A Patrol Police Location-Allocation Model Using Combined Analytic Hierarchy Process and Goal Programming

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Abstract

Patrol is the unit of every police department that answers calls, delivers service, prevents crime, and is considered the core of policing. Police patrol can provide much more service when assigned optimally. Due to the limited number of police but unlimited service requirements, police decision-makers have to properly apportion its allocation while also properly considering the designated locations. The patrol police location-allocation problem aims to determine the assignment of patrol police to strategic locations in an optimal manner. This problem usually involves many factors that may be conflicting in nature.

This study introduces the analytic hierarchy process (AHP) and goal programming methodology to solve the patrol police location-allocation problem for Cagayan de Oro City. Results of the study show that the proposed model provides better police visibility and maximum protection compared to the current patrol police assignment around the city.

Keywords*: AHP, Goal Programming, Patrol Police, Location-Allocation, Philippines*

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1.0 Introduction

Crime is defined as an action that constitutes an offense that may be prosecuted by the state and is punishable by law. People are greatly affected by crime, both due to the cost of crime and the decline in the quality of life that citizens suffer as a result of crime. According to World Bank, the Philippine crime rate & statistics for 2016 was 10.98, which increased by 16.2% from 2015. While in the first six months of 2015, the number of crimes committed in the Philippines had increased by about 46% compared to the same period last 2014 (Felipe, 2015). Crime is evidently a negative externality that requires a systematic approach to reduce its occurrences and abridge its increasing percentage.

Crime prevention consists of strategies and measures that aim to reduce both the risk of crimes occurring and their harmful effect on society. Crime prevention is the primary obligation of every police officer. A police officer, also known as a policeman, is a represented body of persons empowered by every state. They are primarily responsible for apprehending offenders, preventing and detecting crime, providing protection and assistance to the general public, and maintaining public order. With several functions, it takes all necessary precautions to maintain public safety. In a study, Sherman (1998) mentioned several policing activities to prevent crime and identified effective patrolling as one solution for how the police force can prevent crime.

Patrol operation forms the backbone of policing. Thus, it is considered the most essential and visible operation of a police department. Meanwhile, beat patrol is the deployment of officers in a given community to prevent and deter criminal activity that provides day-to-day services to the community. Patrol work, by contrast, is inherently dangerous. The scheduling and shift work of every police patrol as well as the assigning of beat areas both cause problems for most police-decision officers. Thus, a systematic and effective police patrol location-allocation system is critical. However, because of the limited number of police officers with unlimited services and a set of demand locations that require them, the police decision-maker has to assign allocation appropriately.

Goal programming (GP), an optimization program, is a branch of multi-objective optimization that is, in turn, a branch of multi-criteria decision analysis (MCDA). It can be considered an extension or generalization of linear programming to handle multiple, usually conflicting objective measures. It provides the best satisfying solution under various resources and priorities of the goals. The formulation of goal programming is similar to that of linear programming problems. The major differences are an explicit consideration of goals and the various priorities associated with different objectives.

The analytic hierarchy process (AHP), first introduced by Saaty (1980), on the other hand, enables the decision-maker to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of qualitative and quantitative factors systematically under conflicting and multiple criteria.

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 they would allocate them. AHP provides an ideal ranking process for selection. GP, on the other hand, aids in decision-making by considering relevant constraints that exist in many decision settings.

Using combined Analytical Hierarchy Process (AHP) and Goal Programming (GP), this study allocates patrol police in Cagayan de Oro City to be designated efficiently in different locations in the city. Specifically, this study determines the police patrol general characteristics, police provision and how they currently allocate their men to maximize safety and police visibility, evaluates possible beat patrols using AHP, and develops a GP model for the patrol police location-alloc;ation problem.

2.0 Methodology

This paper used two methodologies for solving the location-allocation problem for patrol police. AHP was first implored to evaluate each beat location, thereby determining the top five criteria for classifying the beat areas. After identifying beat locations, a GP model is formulated using inputs from the results of the AHP.

