Simulation of a Computational Model for the Performance Analysis of Mobile Police Bases in Apprehending Drug Dealers in the City of Itanhaém (São Paulo/Brazil)

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Abstract. In this study, we developed a computational model to simulate the number of arrests made by police when using mobile police bases. For a simulation period of twelve months, the results showed that the use of more mobile bases did not always lead to more arrests. Moreover, it was observed that if an equal distribution of police officers might jeopardize the number of arrests. We proposed an unbalancing model in order to promote the police workload distribution. The simulation showed that the model can produce beneficial results with only a negligible imbalance.

Introduction

According to [3], Brazil is plagued by extreme violence, originating from multiple factors such as its poor economic condition, cultural differences, and wars between factions. For every 100,000 inhabitants, Brazil sees 27.1 homicides. Much of this violence can be attributed to organized crime linked to drug trafficking [11]. Therefore, curbing any form of trafficking, regardless of its nature, can help reduce the number of homicides.

As mentioned by [12], the implementation of the pacifying police unit (UPP) is strategic and is based on geoprocessing; it identifies regions with a high incidence of theft. However, as the world of crime is highly dynamic, many of the UPPs in Brazil have been replaced by mobile modules.

A mobile module (or mobile police base) is a vehicle that reinforces ostensive patrolling, bringing the police closer to the community, in addition to favoring the arrival of police officers when there is a crime-related incident.

According to [7], by patrolling through mobile police bases, the police can typically respond to drug-related incidences within a 2 km radius, while some authors argue that they can cover a greater distance. The module can remain at a certain location and even change its position in response to a specific incident.

In each mobile police base, a team patrols its surroundings and makes arrests if it identifies a crime. Police officers can perform patrolling in several ways, including in motorcycles, bicycles and even on foot. According to [2], the use of mobile police bases aims to reduce crime with low offensive potential.

According to [6], the city of Itanhaém (located on the coast in the state of São Paulo, Brazil) has the highest rate of exposure to violent crime. Hence, attempts to reduce such crime are prioritized by municipal authorities.

With this background, in this study, we developed a computational model to predict the performance of mobile police bases in apprehending illicit drug traffickers. The model runs using information for the city in question.

The remainder of this paper is divided into four sections. The first part describes the methods used in the research, methodology, and types of data collected. The model used in the simulation is discussed in the second part. The third part presents the results (obtained under balancing/unbalancing conditions), discussion of the results, and statistical analysis. Finally, we draw our conclusions.

1 Material and Methods

The method chosen for this study was a computational model, and the computational results obtained were quantitative, that is, the number of arrests, the size of the vulnerable area not covered by police bases, and the total cost incurred by the city hall. Because of the difference between the distribution of traffickers along the crowns as shown in fourth section, the performance of the arrests carried out by the police may be jeopardized, mainly due to the lack of police. Thus, an unbalanced model based on the workload was proposed. The results were compared with those obtained using a balanced model.

2 Model Police / Drug Dealer

2.1 Determining the coverage and vulnerable areas

Let $N_{current\ period}$ mobile police bases be randomly located in the total area of the city, denoted by A_T. The coordinates can be represented as $(x_{i=1}, y_{i=1}) \neq (x_{i=2}, y_{i=2}) \ldots \neq (x_{i=N\ current\ period}, y_{i=N\ current\ period})$.

If the coverage radius of each mobile police base i is R_i, the areas supervised by all the police bases are (1):

$$OA_{Ncurrent\ period} = \sum_{i=1}^{Ncurrent\ period} \pi . R_i^2 \qquad (1)$$

As R_i can assume any positive value, an overlapping area may exist. If there are K overlapping areas with L police stations, the area occupied by police bases can be expressed as (2):

$$OA'_{Ncurrent\ period} = OA_{Ncurrent\ period} - \sum_{L=2}^{N} \sum_{ii=1}^{K} OLA_{L,ii}, \quad \text{with L} \ \forall \ \text{i} \qquad (2)$$

Here, OLA represents the overlapping area, and ii is the counter of K overlapping areas. For example, if $L = 3$ and $K = 4$, there are four occurrences in the three overlapping areas.

