

## Reconfiguring Police Reporting Districts in the City of Buffalo

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### **Abstract:**

This paper describes a study that was undertaken to reconfigure the police reporting districts used by the Buffalo Police Department in the city of Buffalo, New York. We begin by relating the current configuration of these districts and the resulting problems which necessitated reconfiguration and in turn, motivated this study. This is followed by a description of the solution methodologies that were proposed. The first approach proposed was an optimization based one that attempted to model this as a multi-objective *Set Partitioning* problem. After a preliminary study, the approach was abandoned because of unsatisfactory performance. A second, more practical approach was considered. This one relied on using *Census Block Groups* as defined by Bureau of Census of the US Department of Commerce. With some minor adjustments, the second solution approach successfully addressed the unique needs of this reconfiguration problem of the Buffalo Police Department. Therefore, a reconfiguration plan based on the second methodology was used in proposing the reconfiguration of these police reporting districts.

**Figure 1: Current R-district  
and Sector Configuration in the City of Buffalo** (January 1998)



### **Article:**

#### ***Introduction: Background and Motivation***

This paper describes a study that was undertaken on behalf of the police department of the city of Buffalo, New York – the Buffalo Police Department (BPD). In its operations, BPD divides the city of Buffalo into five police districts, named A, B, C, D, and E. Patrol operations among these districts are assumed to be independent of

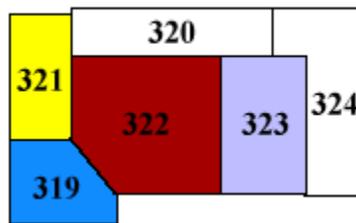
each other. Therefore, a patrol car that is assigned to a particular district is not allowed to respond a call from another districts. Furthermore, each district is divided into four police sectors; these districts and the sectors are shown in Figure 1.

The patrol operations among the sectors of the same district are not independent; in other words, the patrol cars may pass through the borders of sectors in the same districts. Since there are five districts and each district has four sectors, there are twenty sectors in the present configuration in the city of Buffalo. BPD further divided each sector into 400 smaller subdivisions, that are referred to as Reporting Districts (R-Districts). These R-Districts are considered the atomic reporting units in the city of Buffalo. The boundaries of these R-Districts are delineated by visible features such as streets, roads, waterways, railroad tracks etc. In order to track the crime activity in a R-district, BPD uses a choropleth mapping to report call volumes; in other words, the R-Districts are coloured according to their call volumes. For example, if the annual call volume of a particular R-District is between 30 and 360 inclusively, that R-District is coloured white. The colour-coding scheme used by BPD and a sample of colour-coded R-districts is shown in Figures 2 and 3 respectively.

**Figure 2: Colour coding**

	<b>Colours</b>	<b>Call Volume</b>
Brown		1330 - 6430
Blue		930 - 1330
Green		700 - 930
Purple		510 - 700
Yellow		360 - 510
White		30 - 360

**Figure 3: Colour coded representation of R-Districts.**



However, the present configuration of R-Districts had several problems, which were significant enough that the BPD wished to redefine the entire set. Perhaps the largest of these difficulties faced by BPD was that the present configuration of these R-Districts led to wide disparities in the reported crime statistics for the different R-Districts. A cursory examination would reveal that this non-uniformity was directly related to the fact that that the R-Districts were of various geographical sizes, which led to large differences in call volumes among neighboring R-Districts. A case in point is the one shown in Figure 3; it is readily seen from there that the R-District 322 is twice as big in area compared to the surrounding R-Districts and also has a proportionately larger call volume. This non-homogeneity of R-Districts leads to problems in maintaining uniformity in terms of workload assigned to police officers responsible for each of the R-Districts, and therefore forced BPD to examine the issue of reconfiguring these R-Districts.