The study used data gathered from 4 Police Stations under the Central Business District (CBD) of Cagayan de Oro City, namely, Police Station 1 (Divisoria), Police Staton 2 (Cogon), Police Station 3 (Agora), and Police Station 9 (Macasandig). Gathered data include the general characteristics of a patrol police's provisions, responsibilities, nature of duty and line of service, the process of how police heads allocate patrol officers and their corresponding workload, availability of each police patrol, beat patrol area, and identified area of responsibility. A site visit was also conducted to determine additional information regarding each beat area.

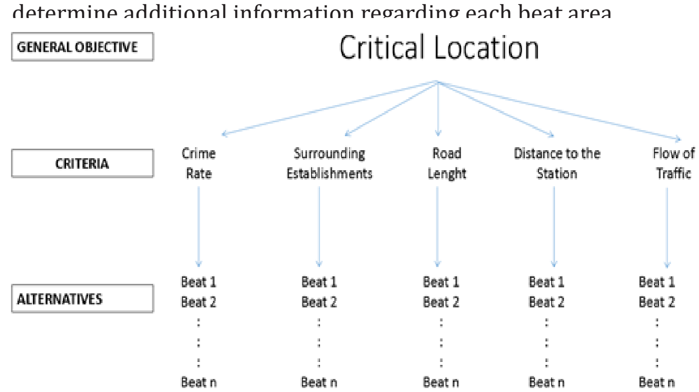

Figure 1. Problem Hierarchy for Morning Shift

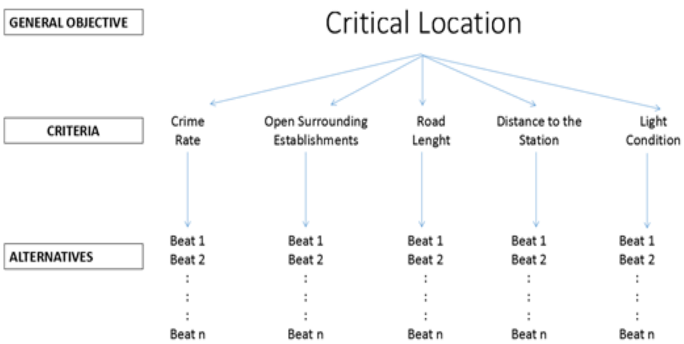

Figure 2. Problem Hierarchy for Night Shift

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 (See Figure 1&2). 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.

The main criteria in evaluating beat patrol were determined by conducting an interview and survey through questionnaires of the station commanders or head of the operations in the said police stations under the Central Business District (CBD) of Cagayan de Oro City. The top five criteria for morning shift were identified as the crime rate, the surrounding establishments, flow of traffic, road length, and the distance to the station. On the other hand, the top five criteria for night shift were identified as the crime rate, open surrounding establishment, lighting condition, road length, and the distance to the station. Then, each beat area location was served as decision alternatives and was considered as the lowest level of the hierarchy problem. Criteria for morning and night shifts are different due to differences in crime incidents and security from time to time.

After the criteria are determined, the basic AHP procedure is applied, as follows.

Step 1. *Develop the weights for criteria.*

To compute the weights for the different criteria, the police station heads were requested to specify their judgments about the relative importance of each criterion in terms of its contribution to the achievement of the overall goal and have 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 matrix A represents the importance of the j^{th} criterion relative to the k^{th} 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 between the two criteria is measured according to a numerical scale of 1 to 9, as shown in Table 1.

Table 1. Scale of Relative Importance

Value of	Definition
1	*j* and *k* are equally important
3	*j* is slightly more important than *k*
5	*j* is more important than *k*
7	*j* is strongly more important then *k*
9	*j* is absolutely more important then *k*
2,4,6,8	Intermediate values between the two adjacent judgments
Reciprocals of above nonzero	If activity *j* has one of the above nonzero numbers assigned to it when compared with activity *k*, then j has the reciprocal value when compared to k.

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 1. Finally, the *criteria weight vector* ***w*** *(*that is an *m*-dimensional column vector*)* is built by averaging the entries on each row of A_{norm}.