Thus, the remaining (vulnerable) areas represented by the RA variable can be expressed as follows (3):

$$\begin{cases} RA_1 = A_T - OA_{Ncurrent\ period} \ \lll == \\ \quad without\ overlapping\ area \\ RA_2 = A_T - OA'_{Ncurrent\ period} \ \lll == \\ \quad with\ overlapping\ area \end{cases} \qquad (3)$$

If RA (both) is the region farthest from police stations, i.e., the preferred area for criminals, then the objective is to minimize RA.

The focus here is on dealing with nonoverlapping areas covered by the police bases; then, we can represent RA_1 through expressions (4), (5), and (6):

$$min\ RA_1 = A_T - \max\{OA_{Ncurrent\ period}\}, \quad \text{where } 0 < \max\{OA_{Ncurrent\ period}\} < A_T \text{ to avoid } RA_1 \text{ becoming negative} \qquad (4)$$

$$min\ RA_1 = A_T - \pi \cdot max\{ \sum_{i=1}^{Ncurrent\ period} R_i^2 \}, \quad \text{with } \pi \cdot max\{\sum_{i=1}^{Ncurrent\ period} R_i^2\} \leq A_T \qquad (5)$$

$$min\ RA_1 = A_T - \pi \cdot \{\max R_1^2 + \max R_2^2 + + \cdots + max\ R_{Ncurrent\ period}^2 \} \qquad (6)$$

From these expressions, it can be noted that while the coverage radius are different, it is not possible to maximize each R_i. To achieve the highest value of R_i, it is necessary for all of them to be equal by positioning them as equidistantly as possible between the police bases. Thus, the expression can be summarized as (7):

$$\{ min\ RA_1 \} = A_T - N_{current\ period} \cdot \pi \cdot R^2 \qquad (7)$$

2.2 Equidistant positioning of police bases

To calculate RA_1, two unknown variables must be defined that are mutually dependent. In the case of equidistant positioning of police bases, the variables are inversely proportional ($N_{current\ period}$ and R).

Once $N_{current\ period}$ is defined, it is possible to determine R and the desired value of RA_1.

For a given value of $N_{current\ period}$, with the expression proposed by [1], called the distribution degree Φ shown in (8), the shortest distance between equal objects can be as large as possible. The unit of measurement was distance.

The authors used this expression to define the positions of machines in a physical arrangement study on factories. The lower the degree of distribution, the better the result; that is, the more equidistant the objects. Similarly, police bases (equal objects) can be positioned equidistantly.

To obtain one of the variables described in (8), we need to solve (9):

$$\Phi = \sum_{j=1}^{NO} \sum_{n_j=1}^{NO_j} \frac{\delta_{n_j}}{NO \cdot NO_j} \qquad (8)$$

$$\delta_{n_j} = \sum_{k \neq j}^{N} d_{n_j k}^{*} \qquad (9)$$

Here $d^*_{n_jk}$ is the distance between the n^{-th} object of type j and the closest object of type k; $n_j = n^{-th}$ object type j; NO_j is the number of objects type j; NO represents the types of objects.

In this study, NO is equivalent to $N_{current\,period}$. To computationally obtain the distribution degree, the authors argue that metaheuristics should be used to obtain the degree of distribution. This is because the computer tests different positions that each police base can occupy, thus reducing the computational search time. The distribution degree is calculated for each police base allocation.

[8] developed a genetic algorithm (GA) to determine the distribution degree. When performing numerous trials (generations in the GA), the degree of distribution that presents the lowest degree of distribution is the most equidistant possible placement between objects. Therefore, in this study, we developed a GA. Because there are only two types of objects (police bases and positions not occupied by police bases), it is not necessary to perform many generations in this case.

