



Neutrosophic DEMATEL in the Analysis of the Causal Factors of Youth Violence

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Abstract

This study is based on conducting surveys and multicriteria decision methods to determine the main factors influencing youth violence in Ecuador. To do this, a sample made up of young perpetrators of various types of crimes and other agents involved in the process in the city of Guayaquil is analyzed. The analysis carried out is based on the use of the DEMATEL method in its neutrosophic version so that the indeterminacies of the real world can be handled. The result obtained reveals that the factors with the highest incidence in youth violence in the analyzed sample are substance abuse or delinquency by parents, poor surveillance and supervision of children by parents, poor disciplinary practices, and emotional deficiencies of the parents, as well as exposure to domestic violence. It is recommended that prevention actions to minimize the proliferation of youth violence focus on these aspects for greater optimization of the results.

Keywords: youth violence; DEMATEL; neutrosophy; Ecuador; causal factors

1. Introduction

Violence is one of the main causes of death in the population aged between 15 and 44 years. It is responsible for 14% of deaths in the male population and 7% in the female population. Every year, more than 1.6 million people worldwide lose their lives violently [1]. For every person who dies from violent causes, many more are injured and suffer from a variety of physical, sexual, reproductive, and mental problems. On the other hand, violence imposes a huge financial burden on national economies each year, in the billions of dollars, in health care, judicial, and police expenses, and loss of productivity [2]

Youth violence encompasses a range of aggressive acts ranging from bullying and fighting to more serious forms of assault and homicide [3]. In most cases, the representativeness of the main perpetrators and the main victims of the homicides are the male sex. It is estimated that, in 2000, youth violence claimed the lives of 199,000 young people, representing a rate of 9.2 per 100,000. The highest rates of youth homicide are in Africa and Latin America, and the lowest correspond to Western Europe and some areas of Asia and the Pacific[4].

With the notable exception of the United States, most of the countries with youth homicide rates above 10 per 100,000 are developing countries or countries in the throes of social and economic change. It is estimated that for every young person killed as a result of violence, between 20 and 40 suffer injuries that require hospital treatment. In some countries, such as Israel, New Zealand, and Nicaragua, this proportion is even higher [5].

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According to the Report on Citizen Security and Human Rights, the Latin American and Caribbean region is one of the regions in the world with the highest rates of juvenile crime [6]. Ecuador is currently going through a period of national violence that is expressed through the actions of organized gangs that attack, rape, kidnap and kill indiscriminately, creating growing social anguish. In 2020, Ecuador registered the second highest growth in homicide rates in Latin America and the Caribbean, with Guayaquil being the most violent city in the country. By the end of the year, the country had 1,357 murders, up from around 1,188 in 2019.

In this scenario, the preventive action and reintegration strategies must be strengthened and focused on the key factors that cause such a situation. In this sense, it is decided to carry out the current investigation to determine those critical factors that affect the high levels of youth violence in the city of Guayaquil. Furthermore, the analysis of the existing situation was supported by the application of surveys to a group of young perpetrators of crimes of various kinds, to determine some of the factors that they consider key in the incidence of the study problem.

On the other hand, the Decision Making Trial and Evaluation Laboratory (DEMATEL) method distinguishes the key factors and the causal relationships between them. This technique is characterized by its high efficiency and the simplicity of its principle in solving multicriteria decision problems [8] - [10]. Multiple decision problems are based on the criteria of a group of experts on the subject, through the evaluation of certain criteria, around a set of alternatives, in which they seek to find the best alternative evaluated. This method consists of matrixes that include expert evaluations of the cause-effect relationship of a group of criteria or selected factors [8].

To enrich this technique and in a way that minimizes the impossibility of traditional multicriteria decision methods to handle indeterminate and inconsistent data intrinsic to the real world, it is combined with the neutrosophic sets proposed by, which generalizes the concepts of the classical set, fuzzy set (FS), intuitionist fuzzy set (IFS), intuitionist fuzzy set valued by intervals (IVIFS), etc. Neutrosophy is the branch of philosophy that studies the origin, nature and scope of neutralities [12] - [15].

Logic and neutrosophic sets are generalizations of Zadeh's logic and fuzzy sets, of Atanassov's intuitionist logic [16]. The inclusion of neutrosophic sets in the method allows the uncertainty of the decision-making process to be taken into account, including indeterminacies. Experts will evaluate in linguistic rather than numerical terms, which is the most natural form of measurement in humans.