However, the pairwise comparison in a judgment matrix are considered to be adequately consistent if the corresponding consistency ratio (CR) is less than 10%. The CR is calculated by computing first the consistency index (CI). This is done by adding the columns in the judgment matrix and multiply the resulting vector of priorities vector by the vector 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 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

Step 2. *Develop the rating/scores for each decision alternative for each criterion.*

The beat areas, serving as location decision alternative, is compared against each other decision alternatives with respect to one particular decision criterion at a time. An evaluation scale (as shown in Tables 3 and 4) translates the decision maker's evaluation into numbers.

Table 3. Evaluation scale for morning shift

Critical Value	Crime Rate	Surrounding Establishment	Flow of Traffic	Road Length	Distance to the Station
1	Very Low	Very Few	Smooth	Very Short	Very Near
2	Low	Few	Normal	Short	Near
3	Average	Average	Slightly Busy	Medium	Average
4	High	Several	Busy	Long	Far
5	Very High	Numerous	Very Busy	Very Long	Very Far

Table 4. Evaluation scale for night shift

Critical Value	Crime Rate	Open Surrounding Establishment	Lighting Condition	Road Length	Distance to the Station
1	Very Low	Very Few	Smooth	Very Short	Very Near
2	Low	Few	Normal	Short	Near
3	Average	Average	Slightly Busy	Medium	Average
4	High	Several	Busy	Long	Far
5	Very High	Numerous	Very Busy	Very Long	Very Far

Once the weight vector and the score matrix is computed, AHP obtains a vector of global scores by multiplying the weight vector and score matrix. Implementing these steps results in a preference vector weighting where the greater weight of the beat location implies more unsafe and prone to crimes, and hence requires more patrol police in the said beat area. The weights are then used to determine the allocation of police in the beat areas considered based on the predetermined criteria.

By considering the classification of beat areas obtained through AHP, this study formulates a GP model that satisfies police station goals in utilizing the available number of police as well as deploying them in a beat area where their services are highly needed without compromising the other beat area under their respective area of responsibility (AOR). Below presents the definition of the GP model's variables, constants, and objectives function are presented.

Let

$$x_{ij} = \begin{cases} 1, \text{ if the ith policeman is assigned to the jth beat} \\ 0, \text{ if the ith policeman is not assigned to the jth beat} \end{cases}$$

d_i^{p-} = *negative deviation from the ith policeman* (assigning less assignment to a policeman than desired)

d_i^{p+} = *positive deviation from the ith policeman* (assigning more assignment to a policeman than desired)

d_j^{b-} = *negative deviation the jth beat* (assigning less policeman to a beat than desired)

d_j^{b+} = *positive deviation from the jth beat* (assigning more policeman to a beat than desired)

Where:

n = total number of beats to assign
m = total number of policemen to assign
p_i *= required number of the assignments of a policeman*
b_j *= required number of policeman for each beat*

The constraints can be grouped into two categories. Equation (1) represents a set of goals needed to be satisfied to ensure that the department allocates all the policemen in a beat area while Equation (2) represents the assignment of the beat to the policeman, constrained by the respective b_j.

$$\sum_{j=1}^{n} x_{ij} + d_i^{p-} - d_i^{p+} = p_i \qquad (for\ i = 1,2,\ldots,m) \qquad (1)$$

$$\sum_{i=1}^{m} x_{ij} + d_j^{p-} - d_j^{p+} = b_j \qquad (for\ i = 1,2,\ldots,n) \qquad (2)$$

The objective function in equation (3) below has 2 priorities:

$$Z = P_1 \sum_{i=1}^{m} x_{ij} (d_i^- - d_i^+) + P_2 \sum_{j=1}^{m} x_j (d_j^- - d_j^+) \qquad (3)$$

The first priority, P_1, is designed so that each policeman assigned to a specific beat is satisfied and the second priority, P_2, is represented by the set of beat requirement assignment goal. Hence, the complete GP model used in this study is the following:

Minimize $Z = P_1 \sum_{i=1}^{m} x_{ij} (d_i^- - d_i^+) + P_2 \sum_{j=1}^{m} x_j (d_j^- - d_j^+)$

subject to

$$\sum_{j=1}^{n} x_{ij} + d_i^{p-} - d_i^{p+} = p_i \qquad (for\ i = 1,2,\ldots,m)$$

$$\sum_{i=1}^{m} x_{ij} + d_j^{p-} - d_j^{p+} = b_j \qquad (for\ i = 1,2,\ldots,n)$$

$$x_{ij} \geq 0 d_i^{p+} \geq 0, d_i^{p-} \geq 0 d_j^{p+} \geq 0, d_j^{p-} \geq 0$$

The above GP model is then solved using Excel® solver.