Finally, it is possible to calculate the distance between police bases and consequently obtain the desired circular radius (10):

$$R = \frac{1}{2} \cdot \min\{SQRT[(x_{i=1} - x_{i=2})^2 + (y_{i=1} - y_{i=2})^2]; \quad SQRT[(x_{i=1} - x_{i=3})^2 + (y_{i=1} - y_{i=3})^2]; \ldots; \quad SQRT[\left(x_{i=Ncurrent\,period-1} - x_{i=Ncurrent\,period}\right)^2 + \quad +\left(y_{i=Ncurrent\,period-1} - y_{i=Ncurrent\,period}\right)^2]\} \tag{10}$$

2.3 Determining the number of police officers and the number of drug dealers

The total number of police officers working in a region is considered. Using $Y\%$ (the percentage of police officers working in regions covered by police bases), we can calculate the number of police officers per police base ($n_{i\ police}$). Therefore, the difference $(1 - Y)\%$ corresponds to the effective personnel working in vulnerable regions, under the condition that $Y\% > (1 - Y)\%$.

For the total number of traffickers operating in the region, if $X\%$ operate in vulnerable areas, the remaining $(1 - X)\%$ will operate in coverage areas.
These established inequalities are due to the fact that police officers are at a greater risk in more vulnerable areas. However, it is not convenient for traffickers to operate close to police bases because these areas are a greater risk to drug dealers.

For a given number of mobile bases N, it is possible to estimate the number of traffickers for each mobile base i, represented by $n_{i\ drug\ dealers}$.

The coverage area of each police base i was divided according to the number of circular crowns adopted. For example, if there are two crowns, the height of each crown is $R/3$. In addition to the two circular crowns, there will be an internal circle with a radius of $R/3$. It can simply be called a circular crown. In these cases, the area of the circular crown will always be greater than that of the adjacent interior.

The number of police officers at each police base was equally distributed by each circular crown. For traffickers, the preferred active areas are external crowns.

The initial positions of each police officer and each drug dealer are different from each other and randomly established. For each police base, we established an arrest performance target to be used in decisions regarding hiring police officers. The target is defined as the expected number of arrests EA_i.

2.4 Determining the number of arrests and calculating the total cost

As the simulation progressed, new values of N were obtained, which in turn changed the configuration of police base positions in the A_T area. This is because, if the number of arrests reaches a certain number, physical structures with a mobile police base will be required.

The number of arrests carried out on a given day depends on the movement of traffickers and police. However, their movements differed. In the case of the drug dealer, the subject performed move–stop exercises.

Considering the time for which the dealer remained in the same location, this can be represented by the following equation (11):

$$\frac{s_1}{v_1} + \frac{s_2}{v_2} + \cdots + \frac{s_n}{v_n} = WJDD - n.\,t_{standing\ up} \tag{11}$$

where $WJDD$ represents the work journey of the drug dealer; n represents the number of dealers; s represents the distance traveled by each trafficker; v represents the displacement speed of each trafficker; and t represents the time spent at the site.

If the speed is constant throughout the path taken and represents all the distances by $\bar{S}$, then the expected number of locations reached on the workday is (12):

$$N_{locations\ drug\ dealer} = WJDD / \left(\frac{\bar{S}_{drug\ dealer}}{v_{drug\ dealer}} + t_{standing\ up}\right) \tag{12}$$

In the case of a police officer, movement is interrupted only to apprehend a drug dealer. Hence, we omitted the stop time. The expression is shown in (13):

$$\frac{s_1}{v_1} + \frac{s_2}{v_2} + \cdots + \frac{s_{n'}}{v_{n'}} = WJPO \quad (13)$$

where *WJPO* is the work journey of the police officer; *n´* represents the number of police officers; *s* represents the distance traveled by each officer; *v* represents the displacement speed of each officer.

If we assume that the displacement speed of the police officer is constant and if we represent all distances covered by $\bar{S}$, then the expected number of locations that can be reached by the police officer can be expressed by (14):

$$N_{locations\ police\ officer} = WJPO / \left(\frac{\bar{S}_{police\ officer}}{v_{police\ officer}}\right) \quad (14)$$

When both the locations are identical, an arrest occurred. Due to the arrests, the number of drug dealers is subtracted. The police officer sends a delinquent to a mobile base for registration and other administrative activities. Therefore, the on-site actions of the officer become inactive. Activity is resumed only the following day. The subtracted number of traffickers is immediately replenished the following day.

