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Finding the Optimal Allocation of Checkpoints Using the Dynamic Programming method

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Abstract:

This research aims to use the competent mathematical method through which it is possible to find the best allocation for the main checkpoints in one of the Iraqi Governorates, which contains 17 administrative units. The Dynamic Programming (DP) method and the method of background calculations were used for this method. The problem of the research lies in the fact that many administrative units in this governorate are subjected to organized attacks by terrorist gangs, which lead to the loss of the lives of many citizens, security forces, as well as private and public properties for them. The security reality of some administrative units requires a set of important data through which the best solutions are found to preserve these administrative units from terrorist and criminal operations and incidents. Therefore, this research focused on the use of one of the important scientific methods, the DP method, to find the Optimal Allocation (OA) of checkpoints in those administrative units, which hopefully contributes to reducing terrorist attacks, breaches, and other criminal incidents. The researchers used the checklist, which contains many questions that were asked of some civilians and state employees. The results proved to us that the proposed allocation will lead to an increase in the population density in the governorate by about 38 thousand people through the reallocation of checkpoints to administrative units, as some of them need to reduce the number of checkpoints and others need to increase the number of checkpoints. The used program is Excel.

Paper type: Research Paper
Keywords: Dynamic Programming, Optimal Allocation, Checklist

1.Introduction:

In this research, we are going to study the allocation of checkpoints to administrative units in one of the Iraqi governorates, through which the highest percentage of preservation of the population of this governorate is achieved. The allocation problem is considered one of the important problems in the field of operations research, and it is one of the applications of linear programming (Taha, 2011). It is also a special case of the transfer problem, which assists in decision-making. There are several methods and ways to solve the allocation problem, and one of these methods is the DP method, through which the optimal solution is found and the best decision is made where the DP style is considered as one of the most important mathematical methods used in sequential decision-making (Hillier, 7th edition). This method does not have a single model that can be applied to all problems; rather, it relies on breaking down the main problem into smaller problems and finding the optimal solution for each smaller problem. This is the general principle of DP (Al-Ashari, 2008). It is also considered a significant method for solving optimization problems, providing a valuable tool for production planning and optimal decision-making (Batikh.2009). The idea behind DP is to decompose the main problem into sub-problems aimed at finding the optimal value for a single variable. The advantage of decomposition lies in dealing with a single variable only (Taha, 2011). Subsequently, finding the solution and making the optimal decision rely on solving these sub-problems (Abbas, 2018). The DP determines the optimal solution for a multi-variable problem by dividing it into stages, making it much easier mathematically than dealing with all variables simultaneously (Khalaf, 2021). It is suitable for a wide range of engineering problems that exhibit characteristics of intertwined sub-problems. Besides DP is a simple, gradient-free, efficient, and inevitable optimization method that ensures the optimal solution (Can et al., 2012; Mahmoudimehr, 2018). This approach was applied in one of the Iraqi provinces facing numerous criminal, terrorist, and security challenges. The province comprises seventeen administrative units, each with fixed control points that maintain the security of the area. Our effort, using the DP approach, aimed to restructure these control points in the seventeen areas, preserving the lives of the residents in these regions.

1.1 Literature Review:

There have been several studies discussing the DP method and optimal allocation (AO), including:

The study of Og et al. (2014) which addressed the OA of police patrols to prevent crime using DP in Benin City, Nigeria. The research aimed to protect the community and secure the area from crimes such as murder, kidnapping, robbery, and armed robbery. Data were collected from the Nigerian Police Headquarters on crime statistics for eight major routes in Benin City. Ten police patrols were allocated to these routes, and DP resulted in the best probability of crime prevention, reaching 0.0317. This was achieved by assigning five or four patrols to the Oslo route and five or six patrols to the Sable route. This the possibility of a police patrol initiating crime interception is the best value at any guideline method of allocation that has ever deduced.

