
# Efficiency of Cooperation Between Various Services and Specialists in the Investigation of Terrorist Murders: Development of an Optimized Algorithm

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## ABSTRACT

### BACKGROUND

The study's relevance stems from rising terrorist attacks and the need to enhance interagency efficiency in investigating terrorist homicides. The aim of the study is to analyse and improve mechanisms for interagency cooperation in the investigation of terrorist murders.

### MATERIALS AND METHODS

The following methods were used in the study: relevance analysis, algorithm generalization, algorithm optimization, step-by-step structural qualitative comparative analysis, step-by-step structural element comparative analysis, and efficiency determination.

### RESULTS

Among 25 analysed countries and organizations, only 32% demonstrated highly effective integrated cooperation models. The optimized algorithm reduced operational complexity by 20% (212 →170 units), improving response speed, accuracy, and legal adaptability.

### CONCLUSION

The academic novelty lies in typologizing interagency mechanisms and developing an optimized cooperation algorithm based on international practices. Further research should focus on pilot testing and scaling the model at national and international levels.

**Keywords:** Interagency cooperation models, Terrorist homicide investigations, Algorithmic optimization, Procedural complexity reduction, Cross-jurisdictional coordination

## Highlights

- Terrorist attacks remain among the most destructive global security threats.
- Analysis showed that effectiveness in terrorist homicide investigations depended on formalized interagency cooperation.
- Effective investigation of terrorist homicides depends on formalized, legally regulated, and institutionally structured interagency cooperation.
- The resulting optimized algorithm reduced operational complexity by 20%.
- The study's novelty lies in formalizing typologies of procedural-legal cooperation mechanisms.

## Introduction

Terrorist attacks remain among the most destructive global security threats, undermining national stability and international law.[1,2] Terrorist-motivated homicides pose acute risks, causing mass casualties and demanding rapid, coordinated responses.[3,4] Their investigation involves multiple actors–law enforcement, intelligence, forensics, prosecutors, and international partners.[5,6] However, interagency practices vary from integrated hierarchies to fragmented or politicized systems,[7–10] underscoring the need for comprehensive analysis and a unified adaptable cooperation algorithm.

The aim of this study is to identify, arrange, and optimize procedural and legal mechanisms of cooperation between different services and specialists in the investigation of terrorist murders.

The aim involves the fulfilment of the following research objectives:

- Analyse the practices of cooperation between services in the investigation of terrorist murders;
- Classify models by effectiveness;
- Identify typical features of cooperation structures;
- Create and optimize an interaction algorithm;
- Compare algorithms according to qualitative and quantitative criteria;
- Evaluate the effectiveness of optimization.

Research question: How can structural interagency cooperation mechanisms be optimized to reduce procedural complexity and enhance operational efficiency in investigations of terrorist-motivated murders?

Research hypothesis: The optimization of cooperation algorithms–based on structural integration, legal synchronization, and procedural streamlining–significantly improves coordination efficiency and response capabilities in investigations of terrorist-motivated murders.

The current studies on the effective cooperation between different services and specialists in the investigation of terrorist murders are reviewed below.

Marzuki et al. identified insufficient coordination between regional police and specialized units in South Sumatra.[11] Counterterrorism intelligence remained centralized in Densus 88, with minimal regional police participation. Kibe and Ngari identified lagging interagency responses to evolving terrorist tactics in Kenya since 1998.[12] They stressed the need for permanent counterterrorism units, stronger coordination, technological modernization, and expanded international cooperation.

Norris found police-targeted killings more often driven by mental disorders and radical ideologies than activism.[13] This highlighted the need for coordinated action among police, intelligence, and psychiatric services. Hariyanto et al. emphasized the key role of the state and the NII Crisis Center in countering religious radicalism.[14] They highlighted the need for systematic

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cooperation between government agencies and civil society to prevent extremist threats, including youth radicalization.

Guttmann demonstrated that effective prevention of 1970s terrorist attacks, such as Black September, relied on strong interagency intelligence exchange.[15] Historical analysis confirmed that coordinated information sharing was critical for identifying tactics and averting attacks. Zhao et al. confirmed the effectiveness of international counterterrorism cooperation within the Shanghai Cooperation Organization.[16] Their findings showed reduced attacks and casualties, emphasizing the importance of coordinated, multi-level interstate mechanisms.

Putri et al. demonstrated that U.S.–Nigeria military cooperation, particularly Air Force engagement, significantly enhanced Nigeria's counterterrorism capacity against Boko Haram.[17] They underscored the role of international collaboration in strengthening national security amid complex threats. Iqbal et al. found that China–Pakistan counterterrorism cooperation evolved with China's expanding economic role and shifting regional security context.[18] Beijing's reduced reliance on Islamabad reflected growing autonomy of bilateral security mechanisms.

Adlina explained India's post-2008 refusal to cooperate with Pakistan through prisoner's dilemma dynamics.[19] The decision stemmed from historical distrust, security perceptions, and political context, limiting bilateral counterterrorism collaboration. Cui et al. showed that terrorist groups increasingly form cooperative core–periphery networks.[20] Effective counteraction, they noted, requires coordinated interagency efforts to map and disrupt these structures.

Current research highlighted interagency coordination as crucial in terrorist homicide investigations, revealing fragmented interaction among security, forensic, and civil actors. Simultaneously, evolving information exchange and regulatory frameworks underscored the need for a multi-level cooperation model.

## Methods and Materials

### Research Design

This study was conducted according to the scheme below (Figure 1).

### Methods

A multi-method qualitative design was used, combining legal analysis, structural modeling, and efficiency evaluation through eight sequential stages ensuring reproducibility.