Therefore, the ratio of the number of police officers to the number of drug dealers can be expressed as (15):

$$f = \frac{N_{locations\ police\ officer}}{N_{locations\ drug\ dealer}} \quad (15)$$

For example, if the result of *f* is eight, this indicates that there are eight police movements reaching eight different locations against one trafficker movement (reaching one new location). The variable *f* corresponds to the number of loops to be executed by the computational model to determine new police positions based on the number of positions reached by the traffickers. Thus, for each *i*, if the positions of the dealer and police are the same, then an arrest is made ($A_{i\ current\ period}$).

For the entire month, the total cost can be calculated as follows (16):

$$TC = PC \cdot \sum_{i=1}^{N} n_{i\ police} + N \cdot SPC \quad (16)$$

where *TC* represents the total cost; *N* represents the number of mobile bases; *n* represents the number of police officers in base *i*; *PC* represents the cost incurred in the deployment of each police officer; and *SPC* represents the monthly cost to maintain the physical structure of each mobile base.

The sum of officers from all mobile police bases must be calculated because this information is used to determine the number of officers from each mobile base in the next period. The total number of police officers operating in the coverage areas is (17):

$$Total\ number\ of\ police\ officers_{current\ period} = \\ = \sum_{i=1}^{N_{current\ period}} n_{i\ current\ period} \quad (17)$$

2.5 Updating the number of police officers and drug dealers for the next period

The updated number of police officers for the following month is based on the expected number of arrests.

The number of police officers required for each mobile base *i* in the next period can be calculated using Equations (18), (19), and (20). If the number of arrests in the current period is higher than the expected number, the difference must be added to the current number of police officers (18). If the number of arrests in the current period is lower, the difference must be subtracted (19). However, the number of police officers remains the same (20):

- If $A_{i\ current\ period} > EA_i$ then $n_{i\ next\ period} =$
$$= n_{i\ current\ period} + [A_{i\ current\ period} - EA_i] \quad (18)$$
- If $A_{i\ current\ period} < EA_i$ then $n_{i\ next\ period} =$
$$= n_{i\ current\ period} - [EA_i - A_{i\ current\ period}] \quad (19)$$
- If $A_{i\ current\ period} = EA_i$ then
$$n_{i\ next\ period} = n_{i\ current\ period} \quad (20)$$

We established the total number of police officers required for the next period (21) as follows:

$$Total\ number\ of\ police\ officers_{next\ period} = \\ = \sum_{i=1}^{N_{current\ period}} n_{i\ next\ period} \quad (21)$$

The difference *d*, expressed in Equation (22), between the number of police officers in the current period and that in the next period determines whether there is a need to change the number of mobile bases. When the cost of the required police officers is greater than the cost of the mobile base, more mobile bases are added:

$$d = Total\ number\ of\ police\ officers_{next\ period} - \\ Total\ number\ of\ police\ officers_{current\ period} \quad (22)$$

Thus, we can establish some rules, as expressed in equations (23) and (24).

If the difference is positive,

$$\left.\begin{array}{r} d \cdot PC \geq SPC + n_{i\,current\,period} \cdot PC \\ N_{next\,period} = N_{current\,period} + 1 \end{array}\right\} \quad (23)$$

If the difference is lower than or equal to zero, then

$$\left.\begin{array}{r} |d| \cdot PC \geq SPC + n_{i\,current\,period} \cdot PC \\ N_{next\,period} = N_{current\,period} - 1 \end{array}\right\} \quad (24)$$

With the new value of $N_{next\,period}$ determined, we can obtain R and consequently the values of RA_1 and so on.

Regarding the number of traffickers, the integration of new traffickers occurs daily. This implies that the total number of traffickers is always fixed.

3 Simulation of the Model

3.1 Definition of the input parameters and discussion of results

The city of Itanhaém (in São Paulo) has an estimated area of 600 km^2 according to [9]. [4] recorded that the average estimate in the state of São Paulo is one police officer per 488 inhabitants. Thus, according to [9], if the city of Itanhaém has approximately 103,000 inhabitants, the city is estimated to have 211 police officers. There is no precise information on the number of drug dealers in the cities in São Paulo. However, if we use [5]'s data as a reference, which states that the ratio is four drug dealers per police officer in Rio de Janeiro, we estimate approximately 800 drug dealers.