2. Methods and techniques

Definition 1 ([17]) Let X be a space of points (objects) with generic elements in X denoted by x . A single-valued neutrosophic set (SVNS) A in X is characterized by truth-membership function $T_A(x)$, indeterminacy-membership function $I_A(x)$, and falsehood membership function $F_A(x)$. Then, an SVNS A can be denoted by $A = \{x, T_A(x), I_A(x), F_A(x) \mid x \in X\}$, where $T_A(x), I_A(x), F_A(x) \in [0, 1]$ for each point x in X . Therefore, the sum of $T_A(x)$, $I_A(x)$ and $F_A(x)$ satisfies the condition $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$ [18].

Definition 2 ([19]) Let $E_k = (T_k, I_k, F_k)$ be a neutrosophic number defined for the rating of k -th decision-maker. Then, the weight of the k -th decision-maker can be written as:

$$\psi_k = \frac{1 - \sqrt{[(1 - T_k(x))^2 + (I_k(x))^2 + (F_k(x))^2]/3}}{\sum_{k=1}^p \sqrt{[(1 - T_k(x))^2 + (I_k(x))^2 + (F_k(x))^2]/3}} \quad (1)$$

Further, in achieving a favorable solution, group decision-making is important in any decision-making process. Therefore, all the individual decision-maker assessments need to be aggregated to one aggregated neutrosophic decision matrix in the group decision-making process. This can be done by employing the single-valued neutrosophic weighted averaging (SVNWA) aggregation operator proposed by Ye [20].

Definition 3 ([20]) Let $D^{(k)} = (d_{ij}^{(k)})_{m \times n}$ be the single-valued neutrosophic decision matrix of the k -th decision-maker and be the weight vector of decision-maker such that each $\psi = (\psi_1, \psi_2, \dots, \psi_p)^T$, $\psi_k \in [0, 1]$, $D = (d_{ij})_{m \times n}$ where

$$d_{ij} = \langle 1 - \prod_{k=1}^p (1 - T_{ij}^{(p)})^{\psi_k}, \prod_{k=1}^p (I_{ij}^{(p)})^{\psi_k}, \prod_{k=1}^p (F_{ij}^{(p)})^{\psi_k} \rangle \tag{2}$$

Definition 4 ([19], [21]) Deneutrosophication of SVN \tilde{N} can be defined as a process of mapping \tilde{N} into a single crisp output for $x: \tilde{N} \rightarrow \psi^* \in X$. If \tilde{N} is discrete set then the vector of tetrads $\tilde{N} = \{(x | T\tilde{N}(x), I\tilde{N}(x), F\tilde{N}(x)) | x \in X\}$ is reduced to a single scalar quantity $\psi^* \in X$ by deneutrosophication. The obtained scalar quantity $\psi^* \in X$ best represents the aggregate distribution of three membership degrees of neutrosophic element $T\tilde{N}(x), I\tilde{N}(x), F\tilde{N}(x)$. Therefore, the deneutrosophication can be obtained as follows.

$$\psi^* = 1 - \sqrt{[(1 - T_k(x))^2 + (I_k(x))^2 + (F(x))^2]/3} \tag{3}$$

Decision-making normally involves human language or is commonly referred to as linguistic variables. A linguistic variable simply represents words or terms used in human language. Therefore, this linguistic variable approach is convenient for decision-makers to express their assessments. For example, ratings of criteria can be expressed by using linguistic variables such as very influential (VI), influential (I), low influential (LI), no influence (NI), etc. Linguistic variables can be transformed into SVNNS as shown in Table 1.

Table 1: Linguistic variable and Single Valued Neutrosophic Numbers (SVNNs). [19]

Integer	Linguistic variable	SVNNs
0	No influence / Not important	(0.1,0.8,0.9)
1	Low influence / important	(0.35,0.6,0.7)
2	Medium influence / important	(0.5,0.4,0.45)
3	High influence / important	(0.8,0.2,0.15)
4	Very high influence / important	(0.9,0.1,0.1)

3. Methodology

To determine which are the most relevant elements that affect the high levels of youth violence in the city of Guayaquil, the use of the DEMATEL method in its neutrosophic variant is proposed through the steps outlined below [9].