Ratna et al. (2015) focused on using DP to allocate doctors to health centers. The research goal was to provide the best patient service by allocating ten doctors to three health centers based on visitor (patient) numbers over ten months. The reverse dynamic approach showed optimal allocation, adding one doctor to the first clinic, eight doctors to the second clinic, and one doctor to the third clinic. This allocation would address the needs of 4,418 patients.

Amuji et al. (2017) discussed the benefits of DP in scheduling courses in Nigerian universities. The study addressed challenges faced by lecturers in course allocation, optimizing the allocation of teaching hours to achieve 12 ideal hours for each lecturer per semester.

Abbas (2018) studied the strategic determination of the optimal solution using DP for establishing power stations in Iraq. The critical path method was employed to find the optimal solution for the project completion time using backward DP. The research highlighted the effectiveness of DP in finding the optimal strategy for project completion.

Khalaf (2021) applied DP to maximize the performance of the Iraqi armed forces and determine their optimal paths. The study focused on two strategies: maximizing the performance of the Iraqi armed forces and minimizing the arrival time for optimal paths. DP was used to allocate ten brigades to four border regions, resulting in the optimal assignment of two brigades to the first region, three to the second, four to the third, and one to the fourth, ensuring the best performance.

Jalal et al. (2021) used fuzzy DP to find the optimal solution for sales in a cement manufacturing company. The study, conducted at the Badush Cement Factory, applied both fuzzy logic and DP methods through MATLAB. The integration of fuzzy logic with DP yielded optimal sales volume, providing an opportunity to find ideal solutions.

Hassan (2021) utilized DP to address allocation problems in the Raji Beverage Production Company. The study focused on the allocation problem for a group of beverage companies using DP. The researcher collected machine failure times to calculate the probability of failure for each task. The study revealed that the optimal policy was to allocate tasks based on the first task.

Senthilnathan (2022) used the route determination model (RDM) to minimize the distance from origin to destination, leading to cost reduction and increased company profits. Both forward and backward DP approaches were applied. The results indicated the shortest route from origin to destination as starting from the origin, moving to route 2, then to route 5, and reaching destination D, covering a distance of 110 km, the shortest distance achieved using this method.

The research problem lies in the lack of utilization of scientific and mathematical methods in allocating checkpoints to administrative units, leading to a lack of control over terrorist and criminal incidents in some of these administrative units in the province. This results in the loss of the lives of citizens as well as state personnel and private property. This study aims to employ DP to find the OA of Checkpoints for the main administrative units.

The objective is to maximize security and stability in these administrative units, consequently increasing the survival rates of both citizens and government personnel.

2 .Materials and Methods:

The mathematical approach used in this research is the DP Method, which is considered one of the most important techniques in operations research.

2.1 The Mathematical Principles Essential for Dynamic Programming:

1. The problem to be addressed using DP must be divided into stages, where decisions are made at each stage. For instance, in a multi-period production process determining the optimal batch size for incoming materials, the stages represent different time points (Hillier, 9th edition).
2. Each stage in the problem must have a specified number of state variables associated with it. The state variables at each stage are parameters that capture relevant information at that particular stage (Hillier, 7th edition).
3. The impact of a decision at each stage transforms the current state into a state linked to a future stage. In other words, the decision made at a specific stage affects the state or states of the subsequent stage (Khalaf, 2017).
4. A recursive mathematical relationship must be established to provide the optimal solution for each stage of the problem. This relationship depends on the associated state, meaning that the state of the current stage influences the solution and, consequently, the state of the next stage (Afaq, 2010).

