AN ANALYTICAL HIERARCHY PROCESS (AHP) APPROACH TO DETERMINING PATROL BEAT LOCATIONS AROUND CAGAYAN DE ORO CITY, PHILIPPINES

Rhoda A. Namoco*, Jenefer B. Vallar and Aristeo L. Abecia

Department of Applied Mathematics, University of Science and Technology of Southern Philippines, Cagayan de Oro City, Philippines

*rhoda.namoco@ustp.edu.ph

ABSTRACT**:** *Police visibility is considered one of the major strategies for the deterrence of crime in the community. Police patrol can provide much more service when they are assigned in an optimal manner. Due to the limited number of police available, police decision-makers are faced with the difficulty of carefully allocating the available police while properly considering the locations they are assigned to. In this study, we explore the use of the analytic hierarchy process (AHP) in order to decide which locations in the city must the patrol police be assigned. Interviews were conducted among police administrators to determine the various factors that are considered in deciding on beat patrol locations. Results show that different criteria are included in the decision-making for day assignments and for night assignments. Moreover, the study was also able to identify the various weights associated with the different criteria. Results of the study can be used as inputs for solving the location-allocation problem for patrol police around the city.*

Keywords. Patrol police, analytical hierarchy process, decision making.

1 INTRODUCTION

Society is strongly affected by crime, both due to the cost of crime, as well as the decline in the quality of life that citizens suffer as a result of the crime. In the first six months of 2015, the number of crimes committed in the Philippines had increased by about 46 percent compared to the same period last 2014 [1]. Records showed that theft, car theft, physical injuries, and rape were among the crimes that had a huge increase. Crimes are clearly negative externality that requires a systematic approach to achieve a serious reduction.

Crime control is the main obligation of every police officer. They are generally charged with the apprehension of criminals and prevention and detection of crime, protection, and assistance to the general public, and the maintenance of public order. With several functions, it includes taking all necessary steps to ensure public safety. In the study of Sherman, et.al [2], it was mentioned that several policing activities to prevent crime and identified effective patrolling as one solution to how the police force can prevent crime.

Patrol is regarded as the "backbone" of policing since it compromises 60 to 80% of any police department. It is the most important and visible operation of a police department. Patrol is the unit that answers calls, delivers service, and prevents crime. The scheduling and shift work cause problems and /or stress for most police-decision officers. Thus, a systematic and effective police patrol location allocation is greatly needed. Due to the limited number of the police force with unlimited services and a set of demand location that needs them, the police decision maker has to properly apportion its allocation.

Zhang and Brown [3] discussed the characteristics of the police patrol district design problem from the perspective of past and current work. In their paper, they presented and evaluated patrol districting plans generated using a parameterized redistricting procedure using an agent-based simulation model. Results of their study were then used for the Charlottesville Police Department and the solution generated showed improvement on both average response time and variation of the workload through the complete simulation study. Simulation results further showed that patrol performance can be improved compared with the current districting solution.

In addition, Curtin, *et al.* [4] presented a new method for determining efficient spatial distributions of police patrol areas. The study employed a traditional maximal covering model formulation and an innovative backup covering formulation which provided alternative optimal solutions to policy decision-makers. Consequently, the study was able to develop a method for integrating geographic information systems (GIS) with linear programming optimization to generate and display alternative optimal solutions and to formulate an innovative backup coverage model that is appropriate for police patrol area design. The proposed method was then applied to the police geography of Dallas, Texas, and showed that optimal arrangement can substantially improve police efficiency. Canoy, et. al (5), on the other hand, introduced the concept of restrained domination which find applications in the positioning of guards in relation to prisoners.

Some allocation models on police patrol are typically formulated using integer linear programming models. Namco, et. al [6] solved the police assignment problem of the different police stations within the central business district in Cagayan de Oro City using integer programming. They determined the number of policemen to assign and where to position them during their shift to attain maximum protection and police visibility. The result of their study showed that the proposed police assignments of a police station in the central business district of Cagayan de Oro City are better than their current police assignment. However, their study only focused on using existing beat patrol areas as specified by the police officers. There is still an open possibility to attain an optimal solution by maximizing the selection of beat patrol and allocation of police patrol.

The analytic hierarchy process (AHP) is a method proposed by Saaty [7]. It considers a set of evaluation criteria and a set of alternative options among which the best decision arrives. It involves breaking down the problem into a standardized set of components and organizing them according to a hierarchy in order to incorporate significant quantities of information and present a more comprehensive portrait of the problem. The pairing of the elements at each level of the hierarchy is done by assigning a weight to each element as shown in Table 1.

Since the various elements are paired using subjective means, the AHP method uses a Consistency Index that enables to test of the consistency of judgments systematically.

