RITHMS Digital Platform: Social Network Analysis for Intelligence-Led Policing of Cultural Heritage Crime

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Abstract The European Union-funded project RITHMS (Research, Intelligence and Technology for Heritage and Market Security) offers a network-focused approach to tackling cultural heritage crime, particularly trafficking. The project brings together a consortium of researchers, data analysts, law enforcement agencies, and scientific institutes across Europe to integrate interdisciplinary data in a platform to address the illicit trade using social network analysis (SNA). Data have been gathered from a range of open sources to enable reconstruction and examination of a sprawling network of actors involved in the circulation of cultural goods. Analysis of this network has the potential to reveal valuable information and insights about the circulation of cultural goods and the character of individual transactions. This chapter first offers theoretical background for the core concepts at the root of the project, namely trafficking, SNA, and the collection of open data. It then explores three case studies that highlight diverse approaches to data analysis which emphasise the value of open-source intelligence and promising methods for intelligence-led policing of and research into cultural goods crimes. This research reinforces the importance of an interconnected analysis among isolated datasets and encourages a broader approach to studying the circulation of cultural goods using these open sources.

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1 Introduction

The European Union (EU)-funded project RITHMS[1] (Research, Intelligence and Technology for Heritage and Market Security) offers a novel approach to tackling cultural heritage crimes, particularly trafficking and illicit trade (RITHMS 2024b). The analytical approach at the heart of the project is social network analysis (SNA), which investigates the structure of interactions among actors in a network using graph theory. Intended primarily for use by European law enforcement agencies (LEAs), the RITHMS platform builds a multi-layer social network graph (SNG) from structured and unstructured data collected from a range of diverse sources. Analysis of this network's layers has the potential to reveal valuable information and insights on the circulation of cultural goods and the character of individual transactions and relationships.

This chapter first offers a theoretical background for the key concepts at the heart of the RITHMS project, particularly cultural goods trafficking and social network analysis. This serves as a foundation for discussing the platform's key components, which comprise diverse functions for analysing the network dynamics of the art market. It then illustrates the methodological considerations which emerged relating to the consolidation of open data for addressing these activities, focusing on the integration of provenance databases and repositories of stolen and missing cultural goods. Three diverse case studies are used to demonstrate how the analytical approaches employed by RITHMS offer novel technological techniques and methods for enhancing intelligence-led policing of cultural heritage crimes. The chapter concludes by reflecting on the ethical considerations of these technologies, common limitations of SNA research, and additional opportunities for research and investigation. The insights for cultural heritage scholarship and law enforcement provided throughout the chapter highlight the value of an interconnected analysis among isolated open data sources and promote an interdisciplinary, semi-automated approach to studying the circulation of cultural goods.

2 Cultural Goods Trafficking

The term 'cultural goods' refers to objects that relate to human culture and the expression of cultural identity, including (but certainly not limited to) artworks, archaeological finds, coins, books, and jewellery (Europol n.d.; Lazăr 2015; Brodie et al. 2019). While there are significant overlaps with similar terms such as 'cultural

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heritage' and 'cultural property,' these objects are commonly considered 'goods' in a commercial sense (particularly in policy and legislation) because of their commodification on the open market and susceptibility to illicit trade (Europol n.d.; Brodie et al. 2019; Hardy 2020). An international interest in thwarting the trafficking of these items has resulted in a sweeping set of policy and advocacy documents which include, in Europe, the EU Action Plan against Trafficking in Cultural Goods, the European Parliamentary Research Service's Briefing on the Illicit Trade in Cultural Goods, and the designation of 'cultural goods crime' as one of Europol's priorities in the fight against organised criminal activity (Europol n.d.; Zygierewicz 2017; European Commission 2022).

These efforts seek to disrupt a broad category of crimes that includes theft and looting, trafficking and smuggling, forgery, vandalism, destruction, and illegal import and export (Manacorda and Chappell 2011; Brodie et al. 2019; Fabiani and Marrone 2021). Of these, this chapter focuses on cultural goods trafficking: a blanket term that encompasses all unlawful activities related to the transfer of ownership of cultural objects (Boz 2018; Brodie et al. 2022; Erken and Turksen 2023). This category of misconduct is also closely linked to other typologies of criminal activity and occurs within a vast network of both licit and illicit behaviours; for example, the trafficking of cultural goods has been linked to the financing of extremist groups and organised crime syndicates as well as the perpetration of other criminal activities such as tax and sanctions evasion, drugs and weapons trafficking, and cybercrimes (Al-Azm and Paul 2019; Ermasova et al. 2019; Hardy 2021b). The criminal phenomenon of trafficking affects local communities, archaeological sites, cultural institutions, and art markets around the world and is frequently transnational, crossing borders to move goods from 'source' countries to 'market' countries where criminal actors can more easily find buyers for undocumented and unprovenanced items[2] (Chappell and Polk 2011; Campbell 2013). Increasingly, new technologies are being developed, tested, and implemented for the investigation and policing of these crimes to address their interdisciplinary and international nature (D'Ippolito 2014; Graham et al. 2023a, b; Giovanelli and Traviglia 2024), as will be discussed at length in the present chapter.

With the ratification of the 1970 UNESCO[3] Convention, an illicit system articulated in three stages (export, import, and transfer of ownership) was formally recognised at the international level as "one of the main causes of the impoverishment of the cultural heritage of the countries of origin" (UNESCO 1970, Art. 2.1). Now, 50 years later, the Council of Europe Convention on Offenses relating to Cultural

[2] This is a generalisation of trade patterns, which tend to flow from the Global South and East to the Global North and West. However, as Byrne (2016) has compellingly argued, this simplification of the international flow of looted antiquities often implies passivity on the part of 'source' countries, and "a grading of countries according to the consumability of their archaeology by Western collectors" (p. 349). For Thailand and the Philippines—the context in which he writes—this simplification replicates the global imbalance of economic power in the realm of cultural agency, diminishing local influence.