5. For each state and specific stage of the problem, the sequence of optimal decisions relies on the decision made in the preceding stage. This implies that the chosen path for decisions is based on the choices made in previous stages, forming a series of dependent decisions (R. Luus, 2008).
6. DP provides a systematic procedure by working backwards, starting with the final stage of the problem and progressing towards the ultimate solution. Decisions are made for each stage, and problems can also be solved by working forward to reach the final stage (Kupta et al., 2008).
7. The recursive relationship is defined as the optimal policy for stage n, relying on the optimal policy for the subsequent stage (n+1). The recurrence relation for finding the optimal allocation is illustrated below, along with an explanation of the symbols mentioned in the equation (1):

$$f_n^*(s) = \min(c_n\ x_n + \ f_{n+1}^*\ (x_n)) \qquad (1)$$

N = Number of Stages
n = Current Stage (e.g., n = 1, 2, 3,… N)
Sn = Current State at Stage n
Xn = Decision Variable for Stage n
$fn(Sn, Xn)$ = Objective function for Stages ($n, n+1$…, N)
In the case where the system begins with Sn at Stage n

2.1.1 The Advantages of The Dynamic Programming :
For DP, there are several advantages, including (Atikpo et al., 2017; Khalaf, 2021):
a)DP determines the optimal solution for a multi-variable problem by dividing it into stages, with a sub-problem for each stage aiming to find the optimal value for only one variable. The distinctive advantage lies in dealing with a single variable, which is much easier mathematically than handling all variables simultaneously. The model consists of a set of consecutive equations connecting different stages of the original problem in a way that ensures the best possible solution for the original problem, ultimately including all the optimal solutions obtained when solving sub-problems for different stages.
b) It is Perfectly Suitable for Multi-Stage, Multi-Point, or Sequential decision-making processes.
c)It is suitable for linear or non-linear problems, discrete or continuous variables, deterministic, and probabilistic problems.
d) DP attempts to exploit properties (optimal substructure and overlapping sub-problems) to provide a more reasonable solution than heuristic and trial-and-error solutions.

2.1.2 The Principle of Optimization:
• The optimality principle states that the optimal policy has the property that, regardless of the initial state and the initial decision, the remaining decisions must form an optimal policy concerning the state resulting from the initial decision (Bellman, 1972).
• This principle means that a wrong decision made at some stages does not prevent the optimal decision-making for subsequent stages. This principle is the fundamental basis for the DP technique. In light of this, we can formulate the recursive relationship, enabling us to make optimal decisions at each stage (Murthy, 2007).
• The Optimality Principle does not delve into the details of how to improve the sub-problem, and the reason is the general nature of the sub-problem. It can be linear or nonlinear, and the number of alternatives can be limited or unlimited. The optimality principle works to decompose the original problem into more computationally manageable sub-problems (Taha, 2017).

2.1.3Assumptions of Dynamic Programming :
Here are the assumptions of DP (Amuji et al., 2022):
1. The optimal decision in the future stage is independent of the optimal decision in the previous stage.
2. The optimal solution contains optimal sub-solutions.

3. The Problem has overlapping sub-problems. Through the recursive relationship, we can find the optimal solution if the problem has an ideal sub-structure. If the problem involves overlapping sub-problems, we can calculate each sub problem only once through recursive execution.
These three conditions are necessary and sufficient for the application of DP.

2.1.4 Methods of Dynamic Programming Solution

There are two methods to find the OA in DP, (Taha, 2007; Naji, 2011; Khalaf, 2017):

1- Forward Computation Method:

This method relies on the values of the functions arranged in ascending order. The recursive equation is first used to calculate the value of the initial function, denoted as F (1), in the first stage, subsequently, F (2) is calculated in the second stage. This process continues, computing the functions one after another until reaching the function F (N), which represents the final function of the recursive equation. This method is known as "Forward Computation," as illustrated in the equations (2, 3 and 4) as follows:

$$fn(sn, xn) = cn(xn) + f^*_{n-1}(xn) \qquad (2)$$

$$f^*_n(s_n) = max_{xn=0,1,\ldots sn}\{c_n(x_n) + f^*_{n-1}(s_n - x_n)\} \qquad (3)$$

OR

$$f^*_n(s_n) = min_{xn=0,1,\ldots sn}\{c_n(x_n) + f^*_{n-1}(s_n - x_n)\} \qquad (4)$$

2- Backward Computation Method:

The second method involves solving recursive equations by computing the values of functions F (i) in a manner opposite to the first method, arranging the functions in descending order. In this approach, the recursive equation is used to find the return value for the final stage, N. Then, a step-by-step descent is performed using the same recursive equation to find the return values for the other stages until reaching the initial stage. This method is known as "Backward Computation," and it can be illustrated in the equations (5, 6 and 7) as follows:

$$fn(sn, xn) = cn(xn) + f^*_{n+1}(xn) \qquad (5)$$

$$f^*_n(s_n) = max_{xn=0,1,\ldots sn}\{c_n(x_n) + f^*_{n+1}(s_n - x_n)\} \qquad (6)$$

OR

$$f^*_n = min_{xn=0,1,\ldots sn}\{c_n(x_n) + f^*_{n+1}(s_n - x_n)\} \qquad (7)$$

Forward and backward recursion relationship for the last stage will always be of the form:

$$f^*_n(s_n) = max_{xn=0,1,\ldots sn} f_n(s_n, x_n) \qquad (8)$$

OR

$$f^*_n(s_n) = min_{xn=0,1,\ldots.sn} f_n(s_n, x_n) \qquad (9)$$

In This study, the backward computation method of DP was employed to obtain the optimal solution.

2.2 Data Collection Method:

After obtaining the population density for each administrative unit from the statistics department in this province, a checklist was used. This checklist included numerous important questions posed during personal interviews with citizens and government employees, both civilian and military. The answers were obtained and analysed. Table 1 illustrates the checklist and the questions posed in it.

Table1 : The Checklist and the Questions Posed

NO	Phrases	Fully documented Fully applied	Partially documented Fully applied	Undocumented Fully applied	Fully documented Partially applied	Partially documented Partially applied	Undocumented Partially applied	Undocumented Not applicable
		6	5	4	3	2	1	0
1	Checkpoints contribute to providing security to the region		√					
2	Checkpoints seek to increase police security capacity		√					
3	Checkpoints are intended to protect from terrorist attacks		√					
4	The security capacity of citizens increases by increasing the number of checkpoints	√						
5	Checkpoints reduce the free movement of people dangerous to public security	√						
6	Checkpoints reduce the crime rate		√					
7	Checkpoints contribute to the provision of security for the movement of goods and trade		√					
8	Checkpoints reduce the speed of movement of goods from one place to another				√			

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9	Checkpoints contribute to the movement of cars in other ways to avoid traffic density				√			
10	Checkpoints operate to provide routes for emergency vehicles and ambulances		√					
11	Checkpoints contribute to increased traffic control		√					
12	Checkpoints contribute to reducing the occurrence of violations			√				
13	Checkpoints contribute to reducing accidents.			√				
14	Checkpoints contribute to the protection of employees while performing their work.	√						
15	Checkpoints serve to provide the right environment for All Society.	√						

3.1 The analysis of the checklists:

Table 2 shows the analysis of the checklist that has been analyzed.

Table 2: The analysis of the checklist

NO	Phrases	Fully applied	Fully applied	Fully applied	Partially applied	Partially applied	Partially applied	Not applicable
		Fully documented	Partially documented	Undocumented	Fully documented	Partially documented	Undocumented	Undocumented
1	Duplicate	23	35	7	2	4	4	0
2	Weights	6	5	4	3	2	1	0
3	Total	138	175	28	6	8	4	0
4	Mean = sum (frequency * weight) / sum of frequencies	4.786						
5	Percentage = Mean / Highest Score on the Scale	0.7977						