The second major objection that BPD had to the present definition of R-Districts is that they were not originally delineated on the basis of any standard theoretical or practical criteria, other than using some visible feature of the city. As a result, the only statistical output that could be obtained from the present configuration of current R-Districts was call volumes. Due to this, they were not suitable for use by other city/municipal agencies. BPD was interested in changing this – they wanted these R-Districts to be defined in such a manner that demographic

information such as population, ethnic breakup, income levels etc, would be available easily and other agencies could also use them. Unfortunately, due to regulatory concerns, this reconfiguration had to be done without changing the current boundaries of five police districts. This led them to contact the authors as a part of a research team to investigate the issue of changing the current configuration and redefining the R-Districts so as to address their concerns.

## **Methodology**

In this section, we will describe the two different approaches that were taken in solving the redistricting problem faced by BPD. The first one was theoretical formulation and did not yield promising results; as a result it was abandoned after initial analysis. A second, more practical approach was taken and provided good solutions. Hence it was this second approach was taken in redefining the R-Districts.

### **Theoretical approach (set partitioning)**

An examination of the redistricting problem faced by BPD immediately reveals the following features/requirements:

- (i)** the new R-Districts would have to as homogenous as possible in terms of population, area (square miles), and call volume.
- (ii)** Each R-District would have to be compact and contiguous.
- (iii)** BPD expected the new configuration to yield other demographic data easily and be suitable for use by other agencies.
- (iv)** Finally the new configuration would have to obey the existing boundaries of the five police districts in the city of Buffalo.

The above properties immediately reveal that the redistricting problem faced by BPD is a complex variant of the well-known set partitioning problem (Nemhauser and Wolsey 1988). One of the earliest such districting problem was studied by Hess et al (1965), where they modelled it along the lines of a location-allocation problem. Due to the inherent complexity of this problem, optimal solutions are difficult to obtain; hence, they proposed heuristics for it. Their work was followed by Fleischmann and Paraschis (1988), who used a modification of their method. Thoreson and Littschwager (1967) also used another heuristic approach for the problem. In contrast, Garfinkel and Nemhauser (1970) used an exact solution methods based on integer programming.

Recent work on these problems includes the one by Hojati (1996) which is based on the earlier works of Hess et al (1965) and Fleischmann-Paraschis (1988) and Mehrotra et al (1997), which adopted the integer programming approach of Garfinkel and Nemhauser (1970). However, two points need to be noted here regarding the previous work done on districting problems. First, all the models mentioned above have contiguity, compactness, and population constraints and only seek to optimise one measure of disparity. Second, the number of districts needed is known at the beginning of the problem. Finally, the solution methodologies developed in these papers have been applied on the problems having a small number of atomic population units. For example, Hojati (1996) used 42 atomic units, Mehrotra et al used 46 atomic population units, Hess et al used about 100 atomic population units.

By contrast, the problem of redistricting problem faced by BPD had some major differences from the models discussed above. Like the other problems discussed before, our problem also has contiguity and compactness requirements. However, unlike these models, where the objective is to minimise non-uniformity between the resulting districts only in terms of populations, our objective was to minimise non-uniformity with respect to several criteria such as, area, call volumes for each priority class, and some non-quantitative measures related to the demographics of the population (income levels, ethnic backgrounds, education levels etc). When viewed

this way, it is easily seen that the resulting formulation is that of a multi-objective set partition problem and this fact was a major reason for the failure of the mathematical approach. Our initial tests demonstrated that even with state-of-the-art hardware, the problem was too large to solve even for a single measure of disparity. In the current configuration of Buffalo, there were about 400 R-Districts, which were made of smaller atomic population units. Therefore regardless of what we chose as the atomic unit in the mathematical formulations, their number would be at least about 400, which was four times as large as the largest data set reported in the literature. And this for only one measure of disparity, ie one objective, where we had several.

In addition, there were other factors that led us to abandon the mathematical approach. These arose primarily from the fact that BPD had several non-quantitative requirements that the new configuration was supposed to satisfy. First, BPD wanted the R-Districts to be as small as was practical to implement. Second, BPD wanted them defined in such a manner that even other agencies could use them. Finally, there was the issue of time: BPD needed a solution that would be easy and quick to implement. All factors considered, after initial experimentation, we found that the mathematical approach, based on adapting the methods available in the literature, failed to yield solutions that were acceptable to BPD. Therefore, a different approach to the problem was found to be necessary.