[3] The United Nations Educational, Scientific and Cultural Organization.

Property (the 'Nicosia Convention') is encouraging the criminalisation of a set of activities that represent the most harmful behaviours making up the illicit chain of trafficking: theft and unlawful excavation, illegal export and import, acquisition and placing on the market cultural objects of undocumented or illegal origin, falsification of documents, destruction and damage (which could occur in any stage), and aiding or abetting these criminal offences (Council of Europe 2017).

The various activities that enable this trafficking chain involve several distinct but connected actors. Of these, looters represent one of the greatest threats to archaeological sites—but they rarely work alone. Hardy (2021a) has illustrated how metal detectors, which would ordinarily be a huge investment for a full-time minimum wage-earner in lower-income countries, are often acquired through cost-sharing and profit-sharing arrangements among a group of would-be looters or between a dealer and a looter. He cites the examples of Croatia, Serbia, and Bosnia and Herzegovina, in which, at the time of writing, mean net monthly incomes of €905, €536, and €495, respectively, made individual ownership of a metal detector (priced around €650–750) nearly impossible (Ćirić et al. 2005; Hardy 2021a, p. 172, p. 184). Rather, cost-sharing arrangements make metal detecting a more accessible source of revenue for would-be looters in these countries and serves as evidence of collaboration among different actors in the trafficking chain. Such mutually beneficial relationships are not uncommon in the trafficking world, where each individual represents a link in a chain that connects the original, illicitly-acquired object with a final buyer (Watson and Todeschini 2007; Chappell and Polk 2011; Hardy 2021a, b); the division of labour represented by this chain similarly reflects the network's international scope, as goods acquired in so-called 'source' countries are transported to 'market' countries for sale (Chappell and Polk 2011; Campbell 2013; Palombo and Yates 2023).

Of course, dealers and looters are not the only figures fuelling and fostering the illicit flow of cultural goods. Other roles in the chain of trafficking are equally important, although more difficult to identify and prove in court (Mackenzie 2019, 2020). Indeed, a wide range of professionals can participate in trafficking networks, representing pivotal links that facilitate the illicit transit, acceptance, and commercialisation of the artefacts (Brodie 2005, 2011a, b, 2014a, b, c). For example, evidence has been collected of scholars providing false letters of expertise to produce fake provenance; auction catalogue authors manipulating provenance information by omitting certain locations or previous owners that could raise red flags; and restorers heavily intervening on cultural objects to hide evidence of illegal excavation or make them more difficult to identify (Watson and Todeschini 2007; People v. Wiener 2016; Mackenzie and Yates 2020). This creates an impression of collusion among trafficking networks and cultural heritage experts that threatens the legitimacy and authority of experts in the field. This has been reinforced by high-profile cases of scholars, historians, and other experts charged with abetment of trafficking activities, such as the 2005 indictment of Getty Museum curator Marion True and the 2019 case by New York prosecutors against British art dealer and author Douglas Latchford (Watson and Todeschini 2007; Brodie 2014b, c; Picciano 2023). Both cases also highlighted the international nature of cultural goods trafficking, which

involved artefacts from Cambodia and southern Europe, respectively, illicitly acquired by buyers and museums in the United Kingdom (UK) and United States of America (USA).

Organised criminal networks habitually leverage the same routes for different categories of illicit objects, such as drugs and weapons in addition to cultural goods (Hardy 2021b; Hunt 2021; UNODC 2022). Further, high-profile cases of seizures and arrests often highlight the involvement of multiple countries, such as in a 2016 case where Ukrainian police recovered 17 artworks that had been looted from Castelvecchio Museum in Verona, Italy, and smuggled to Odessa via Moldova (Associated Press 2016). Similarly, Operation Pandora, coordinated by Europol each year since it began in 2016, has seen a crackdown on antiquities smuggling across Europe and led to the recovery of around 11,000 artefacts and the arrests of 60 people across 14 European countries in 2022 alone (Europol 2022; Begley 2023). Another accomplishment of the operation has been the identification of certain organised crime networks that have enabled the trafficking of cultural objects as well as other illicit goods including drugs, tobacco, and weapons.

This brief overview highlights the international and collaborative nature of cultural goods trafficking, which suggests equally interdisciplinary mechanisms are required to police cultural heritage crimes. New tools should promote collaboration among different law enforcement stakeholders, enable effective sharing of information and interoperability among existing open resources, and take advantage of promising new developments in technology which are enabling new avenues for data analysis. Able to highlight and reconstruct the often-obscure connections among various actors in the chain of trafficking, the network-focused RITHMS platform holds great potential for tackling such a diverse landscape of illicit activities.

3 Social Network Analysis and Other Analytical Methods

Viewing the trade of cultural goods as a complex network composed of nodes (actors) and edges (either inferred or known interactions and relations among actors) with notable topological characteristics fits well with foundational concepts of network analysis (Newman 2003; Barabási and Pósfai 2016). This analytical approach is well-suited to understand the flow of goods and information within markets because the methods and technologies it leverages allow for the extraction of insights on influential actors (individuals, organisations, and other entities) and a greater appreciation of how objects and information flow, the routes they take, and where bottlenecks in communication may exist (Granovetter 1985; Jackson 2010).

Network models have been applied to the analysis of art trade since the late 1960s, particularly within the realms of visual and contemporary art markets (Yogev and Grund 2012). They have also been explored in other disciplines of arts and humanities research, including investigations into archaeological and art world networks (Meirelles et al. 2014; Brughmans and Peeples 2023). Writing specifically on

the illicit antiquities market, Campbell (2013) describes the network as 'fluid', highlighting the transnational nature of these systems (see also Palombo and Yates 2023). This fluidity is reflected, in part, by the ways in which various actors communicate and interact within the network, as outlined in the previous section. Further, as with trafficking networks for other goods, such as drugs and weapons, routes taken by traffickers are not permanent but rather evolve over time (Brodie et al. 2019). A holistic network model appreciates the ways in which systems transcend national boundaries and the various factors which impact their longevity, relying on a range of actors across a broad geographic and temporal scope.