The source: Prepared by the researchers based on the Excel program

Depending on the percentage and population density, we can use DP to find the best allocation, which achieves the preservation of the largest number of lives of the inhabitants of this province, for example, when allocating one checkpoint, the percentage in administrative unit 1 is 0.7977 and depending on the population of this area, which is approximately 42030 people, the percentage is multiplied by the population density (0.7977* 52685= 42030), that is, the checkpoint will keep about 42 thousand people from the population of this administrative unit, which will prevent the entry of cars. This is except for the role of intelligent and national security, as well as the points of mobile inspection and patrols in the area and the cooperation of the community with the security forces, which is one of the essential elements for the preservation of the area. When allocating two checkpoints, the percentage will be 0.83109, and when multiplied by its population, it will maintain approximately 43786 (0.83109* 52685 = 43786). These results above represent Administrative Unit No. 1, but in other administrative units, the table below shows the results when allocating checkpoints in all administrative units, which are 17 administrative units, where the same formula was used above in administrative unit No. 1 and the population of administrative unit No. 2 (32108), No. 3 (138747), No. 4 (91486), No. 5 (155416), No. 6 (44435), and No. 7 (207464), No. 8 (68109), No. 9 (215737), No. 10 (80715), No. 11 (55943), No. 12 (260875), No. 13 (20838), No. 14 (77521), No. 15 (94014), and No. 16 (124661). The last administrative unit has a population of (92068) and table 3 shows that.

Table 3: Population figures for each administrative unit are maintained when allocating checkpoint scores.

Areas \ Control	1	2	3	4	5	6	7	8	9	10	11	12
1	42030	43786	43786	43786	43786	43786	43786	43786	43786	43786	43786	43786
2	25258	26185	26185	26185	26185	26185	26185	26185	26185	26185	26185	26185
3	56731	96505	113462	119322	119322	119322	119322	119322	119322	119322	119322	119322
4	34967	72171	75424	77863	77863	77863	77863	77863	77863	77863	77863	77863
5	38680	55250	101191	115352	128477	128477	128477	128477	128477	128477	128477	128477
6	12145	22908	35548	36732	36732	36732	36732	36732	36732	36732	36732	36732
7	78372	166662	167814	169805	173785	173785	173785	173785	173785	173785	173785	173785
8	26483	54184	55996	57967	57967	57967	57967	57967	57967	57967	57967	57967
9	33079	80060	112661	147657	161561	169713	188888	188888	188888	188888	188888	188888
10	26186	43226	66544	68696	68696	68696	68696	68696	68696	68696	68696	68696
11	44256	45873	47738	47738	47738	47738	47738	47738	47738	47738	47738	47738
12	27244	50435	85797	126959	182612	200004	218552	218552	218552	218552	218552	218552
13	16253	16531	16809	16809	16809	16809	16809	16809	16809	16809	16809	16809
14	15847	41171	61326	62869	64600	66151	66797	66797	66797	66797	66797	66797
15	21518	35505	50140	76245	79379	80225	80225	80225	80225	80225	80225	80225
16	53741	98066	104160	107761	107761	107761	107761	107761	107761	107761	107761	107761
17	21072	40714	75699	77745	77745	77745	77745	77745	77745	77745	77745	77745

27	26	25	24	23	22	21	20	19	18	17	16	15	14	13
43786	43786	43786	43786	43786	43786	43786	43786	43786	43786	43786	43786	43786	43786	43786
26185	26185	26185	26185	26185	26185	26185	26185	26185	26185	26185	26185	26185	26185	26185
119322	119322	119322	119322	119322	119322	119322	119322	119322	119322	119322	119322	119322	119322	119322
77863	77863	77863	77863	77863	77863	77863	77863	77863	77863	77863	77863	77863	77863	77863
128477	128477	128477	128477	128477	128477	128477	128477	128477	128477	128477	128477	128477	128477	128477
36732	36732	36732	36732	36732	36732	36732	36732	36732	36732	36732	36732	36732	36732	36732
173785	173785	173785	173785	173785	173785	173785	173785	173785	173785	173785	173785	173785	173785	173785
57967	57967	57967	57967	57967	57967	57967	57967	57967	57967	57967	57967	57967	57967	57967
188888	188888	188888	188888	188888	188888	188888	188888	188888	188888	188888	188888	188888	188888	188888
68696	68696	68696	68696	68696	68696	68696	68696	68696	68696	68696	68696	68696	68696	68696
47738	47738	47738	47738	47738	47738	47738	47738	47738	47738	47738	47738	47738	47738	47738
218552	218552	218552	218552	218552	218552	218552	218552	218552	218552	218552	218552	218552	218552	218552
16809	16809	16809	16809	16809	16809	16809	16809	16809	16809	16809	16809	16809	16809	16809
66797	66797	66797	66797	66797	66797	66797	66797	66797	66797	66797	66797	66797	66797	66797
80225	80225	80225	80225	80225	80225	80225	80225	80225	80225	80225	80225	80225	80225	80225
107761	107761	107761	107761	107761	107761	107761	107761	107761	107761	107761	107761	107761	107761	107761
77745	77745	77745	77745	77745	77745	77745	77745	77745	77745	77745	77745	77745	77745	77745