1. *Identify the elements that affect youth violence:* Through semi-structured interviews to a population of interest and brainstorming, a set of influencing factors is determined in the subject under study. The experts are then asked to evaluate the direct influence between the factors through paired comparisons, using the score shown in Table 1.
2. *Determine the relative importance of the experts:* The expert group has its importance values based on their level of experience and knowledge of the decision problem. Therefore, the weight of each decision-maker may be different from that of other decision-makers. The weight of each decision-maker is considered with linguistic variables and is transmitted in SVNN to later be identified using equation (1).
3. *Converting the language assessments given by the SVNN experts:* From the individual integer matrices obtained from the expert evaluations, the individual neutrosophic matrices of the decision-makers are constructed according to what is indicated in Table 1.
4. *Get the initial direct relationship matrix:* To obtain the initial direct relationship matrix in the form of crisp numbers, the neutrosophic matrices of the individual decision-makers need to be aggregated and deneutrosophicated using equations (2) (3) respectively.
5. *Identify cause-effect relationships between factors using the DEMATEL method:* Based on the aggregate direct relationship matrix A obtained in step 4, the total relationship matrix T can be easily calculated using equations (4-6) as shown below:

$$D = A * S \tag{4}$$

Where

$$S = \frac{1}{\max_{1 \leq i \leq n} \sum_{j=1}^n a_{ij}} \quad (5)$$

$$T = D * (I - D)^{-1} \quad (6)$$

where I is the identity matrix.

From this, the cause-effect relationship diagram $(r_i + c_i, r_i - c_i)$

6. *Analyze the cause-effect relationship diagram.* The $(r_i - c_i)$ indicates the importance of each factor while $(r_i - c_i)$ is the net cause or effect group. The $(r_i + c_i)$ is called "Prominence" and it measures the degree of the central role played by the factor or criterion within the system. While $(r_i - c_i)$ is called "Ratio" and it means the effect that the factor or criterion produces in the system. If $(r_i + c_i) > 0$ the factor or criterion is located in the group of causes, 2. If $(r_i - c_i) < 0$ the factor or criterion is located in the group of effects. The pairs $(r_i - c_i)$ and $(r_i + c_i)$ can be represented graphically to give decision-makers a graphic idea about the system.

4. Results and discussion

A qualitative, descriptive, and cross-sectional investigation was carried out in Guayaquil, Ecuador, during the second quarter of 2021 to determine the influence of the main factors of the criminal attitude of adolescents and young people in the area. The study population comprised twenty-two young offenders included in restorative justice programs and 3 institutional actors involved in handling cases of juvenile violence.

Thus, the selection consisted of searching for minor offenders and the professionals in charge of the care, monitoring, and evaluation of these young people. The information was collected through semi-structured interviews, with open questions, and in a colloquial tone, with the supervision of social workers and psychologists who were members of the analysis groups and experts.

This research showed that socio-family conflicts influence adolescents who engage in criminal activities. There are conditions in the adolescent's life, in his family and community context, that increase the possibility of him committing a crime. The main factors identified, as well as their coding for better manipulation of the information, are shown below:

Table 2: Coding of the indicated factors.

Coding	Identified factors
B.Dis.	Behavioral disorders
Low.C	Low commitment to school and school failure
Unemp.	Unemployment
Viol.	Exposure to violence in the family
Sup.	Little supervision and supervision of children by parents
Disc.	Bad disciplinary and affective practices of parents
Par.Subs.	Parental substance abuse or delinquency
Gang	Association with fellow criminals and/or gang membership
Alcoh	Access to alcohol and its abuse
Income	Great income inequality
Poor	Poverty
Gov.	Quality of a country's governance (its laws and level of application, as well as education and social protection regulations)

Tables 3, 4, and 5 represent the comparative evaluations by pairs of criteria issued by decision-makers 1, 2, and 3, respectively. Table 6 shows the weights of the decision-makers in their linguistic form and their conversion to SVNN. The assessment of Experts 1 and 2 is considered to be very important, while Expert 3's is important.

Table 3: Evaluation of the degree of influence between factors. Expert 1.