Key applications of SNA include the work of D'Ippolito (2014), who designed two network models focused on the convicted antiquities smuggler and art dealer Giacomo Medici. These models demonstrated Medici's significant influence within the network and its fluid, non-hierarchical structure by employing measures like degree, eigenvector, betweenness, and closeness centrality. Similarly, Tsirogiannis and Tsirogiannis (2016) built network models on data surrounding the so-called 'Medici Conspiracy' (Watson and Todeschini 2007), creating new algorithms for transaction-based pathfinding and missing link prediction. Fabiani and Marrone (2021) showcased the potential of social network analysis by tracing over 30,000 individual items using catalogued provenance, shedding light on transit routes, pathways, and the connection between sale results and the recurrence of items in subsequent auctions. Their analysis also highlighted the role of private dealers in these networks. Further, Giovanelli and Traviglia (2024) have developed a semi-automated system to construct a knowledge graph (KG) of provenance events related to market-circulating objects, utilising existing named entity recognition (NER) techniques. This work projected both a bipartite actor-object network and a monopartite actor-actor network to reveal different patterns. Brennan and Tsirogiannis (2022) applied KGs specifically to the field by incorporating forensic data collected by Christos Tsirogiannis about 48 trafficked objects linked to Giacomo Medici, Gianfranco Becchina, and Edoardo Almagià (Giovanelli 2021; Pellegrini and Rizzo 2021). Finally, Graham et al. (2023b) have processed 129 entries from the Trafficking Culture Encyclopaedia, manually tagging entities and relationships and applying embedding modules for link predictions. This method revealed previously unknown connections between various actors, which led to identifying further patterns after deepened research (Yates and Graham 2023). To address the time-consuming nature of manual tagging, Graham et al. (2023a) subsequently explored automated KG population using prompts for large language models. Although less precise, this approach produced comparable results.

The value of SNA for investigations into cultural goods trafficking is, thus, increasingly recognised in interdisciplinary scholarship. The RITHMS project builds upon these innovative solutions and methods to streamline the intelligence and monitoring processes with research on the automation of data collecting and processing tasks. Although it will not be explored in detail in the present chapter, the project also proposes new opportunities for intelligence-led policing through the integration of open data with data from private sources (including mobile networks, satellite imagery analysis reports, and restricted police intelligence). These

undertake to address a complex international criminal phenomenon with equally complex but promising technological solutions. What will be explored in this chapter is the promising opportunity for intelligence-led policing (see Scuro, this volume) presented by consolidated open datasets. Further, the data visualisation methods and tools that convey this research significantly enhance end-users' abilities to comprehend the valuable insights hidden within structured datasets, effectively transforming abstract statistics into actionable knowledge (Few 2014).

After a brief introduction to the platform itself, this chapter will outline the methods of data collection that fed this dataset as well as the legal considerations of automated and semi-automated research on open-source intelligence (OSINT). It then presents three case studies that demonstrate the value of these diverse datasets and reinforce the importance of SNA and other analytical approaches for research into the circulation of cultural goods. These studies relied on a range of methods and analytical approaches for researching cultural heritage crimes, including two different but complementary types of network analysis; *ego* network analysis examines an individual's role within a system and their influence on other individuals, while *whole* network analysis focuses on more general patterns of network dynamics and its overall structure (Perry et al. 2018). Both vantage points can offer valuable insights for investigations into the ways in which cultural objects flow through social systems. Complementing these are other analytical methods including exploratory data analysis, which was an important first step in identifying shared characteristics among datasets and highlighting patterns to investigate further (Chatfield 1986; Windhager et al. 2019). From this, and a combination of manual, semi-automated, and automated data processing operations, predictions are outlined for new opportunities for research, derived from predictive analysis based on historical trafficking cases (see also Graham et al. 2023b; Li et al. 2024). Land and other trade routes are equally important factors in this research, lending a dimension of spatial analysis to the case studies that sheds further light on the channels through which illicit cultural goods are transited (Brodie et al. 2019). Together, these methods offer promising opportunities for intelligence-led policing of cultural heritage crimes, of which cultural goods trafficking comprises a significant part.

4 The RITHMS Platform

At the core of the RITHMS project lies a sophisticated platform developed by a consortium of researchers, computer scientists, and law enforcement agencies across Europe. The tool, which will be used exclusively by law enforcement agencies, is designed to aggregate, correlate, and analyse OSINT with additional data from complementary sources as needed and/or by the end-users themselves, to construct a comprehensive KG and layered social networks. These layers yield crucial insights into trade patterns, allow the recognition of overlaps between licit and illicit activities, and facilitate the identification of individuals and patterns involved.

The platform features four main components. First, a set of automated data collection modules targets a diverse array of information sources, such as existing databases, specialised publications and newspapers, websites of market actors (e.g., auction houses and art galleries), social media, and other web-based public repositories. These modules comprise web scrapers (written in the Python programming language) that have been customised for each source to ensure accurate and comprehensive data collection; those discussed throughout this chapter were developed by the Centre for Cultural Heritage Technology (CCHT) of the Italian Institute of Technology (IIT). The second component, a core module, organises and manages the KG using a robust and detailed ontology. This ontology was designed by the European Software Institute (ESI)—the technical partner responsible for the development of the platform itself—around two main pillars. The first pillar is a domain-specific taxonomy that enables the classification of different types of actors such as individuals and organisations, cultural objects, dates, locations, and events. The second pillar is a complementary system of intelligence-based labelling that allows the end-users to assign specific interactions among the actors and patterns in these interactions. This structured approach enables seamless integration of diverse datasets while maintaining their inherent or hypothetical relationships. The third component comprises a multi-layered social network (Pio-Lopez et al. 2021) that correlates various patterns and applies different analytical algorithms, ranging from conventional SNA methods (Sandra et al. 2021) to advanced machine learning techniques such as graph neural network-based link prediction (Li et al. 2024). To tackle the unstructured nature of most of the data sources, the CCHT has fine-tuned natural language processing (NLP) models to autonomously generate nodes and relationships with contextual awareness (Ferro et al. 2025; Yang et al. 2021). The last component of the platform is a server-based desktop user interface engaged with data visualisation and data communication. It comprises diverse functionalities, allowing end-users (LEAs) to perform actions on the data, such as queries, traversals, and transformations on which to base analyses (e.g., topology analysis) and hypotheses (e.g., link prediction) about the interactions among data objects. Finally, the user interface allows for manual data entry to permit users to input and analyse other relevant data obtained from other, closed, sources.