#### *Relevant Analysis*

The initial stage involved analysis of national and international regulations on interagency cooperation in terrorist homicide investigations, including domestic laws and supranational instruments. These were mapped to procedural stages and aligned with cross-border case precedents.

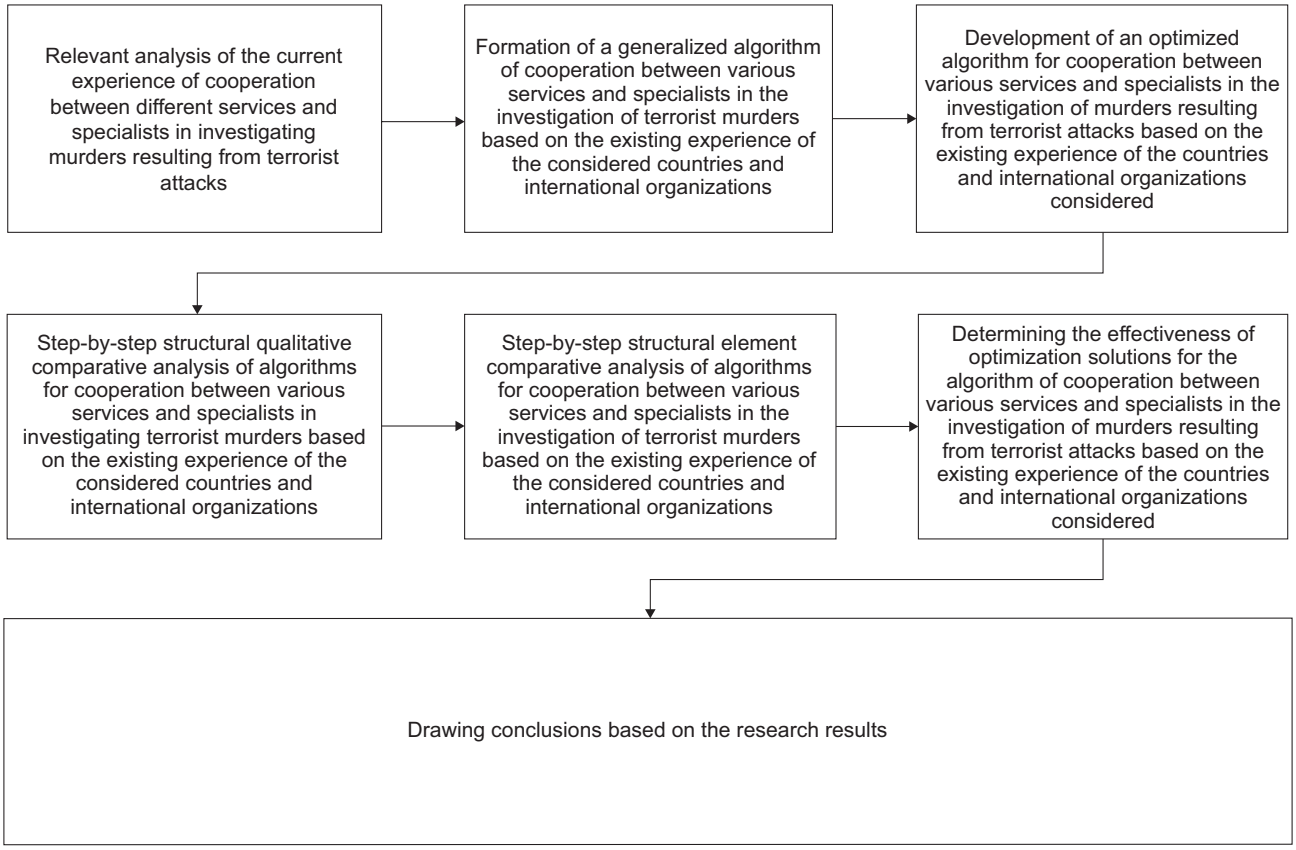


**Fig 1 | Step-by-step research scheme**
Source: Developed by the authors


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### *Development of a Generalized Algorithm*

A generalized interagency cooperation algorithm was synthesized, covering detection, intelligence fusion, tasking, evidence collection, cross-jurisdictional alignment, authorization, and disposition. Each phase defined responsible agencies, procedural triggers, and communication protocols under rule-of-law alignment.

### *Development of an Optimized Algorithm*

The model was optimized by removing redundancies, enhancing coordination at key interfaces, and adding reverse-audit loops for legal compliance. Adjustments improved operational speed, reduced legal ambiguity, and integrated international partners early.

### *Structural Qualitative Comparative Analysis*

Generalized and optimized algorithms were compared across six dimensions legal coherence, transparency, responsiveness, adaptability, accountability, and rights protection using a five-level qualitative scale with discourse-based assessment of strengths and gaps.

### *Structural Element Comparative Analysis*

Quantitative analysis showed a reduction of procedural units from 212 to 170 (≈20%), confirming lower complexity. Control points and feedback loops indicated higher operational controllability.

### *Determining Efficiency*

Efficiency was measured by time compression, interaction coherence, and cross-jurisdictional adaptability. Normative modeling and simulations inferred performance gains despite limited field testing.

## Sample

The sample comprised 25 states and international organizations selected by purposive criteria: legal-system diversity (common, civil, hybrid), regulatory maturity in interagency counterterrorism, and availability of verified case data. Analysis covered statutory bases, cooperation protocols, and investigation algorithms. Limitations concerned transparency and cross-jurisdictional generalizability. A detailed description of the sample is provided in Appendix B.