	B.Di s	Low. C	Unemp .	Viol .	Sup .	Disc .	Par.Subs .	Gan g	Alco h	Incom e	Poo r	Gov .
B.Dis.	-	VI	VI	NI	LI	NI	NI	VI	MI	LI	NI	NI
Low.C	LI	-	LI	NI	LI	MI	MI	LI	LI	MI	I	NI
Unemp	MI	LI	-	LI	NI	NI	LI	MI	MI	VI	VI	NI
Viol.	VI	VI	MI	-	I	MI	NI	VI	VI	MI	LI	NI
Sup.	I	VI	VI	VI	-	VI	VI	VI	VI	VI	VI	NI
Disc.	VI	VI	I	VI	VI	-	VI	VI	I	MI	I	NI
Par. Subs.	I	VI	I	VI	VI	VI	-	I	VI	MI	MI	NI
Gang	MI	I	I	MI	MI	LI	NI	-	I	MI	MI	NI
Alcoh	VI	VI	VI	I	MI	LI	LI	MI	-	MI	MI	NI
Income	I	NI	MI	NI	MI	MI	LI	MI	LI	-	LI	NI
Poor	LI	LI	MI	LI	LI	I	NI	LI	NI	LI	-	NI
Gov.	NI	NI	VI	NI	NI	NI	LI	VI	VI	VI	VI	-

Table 4: Evaluation of the degree of influence between factors. Expert 2.

	B.Di s	Low. C	Unemp .	Viol .	Sup .	Disc .	Par.Subs .	Gan g	Alco h	Incom e	Poo r	Gov .
B.Dis.	-	VI	VI	NI	LI	NI	NI	VI	MI	LI	NI	NI
Low.C	LI	-	LI	NI	LI	MI	MI	LI	LI	LI	I	NI
Unemp	MI	MI	-	LI	NI	NI	LI	MI	MI	VI	I	NI
Viol.	VI	VI	MI	-	I	MI	NI	MI	VI	MI	LI	NI
Sup.	I	I	VI	VI	-	VI	MI	VI	I	VI	VI	NI
Disc.	VI	VI	I	VI	VI	-	I	VI	I	MI	I	NI
Par. Subs.	I	I	I	I	VI	VI	-	I	VI	MI	NI	NI
Gang	MI	I	I	MI	NI	LI	NI	-	I	MI	MI	NI
Alcoh	VI	VI	VI	I	MI	LI	LI	MI	-	MI	MI	NI
Income	I	NI	MI	NI	MI	MI	LI	MI	LI	-	LI	LI
Poor	LI	LI	MI	NI	LI	I	NI	LI	NI	LI	-	NI
Gov.	NI	NI	VI	NI	NI	NI	LI	VI	VI	VI	VI	-

Table 5: Evaluation of the degree of influence between factors. Expert 3.

	B.Di s	Low. C	Unemp .	Viol .	Sup .	Disc .	Par.Subs .	Gan g	Alco h	Incom e	Poo r	Gov .
B.Dis.	-	VI	VI	NI	VI	NI	LI	VI	I	LI	NI	NI
Low.C	LI	-	LI	NI	LI	MI	MI	LI	LI	LI	I	NI
Unemp	MI	MI	-	LI	LI	NI	I	MI	MI	VI	I	NI
Viol.	VI	VI	MI	-	I	MI	NI	MI	VI	MI	LI	NI
Sup.	I	VI	VI	VI	-	VI	VI	VI	I	VI	VI	NI
Disc.	VI	VI	I	VI	VI	-	I	VI	VI	MI	I	NI
Par. Subs.	I	I	I	I	VI	VI	-	I	VI	MI	NI	NI
Gang	MI	I	MI	I	NI	LI	NI	-	I	MI	MI	NI
Alcoh	VI	VI	VI	I	MI	LI	LI	MI	-	MI	MI	NI
Income	I	LILI	MI	NI	MI	MI	LI	MI	LI	-	LI	NI
Poor	LI	LI	MI	NI	LI	I	NI	LI	NI	LI	-	LI
Gov.	NI	NI	VI	NI	MI	NI	NI	VI	VI	VI	VI	-

The importance of experts on this particular topic is not the same for all three. The importance of each decision-maker expressed by a linguistic variable with its corresponding SVNN is shown in Table 5. The numerical importance of the experts is determined by using equation (1).