3.0 Results and Discussion

In this section, the presentation of results is dividedinto in two parts, namely, results for AHP and results for solving the GP model.

3.1 Results for AHP

Tables 5 and 6, each criterion listed on the left is compared with each criterion listed on top, depicting as to which is more important with respect to the goal of selecting the most critical beat area. This pairwise matrices were formulated based on the consolidated expert judgment of the police heads.

Table 5. Pairwise matrix for morning shift

Criteria for Morning SHIFT	Crime Rate	Surrounding Establishements	Flow of Traffic	Road Length	Distance to the Station
Crime Rate	1	3	5	7	9
Surrounding Establishements	1/3	1	3	5	7
Flow of Traffic	1/5	1/3	1	4	4
Road Length	1/7	1/5	1/4	1	3
Distance to the Station	1/9	1/7	1/4	1/3	1

Table 6. Pairwise matrix for night shift.

Criteria for Night SHIFT	Crime Rate	Open Surrounding	Lighting Condition	Road Length	Distance to the Station
Crime Rate	1	2	4	6	9
Open Surrounding	1/2	1	2	2	7
Lighting Condition	1/4	1/2	1	2	3
Road Length	1/6	1/2	1/2	1	2
Distance to the Station	1/9	1/7	1/3	1/2	1

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 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 7, a weight of each criterion has been developed with a consistency ratio of 0.07 for morning shift and 0.09 for night shift, which are both less than 0.10.

Table 7. Resulting weights for each criterion.

Criteria for Morning SHIFT	Weights	Criteria for Night SHIFT	Weights
Crime Rate	0.50	Crime Rate	0.48
Surrounding Establishements	0.26	Surrounding Establishements	0.30
Flow of Traffic	0.14	Lighting Condition	0.21
Road Length	0.07	Road Length	0.19
Distance to the Station	0.04	Distance to the Station	0.07
Consistency Ratio	0.07	Consistency Ratio	0.09

On the other note, Tables 8 to 11 show scores for each decision alternative or the beat area per station, per shift, and their rank according to its priority. The beat, which got a rank of 1, means it has the highest priority and thus implies that the said beat location needs more policemen.

Table 8. AHP Result for Station 9

Station 9 - Macasandig *Morning Shift*		Crime Rate	Surrounding Establishments	Flow of Traffic	Road Length	Distance to the Station	Score	Rank
Velez/Fernandez St - 1st-2nd-3rd-8th-21st-15th-Street to Rotunda Velez	Beat 1	5	4	3	3	2	4.225752541	1
2nd/8th-Hayes-12th-31st-upper 20th-15th-21st-8th-3rd to 2nd Street	Beat 2	3	3	4	3	3	3.137176537	2
Rotunda-15th-26th-Fern hill-M Chavez Street-Tibasak Rd. to Elena Homes	Beat 3	3	2	2	2	3	2.537228511	3
Mandumol Road-Aluba Buena Oro-South View Homes-Woodland Heights-Aroville Subdivision to Melicia Homes	Beat 4	2	1	1	4	5	1.844210707	4
Station 9 - Macasandig *Night Shift*		Crime Rate	Open Surrounding Establishments	Lighting Condition	Road Length	Distance to the Station	Score	Rank
Velez/Fernandez St - 1st-2nd-3rd-8th-21st-15th-Street to Rotunda Velez	Beat 1	5	3	2	3	2	4.432839748	1
2nd/8th-Hayes-12th-31st-upper 20th-15th-21st-8th-3rd to 2nd Street	Beat 2	3	3	3	3	3	3.742320285	2
Rotunda-15th-26th-Fern hill-M Chavez Street-Tibasak Rd. to Elena Homes	Beat 3	3	2	3	3	3	3.254787313	3
Mandumol Road-Aluba Buena Oro-South View Homes-Woodland Heights-Aroville Subdivision to Melicia Homes	Beat 4	2	1	2	2	5	2.79468696	4

