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RESEARCH ARTICLE

Multicriteria Decision Model to Support the Evaluation of Common Jurisdiction Violence in the Capital Cities of the States of Mexico

JUAN CARLOS LEYVA LÓPEZ¹, SILVESTRE FLORES GAMBOA², EFRAIN SOLARES³, MARTÍN LEÓN SANTIESTEBAN¹, RAYMUNDO DÍAZ⁴, AND ABRIL FLORES³

¹Department of Economic and Management Sciences, Universidad Autónoma de Occidente, Culiacán 80020, Mexico

²School of Tourism, Universidad Autónoma de Sinaloa, Mazatlán 82100, Mexico

³Facultad de Contaduría y Administración, Universidad Autónoma de Coahuila, Torreón 27000, Mexico

⁴Tecnológico de Monterrey, Monterrey 64849, Mexico

Corresponding author: Juan Carlos Leyva López (juan.leyva@uadeo.mx)

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ABSTRACT The capital cities of the states of the Mexican Republic present a considerable heterogeneity in terms of their level of public security, so their correct characterization is an essential requirement, but not sufficient, for the elaboration of public policies for the prevention of crimes in the common jurisdiction. In this paper, we propose a multicriteria decision model based on the hierarchical ELECTRE III method that assists in how a policy maker can carry out this task. The objective of the work is to measure and compare the incidence of crimes of common jurisdiction in the capital cities of the states of the Mexican Republic. This model compares public security in 31 capital cities, adapting the situation as a multicriteria ranking problem to order the different capitals by their level of public security. The results showed that the model could identify the level of comprehensive public security of a capital city compared to the rest. Similarly, it also shows the disparities of this phenomenon between capital cities in relation to high, medium and low impact crimes.

INDEX TERMS Multicriteria decision analysis, public policies, state capitals cities, crimes of common jurisdiction, hierarchical ELECTRE III method.

I. INTRODUCTION

Common law crimes are understood to be those that directly affect people, that is, crimes in which the effect of the offense falls solely on the person affected by the offender's conduct. The state and municipal police ensure that they prevent and address this type of crime.

The territorial organization of Mexico is defined as a federal state governed in the form of a republic. It is divided into 31 states, where the offices of the state's central government are capital cities and urban centers with strong economic, administrative, social, and cultural components. Each of these capital cities has a different history. Their sociodemographic

profile, economic potential, and institutional capacities related to public security differ [1]. However, they share common characteristics, and all suffer to a greater or lesser extent from the scourge of insecurity and violence.

According to [2], "violence has worsened in Mexico in the last decade, and it is currently pervasive in most urban areas" and near the US border [3]. As a result, the year 2020 continued to record a high rate of criminal incidence in the national territory (1,841,188 common law crimes), particularly the increase in intentional homicides (28,830), which have spread to most of the country, resulting in 22.56 deaths for every 100 thousand inhabitants. However, the problem is more concentrated in some states than in the rest of the states; therefore, the Federal Government has identified the most violent territories that concentrate the highest number of murders registered that year [4].

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Measuring and comparing the incidence of common jurisdiction crimes in the capital cities of the states of the Mexican Republic is a complex issue because each capital city needs to be assessed in multiple dimensions or objectives (e.g., strengthening the level of public security in capital cities, increase the level of crime prevention, maximize the use of resources, reduce the response time of security forces, overcome structural and normative restrictions, etc.). On the other hand, the condition of a city is dynamic because the operational circumstances of the crimes might vary, consequently altering the evaluation features; for example, the weight (or relative importance) of each dimension may change over time. For these and other reasons, the dynamism and complexity of common jurisdiction crimes in the capital cities of the Mexican states require that policy makers (PMs) make carefully planned decisions. In this sense, [5] explores the use of a spatio-temporal dashboard to study the crime rate in a Mexican state. In addition, [6] provides a set of policing strategies as a function of criminal complaints in the Brazilian context.

The evaluation of the incidence of common jurisdiction crimes in the capital cities of Mexico is an essential activity in the planning of public security, not only because 17.9 percent of the total population of Mexico resides there, but also because they use a considerable amount of human, economic, and technical resources [7]. Moreover, public security and crime victimization have a direct impact on the quality of life of the population [8], [9], [10]. Due to the magnitude of the problem, there is a need to develop formal procedures for deciding what relative level of public security capital cities have, and what public security planning strategy is best suited for the three levels of government to use in order to achieve their goals [11]. Hence, the central questions of this paper are: how can all the dimensions (seen as decision criteria) be integrated into a model or procedure to assess the relative level of public security in a capital city? What model can policy makers use to establish the best ranking of the capital cities that reflects their relative level of public security and symbolizes the government goals? Which capital cities of the Mexican Republic are the safest and which are the most insecure? Furthermore, what are the dimensions that explain its location in the national ranking?