The available software for building such a computational model is Dev-Pascal (Pascal language); the simulation was done on a PC with i3-10100 CPU, 8 cores, 3.6 GHz, 4.1 GB of RAM.

Based on the information obtained from the aforementioned city, in this study, the dimensions were set to 25 km × 25 km; the total number of available police officers in the city was 250 and updated monthly. The total number of traffickers operating throughout the city was fixed at 1000. The initial number of mobile police bases was 13 (N_{initial} = 13), and *Y%* was taken as 70%. Therefore, the number of police officers working in mobile bases was 250; *Y%* = 175, and in vulnerable areas, there were 75 police officers.

The number of traffickers with *X*% = 80% that are active in vulnerable areas was 1000; in coverage areas, *X%* = 800, and the number of traffickers was 200. Thus, per police base, the estimate was

$$n_{i\,police\,officer} = trunc\,(175\,/\,N_{i\,initial}).$$

The number of traffickers acting per police base could be estimated through

$$n_{i\,drug\,dealers} = trunc\,(200\,/\,N_{i\,initial})$$

The dealer distributions for the three circular crowns (interior to exterior) were 0%, 20%, and 80%. The trafficker's working day was established using the relationship

$WJDD = 3h$; $v_{drug\,dealer} = 0.7$ m/s;
$\bar{S}_{drug\,dealer} = 10$ m; $t_{standing\,up} = 0.25$ h;
$v_{police\,officer} = 35$ km/h; $\bar{S}_{police\,officer} = 40$ m.

PC corresponds to the salary and fuel cost per month = R$5000.00; *SPC* corresponds to fuel and van rental per month = R$20.000,00; EA_i = 40% de $n_{i\,\text{police}}$.

To run the GA, we adopted five generations with 20 individuals in the population, a probability of 80% for crossover, and 2% for mutation.

Table 1 presents the simulation results. The first row shows the performance when 13 mobile police bases were used, resulting in 359 arrests. The outermost circular crowns saw a greater number of arrests. The vulnerable area not covered by police bases was 461.64 km^2, with a total cost of R$1105K.

The results showed that the installation of more police bases cannot always increase the number of arrests, as was the case between months 4 and 8.

By separately analyzing the results of the two groups, we found that the number of arrests in the case of more mobile bases (from 10 to 13) averaged at 723.25, and the number of arrests in the case of fewer bases (7 to 9) averaged at 768.5. From this, we can conclude that, in general, a greater number of mobile bases does not necessarily result in a greater number of arrests.

The results showed that working with more police bases does not always result in a lower vulnerable area.

By observing the three-performance metrics, namely the "total arrests," "vulnerable area," and "total cost," it is not possible to reach the best value considering all the three metrics. Notably, the reduction in the number of police bases seems to have a strong influence on the total cost reduction, as was the case in months six to seven as well as in months three to four.

Statistically, if the number of traffickers at the beginning of each month is defined as 1000, and if we consider that 80% of months should have more than 1000 arrests, it indicates that the number of circular crowns used produces a satisfactory performance.

Month	Number of mobile police bases	Number of arrests			Total arrests	Vulnerable area (km²)	Total cost (R$)
		First crown (inner-most)	Second crown	Third crown (outer-most)			
1	13	0	154	205	359	**461.64***	1105K
2	12	0	444	713	**1157***	587.30	1080K
3	11	0	452	571	**1023***	590.44	1045K
4	10	0	103	251	354	**467.92***	1050K
5	9	0	276	507	783	561.38	1035K
6	8	0	273	433	706	562.17	**1000K***
7	7	0	332	531	863	570.02	**980K***
8	7	0	379	636	1015	581.02	**980K***
9	7	0	354	539	893	570.02	**980K***
10	7	0	324	544	868	570.02	**980K***
11	7	0	223	377	600	531.54	**980K***
12	7	0	152	268	420	487.56	**980K***
Total					**9041**		

Table 1: Simulation results, with three circular crowns, registered at the end of each month, throughout the months of the year. Two best values are highlighted.