While it is outside the scope of this chapter to present the platform in greater detail, this overview is essential for outlining the importance of open data to the project and contextualising the conditions within which these data were gathered and will be used. Further, this limited introduction draws connections between the analytical tools discussed in the previous section with the initial problem the platform aims to address: cultural goods trafficking. The methodology for data collection and the legal framework that enabled it will be detailed in the next section, while the opportunities, limitations, and ethical considerations of the platform's use are explored in the discussion that comprises Sect. 6. By enabling innovative analytical approaches towards the examination of open data on the circulation of cultural goods, LEAs will be empowered with enhanced investigative capacity to monitor, detect, analyse, and act on inexplicit patterns of illicit cultural heritage trade more effectively than ever before.

4.1 Methodology for Data Collection

In the initial phase of project development, the CCHT developed data collection modules to automate the gathering of information from 30 public databases of stolen, missing, unprovenanced, and protected cultural goods. These included the Federal Bureau of Investigation's National Stolen Art File, the German Lost Art Foundation's Lost Art Database, and the Romanian Police's public database of stolen cultural objects, as well as those discussed later in this chapter and many others. These tools are automated web scrapers that can be run manually, scheduled, and/or parametrised to limit the collection of data to certain results (for example, to only collect data on objects of type 'painting,' or to limit results to items stolen before a certain date). For the purposes of RITHMS project, all available data was gathered from each source, which in most cases included at least basic object data (for example, title, year of creation, author, materials or object type, dimensions, etc.) and in many cases also included information about the object's provenance or historical chain-of-ownership (for example, that a museum acquired the piece from a specific collector, or that an object was stolen from a private residence in Paris on a specific day). Data collection was performed with a combination of the *Requests*, *BeautifulSoup*, and *Selenium* packages of Python, depending on whether the data source was static (i.e., the page's source Hypertext Markup Language (HTML) could be automatically parsed) or dynamic (i.e., where the implementation of JavaScript in the page's source code necessitated the use of a web driver to replicate normal user behaviour). Additional methodological considerations for individual case studies presented in this chapter have been outlined in the corresponding sections below, to further contextualise and illustrate the individual procedures of data collection, processing, and analysis required for each case study.

Before discussing the legal framework within which data collection and analysis occurred, it is important to clarify the working definition of 'open data' used in this research. While 'open-source' and 'open' data are related concepts, 'open-source' data refers to data that is made available with a license that allows users to access, modify, and redistribute it, typically for software development or research purposes. In contrast, open data refers to data that is made available to the public for free and without restrictions, often with the intention of promoting transparency and public good. In our research, we utilised publicly available data within the broader context of OSINT research, where sourcing from openly accessible but legally bounded data is key. Legal considerations are crucial in both cases; open-source data may involve licensing agreements that dictate how the data can be used, while open data may be subject to privacy laws, data protection regulations, and restrictions based on intellectual property.

In terms of legal right to collect and process data, it should be noted that the activities conducted on public, open-access websites as part of the RITHMS project and the research presented here comply with EU Directive 2019/790 (Directive (EU) 2019/790, 2019, Title II, arts. 3–4), which has been transposed into Italian law through Legislative Decree 177/2021, specifically introducing articles 70-ter

and 70-quarter into Italy's national Copyright Law 633/1941 (Legislative Decree n. 177, 2021, art. 1, par. 1(i)). Pursuing the lead institute's (the Italian Institute of Technology) legitimate interest to carry out scientific research (GDPR art. 6, par.1(f), Data Protection Commission 2019),[4] compliance with the key principles of the General Data Protection Regulation (GDPR) has also been ensured, particularly with regard to data gathering and storage, and an informative notice has been published on the RITHMS website in accordance with GDPR art. 14, par. 5(b) (RITHMS 2024a). Further, data collected for this chapter were restricted to only what was necessary for the immediate research need, and the mechanisms of data collection and processing were documented thoroughly to facilitate accountability and transparency. Additional ethical considerations on the use of open data for research on cultural heritage crimes and the ethical use of the platform are discussed in Sect. 6. Data collected for RITHMS project has produced the largest known consolidated non-police dataset of looted, missing, protected, and unprovenanced cultural goods (Leeson et al. 2025). Preliminary processing of this data facilitated the extraction of over two million entities (cultural objects, people, events, and other actors) linked to the circulation of cultural goods and the initial correlation and examination of object and entity data. Chronologically, this dataset includes information on the circulation of cultural goods from the year 1800 to the present day; geographically, Europe and the Americas are most well-represented, though data sources also include information on objects that originated in Middle Eastern, African, and southeast Asian contexts. While the ability to publicly reproduce the entire consolidated dataset is limited by copyright protections and pending reproduction rights from individual database managing authorities, the publication of an abridged version of this data is anticipated to follow the end of RITHMS project in October 2025. The following section discusses some of the initial case studies which have been conducted on this data, outlining the opportunities for intelligence-led policing of cultural heritage crimes and the value of automated and semi-automated analytical approaches for examining and visualising this information.