Only a few specialists have addressed the problem of evaluating the incidence of crime in a set of cities using a multicriteria approach (e.g., [6], [12], [13]). Instead, most have focused on identifying the factors that influence public insecurity in a city and their level of impact using a multidimensional statistical method (e.g., [14], [15], [16]). Among these works, some tend to assess the performance of various factors or schemes through a cost function, this function merges several measures that influence the public security in a city [17]. For example, costs could be calculated according to the perspectives of the victims, government, and society, such as lost productivity, pain and suffering, medical expenses, and the criminal justice system being integrated

into cost models [18]. Other researchers evaluate the public security in a city by examining various factors independently, where a specific analysis is performed, factor by factor; for example, crimes such as robbery or homicide, or comparing crime rates between two or more cities [19].

We can observe that the previous approaches do not include all the necessary aspects to evaluate and compare the incidence of common jurisdiction crimes in a group of cities. Note that this problem combines multiple objectives or criteria, some of them in conflict with each other; moreover, goals cannot always be stated in terms of value or utility merged into a value or utility function. Furthermore, occasionally representing an objective in a value or utility criterion can produce a loss of information, especially when it is difficult to measure the consequences of the value or utility (the words factors, attributes, objectives, and criteria are used interchangeably in this paper).

It is difficult to assess the incidence of common jurisdiction crimes in a group of cities by comparing several criteria simultaneously. Consequently, it is crucial to build a procedure that allows a complete evaluation among capital cities. This evaluation must include all the criteria, regardless of the incommensurability between some criteria. Furthermore, the evaluation method must consider the rationality of policy makers, since this procedure implies representing the goals and changes of government at the different levels of government; in this way, the evaluation procedure should elicit the preferences of a certain policy maker in a particular situation.

The problem of ranking the capital cities by their level of public security can be addressed with Multicriteria Decision Analysis (MCDA) methods. Traditionally, the approach to decision-making problems has been carried out mainly with methods based on a single dimension. Given the occurrence of increasingly complex problems, multidimensional approaches have emerged to address these types of problems in a more realistic way. MCDA methods are one of the approaches to address this type of problem [20]. The purpose and scope of MCDA is to support decision makers in solving these types of problems [21], [22].

Multicriteria-based methods have been widely applied to many real-world decision problems including agriculture, environment, finance, education, project selection, personnel, and services. However, as far as we know, the multicriteria approach has not yet been applied to address how to rank the capital cities per their level of public security.

This work aims to recommend an evaluation support model based on a multicriteria approach that determines the best ranking of the capital cities for their level of public security according to the features of each city. The model is presented as an instrument of the public organization that offers an efficient procedure that adds value to the evaluation process. The tool performs a pairwise comparison between a set of capital cities considering all the criteria involved in the evaluation process.

The multicriteria decision analysis tool used to carry out the evaluation and final ranking of the capital cities is the hierarchical ELECTRE III (*h*-ELECTRE III) method [23], [24], which through its criteria hierarchy, outranking, and preference and indifference thresholds concepts make it an acceptable way to be used in situations such as those presented in the study. It should be noted that for the exploitation of the comprehensive fuzzy outranking relation and the partial fuzzy outranking relations related to non-elementary criteria, a multiobjective evolutionary algorithm (MOEA) was used [20], [25]. The result of this MOEA is a ranking (a total preorder of classes of alternatives) of the 31 capital cities with the best public security in decreasing order of evaluation. The study analyzed data generated from the 2020 annual cut-off, available in the databases of the Executive Secretariat of the National Public Security System (SESNSP) and the National Institute of Statistics and Geography (INEGI).

The work is divided into seven additional sections to this one. The second section presents material and methods and incorporates the procedure for designing the decision model. The following section describes the steps to build the multicriteria decision aiding model. The fourth section presents the inter-criterion evaluation and the model presentation. The fifth section presents the results and discussion in the context of the multicriteria ranking problem. The sixth section illustrates the sensibility analysis. The seventh section presents the analysis and discussion of the results in the context of the public security problem. Finally, in the eighth section, the conclusions and potential future work are presented.

