not close and so PLUSX contains a series of editing and cleaning routines which automatically close polygons within a certain user specified tolerance. The second method of storing data is the Pairwise Contact (PC) method where the arcs of the polygon network are recorded together with information identifying the polygons on either side of the arc. This data is internally consistent and represents a more efficient way of storing and manipulating it. An example of these procedures together with those methods used in two other well known mapping systems is shown in Figure 1.

The PC data may be allocated directly to the desired grid system or may be stored for further use. The gridded output is written in an efficient manner in order to minimize storage space. The method is known as the 'multiplier identifier' format. The first record in a data file which describes the gridded map provides information on the number of rows and number of columns in the map and the type of information stored. That is to say whether it is numeric or alphanumeric. The remaining records contain two pieces of information. The first is the multiplier which indicates the number of times a particular classification occurs without interruption on a row of the grid and the second is the identifier which is simply the classification in question. Figure 2 shows part of a gridded output file produced by the PLUSX system.

Running PLUS/2

The PLUS/2 system operates on these gridded output files. It is

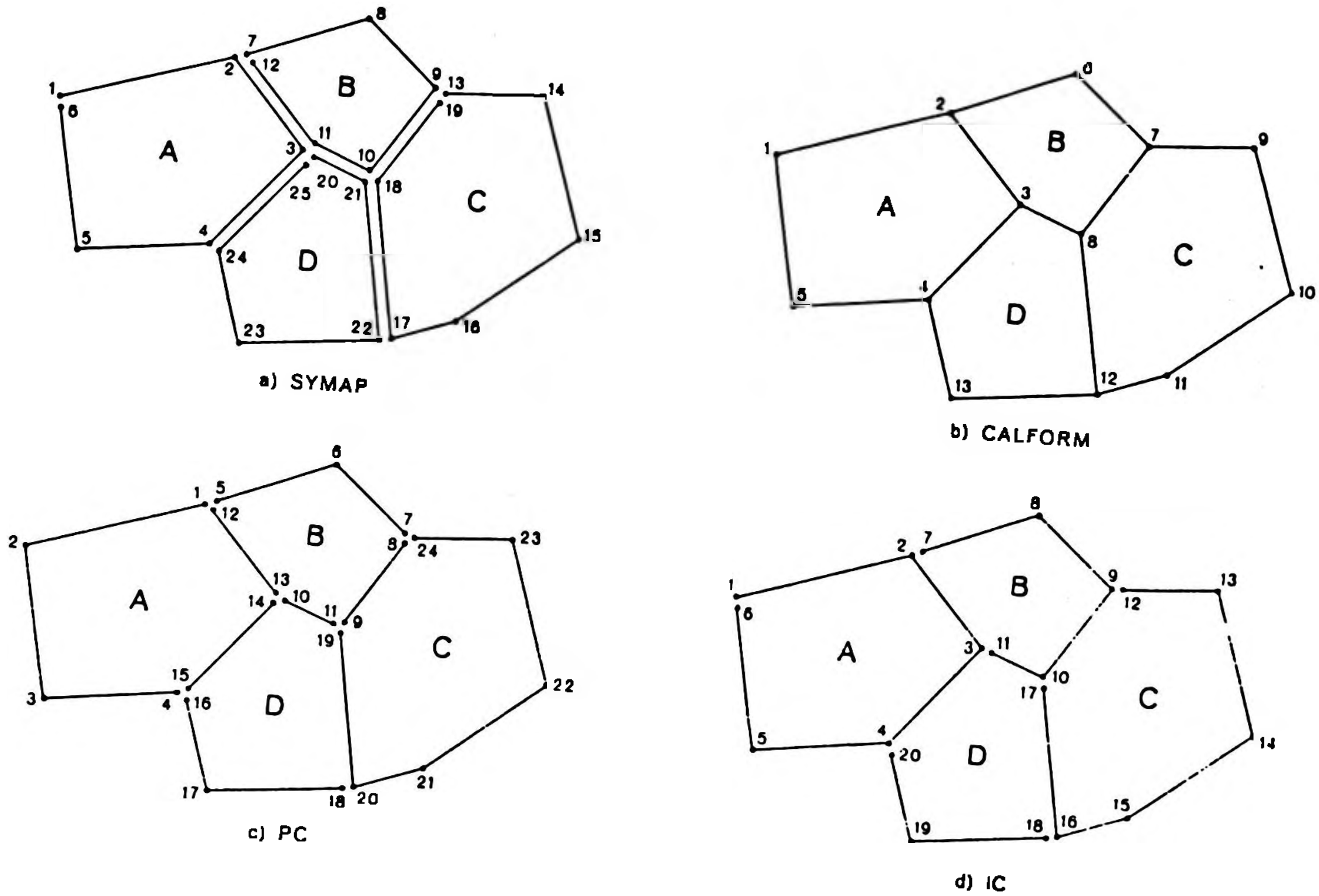

Figure 1. Four Alternative Methods of Digitizing Polygons (after Goodchild 1976)

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1     222233332233332222333322222233233554444444555555555505550006
2     222233322333333332333322222222244444444444555555555550550000
3     222223322333333333333332222222244444444444455555555555000000
4     222223323333333333333333222222225544444444444555555500005500
5     222223223333333333333333222222222254444444444555500000055500
6     222223322333333333333332222222222445444444444455550000000000
7     222223322233333333333332222222222445544444444455500000000000
8     222222233333333333333222222222222245554444444454500000000000
9     222222222223333333333233322322222444434444555444500000000000
10    222222222223333333333332222233232333444355555544050000000000
11    222222222223333333333322222222332344444435355555555000000000
12    222222222223333333333333333223232232355444444445555555500000000
13    222222222223323333333233322323322554444444445555555555550005
14    222222222222222223332233332222333334445544444455555555555555