Table 9. AHP Result for Station 1

Station 1 - Divisoria *Morning Shift*		Crime Rate	Surrounding Establishments	Flow of Traffic	Road Length	Distance to the Station	Score	Rank
Cham's Convenience Store, Capistrano Corner Gearlan Sts. Fronting City Hall to Pabayo Corner Gaerlan Sts	Beat 1	5	4	4	3	1	4.326943061	2
Mc Donald's Corrales corner Chaves St. to Dynasty Hotel, Tiano Bros corner Hayes Sts	Beat 2	3	3	4	3	2	3.10119052	3
Corrales corner Hayes St. to Corrales corner Jr. Borja Sts	Beat 3	3	2	2	3	3	2.603569892	4
Capistrano corner Cruz Taal St. up to Capistrano corner Montalvan Sts	Beat 4	2	1	1	2	2	1.603569892	6
Gaisano Outpost, Nazareno Church, CU	Beat 5	5	5	4	3	3	4.658168666	1
Capistrano corner Gearlan St. Fronting City Hall	Beat 6	2	2	1	3	2	1.929164845	5
Station 1 - Divisoria *Night Shift*		Crime Rate	Open Surrounding Establishments	Lighting Condition	Road Length	Distance to the Station	Score	Rank
Tiano-Kalambagohan Sts to Tiano Nacalaban Sts	Beat 1	5	5	2	3	1	4.952982101	2
Mc Arthur Park to include Capitol ground to Makaham bus corner Velez st	Beat 2	3	3	3	3	2	3.672350715	3
Mc Donald Corrales corner Chaves St. to Dynasty Hotel Tiano Bros. corner Chaves-St.	Beat 3	3	2	2	3	3	3.2408023	3

Table 10. AHP Result for Station 2

Station 2 - Cogon Morning Shift		Crime Rate	Surrounding Establishments	Flow of Traffic	Road Length	Distance to the Station	Score	Rank
Jr. Borja St. Guillermo St to Jr Borja St-Mortola St	Beat 1	1	3	2	3	3	1.860338476	8
Ramon Chavez- Capt.v Roa St-to Ramon Chavez St-Osmena St	Beat 2	1	2	3	2	2	1.635934043	10
Jr. Borja St-Guillermo St to Jr Borja Extension-Quirino St & Osmena Hayes St	Beat 3	1	3	2	4	2	1.89069384	7
Brgy.31	Beat 4	1	1	3	5	5	1.683662668	9
Yacapin St. Osmena St	Beat 5	2	3	2	3	2	2.325594952	4
Jr. Borja-Aguinaldo St	Beat 6	1	2	3	2	2	1.635934043	10
Osmena St-Justo Ramonal to CM Recto	Beat 7	3	2	2	4	4	2.705897291	3
Brgy Indahag Area	Beat 8	1	1	1	3	5	1.276626832	5
Yacapin Aguinaldo to Yacaoin Daumar St	Beat 9	1	3	3	3	3	1.997515012	4
Ramon Chavez-Corrales to Daumar St	Beat 10	1	3	4	2	2	2.032364151	3
Guillermo-Yacapin to Capt. Roa St	Beat 11	4	2	3	3	2	3.206002906	2
Hayes-Corrales to Yacapin Corrales	Beat 12	4	4	4	4	3	3.964013983	1

Station 2 - Cogon Night Shift		Crime Rate	Open Surrounding Establishments	Lighting Condition	Road Length	Distance to the Station	Score	Rank
Yacapin/Osmena St to Capt V Roa St	Beat 1	5	3	2	3	2	4.432839748	1
Jr Borja/Capt V Roa to Ramon Chavez & Daumar St Osmena Yacapin	Beat 2	3	3	3	3	3	3.742320285	2