II. MATERIALS AND METHODS

In this section, we apply a process for solving problems and building multicriteria decision models improved by [26]. This procedure is based on Simons’s decision-making process model, applying the successive refinement technique [27] to resolve MCDA problems. In the subsequent refinement technique, the analyst can return, at any step, from one step back to any other previous step as many times as necessary. This return may or may not indicate the adjustment of successive steps. This succession of actions consists of a recursive procedure, and the return makes it possible to improve the process with better results for the entire process. The system for building multicriteria models is shown in Fig. 1.

The procedure used in this work consists of three main phases. First, a preliminary stage is operated, in which the main elements of the MCDA problem are addressed, and the Problem Structuring Methods (PSM) [28] are applied to structure the problem. Using the PSM, the analyst has the adequate support to organize the information from the actors of the decision process. It comprises of the following actions: (i) Identify the PMs, involving an explanation of who and how many they are; (ii) Determine the objectives; (iii) Based on the objectives settled in (ii), describe measurable, operational and understandable criteria; (iv) Distinguish the multicriteria decision problem (choice, sorting, ranking) and define the set of alternatives, and (v) Detect the existing

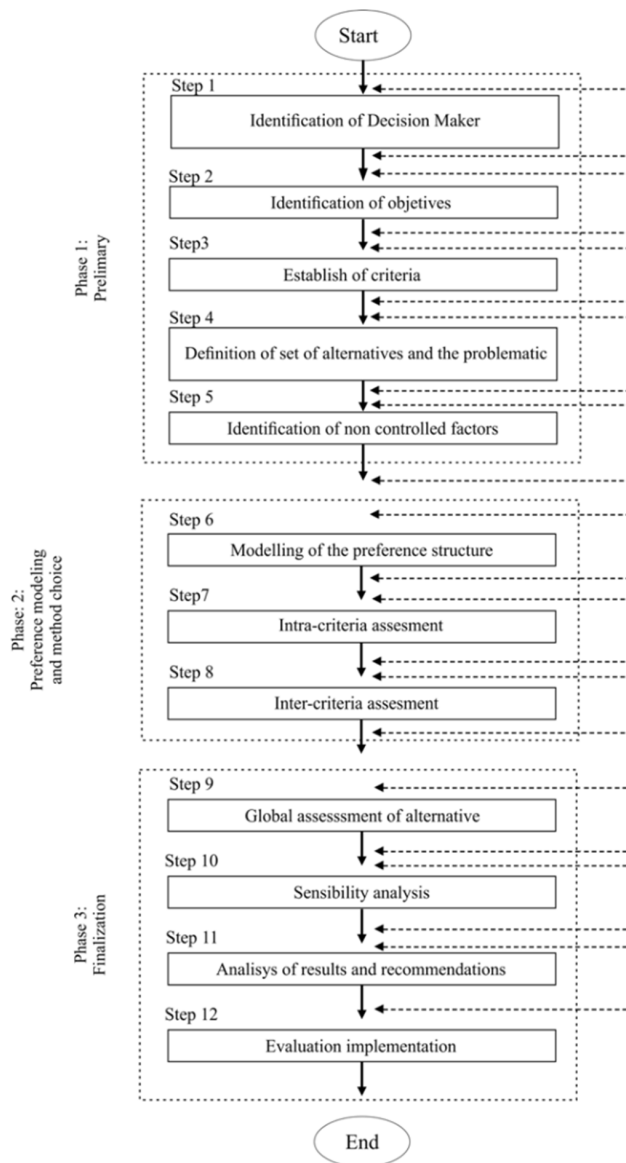


FIGURE 1. Phases and steps for the design of a multicriteria decision model. (Adjusted from [26]).

factors in the multicriteria decision problem that are not under the control of the PMs, and remove them from the design of the multicriteria model.

Preference modeling is conducted in the second phase, and the MCDA method is chosen. It includes (i) building the preference structure based on what the PM wants. Here an appropriate multicriteria decision method for the circumstances must be identified. Then, (ii) there is an intracriteria assessment, and (iii) an inter-criteria assessment. At the end of the second phase, the multicriteria decision model is prepared to be used in the third phase. This is a flexible phase in that the three steps of this phase may be done almost simultaneously, exploring a richer insight process. The output of this phase is an already built MCDA model, which serves as the third phase’s entry.

In the third phase, the choice and implementation stages are managed for the final solution of the problem. It begins by (i) evaluating the alternatives utilizing the multicriteria method selected in the second phase. Then, (ii) the constructed model is examined via a sensibility analysis of some significant parameters. To close, (iii) the conclusions based on the results obtained are presented and discussed. Subsequently, suggestions can be made that provide a firm basis for public policy formulation. Finally, it should be considered that it is still feasible to go back and make improvements and modifications to the built model.