The AHP finds applications in various fields of study, including manufacturing, transportation, healthcare, education, defense, and military, among others (8). In fact, Lusdoc and Namoco (9) used AHP to assist high school students in deciding which major to take in the special program in the art classes at a local high school in the Philippines.

The process of making patrol police location-allocation decisions has been a haphazard process of every police-decision maker. Unfortunately, police decision-makers have few resources to guide them in determining the number of officers they need and how would they allocate them. AHP provides an ideal ranking process for selection. LP, on the other hand, aids in decision-making by determining the optimal number of police officers to assign in specific areas considering various criteria.

This study focused on determining the best locations to assign patrol police in Cagayan de Oro City such that they are designated efficiently in different locations in the city using various criteria through the use of AHP. This paper is organized as follows. Section 1 presents background information on the present study. Materials and methods are discussed in Section 2 while results and discussion are presented in Section 3. A brief conclusion is given in Section 4.

2 MATERIAL AND METHODS

In this study, interviews were conducted among police officers and heads of the Cagayan de Oro City Police Office (COCPO) in order to determine the various criteria used in deciding which locations around the city are to be considered as best locations. After the criteria and possible beat locations have been determined, these are then assessed using the AHP. Based on the interview results, the top six criteria for the morning shift are the crime rate, the number of open surrounding establishments, the flow of traffic, area population, road length/accessibility, and the distance to the station. On the other hand, the top six criteria for night shift are the crime rate, number of open surrounding establishments, lighting condition, road length/accessibility, area population, and the distance to the station. It should be noticed that the criteria for the morning shifts slightly differ from the night shift since crime incidents and security requirements differ from time to time.

The computational aspects of AHP involve several steps as outlined by Saaty. The first step in AHP is to develop a graphical representation of the problem. The problem is subdivided into a multilevel hierarchy showing the overall goal of the decision process, each decision criterion used, and the decision alternatives as a candidate for location. The overall goal is to select the high-priority beat area location. Using the criteria determined during the interviews, the basic AHP procedure is then applied in order to develop the weights for the criteria.

In order to compute the weights for the different criteria, AHP has the police station heads specify their judgments about the relative importance of each criterion in terms of its contribution to the achievement of the overall goal and has started creating a *pairwise comparison matrix A*. The matrix A is an $m \times m$ real matrix where m is the number of evaluation criteria considered. Each entry a_{jk} of the matrix A represents the importance of the j^{th} criterion relative to the kth criterion. If $a_{jk} > 1$, then the j^{th} criterion is more important than the k^{th} criterion while if $a_{jk} < 1$, then the j^{th} criterion is less important than the k^{th} criterion. If two criteria have the same importance, then a_{jk} is 1. The relative importance of the two criteria is measured according to the numerical scale of 1 to 9, as shown in Table 1.

Once matrix A is built, the *normalized pairwise comparison matrix* A_{norm} is generated from matrix A by adding the values in each column of matrix A and then dividing each element in the matrix by its total, making the sum of the entries on each column equal to one. Finally, the *criteria weight vector* ***w*** *(*that is an *m*-dimensional column vector*)* is built by averaging the entries on each row of $the\ A_{norm}$. However, the pairwise comparison in a judgment matrix is considered to be adequately consistent if the corresponding consistency ratio (CR) is less than 0.1. The CR is calculated by computing first the consistency index (CI). This is done by adding columns in the judgment matrix and multiplying the resulting vector of priorities by the vector of priorities that yields an approximation of the maximum eigenvector denoted by λ. Then the CI value is calculated using the formula $CI = \frac{(\lambda - n)}{n-1}$. Next, the consistency ratio CR is obtained by dividing the CI value by the Random Consistency Index (RCI) as given in Table 2, where *n* is the number of criteria used. If the CR value is greater than 0.10, then it is advised to re-evaluate the pairwise comparison made in the problem.

Table 1. The analytic hierarchy process rating scales.

Intensity of Importance	Description	Explanation
1	Equally important	Two activities equally contribute to achieving the goal.
3	Moderately more important	Experience and judgment moderately favor one activity over the other.
5	Strongly more important	Experience and judgment strongly favor one activity over the other.
7	Extremely more important	The practice has shown that one activity is very highly favored over the other.
9	Absolutely important	One activity is definitely more probably than the other.
2, 4, 6, 8	Intermediate values	When a compromise is required.
½, 1/3, …, 1/9	Reciprocal values	If activity A has value *x*, when in comparison to activity B, activity B must be given (1/*x*).

3 RESULTS AND DISCUSSION

Tables 3 and 4 show the pairwise comparison matrices for the morning and evening shifts. These pairwise matrices were formulated based on the consolidated expert judgment of the police heads through the conducted survey.