Table 6: Importance of SVNS experts. Own elaboration

	Decision-maker 1	Decision-maker 2	Decision-maker 3
Importance vector	VI	VI	I
Numerical importance	0.3441	0.3441	0.3117

The direct relationship matrix can be obtained by applying equations 2 and 3, as shown in figure 1:

$$A = \begin{bmatrix} 0.000 & 0.859 & 0.859 & 0.132 & 0.490 & 0.132 & 0.207 & 0.859 & 0.660 & 0.349 & 0.132 & 0.132 \\ 0.349 & 0.000 & 0.349 & 0.132 & 0.349 & 0.548 & 0.548 & 0.349 & 0.349 & 0.427 & 0.815 & 0.132 \\ 0.548 & 0.488 & 0.000 & 0.349 & 0.207 & 0.132 & 0.563 & 0.548 & 0.548 & 0.859 & 0.851 & 0.132 \\ 0.859 & 0.859 & 0.548 & 0.000 & 0.815 & 0.548 & 0.132 & 0.732 & 0.859 & 0.548 & 0.349 & 0.132 \\ 0.815 & 0.824 & 0.859 & 0.859 & 0.000 & 0.859 & 0.760 & 0.859 & 0.851 & 0.859 & 0.859 & 0.132 \\ 0.859 & 0.859 & 0.815 & 0.859 & 0.859 & 0.000 & 0.851 & 0.859 & 0.780 & 0.548 & 0.815 & 0.132 \\ 0.815 & 0.851 & 0.815 & 0.851 & 0.859 & 0.859 & 0.000 & 0.815 & 0.859 & 0.548 & 0.307 & 0.132 \\ 0.548 & 0.815 & 0.757 & 0.660 & 0.307 & 0.349 & 0.132 & 0.000 & 0.815 & 0.548 & 0.548 & 0.132 \\ 0.859 & 0.859 & 0.859 & 0.815 & 0.548 & 0.349 & 0.349 & 0.548 & 0.000 & 0.548 & 0.548 & 0.132 \\ 0.815 & 1.000 & 0.548 & 0.132 & 0.548 & 0.548 & 0.349 & 0.548 & 0.349 & 0.000 & 0.349 & 0.214 \\ 0.349 & 0.349 & 0.548 & 0.214 & 0.349 & 0.815 & 0.132 & 0.349 & 0.132 & 0.349 & 0.000 & 0.207 \\ 0.132 & 0.132 & 0.859 & 0.132 & 0.292 & 0.132 & 0.288 & 0.859 & 0.859 & 0.859 & 0.859 & 0.000 \end{bmatrix}$$

Figure 1: Matrix of the direct relationship of the factors.

From it, the normalized initial direct relationship matrix D can be obtained through equations (4) and (5), as well as the total direct relationship matrix T, which can be calculated by using equation (6) as shown below:

$$T = \begin{bmatrix} 0.123 & 0.235 & 0.225 & 0.107 & 0.148 & 0.108 & 0.104 & 0.214 & 0.190 & 0.151 & 0.132 & 0.045 \\ 0.155 & 0.132 & 0.164 & 0.103 & 0.132 & 0.152 & 0.135 & 0.154 & 0.148 & 0.149 & 0.194 & 0.044 \\ 0.193 & 0.207 & 0.000 & 0.133 & 0.128 & 0.119 & 0.142 & 0.189 & 0.183 & 0.208 & 0.851 & 0.209 \\ 0.261 & 0.287 & 0.240 & 0.123 & 0.219 & 0.186 & 0.123 & 0.123 & 0.252 & 0.208 & 0.191 & 0.055 \\ 0.311 & 0.344 & 0.328 & 0.256 & 0.176 & 0.261 & 0.222 & 0.310 & 0.301 & 0.287 & 0.290 & 0.069 \\ 0.309 & 0.340 & 0.317 & 0.252 & 0.263 & 0.165 & 0.227 & 0.305 & 0.289 & 0.250 & 0.280 & 0.067 \\ 0.297 & 0.330 & 0.308 & 0.247 & 0.256 & 0.248 & 0.132 & 0.293 & 0.291 & 0.243 & 0.221 & 0.064 \\ 0.203 & 0.252 & 0.233 & 0.174 & 0.146 & 0.146 & 0.106 & 0.139 & 0.221 & 0.187 & 0.190 & 0.050 \\ 0.257 & 0.281 & 0.267 & 0.206 & 0.189 & 0.163 & 0.142 & 0.222 & 0.156 & 0.206 & 0.208 & 0.055 \\ 0.227 & 0.269 & 0.211 & 0.118 & 0.169 & 0.166 & 0.131 & 0.200 & 0.172 & 0.124 & 0.168 & 0.058 \\ 0.143 & 0.158 & 0.172 & 0.102 & 0.121 & 0.167 & 0.085 & 0.143 & 0.116 & 0.132 & 0.097 & 0.049 \\ 0.152 & 0.171 & 0.240 & 0.115 & 0.137 & 0.119 & 0.116 & 0.225 & 0.220 & 0.217 & 0.218 & 0.034 \end{bmatrix}$$