15    222222222222222222232223322223333333444554444435555555555555
16    222222222222222222322232332323333333344455444444355555555555
17    222222222222222222223332233333333333344444454444455555555555
18    222222222222222222223333232333333333334444444544435555555555
19    222222222222222222233333332335533333333544444544443555555555
20    222222222222222233333323332235533333334445445554444355555555
21    222222222222222333333323332233333333344444555454444443555555
22    222222222222222333333323323333333333344444444544444444555555
23    222222222222222233333333332333333333355544544545445544355555
24    222222222222222233333333322233333333544544544554545544445555
          5    10   15   20   25   30   35   40   45   50   55   60
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Figure 2. Part of the Gridded Output file produced by the PLUSX system

an interactive system written in BASIC for small computers (a PL/1 interactive version has also been written for larger computers which tend to have only the more primitive versions of BASIC available). A variety of operations may be performed on the gridded map and these are listed as Figure 3. These operations fall into three groups. Firstly, there are the housekeeping operations which allow the user to access the information and to display it. Secondly, there are the create operations. With these the user can manipulate the existing data in a variety of ways and create new files subsequent to this manipulation. Finally, there are a series of operations which when used allow the user to tabulate and analyse his data. These procedures are fully described in one of the reports mentioned above (Goodchild, Ross and Swanson 1977) but a few examples which have been run at the University of Calgary will be briefly described.

The first example shows the result of using the 'help' command (Figure 4) and reveals the function of the various commands shown in Figure 3. The second example, Figure 5 (which uses the same data as Goodchild, Ross and Swanson 1977), shows the use of the RECODE option. For the additional functions the reader is referred to the original manual (Goodchild, Ross and Swanson 1977).

The examples shown were run on the University of Calgary's CDC Cyber computer using the BASIC version of PLUS/2. The PLUSX-PLUS/2 system is obviously a powerful tool for the storing, manipulation and analysis of geographical information. In the following section of the paper the use of the PLUSX routines to manipulate data in a particular research project are described in detail.