While perfect consistency during the process is desired, achieving it is not always possible. However, an appropriate level of consistency is necessary to achieve meaningful results. Researchers used a consistency index and consistency ratio as means of checking the consistency of the elicited matrices. Essentially, a consistency ratio of 0.10 or less is considered acceptable as a guideline to use in evaluating matrix consistency. As can be seen in Table 3, a weight of each criterion has been developed with a consistency ratio of 0.08 for the night shift and 0.09 for the morning shift, which is both less than 0.10.

Table 2. RCI values for different values of n.

1	0.00	6	1.24
2	0.00	7	1.32
3	0.58	8	1.41
4	0.90	9	1.45
5	1.12	10	1.49

Table 3. Pairwise comparison matrix for the morning shift.

Criteria for Morning Shift	***Crime Rate***	***Distance to the Police Station***	***Traffic***	***Number of Open Establishments***	***Populati on***	***Road Length/ Accessibility***
Crime Rate	1.00	6.00	4.00	3.00	2.00	5.00
Distance to the Police Station	1/6	1.00	1/6	1/5	1/2	2.00
Traffic	1/4	6.00	1.00	1/2	1/2	4.00
Number of Open Establishments	1/3	5.00	2.00	1.00	3.00	4.00
Population	1/2	2.00	2.00	1/3	1.00	6.00
Road Length/Accessibility	1/5	1/2	1/4	1/4	1/6	1.00

Table 4. Pairwise comparison matrix for night shift.

Criteria for Night Shift	***Crime Rate***	***Distance to the Police Station***	***Number of Open Establishments***	***Population***	***Road Length/ Accessibility***	***Well-lit Areas***
Crime Rate	1.00	4.00	2.00	4.00	5.00	2.00
Distance to the Police Station	1/4	1.00	1/4	1/4	3.00	1/3
Number of Open Establishments	1/2	4.00	1.00	2.00	3.00	1/2
Population	1/4	4.00	1/2	1.00	3.00	1/2
Road Length/Accessibility	1/5	1/3	1/3	1/3	1.00	1/2
Well-lit Areas	1/2	3.00	2.00	2.00	2.00	1.00

Table 5. Resulting in weights for each criterion.

Criteria for Night Shift	Weights	**Criteria for Morning Shift**	Weights
Crime Rate	0.3449	*Crime Rate*	0.3666
Distance to the Police Station	0.0777	*Distance to the Police Station*	0.0555
Number of Open Establishments	0.1805	*Traffic Flow*	0.1412
Population	0.1340	*Number of Open Establishments*	0.2303
Road Length/Accessibility	0.0577	*Population*	0.1649
Well-lit Areas	0.2051	*Road Length/Accessibility*	0.0414

Consistency ratio = 0.08 **Consistency ratio = 0.09**

CONCLUSIONS

In this study, we have demonstrated how AHP can be used to provide a more systematic way of evaluating beat locations to which police patrol are assigned. Results show that in both shifts, the crime rate is a major consideration for deciding whether a specific location would require the assignment of a police patrol.

REFERENCES

1. Felipe, C.S. (2015), "*Philippine Crime Rate up by 46%*." The Philippine Star.
2. Sherman, L.W., Gottfredson, D.C., MacKenzie, D.L., Eck, J., Reuter, P and Bushway, S.D. (1998) "*Preventing Crime: What Works, What Doesn't, What's*

Promising.", Washington, DC: National Institute of Justice, 20 pp. Retrieved from: http://www.ncjrs.gov/pdffiles/171676.pdf

3. Zhang Y., Brown. (2013) "*Police Patrol Districting Method and Simulation Evaluation using Agent-Based Model & GIS*.". Security Informatics 2013 2 (7).

4. Curtin K.M., McCall, K.H., Quiq F., (2007). "*Determining Optimal Police Patrol Areas with Maximal Covering and Backup Covering Location Models*" Network Spat Econ.

5. Canoy, S. R., Tuan, N. and Namoco, R.A., (2014). "*Restrained independent dominating sets and some realization problems*", International Journal of Mathematical Analysis 8 (42). Pp. 2083-2092.

Namoco, R.A., Lago, E.M., Pailagao, R.O., Vallar, J. B. (2017)," *An Integer Programming Approach for Police Allocation in an Urban City in the Philippines*". Indian Journal of Science and Technology 10 (40).

6. Saaty, T.L.(1980), "*The Analytic Hierarchy Process*." McGraw-Hill, New York.

7. Sipahi, S. and Timor, M. (2010), "*The analytic hierarchy process and analytic network process an overview of applications*." Management Decision 48 (5). 775 – 808.

8. Lusdoc, C.S. and Namoco, R.A. (2019), "*Selecting an SPA (special program in the arts) major for high school students using AHP combined with interest inventory*", International Journal of Innovative Research in Education 6 (1).