III. BUILDING OF THE EVALUATION MODEL

This section presents the essential components related to building the model, which is specified in more detail in the previous section.

A. DESCRIPTION OF THE POLICY MAKER AND OTHER ACTORS

Participation in evaluation is in line with the common principle of active participation of key stakeholders as fundamental to good evaluation practice. The main stakeholders may involve public decision makers, technical evaluators, direct and indirect beneficiaries involved in the public policy under evaluation and representatives of the community [29]. In this work, the decision-making scenario is the capital cities of the states of Mexico, where the public security authority of state and federal governments (State and Federal Secretaries of Public Security) is the main policy maker (PM). The design and implementation of the best tactical security strategies depend on them, and that capital cities have the best level of public security possible. In real operations, the State and Federal Secretaries of Public Security have a team of collaborators in the chain of command that provides them with valuable information for more informed decision-making. Thus, other actors are interconnected to the crime prevention activity in the common jurisdiction. These actors are technical specialists, stakeholders, and analysts. Multicriteria Evaluation Methods aim to recreate the different dimensions of the decision-making problem and the different opinions of the various actors [30].

B. IDENTIFYING OBJECTIVES AND THEIR STRUCTURE

Value-Focused Thinking (VFT) methodology [31] was used to structure the insecurity problem in Mexico's state capital cities. The VFT is a multicriteria methodology used to determine how values can improve decision-making. Per this method, it is crucial to establish the values to understand their relations and roles and make their uses easy. Then, structuring values and developing objectives aids a more profound and precise understanding of what decision makers care about in a specified decision context.

According to [31], an objective is the statement of something one wants to achieve. It is described by three distinct elements: decision context, object, and direction of preference. The VFT constructs an objective hierarchical structure

into three primary levels: strategic, fundamental, and means-end objectives [32], [33].

The VFT methodology can be divided into six stages. Here we explain step by step how it was applied to the insecurity problem in Mexico's state capital cities. For that, it was necessary to meet five times with the policy maker. This methodology was used for six months due to the schedule of the policy maker.

1st Stage: Semi-Structured Interviews:

For the application of the VFT methodology, a set of semi-structured interviews was designed. Each interview was designed considering the information we wanted to elicit from the decision maker. The first interview was related to the context of the problem. The application took approximately an hour and a half due to the extension and depth. The subsequent interviews were to validate previous information and obtain new ones generated in tasks done by the policy maker or us, which agreed on each meeting.

2nd Stage: Structuring of the Problem of the Insecurity Problem in Mexico's State Capital Cities:

This section presents the problem more directly and shows how the situation was structured by applying the VFT methodology.

Problem description: During the interview with the policy maker, some interrelated problems were identified. Violence has worsened in Mexico in the last twenty years and is currently pervasive in most urban areas. To such a degree that for the last few years, there has been a high rate of criminal incidence in the national territory. Nevertheless, the problem is focused more on some states of the Mexican republic.

According to the policy maker, measuring and comparing the incidence of crimes in common jurisdictions in the states' capital cities is complex because each capital city needs to be assessed in multiple dimensions.

The capital cities are settled by the 17.9 percent of the total population of Mexico, and these cities are conformed by a considerable volume of human, economic, and technical resources; however, the population's quality of life of these cities is affected by public insecurity.

Due to the magnitude of the public insecurity problem in the capital cities, the policy maker is interested in knowing the relative level of general insecurity that capital cities have, at least concerning the crimes of common jurisdictions. This would help identify the capital cities where there is greater public insecurity and work on designing public policies that help reduce the insecurity problem.

3rd Stage: Identifying and Structuring Objectives:

This stage corresponds to analyzing the obtained information in the second stage to identify and define the policy maker's objectives related to the problem. Here, we identified the fundamental and means-end objectives. Then, we verified their redundancy and relationship to generate a list. After the analysis, we eliminate redundantly and create a hierarchy of primary objectives. This hierarchy was handed over to the policy maker for analysis, modification, or acceptance.

Once we accept the set of objectives and its hierarchy, we define each objective's orientation, maximizing or minimizing. Fig. 2 shows the structure of the objectives based on the VFT approach for the case study.