THE USE OF THE PLUS SYSTEM IN A RESEARCH SETTING

During the period 1973 to 1977 an extensive study of the London, Ontario, Fire Department was undertaken (Waters 1977). One of the prime objectives of the study was to make suggestions regarding the future location of new fire stations and the relocation of existing, but obsolete stations. It was felt that any new fire stations should be located so as to minimize the distance between the total set of fire stations and the future patterns of alarms. Since the future pattern of fire alarms was unknown a number of attempts were made to predict the pattern using multiple regression models together with socio-economic data taken from the 1971 census. These models proved unsuccessful. The failure of the predictive models confirmed the experience of other researchers who had worked in this area. Because of these experiences it was decided to use the pattern of alarms which had occurred in 1973 as the demand surface. During that year there were 2,459 alarms. The location of each of these alarms was therefore recorded in a right-handed cartesian coordinate system.

Housekeeping	Create	Tabulation and Analysis
COVERAGES	CREATE	ANOVA
DELETE	COMBINE	CONTIG
DISPLAY	LINES	CROSSTAB
HELP	OVERLAY	DTAB
RESTART	POLYGON	REGRESS
STOP	RECODE	ROUTE
	RETYPE	TABULATE
	STRIPS	

Figure 3. The Various Functions Available with PLUS/2 system (after Goodchild, Ross and Swanson 1977)

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 79/01/24. 12.28.25.
PROGRAM   PLUS38


COMMAND ? help
RECOGNISED COMMANDS ARE AS FOLLOWS
ANOVA - ANALYSIS OF VARIANCE
COMBINE - ARITHMETIC COMBINATION
CONTIG - EVALUATE CONTIGUOUS ZONES
COVERAGES - LIST COVERAGES IN THE SYSTEM
CREATE - FORM A COVERAGE FROM THE TERMINAL
CROSSTAB - CROSSTABULATE TWO ALPHA FILES
DISPLAY - MAKE A MAP AT THE TERMINAL
DTAB - TABULATE BY DISTANCE FROM A POINT
DELETE - DELETE A COVERAGE
LINES - CREATE A LINES FILE
OVERLAY - COMBINE TWO ALPHA COVERAGES
PLOT - MAKE A HARDCOPY PLOT OF A COVERAGE
POLYGON - CREATE A POLYGON
RECODE - CHANGE THE CODES IN A FILE
REGRESS - REGRESSION ANALYSIS OF TWO COVERAGES
RESTART - REENTER BASE PARAMETERS AND FILE NAMES
RETYPE - CHANGE THE TYPE OF A FILE
ROUTE - FIND A BEST ROUTE THROUGH A COVERAGE
FINISH - END SESSION
STRIPS - CHANGE A LINES FILE INTO A STRIP
TABULATE - TABULATE A COVERAGE
HELP - PRINT THIS LIST
TYPE STOP TO ABORT THE RUN, BACKSPACE TO DELETE
```

Figure 4. The Use of the HELP command in the PLUS/2 system

```
COMMAND ? recode
NAME OF COVERAGE TO BE RECODED? d1
FILE TYPE ALPHA
WHAT IS THE NEW FILE TYPE TO BE ? alpha
NAME OF THE NEW FILE? d4
OPENING FILE IN POSITION 4
NEW SYMBOL OR VALUE FOR 2 IS  ? *
NEW SYMBOL OR VALUE FOR 3 IS  ? *
NEW SYMBOL OR VALUE FOR 5 IS  ? /
NEW SYMBOL OR VALUE FOR 4 IS  ? /
NEW SYMBOL OR VALUE FOR 0 IS  ? /
NEW SYMBOL OR VALUE FOR 6 IS  ? /
FILE CREATED