5 Case Studies

This section offers cursory analyses of several datasets collected within the scope of RITHMS project to highlight research prospects and the patterns that can be gleaned from the mechanisms implemented in the project. It draws attention to the ways in which different analytical approaches, including SNA, can highlight prospects for investigation into trafficking networks, grey areas of the market, and other problematic activities. Further, it reinforces the need for a consolidated dataset to minimise

[4] To ensure the lawfulness and compliance of the research process, IIT conducted a feasibility study and produced a corresponding Data Protection Impact Assessment (DPIA).

data siloes and complement existing research and investigation (Leeson et al. 2025). Through the project's collaboration with implementing LEAs across Europe, these initial opportunities can be translated into actionable results, contributing to the tackling of cultural goods trafficking and other criminal activities by bolstering mechanisms for intelligence-led policing.

Research on individual datasets collected for the project has shed light on the structure of elite social networks and networks of individuals active in the circulation of cultural goods. Leveraging the same methodology for automated data collection through web scraping, Leeson et al. (2024) reconstructed a social network of thousands of individuals who have been sanctioned for their support of Russian military action in Ukraine, including high-ranking oligarchs and individuals in the Russian state apparatus. This research highlighted the place of known art collectors within the network and, through centrality analyses and examination of acquaintance relationships among politically exposed persons, identified grey areas for the trade of cultural goods to continue in violation of international sanctions. Further, this research draws attention to the intersections between cultural heritage crimes and other clandestine activities, particularly white-collar crimes such as tax and sanctions evasion, money laundering, and fraud.

Similarly, Giovanelli et al. (2025) pursued the same methodology for automated data collection from the *Proveana* database of the German Lost Art Foundation, to reconstruct and visualise the networks of individuals, organisations, and events pertaining to the confiscation and circulation of cultural goods during the Second World War. By leveraging social network analysis, this research identified a single individual who served as a bridge between two major periods of state-led confiscations of cultural goods: the first under Nazi Germany during WWII and the second in 1962 under the German Democratic Republic's Ministry for State Security. This study produced insights that would not have been attainable using other methods of data collection or analysis, and this research highlights novel opportunities for research into the post-war provenance of looted objects, which is often incomplete, missing, or falsified (German Lost Art Foundation n.d.-a; Manikowska 2023).

These research projects, secondary to the development of RITHMS platform, leveraged the unique collection of open data to offer substantial insights on the structure and flow of the networks that feed the market for illicit goods. Similarly, the following case studies demonstrate how further research on other datasets collected for the project offers actionable insights on trade patterns and networks which can aid law enforcement efforts to tackling these types of criminal activity. The case studies are presented in reverse chronological order, first examining data on current trends in illicit trade, then considering data on post-1970 trafficking networks, and concluding with a case study on wartime looting during WWII.

5.1 Securius Datenbank

The Securius database is managed by the Federal Criminal Police Office of Germany (Bundeskriminalamt, also BKA) in collaboration with the German State Criminal Police Offices. The database holds records on thousands of cultural goods that have been confiscated by police departments across Germany and that are believed to be linked to criminal activity (Bundeskriminalamt 2024a). At the time of writing, the database holds 5260 object records, which include artworks, watches and jewellery, coins, gold bars, and other unprovenanced items seized during the carrying out of police activities (Bundeskriminalamt 2024a, b). The database is public, allowing anyone to browse the objects and submit a report if they identify an object for which previous ownership is known. Each object page includes at least one photo of the object, a brief description, details of the confiscation (date and place), and contact information of the police department involved, in most cases consisting of a telephone number, the department name, and its postal address. Keywords are also provided for the objects, for example 'coin', 'pendant', and 'gold,' which facilitate data querying and browsing in the raw dataset. While some of these items, particularly jewellery or watches, may not be typically included within the umbrella of 'cultural goods' or 'cultural heritage,' the present study has deferred to the BKA, which has included all such items under the umbrella of "art and valuables" (*Kunst und Wertgegenstände*) (Bundeskriminalamt 2024a). For the purposes of this research, data used were collected from Securius on 8 April 2024.

The development phase of RITHMS produced a data collection module that uses the *Requests* and *BeautifulSoup* libraries of the Python programming language to parse the HTML of each object record and retrieve all the available information. For the current analysis, the locations of all seizures were extracted and geolocalised to visualise the frequency of confiscations across Germany. Figure 1 shows the results of this processing, overlaid on a population density map. Cursory analysis reveals that the frequency of confiscations corresponds generally with the population density of Germany, with most seizures occurring in major cities and clusters that approximately reflect areas of greater concentration.

However, there are two major outliers that warrant further investigation. The first is the city of Hannover, which saw the most objects seized (at 1969; see Table 1). It is worth noting that Hannover is the thirteenth-largest city in Germany in terms of population size, but far exceeds larger cities—including Berlin, Cologne (Köln), and Frankfurt—in number of seizures. Hannover, and its region of Lower Saxony, does not have a particularly high regional crime rate, so the number of cultural goods seized is not a reflection of an overall higher rate of crime (McEvoy 2023). Further, Hannover is not a statistically significant hotspot for seizures of other illicit goods, such as drugs, so the high number of cultural goods seizures is notable (Bundeskriminalamt 2022, p. 59).

The most frequently confiscated items are jewellery and watches. Without further information, it is unclear in which context the cultural objects were confiscated. It is possible, however, that many were pickpocketed; this would explain why these