Statistically, if the number of traffickers at the beginning of each month is defined as 1000, and if we consider that 80% of months should have more than 1000 arrests, it indicates that the number of circular crowns used produces a satisfactory performance.

We observed that three of the 12 months saw arrests above 1000. Therefore, the value of p was 3/12 = 0.37. So we can formulate the following hypotheses for the statistic p:

- H_0: $p \geq 0.8$, if 80% of the months have a performance equal to or greater than 1000 arrests, (25)
- H_1: $p < 0.8$ otherwise.

The value of Z_{test} used in the comparison is

$$Z_{test} = (\hat{p} - p) \;/\; \sqrt{\frac{p(1-p)}{n}} \tag{26}$$

The Z_{test} value was −3.72. For a level of significance of 5%, because -3,72 is lower than $Z_{\alpha=5\%} = -1.64$, the decision was to reject H_0.

3.2 Adaptation of the simulation model with implementation of imbalance

Imbalance per area

Note that when dividing the circumference and equally distributing the number of police in n crowns, the number of arrests in the internal crown was zero, and drug dealers were not involved.

In this study, traffickers preferred external crowns farthest from the base. This led to the idea that police officers should be reallocated differently.

This paper presents two unbalanced procedures. First, police officers are proportionally allocated according to the crown area.

Let $p´$ be the probability that a police officer is located in a given circular crown. If the area increases, then to maintain the same p', a larger number of police officers should be assigned (27).

The steps are as follows:

- Calculate the total coverage area of base *i*.
- Calculate the percentage of each circular crown *p'*;
- Calculate the number of police officers per ring crown using the following equation:
  Police officers in the circular crown
  $= n_{i\ police\ officer} \cdot p'$ (27)

Table 2 shows the results of the imbalance model. Clearly, a different number of police officers should be allocated to each crown to ensure a greater number of arrests. Surprisingly, the performance in the case of four circular crowns approached that in the case of three circular crowns. Thus, the variation in the number of circular crowns with unbalancing does not seem to jeopardize the arrest performance.

	Total arrests	
Month	Balanced	Area-based imbalance
1	359	552
2	1157	508
3	1023	1007
4	354	1591
5	783	3187
6	706	936
7	863	981
8	1015	741
9	893	1834
10	868	348
11	600	841
12	420	378
Total	**9041**	**12904**

Table 2: Comparison between the results obtained under balancing and unbalancing conditions by areas.

We note that the unbalancing model outperforms the balancing model.

Applying the statistical test to the unbalanced results, we find that the *p* value was 4/12 = 0.33. The value of Z_{test} was – 4.07, resulting in the rejection of the hypothesis H_0.

We conclude that, although the number of arrests improved overall, it still did not satisfy the monthly performance conditions.

During the simulation, with the change in the number of mobile bases, the number of traffickers per police base also changed. This means that, for the current approach, the number of police officers remain unchanged, consequently reducing the number of arrests.

This suggests that a greater workload should be assigned to police officers in the most distant crowns. This is the method proposed in this study.

Imbalance per workload

The results suggests that a greater workload should be assigned to police officers in the most distant crowns. This is the method proposed in this study, Equation (28):

$$\beta = \frac{n_{i\ police\ officers} \cdot WJPO}{\Delta + (\sum_{i=0}^{\Delta-1} i) \cdot \alpha} \quad (28)$$

where β corresponds to the workload of the outermost crown; α corresponds to the imbalance factor; Δ corresponds to the number of circular crowns.

Once this value was determined, the other values were assigned according to the circular crown. The closer to the mobile police base, the lower the workload, indicating fewer police officers.

The workload *CHS* (29) of the ε^{th} crown counted from the base can be expressed as follows:

$$CHS = \beta + (\Delta - \varepsilon) \cdot \alpha \cdot \beta \quad (29)$$

Note that in Equation (28), α depends on the number of police officers operating in each police base (which varies temporally), β value, the number of circular crowns, and police's work journey. This means it is not possible to establish a fixed value of α.