Figure 2: Total direct relationship matrix.

After obtaining the total direct relationship matrix, the direct and indirect effects of the indicated elements are determined by analyzing the axes of prominence and relationship for the cause and effect group, as shown in Table 6.

Table 7: Axes of total relationship between elements.

	<i>ri</i>	<i>ci</i>	<i>ri + ci</i>	<i>ri-ci</i>
B.Dis.	1,781	2.6302	4.4112	-0.849
Low.C	1.6615	3.0058	4.6673	-1,344
Unemp.	1,899	2,8449	4.7439	-0.946
Viol.	2,3908	1,9342	4,325	0.4566
Sup.	3.1528	2.0831	5.2359	1.0697
Disc.	3.0637	1.9978	5.0615	1.0659
Par.	2,929	1.6633	4.5923	1.2657
Subs.	2.0467	2.6392	4.6859	-0.593
Gang	2.3499	2,537	4.8869	-0.187
Income	2.0115	2.3613	4.3728	-0.35
Poor	1.4823	2.3967	3,879	-0.914
Gov.	1.9622	0.6369	2.5991	1.3253

The prominence and relationship axes can be plotted and represented graphically to visualize the data and its meaning better, as shown in figure 3.

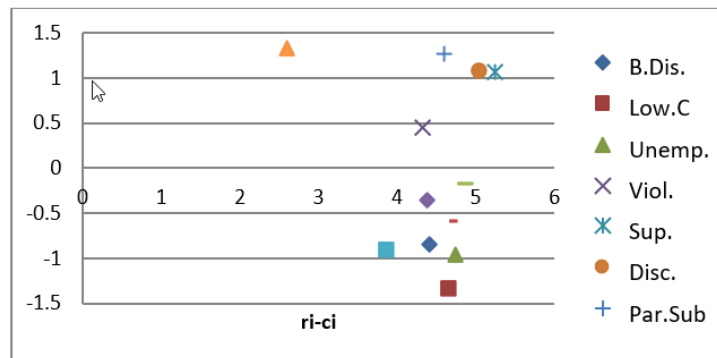


Fig.3: Diagram of causal relationships.

The diagram obtained after the analysis carried out reveals that the poor supervision and supervision of the children by the parents, as well as the bad disciplinary and affective practices of the parents, are two of the most influential elements among all those analyzed, as well as the access to alcohol and its improper consumption. Regarding the causal relationships of the factors, the analysis carried out suggests that the substance abuse or delinquency of the parents, the little vigilance and supervision of the children by the parents, the bad disciplinary practices and affective deficiencies of the parents, as well as exposure to domestic violence, are the main causal factors of the rest of the elements indicated by the experts and young people interviewed.

5. Conclusions

1. Juvenile crime and violence in Ecuador have reached alarming figures for the authorities and the government.
2. This article has proposed applying the neutrosophic DEMATEL method to determine the causal relationships between the influential elements in youth violence in Guayaquil.
3. The use of neutrosophic sets allowed the inclusion of uncertainty, indeterminacy, and the use of linguistic terms to solve complex problems.
4. The evaluation of three experts was carried out, and the conclusion was reached that the factors with the highest incidence among those mentioned are substance abuse or delinquency by parents, poor supervision and supervision of children by parents, bad disciplinary practices. and affective deficiencies of parents, as well as exposure to domestic violence.
5. It is recommended that prevention actions to minimize the proliferation of youth violence focus on these aspects for greater optimization of results.

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