**Practical approach (census block groups)**

Due to the failure of the mathematical approach in yielding suitable solutions, a more practical solution method was investigated. After some investigation, it became apparent that the use of census bureau’s definitions would be a good candidate for the re-Districting problem faced by BPD. To that end, two potential solutions were to use census tracts or census block groups (Economic and Statistics Administration Bureau of the Census, 1994). However, in order to understand the definitions of these terms, it is important to understand the hierarchy of the definitions used by the census bureau; as per these definitions, geographic entities could functionally be grouped into two classes, Legal-Administrative Entities and Statistical Entities as shown in Figure 4. Legal and Administrative entities generally originated from legal actions, treaties, and the like. On the other hand, Statistical Entities evolved from practice, custom, usage, or needs. The hierarchy among these geographical entities is shown in Figure 5.



Figure 4: Census geographic entity classification

<u>Geographic Entity</u>	<u>Type</u>	<u>Number</u>
Nation	Legal	1
Regions	Statistical	4
Divisions	Statistical	9
States and Equivalent Entities	Legal	57
Counties and Equivalent Entities	Legal	3 248
Census Tracts and BNAs	Statistical	50 690
Block Groups	Statistical	229 192
Census Blocks	Statistical	7 017 427

**Figure 5: Census geographical entity hierarchy**

The statistical subdivisions of counties are to provide meaningful count and sample statistics. Among those statistical entities, Census Tracts and Census Block Groups are generally utilised by Department of Agriculture, Department of Defence, Department of Education, and Department of Justice. These statistical entities are delineated using homogeneity and compactness principles. The homogeneity principle mainly involves combining a group of people, housing units, or business establishments with similar characteristics into a single geographic area. Therefore, each geographic has, insofar as feasible, a similar population, economy, land use, and/or physical environment throughout its extent. The compactness of shape is also a desirable quality in a statistical entity; thus, it usually makes sense for their peripheries to be approximately equidistant from the centres. The irregularities or non-compactness (such as snakelike shapes) of shapes are accepted as statistical entities only if they reflect geographical peculiarities related to the population, housing units, or establishments that the area contains.

It was readily apparent that the use of census bureau geographical entity definition would satisfy the most of the constraints in our problem automatically. First, the requirements of compactness and contiguity were automatically satisfied. Second, by using the geographic entity definitions of census bureau, the demographic data requirement and related non-mathematical constraints would be satisfied immediately since those data were already collected and tabulated by the census bureau. Thus it was decided to investigate this solution possibility further. The first consideration was to use Census Tract. A Census Tract is officially defined as follows: (Economic and Statistics Administration Bureau of the Census, 1993 and 1994).

*A statistical subdivision of selected counties -- established by a local committee of data users -- that is a relatively stable basis for tabulating decennial census data.*

Census Tracts are much larger geographic entities compared to Census Block Groups and are permanent areas, intended for statistical purposes. They are bounded by visible, physical features, natural or manmade. Tracts need at least 1,500 residents, but not more than 8,000, with 4000 residents being considered an ideal value. This range of people typically involves from 600 to 3,000 housing units. The boundaries of Census Tracts always follow the boundaries of states and counties. However, after some study, it was concluded that the usage of Census Tracts as R-Districts would give undesirable solutions, much like the mathematical formulation. The primary reason for this was that the Census Tracts were not small enough and therefore the number of Census Tracts were not large enough to satisfy BPD's need. In other words, the numbers of Census Tracts present in the city of Buffalo were less than the current number of R-Districts and as said before, BPD wanted the R-Districts to be smaller than they were in their present configuration.

As a next step, it was decided to use a smaller census geographical entity, either the Census Block Groups or the Census Blocks. A Census Block Group (BG) is officially defined as follows: (Economic and Statistics Administration Bureau of the Census, 1993 and 1994).