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41	40	39	38	37	36	35	34	33	32	31	30	29	28
43786	43786	43786	43786	43786	43786	43786	43786	43786	43786	43786	43786	43786	43786
26185	26185	26185	26185	26185	26185	26185	26185	26185	26185	26185	26185	26185	26185
119322	119322	119322	119322	119322	119322	119322	119322	119322	119322	119322	119322	119322	119322
77863	77863	77863	77863	77863	77863	77863	77863	77863	77863	77863	77863	77863	77863
128477	128477	128477	128477	128477	128477	128477	128477	128477	128477	128477	128477	128477	128477
36732	36732	36732	36732	36732	36732	36732	36732	36732	36732	36732	36732	36732	36732
173785	173785	173785	173785	173785	173785	173785	173785	173785	173785	173785	173785	173785	173785
57967	57967	57967	57967	57967	57967	57967	57967	57967	57967	57967	57967	57967	57967
188888	188888	188888	188888	188888	188888	188888	188888	188888	188888	188888	188888	188888	188888
68696	68696	68696	68696	68696	68696	68696	68696	68696	68696	68696	68696	68696	68696
47738	47738	47738	47738	47738	47738	47738	47738	47738	47738	47738	47738	47738	47738
218552	218552	218552	218552	218552	218552	218552	218552	218552	218552	218552	218552	218552	218552
16809	16809	16809	16809	16809	16809	16809	16809	16809	16809	16809	16809	16809	16809
66797	66797	66797	66797	66797	66797	66797	66797	66797	66797	66797	66797	66797	66797
80225	80225	80225	80225	80225	80225	80225	80225	80225	80225	80225	80225	80225	80225
107761	107761	107761	107761	107761	107761	107761	107761	107761	107761	107761	107761	107761	107761
77745	77745	77745	77745	77745	77745	77745	77745	77745	77745	77745	77745	77745	77745

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42	43786	26185	119322	77863	128477	36732	173785	57967	188888	68696	47738	218552	16809	66797	80225	107761	77745
43	43786	26185	119322	77863	128477	36732	173785	57967	188888	68696	47738	218552	16809	66797	80225	107761	77745
44	43786	26185	119322	77863	128477	36732	173785	57967	188888	68696	47738	218552	16809	66797	80225	107761	77745
45	43786	26185	119322	77863	128477	36732	173785	57967	188888	68696	47738	218552	16809	66797	80225	107761	77745
46	43786	26185	119322	77863	128477	36732	173785	57967	188888	68696	47738	218552	16809	66797	80225	107761	77745
47	43786	26185	119322	77863	128477	36732	173785	57967	188888	68696	47738	218552	16809	66797	80225	107761	77745
48	43786	26185	119322	77863	128477	36732	173785	57967	188888	68696	47738	218552	16809	66797	80225	107761	77745
49	43786	26185	119322	77863	128477	36732	173785	57967	188888	68696	47738	218552	16809	66797	80225	107761	77745
50	43786	26185	119322	77863	128477	36732	173785	57967	188888	68696	47738	218552	16809	66797	80225	107761	77745

3.2 DP model to find the OA for Checkpoints:

After applying Equation 8, the results of the last stage were obtained. While when applying Equation 6, the results of the other stages were obtained

Stage 17

Table 4: Represents checkpoints that have been designated to maintain the highest population

s_{17}	$f^*_{17}(s_{17})$	x^*_{17}
1	21072	1
2	40714	2
3	75699	3
4	77745	4
5	77745	5
6	77745	6
7	77745	7
8	77745	8
9	77745	9
10	77745	10
11	77745	11
.	.	.
.	.	.
.	.	.
.	.	.
.	.	.
.	.	.
.	.	.
.	.	.
.	.	.
..	.	.
.	.	.
.	.	.
50	77745	50

Stage 16

Table 5: Represents checkpoints that have been designated to maintain the highest population.