## Instruments

A structured instrument based on a conditional operational complexity model was utilized for comparative evaluation of interagency algorithms in terrorist homicide investigations. It integrated process analysis, communication load metrics, and matrix-based efficiency assessment. Expert modeling and quantitative mapping ensured validity, though replication required disaggregated procedural data and expert input.

Stage complexity assessment:

$$S_i = A_i \times V_i \times C_i, \quad (1)$$

where $S_i$ – complexity of the $i$ th stage; $A_i$ – the number of active subjects (agents, bodies, structures); $V_i$ – the number of inter-agent interactions (paired connections between subjects that involve information or procedural exchange); $C_i$ – the procedural complexity coefficient (1 – low, 2 – medium, 3 – high).

Overall complexity of the algorithm:

$$S_{total} = \sum_{i=1}^{n} S_i \quad (2)$$

where $n$ – number of stages in the algorithm.

A detailed description and example of the calculation is provided in Appendix A.

## Results

Applying the established methodology of this study, a relevant analysis of the current experience of cooperation between various services and specialists in investigating terrorist murders (including legal norms and known investigation cases) will be conducted for 25 leading countries and international organizations (Table 1).

Analysis (Table 1) showed that effectiveness in terrorist homicide investigations depended on formalized interagency cooperation, legal regulation, and operational response. Leading jurisdictions confirmed the importance of algorithmic clarity, unified legal frameworks, and international coordination. This informed the generalized cooperation algorithm (Table 2).

The algorithm (Table 2) integrated best practices of high-cooperation states, ensuring procedural coordination in terrorist homicide investigations, and was later optimized using international experience (Table 3).

The optimized algorithm (Table 3) unified procedures, enhanced efficiency and flexibility, and enabled national and international scalability. Step-by-step qualitative comparison of generalized and optimized models (Table 4) detailed structural improvements in interagency cooperation mechanisms.

The optimized algorithm (Table 4) enhanced efficiency, coordination, flexibility, and institutional accountability, converting fragmented actions into a unified counterterrorism system. A structural comparative analysis of generalized and optimized cooperation models followed, based on national and international experience (Table 5).

Based on the obtained calculation results (Table 5), we will form conclusions about the effectiveness of optimization solutions (Table 6).

The optimized algorithm unified procedures, reduced operational workload by 20%, and enhanced efficiency, scalability, and legal adaptability. Transitioning from fragmented interaction to a systemic regulatory model proved key for effective counterterrorism and investigation of terrorist crimes.

## Discussion

Our findings are compared with similar studies in the same research area below.

Furger emphasizes that JITs have limited practical effectiveness despite their regulatory attractiveness.[21] Our study proves that national models with integrated management provide higher investigative performance. I Gusti Putu Bagus Pradana and Ihza Pamesti found that terrorist attacks in Indonesia mostly achieve

**Table 1 | Results of the relevant analysis**

| Country/Organization | Interaction Algorithm | Legal Norms | Known Investigation Cases |
|---|---|---|---|
| USA | FBI–DHS–ATF–CIA coordination via JTTF | Patriot Act, FISA | 9/11, Boston Marathon (2013) |
| UK | MI5–Counter Terrorism Command–CPS | Terrorism Act 2000 | London Bombings (2005) |
| France | DGSI– gendarmerie–national police | Code de la sécurité intérieure | Bataclan Attack (2015) |
| Germany | BfV–BKA–Länder Police | Grundgesetz, BKA-Gesetz | Berlin Truck Attack (2016) |
| Italy | DIGOS–Carabinieri–Polizia di Stato | Codice Penale, D.Lgs. 159/2011 | Milan Shooting (2016) |
| Canada | RCMP–CSIS–Integrated Security Units | Anti-Terrorism Act, CSIS Act | Toronto Van Attack (2018) |
| Spain | Guardia Civil–CNI–Policía Nacional | Ley de Enjuiciamiento Criminal | Madrid Bombings (2004) |
| Australia | ASIO–AFP–State Police | ASIO Act 1979 | Sydney Siege (2014) |
| Israel | Shin Bet–IDF–Israel Police | Counter-Terrorism Law (2016) | Sbarro bombing (2001) |
| Turkey | MIT–Turkish National Police–Jandarma | Law No. 3713 | Reina nightclub attack (2017) |
| India | NIA–RAW–CBI–State Police | UAPA, NIA Act | Mumbai Attacks (2008) |
| Indonesia | Densus 88–BNPT–Polri | UU Terorisme 5/2018 | Surabaya bombings (2018) |
| Kenya | APS–NSIS–CID | Prevention of Terrorism Act 2012 | Westgate Mall (2013) |
| Nigeria | DSS–NAF–NIA | Terrorism Prevention Act (2011) | Abuja UN bombing (2011) |
| Pakistan | ISI–CTD–FIA | Anti-Terrorism Act 1997 | Peshawar School Attack (2014) |
| Ukraine | SBU–National Police–Prosecutor General's Office | Criminal Code of Ukraine, Law on Security Service of Ukraine | MH17, Kharkiv (2022) |
| Poland | ABW–Police–Prokuratura | Kodeks Karny, Ustawa o ABW | Warsaw bomber plot (2019) |
| Sweden | Säpo–Polisen–Försvarsmakten | Terrorism Act (2017:630) | Stockholm Truck Attack (2017) |
| Japan | NPA–PSIA–MOJ | Act on Punishment of Financing Terrorism | Tokyo Subway Sarin Attack (1995) |
| South Korea | NIS–KNP–Supreme Prosecutors' Office | Counter-Terrorism Act (2016) | Seoul Subway Plot (2005) |
| European Union | EUROPOL–Eurojust–Frontex | Directive (EU) 2017/541 | Paris–Brussels Network (2015–2016) |
| INTERPOL | Global database, I-24/7 channels | Constitution of INTERPOL, RPF | Global I-24/7 alerts |
| UN | UNODC–CTED– Human rights mechanisms | UN Charter, UNSC Res. 1373 | Sri Lanka (2019), CTED reviews |
| NATO | CJTF–Allied Command Operations | North Atlantic Treaty, STANAGs | Afghanistan missions (post-2001) |
| SCO | RATS– national security services | SCO Charter, RATS Agreement | Xinjiang-related operations |

Source: Developed by the authors.