COMMAND ? display
NAME OF FILE FOR DISPLAY? d4
FILE TYPE ALPHA
ENTER ROW AND COLUMN FOR DISPLAY PAGE ? 1,1

 1   ********************************////////////////////////////
 2   ******************************//////////////////////////////
 3   ******************************//////////////////////////////
 4   *******************************/////////////////////////////
 5   ********************************////////////////////////////
 6   ********************************////////////////////////////
 7   ********************************////////////////////////////
 8   *********************************///////////////////////////
 9   ********************************////*///////////////////////
10   ***********************************///*/////////////////////
11   *********************************//////*/*//////////////////
12   *********************************///////////////////////////
13   *********************************///////////////////////////
14   **********************************//////////////////////////
15   ***********************************//////////*//////////////
16   ************************************////////////*///////////
17   ************************************////////////////////////
18   *************************************////////////*//////////
19   ****************************//********////////////*/////////
20   ****************************//*******//////////////*////////
21   ************************************/////////////////*//////
22   ************************************////////////////////////
23   ************************************//////////////////*/////
24   ***********************************/////////////////////////
         5    10   15   20   25   30   35   40   45   50   55   60
NEW PAGE - YES OR NO? no
```

Figure 5. The Use of the RECODE option in the PLUS/2 system

The next step in the analysis involved the use of what has become known as a location - allocation model (Rushton, Goodchild and Ostresh 1973) to locate the new fire stations and to allocate the alarms to specific stations. The location - allocation program used was a discrete space program which evaluates distance between alarm and fire station using a previously specified street network. Unfortunately, the particular program used, ALLOC4 (Hillsman 1974), while being the largest available at that time was not large enough to handle all the alarms as individual demand points. Consequently, it was decided to amalgamate the alarms into 150 groups since this was the largest number of demand points which the ALLOC4 program could handle. 150 major street intersections in the City of London, Ontario, were thus designated as the new demand points. These are shown in Figure 6. These new demand points were then weighted by the number of alarms which occurred closer to that intersection than to any other.

In order to determine which alarms occurred closest to which intersections the PLUSX routines were used to generate a Thiessen polygon around each region. A Thiessen polygon (also known as a Dirichlet region or Voronoi polygon) encloses all the space on a map (and therefore all the alarms) which is closer to the centre of the given polygon than to the centre of any other polygon. Once PLUSX had generated the net of Thiessen polygons (see Figure 7) the point-in-polygon routine from the PLUSX package was used to establish how many alarms occurred in each region and thus the weighting for each of the 150 major