X16 / S16	$f_{16}(s_{16}, x_{16}) = max\ c_{16}(x_{16}) + f^*_{17}(s_{16} - x_{16})$								$f_{16}(s_{16})$	x^*_{16}
	1	2	3	4	5	.	.	50		
1	53741					.	.	.	53741	1
2	74813	98066				.	.	.	98066	2
3	94455	119138	104160			.	.	.	119138	2
4	129440	138780	125232	107761		.	.	.	138780	2
5	131486	173765	144874	128833	107761	.	.	.	173765	2
6	131486	175811	179859	148475	128833	.	.	.	179859	3
7	131486	175811	181905	183460	148475	.	.	.	183460	4
8	131486	175811	181905	185506	183460	.	.	.	185506	4
9	131486	175811	181905	185506	185506	.	.	.	185506	4,5
.	.	.	.	.	.	.	.	.	.	
.	.	.	.	.	.	.	.	.	.	
50	131486	175811	181905	185506	185506	.	.	107761	185506	$4 to 46$

Thus, the application of Equation 6continues until Stage 1 is reached.

Stage1

Table6: Represents checkpoints that have been designated to maintain the highest population.

$$f_1(s_1, x_1) = max\ \{c_1(x_1) + f_2^*(s_1 - x_1)\}$$

$X1$ \ $S1$	1	2	3	4	5	.	.	50	f_1^*	x_1^*
50	1483621	1472737	1461974	1448849	1434688	.	.	43786	1483621	1

The results revealed the allocation in this province is as illustrated below:

$S_1 = 50,\quad X_1 * = 1 \longleftrightarrow S_2 = 50 - 1 = 49,\quad X_2 * = 1$

$S_3 = 49 - 1 = 48,\quad X_3 * = 3 \longleftrightarrow S_4 = 48 - 3 = 45,\quad X_4 * = 2$

$S_5 = 45 - 2 = 43,\quad X_5 * = 5 \longleftrightarrow S_6 = 43 - 5 = 38,\quad X_6 * = 3$

$S_7 = 38 - 3 = 35,\quad X_7 * = 2 \longleftrightarrow S_8 = 35 - 2 = 33,\quad X_8 * = 2$

$S_9 = 33 - 2 = 31,\quad X_9 * = 7 \longleftrightarrow S_{10} = 31 - 7 = 24,\quad X_{10} * = 3$

$S_{11} = 24 - 3 = 21,\quad X_{11} * = 1 \longleftrightarrow S_{12} = 21 - 1 = 20,\quad X_{12} * = 7$

$S_{13} = 20 - 7 = 13,\quad X_{13} * = 1 \longleftrightarrow S_{14} = 13 - 1 = 12,\quad X_{14} * = 3$

$S_{15} = 12 - 3 = 9,\quad X_{15} * = 4 \longleftrightarrow S_{16} = 9 - 4 = 5,\quad X_{16} * = 2$

$S_{17} = 5 - 2 = 3,\ X_{17} * = 3$

Table 7: Represents the administrative units and the number of checkpoints allocated to each administrative unit.