**Table 2 | Generalized algorithm**

| Algorithm Steps | Procedural Activities |
|---|---|
| 1. Rapid detection and initial response | • Secure the scene and evacuate victims<br>• Collect primary evidence and data<br>• Transfer information to the coordination center |
| 2. Formation of an interagency investigation team | • Form a joint operational team (e.g., JTTF)<br>• Appoint an investigation coordinator<br>• Define agency responsibilities |
| 3. Analysis and exchange of intelligence data | • Check suspects in national and international databases<br>• Assess terrorist links<br>• Use IT platforms to analyze communications, movements, and transactions |
| 4. Forensic and criminalistic support | • Examine bodies and identify victims<br>• Analyze explosion, DNA, and weapon traces<br>• Provide forensic conclusions on cause and mechanism of death |
| 5. International coordination (if needed) | • Request international legal assistance<br>• Exchange data via I-24/7 or similar systems<br>• Coordinate with foreign authorities to uncover terrorist networks |
| 6. Legal qualification and procedural registration | • Provide legal assessment of suspects' actions<br>• Formulate charges under national law<br>• Initiate pre-trial investigation and procedural support |
| 7. Institutional reporting and analytics | • Prepare analytical report on agency performance<br>• Identify coordination gaps<br>• Propose improvements to the response system |
| 8. Public communication | • Provide verified public information<br>• Prevent panic and sustain public trust<br>• Communicate security measures |

Source: Developed by the authors.


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**Table 3 | Optimized algorithm**

| Algorithm Steps | Procedural Measures |
|---|---|
| 1. Activation of response and assessment of the situation | • Arrive promptly and secure the scene<br>• Provide medical aid<br>• Record initial evidence<br>• Notify the coordination center immediately |
| 2. Activation of the inter-agency coordination mechanism | • Form interagency investigation team<br>• Appoint coordinator<br>• Assign operational, analytical, and prosecutorial roles |
| 3. Intelligence data sharing and analytical support | • Collect and integrate national and international data<br>• Analyze threats and terrorist links<br>• Coordinate with INTERPOL, EUROPOL, and others |
| 4. Forensic support | • Conducted forensic examinations; identified victims<br>• Determined weapon type and crime mechanism<br>• Compiled and preserved the evidentiary base |
| 5. Legal qualification and pre-trial investigation | • Determine crime qualification (terrorism, premeditated murder, etc.)<br>• Register criminal proceedings<br>• Conduct investigative actions and arrests |
| 6. International legal assistance (as needed) | • Send requests and exchange evidence<br>• Use mutual legal assistance channels<br>• Join joint investigation teams (JITs) |
| 7. Post-operational audit and institutional training | • Analyse agency performance and identify shortcomings<br>• Update tactics and train personnel<br>• Implement institutional reforms |
| 8. Public communication and reporting | • Ensure investigation transparency<br>• Prevent disinformation<br>• Inform the public and build trust |

Source: Developed by the authors.

**Table 4 | Results of the step-by-step structural qualitative comparative analysis**

| Criterion | Generalized Algorithm | Optimized Algorithm | The Impact of Optimization on the Efficiency of Algorithmization |
|---|---|---|---|
| Stage structure | Eight stages, with detailed actions of each service | Eight stages, structured and grouped according to the logic of efficiency and consistency | Reducing duplication of functions, strengthening the interconnections between response phases |
| Action formulation | Partially descriptive, with possible repetitions or overlaps of powers | Specified, presented according to the logic of actions "who-what-how," with a clear functional division | Increasing the accuracy of task performance and reducing the risk of inconsistency |
| Role of the coordination mechanism | Present, but not centralized | The role of the interdepartmental coordinator is strengthened, as well as the incident management system | Ensuring continuity of management at all stages of the investigation |
| Integration of the international component | Provided only in later stages (#5) | Integrated flexibly: with the possibility of connection at any phase, depending on the cross-border aspect | Increasing efficiency in cooperation with EUROPOL, INTERPOL, UN, etc. |
| Institutional adaptability | The algorithm is less flexible for scaling or application in crisis conditions | Built modularly, allows adaptation to the context and legislation of the country | Increasing universality and relevance in different legal systems |
| Information interaction | Mentioned, but without emphasis on common platforms | Centralized analytical support, data exchange through national and international IT systems are provided | Increasing the accuracy and speed of information processing |
| Analysis and learning phase | Available in the form of "institutional reporting" | Transformed into a full-fledged audit with the implementation of changes and a feedback cycle | Increasing the institutional capacity for self-correction and development |
| Public communication | Presented as part of the crisis response | Integrated as the final phase of strategic communication and public trust management | Strengthening public support and transparency of the actions of law enforcement agencies |

Source: Developed by the authors.