*A grouping of census blocks having the same first digit in their identifying number within a census tract where census blocks are the smallest Census Bureau geographic entity; it generally is an area bounded by streets, streams, and the boundaries of legal and statistical entities. In other words, each Block Group consists of a cluster of contiguous census blocks by the same first digit of their three-digit block number.*

As mentioned above, Block Groups are components of Census Tracts. They need 600 to 3,000 residents, in 240 to 1,200 housing units. Ideal population in a Block Group is considered to be 1,500. The maximum number of Block Groups allowed in a Census Tract is 9. In addition, Block Groups are considered data tabulation and publication units. The published data for each Block Group are age, gender, origin, number of rooms in housing unit, tenure, education, labour force status, income, source of water etc.

Each Block Group is further divided in at most 97 Census Blocks. The minimum size of a Census Block is 30,000 square feet (0.69 acre) for polygons bounded entirely by roads and to ensure compactness, the polygon shapes are measured to eliminate extremely narrow slivers as potential census blocks. At least one side of a

potential Census Block has to be a road feature and finally, a census block is always unique to, and can never cross the boundaries of a census tract. However, demographic data are not kept at the level of Census Blocks; this immediately disqualified them as candidates for defining the new R-Districts.

Thus overall, it was found that using Census Block Groups as the basis for defining new R-Districts had several advantages over other solutions. The Census Block Groups were small enough for BPD’s need, resourceful enough for the BPD’s demographic data requirements, compact, contiguous, equally populated, and useful for the use of any agencies and any purposes. However, recall that the primary motivation for the re-districting was to improve the uniformity of call volumes among the new R-Districts. To present the impact of using census block groups, consider a typical example as shown in Figure 6 – it depicts a small part of the current R-Districts from the second sector D. The total call volumes for these R-Districts were shown in Table1.

**Figure 6: Some of the current R-Districts from Sector D2**



**Table1: Call volumes for R-Districts shown in Figure 6**

<u>R-District Number</u>	<u>Total Call Volume</u>
13016	1122
13017	498
13020	756
13021	682
17018	1705
17020	802
17021	859
17022	628
17023	312
17024	389
17028	945
17029	478
17030	235

As is readily verified from the Figure, all of the six colours in the choropleth were used in this portion of the Sector D2 (with only 13 R-Districts) and several adjacent R-Districts have very different colours (ie call volume distributions).

Shown in Figure 7 is the new configuration of the same portion sector D2 as in figure 6 above, where the census block groups have been used as the new R-Districts. As is verified from the two Figures 6 and 7, under this reconfiguration, the number of R-Districts increases from 13 to 21 in the same portion of Sector D2. We also achieved more homogeneous colour distribution; ie more homogeneous call volume distribution. The approximate call volume distributions are listed in Table 2 (these call volumes were determined approximately

by using the area size of new R-Districts). A quick calculation of the numbers in Tables 1 and 2 will reveal that with the new configuration of R-Districts, the variance of call volumes reduced by 63.19%. Furthermore, since the new R-Districts were Census Block Groups, the new R-Districts were contiguous, compact, had homogeneous population distribution, and the demographic data were already tabulated by the Census Bureau for use by BPD and other municipal agencies.

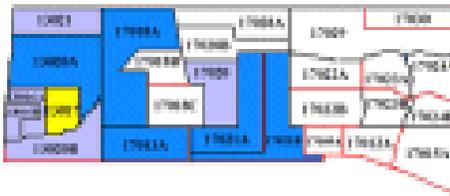


Figure 7: New configuration of R-Districts, which are census block groups

**Table 2: Call volume distribution for new R-Districts**

R-District Number	Call Volume
13016A	561
13016B	561
13017	498
13020A	680
13021	682
17018A	852
17018B	426
17018C	426
17020	702
17021A	900
17021B	900
17022A	314
17022B	314
17023A	156
17023B	156
17024A	195
17024B	195
17028A	470
17028B	470
17029	450
17030	237