Table 11. AHP Result for Station 3

Station 3 - Agora ***Morning Shift***		Crime Rate	Open Surrounding Establishments	Lighting Condition	Road Length	Distance to the Station	Score	Rank
Integrated Bus Terminal Pad, Agora, Market City	Beat 1	5	4	4	3	1	4.326943061	2
Metrobank Outpost, MUST, Petron, Shell, Puregold	Beat 2	3	3	4	3	2	3.10119052	4
Alagar Outpost, ECCS, RCBC	Beat 3	3	2	2	3	3	2.603569892	5
Gaabucayan Extension, Jetti, Luxurios Inn	Beat 4	2	1	1	2	2	1.603569892	8
Gaisano Outpost, Nazareno Church, CU	Beat 5	5	5	4	3	3	4.658168666	1
Osmena Extension, CU, Corrales Elementary School	Beat 6	2	2	1	3	2	1.929164845	6
Gusa Outpost-City Hardware to Factory Outlets, Slers to Petron Gasoline Station	Beat 7	1	2	2	4	4	1.703412303	7
Robinson Gusa/Galaxy Traffic Light, NSO	Beat 8	3	4	3	3	5	3.331225605	3

Station 3 - Agora ***Night Shift***		Crime Rate	Open Surrounding Establishments	Lighting Condition	Road Length	Distance to the Station	Score	Rank
Integrated Bus Terminal Pad, Agora, Market City	Beat 1	5	4	4	3	1	4.326943061	2
Metrobank Outpost, MUST, Petron, Shell, Puregold	Beat 2	3	3	4	3	2	3.10119052	4
Alagar Outpost, ECCS, RCBC	Beat 3	3	2	2	3	3	2.603569892	5
Gaabucayan Extension, Jetti, Luxurios Inn	Beat 4	2	1	1	2	2	1.603569892	8
Gaisano Outpost, Nazareno Church, CU	Beat 5	5	5	4	3	3	4.658168666	1
Osmena Extension, CU, Corrales Elementary School	Beat 6	2	2	1	3	2	1.929164845	6
Gusa Outpost-City Hardware to Factory Outlets, Slers to Petron Gasoline Station	Beat 7	1	2	2	4	4	1.703412303	7
Robinson Gusa/Galaxy Traffic Light, NSO	Beat 8	3	4	3	3	5	3.331225605	3

3.2 Results from Solving the GP Model

After classification of the beat areas is obtained using AHP, a GP model is then formulated for each police station. Each resulting GP model is then solved using Excel Solver.

A similar Excel solver setup is used to solve the GP models for the other police stations. The summarized goal deviation values and the resulting location-allocation per station are shown in Tables 12 to 15. Table 12 shows the resulting location-allocation for Station 9, with beat areas of 4 for both morning and night shifts, coupled with 12 and 7 available policemen in morning and night shifts, respectively. Table 13 shows the resulting location-allocation for Station 1, with 6 beats and 19 available policemen for morning shift while 3 beats and 6 available policemen for night shift. Table 14shows the resulting location-allocation for Station 2, with 12 beats and 18 available policemen for morning shift while 2 beats and 4 available policemen for night shift. Table 15 shows the resulting location-allocation for Station 3, with beat areas of 8 for both morning and night shifts, coupled with 23 and 9 available policemen in morning shift and night shift, respectively.

Table 12. Resulting Location-Allocation for Police Station 9

Station 9 - Macasandig	Beat Area	Number of Police for Morning Shift	Number of Police for Night Shift
1	Velez/Fernandez St-1st-2nd-3rd-8th-21st-15th-Street to Rotunda Velez	4	2
2	2nd/8th-Hayes-12th-31st upper 20th-15th-21st-8th-3rd to 2nd Street	3	2
3	Rotunda-15t-26th-Fern hill- M Chavez Street-Tibas ak road to Elena Homes	3	2
4	Mandumol Road-Aluba Buena Oro-South View Homes-Woodland Heights- Aroville Subdivision to Melicia Homes	2	1