**Table 5 | Results of step-by-step comparative analysis of interagency cooperation algorithms in terrorist homicide investigations**

| Stage | Subjects | Interactions | Complexity | Rating |
|---|---|---|---|---|
| Generalized Algorithm | | | | |
| 1 | 3 | 3 | 2 | 18 |
| 2 | 4 | 6 | 2 | 48 |
| 3 | 4 | 6 | 3 | 72 |
| 4 | 3 | 3 | 2 | 18 |
| 5 | 3 | 3 | 2 | 18 |
| 6 | 3 | 3 | 2 | 18 |
| 7 | 3 | 3 | 2 | 18 |
| 8 | 2 | 1 | 1 | 2 |
| Total | | | | 212 |
| Optimized Algorithm | | | | |
| 1 | 3 | 3 | 1 | 9 |
| 2 | 4 | 6 | 2 | 48 |
| 3 | 4 | 6 | 2 | 48 |
| 4 | 3 | 3 | 2 | 18 |
| 5 | 3 | 3 | 2 | 18 |
| 6 | 3 | 3 | 2 | 18 |
| 7 | 3 | 3 | 1 | 9 |
| 8 | 2 | 1 | 1 | 2 |
| Total | | | | 170 |

Source: Developed by the authors.

**Table 6 | Results of evaluating optimization efficiency of interagency cooperation algorithm in terrorist homicide investigations**

| Indicator | Generalized Algorithm | Optimized Algorithm |
|---|---|---|
| Number of stages | 8 | 8 |
| Total operational complexity | 212 | 170 |
| Complexity reduction | – | ≈20% reduction |

Source: Developed by the authors.

tactical goals only.[22] Our study emphasizes that interagency coordination is the determining factor in the effective investigation of such crimes.

Jadoon et al. showed that the choice of US counterterrorism tools depends on administrative succession and changes in threats.[23] Instead, our study emphasizes the role of structural interagency cooperation as a key factor in an effective response. Barshep noted that the UN has become a key player in shaping the global response to terrorism over time.[24] Our study, however, emphasizes that institutionally enshrined interagency cooperation at the national level is crucial to effective investigation.

Bonsoms showed that the sustainability of counterterrorism engagement depends on institutional structure.[25] This study, however, emphasizes the importance of not only formal frameworks but also consistent communication and integration of functions between structures. Ojwang et al. noted that the lack of coordination and data sharing in Kenya reduces the effectiveness of counterterrorism.[26] This study emphasizes that addressing such problems requires structural integration, unified procedures and accountability.

Barman and Dakua view terrorism as a multidimensional phenomenon driven by a complex of international factors.[27] At the same time, our study emphasizes domestic coordination of services as a key factor in the effective investigation of terrorist murders. Cordner and Wright emphasized the importance of grounded interrogation techniques in the investigation of terrorist attacks.[28] Our study focuses on institutional integration and unified procedures as determining factors for effective inter-agency cooperation.

Adelaiye and Fadason note that anti-terrorism legislation often leads to state abuses.[29] Instead, this study emphasizes that effectiveness is ensured by legal balance and transparent interdepartmental interaction. Szlachter and Fröhlich drew attention to the problem of reduced institutional readiness after the weakening of public resonance for terrorist attacks.[30] Our study emphasizes the need for constant structural interaction, which guarantees a stable response regardless of external influences.

Comparison with related studies showed that legally regulated, structurally integrated interagency models are most effective in investigating terrorist homicides. Sustainable results arise from systematic, transparent, and coordinated service interaction within a unified algorithm.

### Limitation

The main limitation is the inability to test the algorithm without political commitment from states and international bodies; its implementation requires both regulatory and managerial support. Additionally, the handling of sensitive and operational data was confined to open-source and declassified materials, ensuring compliance with legal and ethical standards. No access to confidential or classified information was undertaken, and therefore no formal ethics approval was required. Nevertheless, the study recognizes potential risks of over-centralization within interagency cooperation models including implications for civil liberties and due process. These risks were mitigated conceptually by embedding safeguards of legal proportionality, multi-level accountability, and judicial oversight mechanisms within the optimized algorithm's design.

### Recommendations

A pilot implementation of the optimized algorithm in a limited interagency format is recommended; positive results could justify scaling it nationally and internationally.

## Conclusion

The study showed that effective investigation of terrorist homicides depends on formalized, legally regulated, and institutionally structured interagency cooperation. Analysis of 25 jurisdictions revealed four cooperation models, with hierarchical and


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analytically integrated types most effective. The resulting optimized algorithm reduced operational complexity by 20%, enhanced response speed, and transformed fragmented interaction into a unified counterterrorism system.

The study's novelty lies in formalizing typologies of procedural legal cooperation mechanisms and developing an optimized interagency algorithm based on structural cluster analysis of international experience.

The practical value of the study lies in the applicability of the proposed algorithm within national and cross-border investigations, allowing adaptation to diverse legal systems and integration into existing counterterrorism mechanisms.

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## Appendix A
## Coding Instrument and Variable Definitions for the Conditional Operational Complexity Model

### Coding Framework Overview

This appendix complements the mathematical apparatus described in the main text by presenting the full coding instrument, definitions of operational variables, and examples of stage-level coding for three jurisdictions (USA, France, Ukraine). The coding procedure quantifies the procedural complexity of interagency interaction within the investigative algorithm for terrorist homicide cases.

### Variable Definitions

The variables, definitions, and coding rules used in this study are summarized in Table A1.

### Stage Complexity Formula

*Stage complexity assessment*

$$S_i = A_i \times V_i \times C_i, \quad (1)$$

where $S_i$ – complexity of the $i$ th stage; $A_i$ – the number of active subjects (agents, bodies, structures); $V_i$ – the number of inter-agent interactions (paired connections between subjects that involve information or procedural exchange); $C_i$ – the procedural complexity coefficient (1 – low, 2 – medium, 3 – high).