### **Implementation: results and problems**

In actual implementation, it was found that using Census Block Groups as R-districts, the city of Buffalo would be divided into approximately 410 new R-Districts. As per the requirements of the BPD, these new R-Districts are contiguous, compact and homogeneous in terms of population and area, primarily because these were the exact conditions that the census bureau used when forming the Census Block Groups. Further, their usage also satisfied the unique need of BPD that demographic statistics be easily available for the new R-Districts in a format that is retrievable and useable by other municipal agencies. Finally, the boundaries of the Census Block Groups were drawn by using visible features such as streets, roads, highways, water feature – hence their implementation on the field by the patrolling police cars would not be a problem. Thus, in summary, it can be said that this solution satisfied most of the requirements of BPD. As a result, we recommend their use as the

basis for defining the new R-Districts in the city of Buffalo. The resulting new configuration of the R-Districts for the entire city of Buffalo, obtained by using the Census Block Groups is shown in Figure 8.



Figure 8: New R-Districts (Census Block Groups) of the City of Buffalo

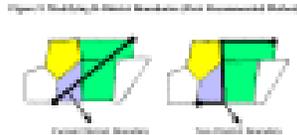


Figure 9: Modifying R-District Boundaries (First Recommended Method)

However, despite the advantages, this new configuration of R-Districts was not without its problems. The most major one of these was that in some districts, the new configuration would require the redrawing of sector and district boundaries. Although changes in the boundaries of sectors did not concern BPD, changing the boundaries of the five predefined districts (A, B, C, D and E) was considered highly undesirable, as that would require permission from higher authorities.

After evaluation of the new configuration in Figure 8, it was determined that there were twenty-two Census Block Groups that conflicted with the current district boundaries. Two methods were proposed to resolve this issue.

The first method was to change the district boundaries according to boundaries of Census Block Groups as shown in Figure 9. The second method was to keep the current district boundaries unchanged and divide the Census Block Groups that were violating the current district boundaries into smaller pieces in such a way that the district boundaries were kept unchanged, as demonstrated in Figure 10. In that figure, there are three R-Districts (block groups) violating the current district boundary; these are numbered as 1, 2 and 3. Since the principal idea of this approach is to keep district boundaries unchanged, those three R-Districts were split by using the current district boundary as shown in the figure. Thus a total of six new R-Districts, 1A, 1B, 2A, 2B, 3A and 3B, would be created using the second method.

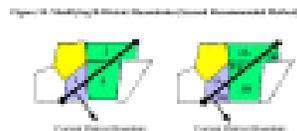


Figure 10: Modifying R-District Boundaries (Second Recommended Method)

The disadvantage of this method was that it would require some extra effort to determine the demographic information such as population, income level etc, since these demographic statistics are available only at the Census Block Group level. In other words, there was a trade-off between keeping district boundaries unchanged and changed and the two solutions that we presented clearly highlighted that. Since the choice of solution method required the decision of authorities higher than BPD, we presented both to them, leaving them to make a choice.

## Conclusion

This paper discusses a study undertaken by the authors to study the problem of reconfiguration of the Reporting Districts used by the police department of the city of Buffalo, New York. Due to the changing demographic needs of the city, BPD wanted these districts to be redefined in unique ways, that imposed several quantitative and non-quantitative constraints on the problem. Our first approach was to model it as a set partitioning problem, along the same lines as previous published works on redistricting problems. However, initial experimentation confirmed that the solutions obtained using this approach were impractical. Thus we adopted a more practical solution approach, focussing on using Census Bureau's geographical entity definitions. It was found that using the Census Block Groups, as defined by the bureau, to form the R-Districts, was the best solution, since it satisfied almost all of the requirements imposed by BPD. Hence, this was the solution that was proposed by us to BPD. However, their implementation did pose some difficulties and we suggested two different ways to address them, leaving BPD to make a choice.

## For the interested reader

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