Table 13. Resulting Location-Allocation for Police Station 1

Station 1 - Divisoria	Beat Area	Number of Police
Morning Shift		
1	Cham's Convenience Store, Capistrano Corner Gaerlan Sts. Fronting City Hall to Pabayo Corner Gaerlan Sts	5
2	Mc Donald's Corrales Corner Chaves St. to Dynasty Hotel, Tiano Bros corner Hayes Sts	3
3	Corrales Corner Hayes St. to Corrales corner Jr. Borja Sts	3
4	Capistrano corner Cruz Taal St. up to Capistrano corner Montalvan Sts	2
5	Gaisano Outpost, Nazareno Church, CU	5
6	Capistrano corner Gearlan st. Fronting City Hall	1
Night Shift		
1	Tiano-Kalambagohan Sts to Tiano Naclaban Sts	3
2	Mc Arthur Park to include Capitol ground to Makahambus corner Velez st	2
3	Mc Donald Corrales corner Chaves St. to Dynasty Hotel Tiano Bros. corner Chaves	1

Table 14. Resulting Location-Allocation for Police Station 2

Station 2 - Cogon	Beat Area	Number of Police
Morning Shift		
1	Jr. Borja St. - Guillermo St. to Jr. Borja St - Mortola St.	1
2	Ramon Chavez - Capt. V Roa St. to -Ramon Chavez St. Osmeña St.	1
3	Jr. Borja St. - Guillermo St. to Jr. Borja Extension - Quirino St. & Osmeña Hayes St.	1
4	Brgy. 31	1
5	Yacapin St. - Osmeña St.	2
6	Jr. Borja - Aguinaldo St.	1
7	Osmeña St. - Justo Ramonal to CM Recto	2
8	Brgy. Indahag Area	1
9	Yacapin Aguinaldo to Yacapin Daumar St.	2
10	Ramon Chavez-Corrales to Daumar St.	1
11	Guillermo - Yacapin to Capt. Roa St.	2
12	Hayes - Corrales to Yacapin Corrales	3
Night Shift		
1	Yacapin/ Osmeña St. to Capt. V Roa St.	3
2	Jr. Borja / Capt. V Roa to Ramon Chavez & Daumar St. to Osmeña Yacapin	1

Table 15. Resulting Location-Allocation for Police Station 3

Station 3 - Agora	Beat Area	Number of Police for Morning Shift	Number of Police for Night Shift
1	Integrated Bus Terminal Pad, Agora, Market City	4	2
2	Metrobank Outpost, MUST, Petron, Shell, Puregold	3	1
3	Alagar Outpost, ECCS, RCBC	3	1
4	Gaabucayan Extension, Jetti, Luxurious Inn	1	1
5	Gaisano Outpost, Nazareno Church, CU	5	1
6	Osmeña Extension, CU, Corrales Elementary School	2	1
7	Gusa Outpost - City Hardware to Factory Outlets, Slers to Petron Gasoline Station	2	1
8	Robinson Gusa / Galaxy Traffic Light, NSO	3	1

Table 16 summarizes the weight deviations obtained from solving the GP models. It can be seen that the first priority of assigning each policeman to a beat was fully achieved. Similarly, the second priority was also fully achieved.

Priority	Weighted Deviation from Goal			
	Station 9	Station 1	Station 2	Station 3
Priority 1 Each policeman assigned to a beat area	0	0	0	0
Priority 2 Beat requirement assignment	0	0	0	0
Goal Achievement	Full	Full	Full	Full

3.3 Comparison between the Proposed Police Location-Allocation to the Existing Police Allocation

To evaluate the result of this study, the resulting police location-allocation will be compared to the existing police allocation implemented by police stations in terms of protection and police visibility. The comparison was measured by multiplying the obtained rank of each beat area to the number of police assigned. This is shown in Tables 17 to 20.

Table 17. Proposed and Current Location-Allocation for Station 9

Station 9-Macasandig		Morning Shift		Night Shift	
	Beat Area	Proposed	Current	Proposed	Current
1	Velez/Fernandez St- 1st-2nd-3rd-8th-21st-15th-Street to Rotunda Velez	4	3	1	2
2	2nd/8th-Hayes-12th-13st-upper 20th-15th-21st-8th-3rd to 2nd Street	3	3	2	2
3	Rotunda-15th-26th-Fern hill-M Chavez Street-Tibasak road to Elena Homes	3	3	2	2
4	Mandumol Road-Aluba Buena Oro-South View Homes- Woodland Heights Aroville Subdiv to Melicia Homes	2	3	2	1