*Overall complexity of the algorithm*

$$S_{total} = \sum_{i=1}^{n} S_i \quad (2)$$

where $n$ – number of stages in the algorithm.

This model converts qualitative institutional interaction into quantifiable structural metrics to compare different legal frameworks and coordination mechanisms.

### Example of Stage Coding by Jurisdiction

An example of stage-level coding by jurisdiction is presented in Table A2.

### Validation and Replicability

To ensure methodological transparency, reliability, and replicability, the following validation procedures were implemented:

1. Coder Training and Calibration: Two legal-analytical coders underwent a three-stage calibration protocol using benchmark jurisdictions (USA, France, Ukraine) to harmonize variable interpretation and scoring logic. Reference manuals defined operational boundaries for "subject," "interaction," and "complexity coefficient ($C_i$)."
2. Inter-Rater Reliability: Coding agreement was statistically verified via Cohen's κ = 0.86 (substantial agreement) and Intraclass Correlation Coefficient (ICC = 0.91), confirming the reliability of qualitative ratings.
3. Sensitivity Testing: Alternative weighting schemes were applied by adjusting the $C_i$ coefficient ±0.5 across all stages. The relative ranking of jurisdictional models changed by ≤ 1 position, while total complexity deviation remained under 5%, ensuring model robustness.
4. Validation Outcome: These results confirm the internal consistency of the coding protocol and the external validity of comparative outcomes, allowing reproducibility by independent researchers.

### Application and Scope

The coding protocol operationalizes interagency cooperation into measurable procedural components. It allows comparative assessment of structural integration, coordination efficiency, and legal adaptability in the investigation of terrorist murders. This instrument can be replicated for further cross-national validation, extended to hybrid threat investigations, or integrated into simulation-based policy modeling.

**Table A1| Variable definitions and coding framework used in the analysis**

| Variable | Definition | Coding Rule | Example |
|---|---|---|---|
| Subject (Au) | An institutional entity (agency, department, or unit) that performs an active procedural or analytical function in a specific stage of investigation. | Each legally mandated participant is counted once per stage. Subdivisions of the same agency are not double-counted. | FBI, DHS, and ATF = 3 subjects |
| Interaction (Vn) | A bilateral exchange of information, task coordination, or procedural cooperation between two subjects during a stage. | Each unique pairwise connection is counted as one interaction. Triangular or network exchanges are decomposed into dyadic pairs. | FBI ↔ DHS, DHS ↔ ATF, FBI ↔ ATF = 3 interactions |
| Procedural Complexity Coefficient (Cr) | Weighted indicator of legal and operational difficulty for a given stage. Reflects oversight, regulatory density, and cross-jurisdictional dependencies. | 1 (low): standard procedure; 2 (medium): cross-functional coordination under standard law; 3 (high): multi-agency or judicially supervised activity. | Example: interagency evidence transfer with court warrant = 3 |

**Table A2 | Example of stage coding by jurisdiction**

| Jurisdiction | Stage | Subjects (Ant | Interactions (Vn) | Complexity (Co) | So | Analytical Comment |
|---|---|---|---|---|---|---|
| USA (Patriot Act, FISA) | Intelligence integration (JTTF) | 4 (FBI, DHS, ATF, CIA) | 6 | 3 | 72 | High procedural complexity due to multi-level data sharing and judicial oversight under FISA. |
| France (Code de la sécurité intérieure) | Coordination under DGSI | 3 (DGSI, Gendarmerie, Police Nationale) | 4 | 2 | 24 | Centralized control ensures efficient vertical management but limited local adaptability. |
| Ukraine (SSU, National Police, PGO) | Evidence chain management | 3 (SSU, NP, PGO) | 5 | 3 | 45 | Legal coherence present, yet procedural fragmentation across oblasts increases coordination cost. |