To define the required range of α for the simulation, we use the input parameters under the condition that $\beta \geq 0$. If the police officer workday is 8 hours, then we can deduce that for $\beta \geq 8$, we must use $\alpha > -1$, in addition to $\alpha \neq 0$. Only negative values were used because of the higher workload in the external crown. Therefore, the α values for the three crowns were −0.9, −0.45, −0.15.

Table 3 shows the results. The benefits can be verified when a higher unbalancing factor (close to balanced $\alpha = 0$) is used.

As the value decreases (the greater the unbalancing), the benefits become evident, confirming that the unbalancing should be based on the workload.

	Months of the year											
	α=-0.15											
Crown 1	0	0	0	0	0	0	0	0	0	0	0	0
Crown 2	121	365	381	158	544	190	103	138	227	250	312	68
Crown 3	413	936	981	543	1298	516	376	402	582	696	857	230
Unbal-anced	534	1301	1362	701	1842	706	479	540	809	946	1169	298
	α=-0.45											
Crown 1	0	0	0	0	0	0	0	0	0	0	0	0
Crown 2	139	343	268	149	317	501	219	199	247	285	229	457
Crown 3	506	1274	1096	816	1238	1811	1108	995	1042	1087	1073	1656
Unbal-anced	645	1617	1364	965	1555	2312	1327	1194	1289	1372	1302	2113
	α=-0.9											
Crown 1	0	0	0	0	0	0	0	0	0	0	0	0
Crown 2	166	211	703	296	529	353	853	885	437	441	468	499
Crown 3	2259	3004	4620	3923	4211	3499	4311	4557	4188	4399	4584	4118
Unbal-anced	2425	3215	5323	4219	4740	3852	5164	5442	4625	4840	5052	4617

Table 3: Results with unbalancing.

So results are:

- For $\alpha = -0.15$, p is 4/12,
- for $\alpha = -0.45$, p is 10/12 = 0.83,
- and for $\alpha = -0.9$, p is 12/12 = 1.

The corresponding Z_{test} values were calculated to be 4.07, 0.26, and 1.73, respectively.

Table 4 presents a comparison with the reference z at a significance level of 5%.

	-0.15	-0.45	-0.9
Unbalanced	-4.07 < -1.64	0.26 > -1.64	1.73 > -1.64
Decision	Reject H_0	Accept H_0	Accept H_0

Table 4: Statistical comparison with unbalancing.

4 Conclusions

In this study, a computational model was constructed for effective policing against drug trafficking, with the objective of simulating performance projections in cases where mobile police bases were implemented, aiming to increase the number of arrests, reduce the number of vulnerable areas, and reduce associated costs.

Using the computational model constructed for this purpose, it was possible to obtain the desired results for a performance comparison. The computational model proved to be versatile, as it could simulate possible changes in the positions of mobile bases, police officers, and particularly drug dealers.

The results showed that when there were areas with police supervision with a low circulation of traffickers, the expected result should be zero arrests, which was verified. This finding suggested that an unbalanced model can be used to reallocate officers in a different manner. When considering the imbalance by the area size (i.e., the larger the area, the higher the number of police officers, or vice versa), more arrests could be made.

Despite the benefits of unbalancing by area size, redistribution might fail. This is because, as the simulation progresses, the numbers of drug dealers and police officers might change. Hence, an unbalanced model was proposed according to the workload of the police officers. With the proposed model and using an intermediate lower value of the unbalancning factor, the obtained results were more promising.

As a proposal for future work, some restrictions could be considered, such as in areas that are difficult for police to access and are already dominated by armed traffickers. This prevents the installation of mobile bases in such locations. As a suggestion for future work, due to the limitations of the software used in this study, it was not possible to analyze the arrests made in areas not covered by police bases. As stated by [10], it is in the peripheries that crime is more organized, suggesting a way that aims to maintain a protection network and eliminate possible competitors. We also suggest the development of new unbalanced models in future studies.

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