Table 18. Proposed and Current Location-Allocation for Station 1

Station 1- Divisoria		***Morning Shift***	
	Beat Area	Proposed	Current
1	Cham's Convenience Store, Capistrano Corner Gearlan Sts. Fronting City Hall to Pabayo Corner Gaerlan Sts	5	4
2	Mc Donald's Corrales corner Chaves St. to Dynasty Hotel, Tiano Bros corner Hayes Sts	3	3
3	Corrales corner Hayes St. to Corrales corner Jr. Borja Sts	3	3
4	Capistrano corner Cruz Taal St. up to Capistrano corner Montalvan Sts	2	3
5	Gaisano Outpost, Nazareno Church, CU	5	3
6	Capistrano corner Gearlan St. Fronting City Hall	1	3
		Night Shift	
1	Tiano-Kalambagohan Sts to Tiano Nacalaban Sts	3	2
2	Arthur Park to include Capitol ground to Makaham bus corner Velez st	2	2
3	Mc Donald Corrales corner Chaves St. to Dynasty Hotel Tiano Bros. corner Chaves-St.	1	2

Table 19. Proposed and Current Location-Allocation for Station 2

Station 2- Cogon		***Morning Shift***	
	Beat Area	Proposed	Current
1	Jr. Borja St.- Guillermo St. to Jr. Borja St. -Mortola St.	1	2
2	Ramon Chavez - Capt. V Roa St. to Ramon Chavez St. - Osmeña St.	1	2
3	Jr. Borja St. - Guillermo St. to Jr. Borja Extension- Quirino St. & Osmeña Haves St.	1	2
4	Brgy. 31	1	1
5	Yacapin St. Osmeña St.	2	2
6	Jr. Borja-Aguinaldo St.	1	1
7	Osmeña St - Justo Ramonal to CM Recto	2	2
8	Brgy. Indahang Area	1	1
9	Yacapin Aguinaldo to Yacapin Daumar St.	2	1
10	Ramon Chavez-Corrales to Daumar St.	1	1
11	Guillermo-Yacapin to Capt. Roa St.	2	1
12	Haves-Corrales to Yacapin Corrales	3	2
		Night Shift	
1	Yacapin/ Osmeña St. to Capt V Roa St.	3	2
2	Jr. Borja / Capt. V Roa to Ramon Chavez & Daumar St. Osmeña Yacapin	1	2

Table 20. Proposed and Current Location-Allocation for Station 3

Station 3 - Agora		Morning Shift		Night Shift	
	Beat Area	Proposed	Current	Proposed	Current
1	Integrated Bus Terminal Pad, Agora, Market City	4	4	2	1
2	Metrobank Outpost, MUST, Petron, Shell, Puregold	3	4	1	1
3	Alagar Outpost, ECCS, RCBC	3	4	1	1
4	Gaabucayan Extension, Jetti, Luxurious Inn	1	4	1	1
5	Gaisano Outpost, Nazareno Church, CU	5	4	1	1
6	Osmeña Extension, CU, Corrales Elementary School	2	4	1	1
7	Gusa Outpost - City Hardware to Factory Outlets, Slers to Petron Gasoline Station	2	4	1	1
8	Robinson Gusa / Galaxy Traffic Light, NSO	3	3	1	2

4.0 Conclusion

This paper demonstrated how the analytical hierarchy process and goal programming model presented can be useful in location-allocation problems, such as assigning the number of policemen in certain beat areas given certain conditions that need to be satisfied. The AHP methodology has been utilized successfully to allow consistent ranking of location alternatives or beat areas. The resulting prioritization data is then used as a ranking system within the structure of GP model.

The combined AHP-GP method offers a systematic approach to the location-allocation decision problem. This study provides the best satisfying solution in terms of providing security within the area of responsibility of each police station in the CBD of Cagayan de Oro City.

This study only considered two goal constraints in its GP model and its application only included stations under the CBD of the Cagayan de Oro City due to unavailability of data. However, it may be interesting to consider all the other stations in Cagayan de Oro for a more efficient location-allocation of beat patrol police.

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