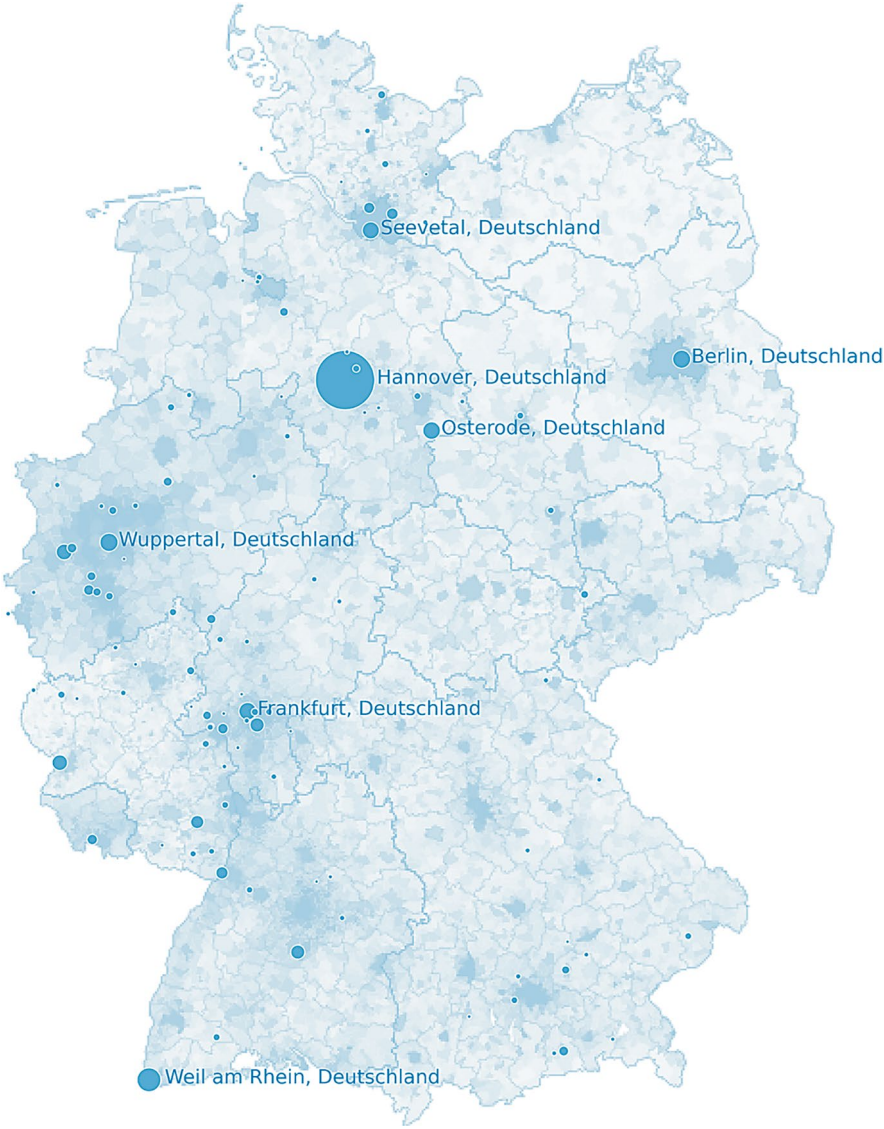

Fig. 1 Seizures of cultural goods in Germany, by city, as reported in the Securius database, with marker size proportionate to the number of seizures. Labels have been added for cities with more than 140 reported confiscations. Data were visualised using the *Geopandas*, *Matplotlib*, and *Shapely* Python packages

items, which for the most part are relatively low value, well-worn, not unique, and confiscated individually, would have been subjected to police seizure. While the practice of pickpocketing certainly has several important differences from the phenomenon of cultural goods trafficking, both are considered activities within the

Table 1 Cities with the most confiscated objects and the most frequently confiscated object in each, extracted from the Securius database

City	Confiscations	Most common objects
Hannover	1969	Jewellery, watches, coins
Weil am Rhein	315	Jewellery, watches
Wuppertal	180	Jewellery, coins
Berlin	177	Jewellery
Osterode	167	Jewellery, coins

broader umbrella of organised property crime (EUCPN 2017), meaning research on the circulation of pickpocketed valuables can shed light on patterns in the illicit trade of other cultural goods, particularly in the lower end of the market. It should also be noted that there is a great disparity between the frequency of pickpocketing events and thefts in Hannover and number of objects confiscated relative to the rest of Germany (Bundeskriminalamt 2022, p. 45), suggesting either police in Hannover are particularly skilful at recovering pickpocketed goods (several times more so than their counterparts in other cities), or that many of these items were trafficked into Hannover from elsewhere in the country or abroad.

The next most frequent category of seized objects is coins, the majority of which date from the sixteenth century to the mid-twentieth-century and/or are limited-edition commemorative coins. Table 1 shows that coins are only a common abstract object type in three of the top five cities: Hannover, Wuppertal, and Osterode. As illustrated in Fig. 1, these three cities are relatively close to each other and somewhat close to the northwestern border with the Netherlands. It should be noted that coins are one of the most frequently excavated objects in the Netherlands due to the country's lenient regulations allowing metal detecting on public and private land (PAN Project 2021; Al Mayadeen English 2023; Kuta 2023). While there are no recent news reports of coins being trafficked from the Netherlands into Germany, the frequency of coins among the seized goods in these three cities could suggest that modern coins, excavated by metal detectorists in the Netherlands, are being brought into Germany where they are then confiscated in small numbers by police during other investigations.

The second outlier is Weil am Rhein, a town in the state of Baden-Württemberg on the southeastern border of Germany. The town is located at the intersection of the borders of Germany, France, and Switzerland and is integrated into the local transport system of the Swiss city of Basel. Of the 315 objects in Securius that were confiscated in Weil am Rhein, most are wristwatches, and the second-most common abstract object type is jewellery. The high frequency of objects confiscated in Weil am Rhein could be explained by the town's location on the border of France and Switzerland and its integration in a Swiss transit system, which make it an advantageous passage for the trafficking of goods originating in these countries (or transiting through these countries from another source). Indeed, as reported in the Global Organized Crime Index report (2023, p. 4) on Germany, German police "have carried out multiple seizures of illegal gold and silver, highlighting the country's role in gold trafficking in the region" and drawing particular attention to recent "cases of

gold trafficking between France, Germany, and Turkey" (see also Eurojust 2023). Further, it is reported that German customs agents seize thousands of counterfeit items at border points in the country, of which the most common types include jewellery and accessories (Global Organized Crime Index 2023, p. 3), echoing the insights provided by the data in Securius. This is further indication that lower-end goods (including counterfeits) tend to be targets for smugglers transporting relatively small and easily concealable valuables across borders within western Europe (Brodie et al. 2019, pp. 73–74).