4th Stage: *Measuring the Achievement of Objectives:*

From the previous stage, the policy maker set that the overall strategic objective in preventing crimes of the common jurisdiction in the capital cities of Mexico is to rank order the capital cities by their relative level of violence in the common jurisdiction. This strategic objective was divided into two fundamental objectives -strengthening the level of public security in capital cities and increasing the prevention of public insecurity in capital cities - both with means-end objectives. For each means-end objective, it is necessary to specify an attribute to measure the degree to which the objective is achieved.

5th Stage: *Quantification of Objectives With a Decision Model:*

In this step, with the aid of the policy maker, we made a description of the attributes and the quantification of the objectives for constructing a decision model. These allow us to clarify, discover the objectives and facilitate decision-making. The means-end objectives are stated using criteria expected to be fused with an MCDA method to evaluate the relative degree of public insecurity in the capital cities. These criteria permit all operational elements that influence the evaluation of the relative degree of general security in capital cities to be integrated. Below, we present a brief description of each means-end objective:

Strengthening public security in capital cities potentially involves improving the prevention of crimes of the common jurisdiction so that they achieve significant reductions in their number, which is a relevant aspect of present and future population public security. In addition, some events can increase the population's perception of public security in the capital cities. Some of these events involve minimizing the number of murders and deprivation of liberty, thus centering on decreasing the number of high-impact crimes in the capital cities. An alternative way to expand public security is to minimize crimes of medium and low social impact and reduce robberies of various types and patrimonial crimes. This type of crime creates an environment of insecurity in the population, making it more vulnerable.

Rising crime prevention in capital cities indicates evaluating and choosing effective procedures to ensure better performance indicators of public security activities such as social inequality and schooling of the population. One option is to provide sufficient financial, material, and human resources to combat public insecurity; guaranteeing enough resources to combat public insecurity will allow better planning of activities to prevent crimes in the common jurisdiction. Poor public security is related to a lack of intelligence and material, human, and economic resources. Police training is an alternative indicator that can be measured to achieve a high level of crime prevention that should be maximized, that is, better use of human and economic resources and adequate time to

face the commission of crimes under the common jurisdiction intelligently, punish lawbreakers for reducing impunity. Efficient resource exercises progressively influence crime prevention. Finally, it is vital to reduce social inequality, which is a primary concern of the three levels of government. This aspect focuses on generating opportunities for personal development in the entire population.

6th Stage: *Creating Solution Alternatives:*

Based on the means-end objectives, jointly with the policy maker, in the following sections, we continue with the process of ordering the capital cities in descending order of violence in the common jurisdiction. For this, we first define the hierarchical structure of the criteria [31], [32], [33]

C. DEFINITION OF A COHERENT FAMILY OF ASSESSMENT CRITERIA

We define a hierarchical structure of criteria. The hierarchical structure of a coherent family of criteria with three levels is represented in Fig. 3. Thirty-one capital cities of Mexico, evaluated on twelve elementary criteria placed at the bottom of the hierarchy tree, have been extracted from public databases [4], [34], [35], [36], [37]. The criteria were established considering the proposed goals of the case study, and they fulfill the properties of no redundancy, completeness, and consistency. All the objectives and criteria considered in this case study were derived from the information provided by this PM, whose system of preferences was the only factor in the following classification of crimes.

Table 1 describes the twelve elementary criteria comprised in the multicriteria decision support model. As can be seen in Fig. 3, High Impact Crimes (HIC), Medium Impact Crimes (MIC), Low Impact Crimes (LIC), Resource Application for Public Security (RAPS), and Social Prevention of Violence and Crime (SPVC) are macro-criteria. The first three constitute the macro-criterion related to Strengthening the level of Public Security in Capital Cities (PSCC); these last two compose the macro-criterion associated with Increasing the Prevention of Insecurity in Capital Cities (PPICC). Murders (M), Kidnappings (K), and Women Rapes (WR) are elementary criteria descending from High Impact Crimes; Property Crimes (PC) and Injuries (I) are elementary criteria descending from Medium-Impact Crimes; Common Theft (CT), Bank Robberies (BR), and Other Crimes (OC) are elementary criteria descending from Low Impact Crimes; Performance Strengthening for Public Security (PSPS) is an elementary criterion descending from Resource Application for Public Security; Perception of Insecurity (PI), Unemployment Rate (UR), and Marginalization (MA) are elementary criteria descending from Social Prevention of Violence and Crime. The policy maker with the support of the analyst defined the classification of the macro-criteria HIC, MIC, and LIC.

The criteria represent the means-end objectives, and each elementary criterion has its functional representation. As described in Sec. III-B (Identifying objectives and their structuration), minimizing high-, medium-, and low-impact