intersections. These were then used as the demand surface for the location - allocation model and the optimal locations for ten fire stations, nine of which were constrained to their existing 1976 locations, are shown in Figure 8, together with the first-due response districts and the maximum response run.

CONCLUSION

This paper has described the basic features of the PLUS system together with one specific example of the system's use in a research project. Obviously, the system has enormous potential for urban and regional planners who require either a quick 'look-see' at the data contained in large, geographical information systems or who wish to manipulate the data for subsequent analysis within or outside of the PLUS system. However, there is one major drawback to use of program packages such as PLUS and this concerns the collection of the initial information. There is no difficulty if the data has already been collected by another agency as is the case with the C.G.I.S. If, on the other hand, the data has to be acquired by the researcher himself, this part of the research can prove the most lengthy, costly and uninspiring part of the project. This was certainly true with the fire station study described above. As a result if systems such as PLUS are to prove truly useful there is a need for agencies at the municipal, regional, provincial and federal levels to

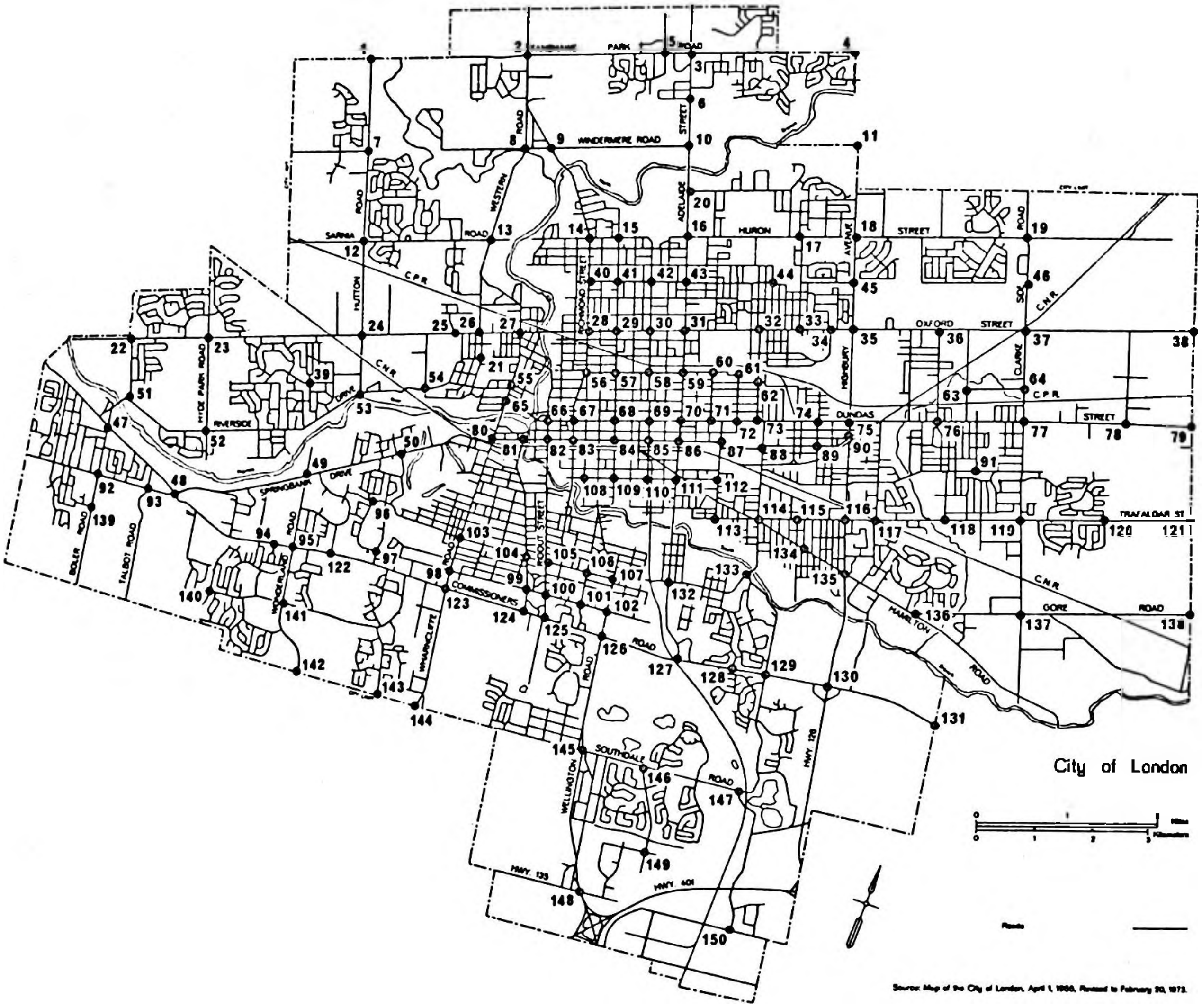

Figure 6. The 150 Major Street Intersections Used as Demand Points in the Location-Allocation Analysis

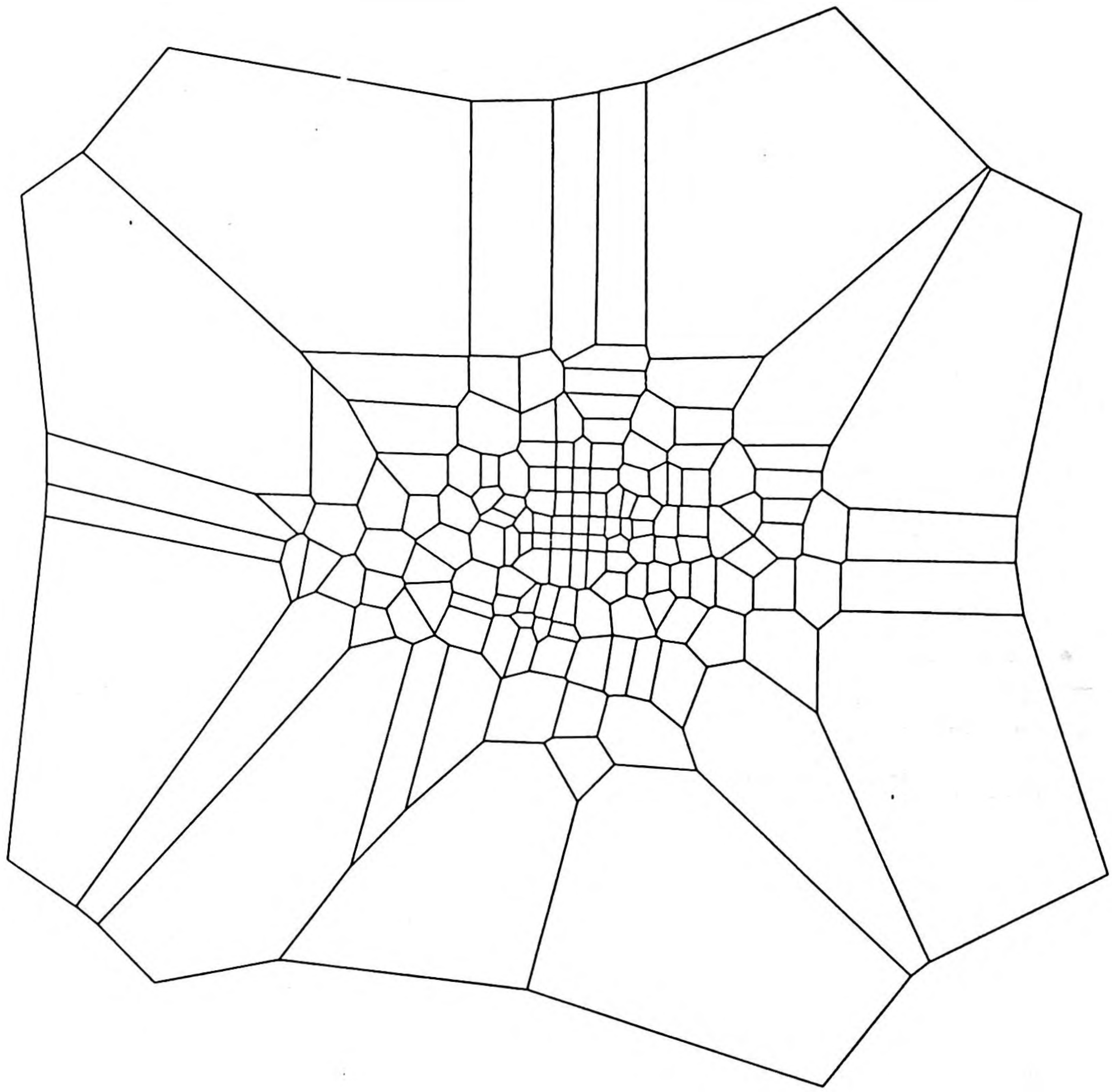

Figure 7. The Thiessen Polygon Net for the 150 Demand Points Shown in Figure 6

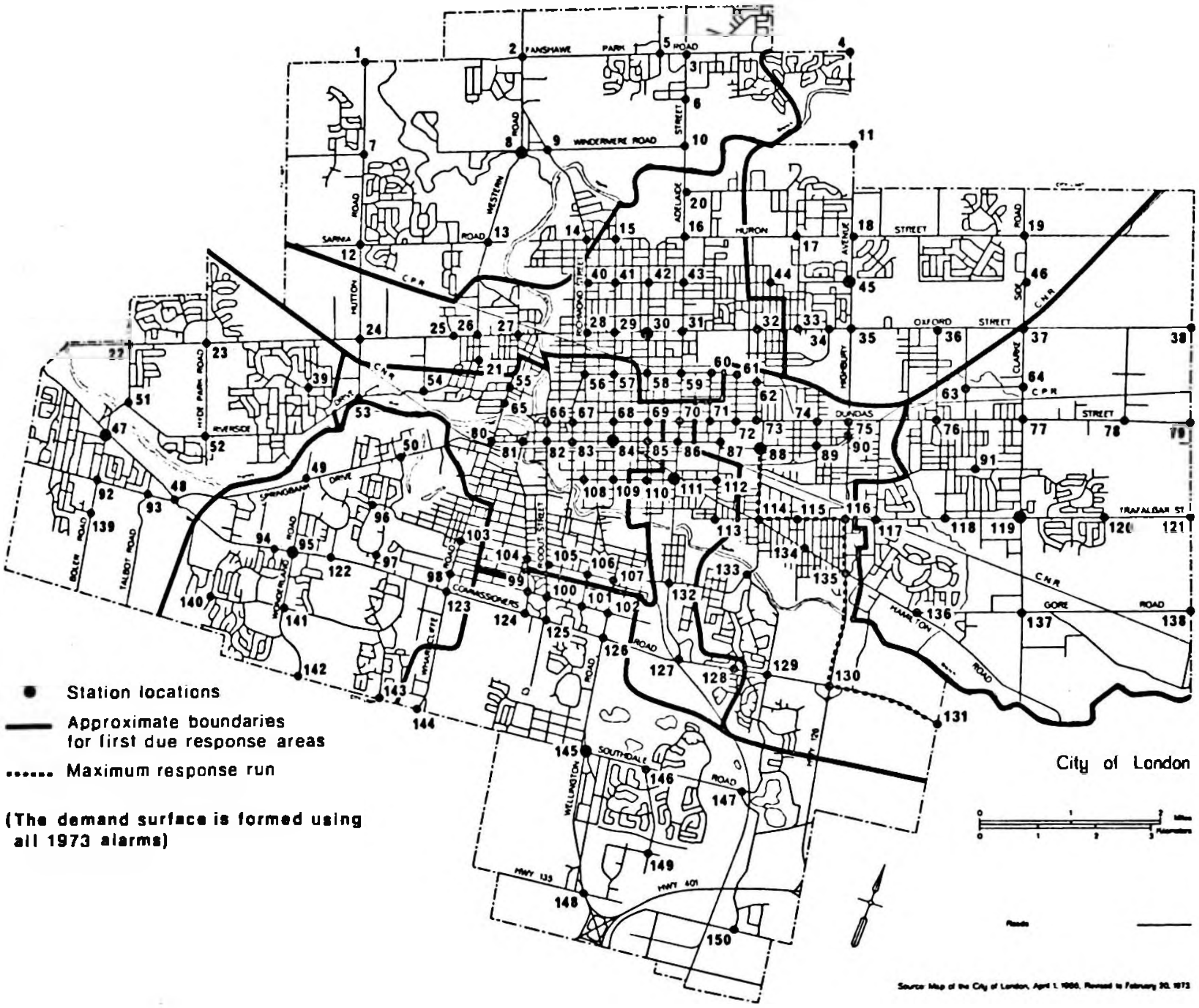

Figure 8. The Optimum Locations and Allocations for Ten Fire Stations - Nine of which are Constrained to their 1976 Locations

record their data in machine readable form. If the data is in point form the coordinates of each point must be recorded along with the appropriate information. If the data pertains to linear features then the coordinates describing each line must be recorded and, lastly, if the information relates to polygons then the coordinates of the polygon boundaries must be provided. Cities such as Calgary with their proposed Geographical Referencing System are beginning to recognise the critical need for machine readable locational information but there is still a long way to go before the urban and regional planners will be able to use systems such as PLUS to their full advantage and before they can appreciate just how much they and all planners need such systems.

Furthermore, if geographical systems are to be developed by various administrative units and jurisdictions systems such as PLUSX can be used to transfer information from one group to another and will thus decrease the need for the costly duplication of data collection. Thus when one group initially collects the data using geographical boundaries of their own choosing a second group can employ the PLUS system to translate the data to spatial units of their choice. In addition, they will also be able to use the system to provide preliminary display and analysis capabilities. Thus with the help of PLUS a variety of groups interested in social and economic planning at various levels of government will not only be able to share their resources for data collection but they will also be able to share and reduce their costs.

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