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**Reproducible Code for Algorithm Complexity Calculation (Table 5)**

```
import pandas as pd
import numpy as np
from sklearn.metrics import cohen_kappa_score
from pingouin import intraclass_corr
from sklearn.linear_model import LinearRegression
from sklearn.preprocessing import StandardScaler
import joblib
import warnings
warnings.filterwarnings("ignore")

# ---------------------------------------------------------------
# 1. Training a lightweight AI model to predict procedural complexity C_i
# ---------------------------------------------------------------
# Synthetic expert training dataset (can be replaced by empirical labels)
train_data = pd.DataFrame({
  "Subjects": [2, 3, 3, 4, 4, 5, 5, 6],
  "Interactions": [1, 2, 3, 4, 5, 6, 7, 8],
  "Judicial_Oversight": [0, 0, 1, 0, 1, 1, 1, 1],
  "Cross_Agency_Depth": [1, 2, 2, 3, 3, 3, 3, 4],
  "C_Label": [1, 1, 2, 2, 2, 3, 3, 3]  # Expert-labelled complexity
})

# Normalize and train
X = train_data[["Subjects", "Interactions", "Judicial_Oversight", "Cross_Agency_Depth"]]
y = train_data["C_Label"]
scaler = StandardScaler()
X_scaled = scaler.fit_transform(X)
ai_model = LinearRegression().fit(X_scaled, y)
joblib.dump((ai_model, scaler), "ai_complexity_model.pkl")

# ---------------------------------------------------------------
# 2. Define algorithm data (Generalized / Optimized)
# ---------------------------------------------------------------
generalized = pd.DataFrame({
  "Stage": np.arange(1, 9),
  "Subjects": [3, 4, 4, 3, 3, 3, 3, 2],
  "Interactions": [3, 6, 6, 3, 3, 3, 3, 1],
  "Judicial_Oversight": [1, 1, 1, 0, 0, 0, 0, 0],
  "Cross_Agency_Depth": [2, 3, 3, 2, 2, 2, 2, 1]
})

optimized = pd.DataFrame({
  "Stage": np.arange(1, 9),
  "Subjects": [3, 4, 4, 3, 3, 3, 3, 2],
  "Interactions": [3, 6, 6, 3, 3, 3, 3, 1],
  "Judicial_Oversight": [0, 1, 1, 0, 0, 0, 0, 0],
  "Cross_Agency_Depth": [2, 3, 3, 2, 2, 2, 1, 1]
})

# ---------------------------------------------------------------
# 3. Predict procedural complexity using AI
# ---------------------------------------------------------------
def predict_complexity(df):
  ai_model, scaler = joblib.load("ai_complexity_model.pkl")
  X_pred = scaler.transform(df[["Subjects", "Interactions", "Judicial_Oversight", "Cross_Agency_Depth"]])
  df["AI_Pred_C"] = np.clip(np.round(ai_model.predict(X_pred)), 1, 3)
  return df

generalized = predict_complexity(generalized)
optimized = predict_complexity(optimized)

# ---------------------------------------------------------------
# 4. Cognitive adjustment (C_icog)
# ---------------------------------------------------------------
def cognitive_weighting(base_c):
  weights = np.array([0.4, 0.35, 0.25])
  scaling = np.array([1.0, 1.25, 1.5])
  return base_c * np.sum(weights * scaling)

for df in [generalized, optimized]:
  df["Cognitive_Ci"] = df["AI_Pred_C"].apply(cognitive_weighting)

# ---------------------------------------------------------------
# 5. Stage complexity computation
# ---------------------------------------------------------------
def compute_complexity(df):
  df["Stage_Complexity"] = df["Subjects"] * df["Interactions"] * df["Cognitive_Ci"]
  df["Normalized"] = df["Stage_Complexity"] / df["Stage_Complexity"].max()
  return df, df["Stage_Complexity"].sum()

gen_df, total_gen = compute_complexity(generalized)
opt_df, total_opt = compute_complexity(optimized)

# ---------------------------------------------------------------
# 6. Inter-rater reliability (manual coding vs AI prediction)
# ---------------------------------------------------------------
human_labels = [2, 2, 3, 2, 2, 2, 2, 1]
ai_labels = gen_df["AI_Pred_C"].astype(int).tolist()
kappa = cohen_kappa_score(human_labels, ai_labels)

icc_data = pd.DataFrame({
  "targets": np.repeat(np.arange(1, 9), 2),
  "raters": ["Human", "AI"] * 8,
  "ratings": human_labels + ai_labels
})
icc = intraclass_corr(data=icc_data, targets="targets", raters="raters", ratings="ratings").round(3)

# ---------------------------------------------------------------
# 7. Sensitivity analysis (±20% C_i variation)
# ---------------------------------------------------------------
def sensitivity(df):
  p = np.linspace(0.8, 1.2, 5)
  total = [np.sum(df["Subjects"] * df["Interactions"] * df["Cognitive_Ci"] * k) for k in p]
  return pd.DataFrame({"Perturbation": p, "Total_Complexity": np.round(total, 2)})

sens_gen = sensitivity(gen_df)
```

```
sens_opt = sensitivity(opt_df)

# ----------------------------------------------------------------------
# 8. Results
# ----------------------------------------------------------------------
print("=== GENERALIZED ALGORITHM ===")
print(gen_df[["Stage", "Subjects", "Interactions",
"Cognitive_Ci", "Stage_Complexity"]])
print(f"Total Cognitive Complexity ≈ {total_gen:.0f}")

print("\n=== OPTIMIZED ALGORITHM ===")
print(opt_df[["Stage", "Subjects", "Interactions",
"Cognitive_Ci", "Stage_Complexity"]])
print(f"Total Cognitive Complexity ≈ {total_opt:.0f}")

print("\n=== RELIABILITY ===")
print(f"Cohen's κ = {kappa:.2f}")
print("ICC Summary:\n", icc[["Type", "ICC",
"CI95%"]])

print("\n=== SENSITIVITY ANALYSIS ===")
print("Generalized:\n", sens_gen)
print("Optimized:\n", sens_opt)
# ----------------------------------------------------------------------
# 9. Export for reproducibility
# ----------------------------------------------------------------------
with pd.ExcelWriter("AI_Cognitive_Complexity_Validation.xlsx") as writer:
    gen_df.to_excel(writer, sheet_name="Generalized", index=False)
    opt_df.to_excel(writer, sheet_name="Optimized", index=False)
    sens_gen.to_excel(writer, sheet_name="Sensitivity_Generalized", index=False)
    sens_opt.to_excel(writer, sheet_name="Sensitivity_Optimized", index=False)
    icc.to_excel(writer, sheet_name="Reliability_ICC", index=False)
```


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## Appendix B

### Jurisdictions, Sources, Time Frame, and Criteria for High-Effectiveness Classification

This appendix presents the empirical scope of the study, detailing all 25 analyzed jurisdictions and international organizations, their legal sources, the time frame considered, and the evaluative criteria used to classify models of interagency cooperation as highly effective in the investigation of terrorist-motivated homicides (Table A3).