Lastly, while the Securius database holds records on the unprovenanced and illicit cultural goods seized by German police, records on seizures of art and artefacts (as opposed to jewellery and accessories) are minimal. Of the over 5000 object records in the database, less than 1% are paintings and other pictures, another less than 1% sculptures, and only 5% coins; most of the remainder are wristwatches and jewellery. On one hand, this makes sense because unique artworks are more readily identified and returned to their rightful owner, leaving the non-unique goods to be registered on a database for public identification. However, a pattern can still be discerned from the locations with the most recovered paintings and sculptures: the cities where the most paintings have been recovered are Braunschweig and Hamburg, and the cities where the most sculptures have been recovered are Hannover and Neumünster. As illustrated in Fig. 2, these cities are all located in the north of the country and in relative proximity to one another. This might suggest that the north of Germany is a more frequent region for the looting or trafficking of these types of objects.

On the other hand, the German government has been criticised for misreporting the illicit trade in cultural goods with so-called "zombie statistics" (Bochereau 2020), and this dataset could be further evidence of that, challenging speculative claims that exaggerated the frequency of cultural heritage crimes in the country. In 2019, for example, the ILLICID project submitted a report that failed to find evidence of a billion-euro market for looted antiquities or proof that the illicit trafficking of cultural goods was financing terrorism and organised crime—claims that have been used to implement heightened regulations on the art trade and a new cultural property law (Fitz Gibbon 2019; Bochereau 2020).

Further, while the exploratory and spatial analyses discussed in this section do suggest a higher frequency of cultural goods crimes in the cities under examination than elsewhere in Germany, this research has been working with the BKA's definition of 'art and valuables,' which includes objects not typically considered by scholarship to fall within the definition of 'cultural heritage.' While much research and policy on the illicit trade tend to focus on art and antiquities, especially those with outstanding historic or artistic significance, jewellery and watches (which comprise the largest category of confiscated objects in Securius) tend to be classified instead as conspicuous or luxury goods (Oosterman and Angelini 2021; Blakeney 2023). The present study joins Oosterman and Angelini (2021) in advocating for more focus on the luxury goods market as a subset in cultural heritage crime research, because the patterns observed in this discipline have many similarities and overlaps with those affecting cultural goods trafficking. Further, it is well-established that

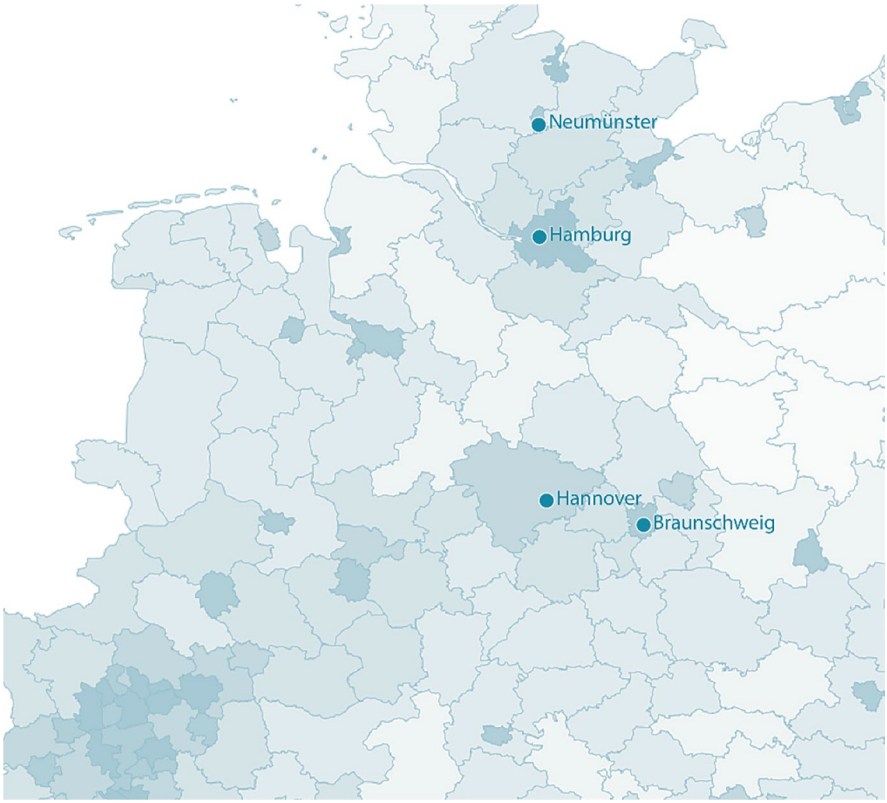

Fig. 2 Northern Germany, showing cities with the most seized paintings and sculptures: Braunschweig, Hamburg, Hannover, and Neumünster

trafficking networks tend to use the same routes for different types of illicit merchandise, including both cultural heritage and luxury goods as well as drugs, weapons, and other goods (Hardy 2021b; Europol 2022; UNODC 2022).

While this case study has highlighted some opportunities for additional investigation into trends of illicit trade, for example the likelihood of coins being smuggled into Germany from the Netherlands, or the increased frequency of art thefts in the country's north, additional research is needed to determine the context of these crimes and whether they are connected to broader trafficking networks across Europe. However, this analysis has reinforced the value of interdisciplinary approaches to open data on cultural goods crimes in Germany, including automated data collection and manual geospatial analysis. It also suggests greater focus be given to low-end cultural goods in scholarship on illicit trade for the patterns that these items can highlight within an international network of criminal activity.

5.2 AAMD Object Registry

The second case study is an examination of the Object Registry of the Association of Art Museum Directors (AAMD), a membership-based association linking the leadership of museums across North America. Within the Object Registry, the AAMD maintains two databases: the New Acquisitions of Archaeological Material and Works of Art database (of objects in AAMD member museums that were acquired after 2008[5] that lack pre-1970[6] provenance), and the Resolutions of Claims for Nazi-Era Cultural Assets database (of objects in AAMD member museums that were subject to claims of Nazi looting during World War II). The present research focused on the first database, which at the time of writing holds approximately 2300 object records. As the registry is continuously being updated, it should be noted that data used for this study were collected on 19 March 2024.