Administrative Units	Number of Designated Checkpoints
1	1
2	1
3	3
4	2
5	5
6	3
7	2
8	2
9	7
10	3
11	1
12	7
13	1
14	3
15	4
16	2
17	3

From the above results, it is evident that some areas had checkpoints added, while others had a reduction in checkpoints. In region number 5, a checkpoint was added, replacing the previous allocation of 4 checkpoints, and now there are 5 checkpoints assigned. This leads to an increase in the population of this administrative unit to the maximum possible. In Administrative Unit Number 9, one checkpoint was added, and in Administrative Unit Number 12, two checkpoints were added, contributing to the preservation of the population in these administrative units. As for the administrative units where checkpoints were removed and their numbers were minimized, the reason is that the presence of these additional checkpoints caused hindrances to the residents of these areas, an increase in traffic congestion, and disruptions to the transportation of commercial goods. Therefore, what we must do is ensure the well-being of the residents in these areas in terms of security, traffic flow, commerce, tourism, and similar aspects. Furthermore, reducing the checkpoints from 58 to 50 signifies a reduction in the costs incurred for each checkpoint, including salaries for personnel, officers, weapons, vehicles, and electrical devices. All of these constitute expenses for the state, it is therefore necessary to consider all conditions. Thus, our primary goal is to preserve the largest possible number of residents in these areas.

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4. Conclusions:

Based on the obtained results, we can conclude that the DP approach is a significant and highly useful mathematical method for obtaining a series of interconnected decisions and finding optimal allocations for checkpoints in this province. This has led to an increase in the preservation of the population in this province, where the city's population has grown to approximately 38,000. This is considered a positive outcome, in addition to reducing the number of checkpoints from 58 to 50. Each checkpoint has its associated costs, including weapons, soldiers, officers, and specific vehicles to each control point. Furthermore, there has been an effort to minimize traffic congestion in these areas as much as possible.

Authors Declaration:

Conflicts of Interest: None

-We Hereby Confirm That All The Figures and Tables In The Manuscript Are Mine and Ours. Besides, The Figures and Images, Which are Not Mine, Have Been Permitted Republication and Attached to The Manuscript.

- Ethical Clearance: The Research Was Approved By The Local Ethical Committee in The University.

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إيجاد التخصيص الأمثل لنقاط التفتيش باستخدام طريقة البرمجة الديناميكية

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مستخلص البحث:
يهدف هذا البحث الى استخدام اسلوب رياضي كفوء يمكن من خلاله ايجاد افضل تخصيص لنقاط التفتيش الرئيسية في احدى المحافظات العراقية والتي تحتوي على 17 وحدة ادارية حيث تم استخدام اسلوب البرمجة الديناميكية وطريقة الحسابات الخلفية لهذا الاسلوب . تكمن مشكلة البحث على انه هنالك العديد من الوحدات الادارية في هذه المحافظة تتعرض لهجمات منظمة من قبل العصابات الارهابية والتي تؤدي الى فقدان حياة العديد من المواطنين والقوات الامنية اضافة الى الممتلكات الخاصة والممتلكات العامة لهم . فالواقع الأمني لبعض الوحدات الادارية يحتاج الى مجموعة من البيانات المهمة التي من خلالها يتم ايجاد افضل الحلول للحفاظ على هذه الوحدات الادارية من العمليات والحوادث الارهابية والجنائية .لذلك ركز هذا البحث على استعمال احد الاساليب العلمية المهمة وهو اسلوب البرمجة الديناميكية لأيجاد التخصيص الامثل لنقاط التفتيش في تلك الوحدات الادارية والتي من المؤمل تساهم في تقليل الهجمات الارهابية والاختراقات والحوادث الجنائية الاخرى . استعمل الباحث قائمة الفحص والتي تحتوي على العديد من الاسئلة والتي تم طرحها على بعض الاشخاص المدنيين وموظفي الدولة . اثبتت لنا النتائج ان التخصيص المقترح سيؤدي الى زيادة الكثافة السكانية بالمحافظة بحوالي 38 الف نسمة وذلك من خلال اعادة تخصيص نقاط التفتيش على الوحدات الادارية حيث ان بعضها يحتاج الى تقليل عدد نقاط التفتيش والبعض الاخر يحتاج الى زيادة عدد نقاط التفتيش.

نوع البحث: ورقة بحثية .
المصطلحات الرئيسة للبحث: البرمجة الديناميكية , التخصيص الامثل , قائمة الفحص