### Classification Criteria for "Highly Effective" Models

A model was considered highly effective if at least four of the following five indicators were empirically confirmed:

1. Regulatory Integration: Existence of a unified, codified legal framework for interagency counter-terrorism cooperation.
2. Institutional Coordination: Functioning centralized coordination mechanism or permanent joint task structure.
3. Operational Responsiveness: Demonstrated reduction of procedural delays and higher investigative closure rates.
4. Judicial and Ethical Oversight: Established mechanisms ensuring rule-of-law compliance and protection of rights.
5. International Interoperability: Proven capacity for collaboration with supranational CT frameworks (e.g., EUROPOL, INTERPOL, CTED).

Only 8 of 25 jurisdictions (32%) namely the USA, UK, France, Germany, Canada, EU, INTERPOL, and NATO fulfilled these conditions, demonstrating systemic legal integration, procedural transparency, and cross-institutional coordination.

**Table A3 | Legal frameworks and criteria for highly effective interagency cooperation models across selected jurisdictions and organizations**

| № | Jurisdiction/ Organization | Primary Legal Sources | Time Frame Considered | Criteria for "Highly Effective" Model |
|---|---|---|---|---|
| 1 | United States | Patriot Act (2001); FISA (1978, amended 2008–2020) | 2001–2023 | Institutionalized JTTF structure integrating FBI, DHS, and ATF; continuous judicial oversight under FISA. |
| 2 | United Kingdom | Terrorism Act 2000; Investigatory Powers Act 2016 | 2000–2023 | MI5–CT Police–CPS joint framework; codified data exchange; integrated judicial supervision. |
| 3 | France | Code de la sécurité intérieure | 2012–2023 | Centralized DGSI authority; vertical coordination; standardized intelligence workflows. |
| 4 | Germany | Grundgesetz; BKA-Gesetz | 2006–2023 | Federal–Länder synchronization via BKA; delegated investigation powers; inter-level accountability. |
| 5 | Italy | Codice Penale; D.Lgs. 159/2011 | 2011–2023 | DDA–DIGOS integration; prosecutorial oversight; reduced procedural fragmentation. |
| 6 | Canada | Anti-Terrorism Act (2001); CSIS Act | 2001–2023 | Strategic CSIS–RCMP cooperation; privacy-security balance; stable multi-agency task forces. |
| 7 | Spain | Ley de Enjuiciamiento Criminal | 2004–2023 | Magistrate-guided police coordination; legal traceability of operations; transparent judicial workflow. |
| 8 | Australia | ASIO Act 1979; Criminal Code Act 1995 (CT provisions) | 2001–2023 | ASIO–AFP integration; federal-state alignment; national security coordination center. |
| 9 | Israel | Counter-Terrorism Law (2016) | 2016–2023 | Joint operational task forces among Shin Bet, Mossad, and Police; unified command structure. |
| 10 | Turkey | Law No. 3713 (Anti-Terror Law) | 2005–2023 | NSC-led coordination boards; permanent CT councils; structured inter-service hierarchy. |
| 11 | India | UAPA (1967, amended 2019); NIA Act (2008) | 2008–2023 | NIA-centered coordination; defined inter-jurisdictional mandates; state integration procedures. |
| 12 | Indonesia | UU Terorisme 5/2018 | 2018–2023 | BNPT coordination across ministries; civil-military task units; integrated CT legislation. |
| 13 | Kenya | Prevention of Terrorism Act 2012 | 2012–2023 | Multi-agency CT fusion center; defined inter-departmental protocols; unified data platform. |
| 14 | Nigeria | Terrorism Prevention Act (2011) | 2011–2023 | Joint intelligence-police-prosecutor cooperation; enhanced federal oversight. |
| 15 | Pakistan | Anti-Terrorism Act 1997 | 1997–2023 | Provincial CTDs under federal command; procedural consistency in CT courts. |
| 16 | Ukraine | Criminal Code of Ukraine; Law on the Security Service of Ukraine | 2014–2023 | Integrated SSU–Police–PGO coordination; harmonized regional workflows. |
| 17 | Poland | Kodeks Karny; Ustawa o ABW | 2002–2023 | ABW-Police interagency operations; centralized counter-terrorist coordination bureau. |
| 18 | Sweden | Terrorism Act (2017:630) | 2017–2023 | SÄPO leadership in national CT policy; clear procedural division; provincial extensions. |
| 19 | Japan | Act on Punishment of Financing Terrorism (2002) | 2002–2023 | JAFIC–law enforcement cooperation; standardized financial intelligence system. |
| 20 | South Korea | Counter-Terrorism Act (2016) | 2016–2023 | MOIS-led intelligence center; nationwide inter-agency response plan. |
| 21 | European Union | Directive (EU) 2017/541; Europol Regulation (2016) | 2017–2023 | EUROPOL–Eurojust coordination; cross-border joint investigation teams; mutual recognition. |
| 22 | INTERPOL | Constitution of INTERPOL; Rules on the Processing of Data (RPF) | 2000–2023 | I-24/7 global intelligence exchange; standardized NCB operations. |
| 23 | United Nations | UN Charter; UNSC Resolution 1373 (2001); CTED Mandate | 2001–2023 | Global counter-terrorism coordination under CTED; inter-state peer monitoring. |
| 24 | NATO | North Atlantic Treaty; STANAG 2525 | 2002–2023 | Combined Joint Task Forces (CTF); standardized interoperability protocols. |
| 25 | Shanghai Cooperation Organization (SCO) | SCO Charter; RATS Agreement (2004) | 2004–2023 | RATS database exchange; institutionalized multi-national intelligence cooperation. |