While most data gathered for the RITHMS project concern objects and collections within Europe, the AAMD and other non-European datasets complement these materials by expanding the coverage of the KG on which the platform relies. Specifically, they help mitigate a common weakness in social network analysis in which the restricted geographic scope of the network graph does not accurately reconstruct the network under study, which is rarely so limited. Rather, the integration of non-European datasets allows the visualisation of connections between trade routes in Europe and those elsewhere in the world, in this case the Americas. It also highlights the same patterns of trafficking which affect other regions, for example (as outlined below), the transit of illicit goods from looted contexts first to Europe and then to North American markets, which served to launder object provenance and disguise illicit origins. The inclusion of American data also helps link other datasets (of European scope) to high-profile trafficking cases, many of which have involved American galleries and museums. For example, the art and antiquities dealers Robin Symes, Robert Hecht, and John G. Bourne, all of whom have been implicated in international antiquities trafficking networks, feature in multiple object provenances in the AAMD Object Registry, problematising these objects and the channels that enabled their acquisition by reputable museums. Lastly, the enrichment of the RITHMS KG necessitated the automated extraction of entities and relationships from unstructured text to reconstruct the sequences of events which make up object provenances. The tool which enabled this was fine-tuned on the AAMD dataset and then further tested on other data gathered for the project, making the AAMD an important step in the technological advancement of the project's mechanisms for data processing.

As with the Securius database, a data collection module was developed that used the *Requests*, *BeautifulSoup*, and *Selenium* packages of Python to parse and gather all the available information on the objects listed in the database. One of the most

[5] The date of the last AAMD acquisition regulations.

[6] Referring to the landmark 1970 UNESCO Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property.

interesting fields of data provided about the cultural objects is 'provenance,' which details the known ownership history of each item (not to be confused with 'provenience,' which refers to the object's place of origin). These fields are unstructured in the database, which means they consist of sentences or paragraphs of information from which specific entities (such as people, locations, and dates) must be extracted. For the purposes of RITHMS project, three natural language processing (NLP) models were fine-tuned to extract entities from the unstructured text integrated into the platform (Ferro et al. 2025). The development phase of the NLP models required annotating entities in the unstructured text, as illustrated in Fig. 3, where tags are displayed using the NER Annotator for Spacy software (NER Annotator for Spacy n.d.). This process trained the model to recognise and extract entities and has been implemented in the final RITHMS platform. Surprisingly, however, issues encountered during this phase were later found to highlight objects in the AAMD database with particularly suspicious provenance. Further examination indicates this methodology may successfully predict opportunities for further investigation into looted and trafficked goods.

In several instances, the NLP model returned errors because it was unable to parse distinct events within a provenance sample due to convoluted or opaque language. One of the records which returned such an error detailed a seated earthenware figure from the Jama-Coaque culture, originating in Ecuador and currently at the Walters Art Museum (see Fig. 4; AAMD n.d.-b). According to the 1970 UNESCO Convention, which recommends restrictions on which objects can be acquired by museums, this piece should not have been acquired by the museum because it lacks sufficient provenance from before 1970 (UNESCO 1970). Until 2008, however, AAMD guidelines for museums only required 10 years of provenance before the museum's acquisition (AAMD 2004). In 2008, these guidelines were updated to be in line with UNESCO's recommendations, requiring proof that the object was either already outside its country of origin by 1970, or that it was exported legally after this date (AAMD 2008). A revision to the guidelines in 2013 clarified that member museums may acquire such unprovenanced objects in cases where they were gifted or donated by bequest before the date of the new guidelines (2008), provided they are also logged in the Object Registry (AAMD 2013). This was the case for the earthenware figure, which, although it was not donated to the museum until 2013, was anticipated since 2005. The provenance listed for this piece is: "Arizona collection; Ron Messick Fine Arts, Santa Fe, New Mexico [date and mode of acquisition unknown]; John G. Bourne, October 3, 1998, by purchase; given to Walters Art Museum, 2013" (AAMD n.d.-b).

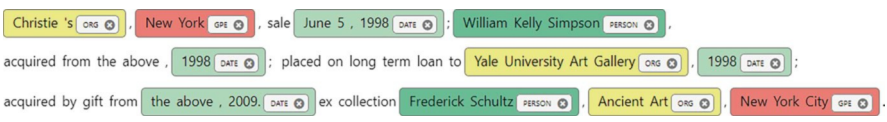

Fig. 3 Example of data annotated for NLP that tags organisations, locations, dates, and people as relevant entities, visualised using NER Annotator for Spacy

Fig. 4 Seated Figure Holding a Box, The Walters Art Museum. Earthenware, originated in Ecuador (photo by the Walters Art Museum, Creative Commons License CC0 1.0)

The reason the NLP model results were unsatisfactory for this object is that the structure of the provenance information is somewhat unclear, devoid of verbs, and includes in square parentheses irrelevant text. These factors all contribute to uncertainty on the part of the model (as well as for human researchers) trying to identify the events involved in the object's historical chain-of-ownership. There are multiple reasons why provenance texts may be vague, oddly structured, or otherwise confusing. In some instances, for example if an object were acquired illegally, ambiguous provenance may be a deliberate attempt to mask the illicit circumstances of the object's acquisition. In other cases, however, it may result simply from a lack of rigour or standards of documentation on the part of the reporting institution.

During manual attempts to reconstruct the chain of ownership that resulted in the object being acquired by the Walters Art Museum, it was ascertained that John G. Bourne is already known to the field of cultural heritage crime and provenance research (Yates 2014). In 1998, the Peruvian archaeologist Walter Alva identified objects in the New Mexico History Museum that he believed had been looted from the site of Sipán in Peru (Atwood 2003). An FBI investigation later determined that the objects had indeed been looted from the site in 1987; they were then trafficked out of the country, rerouted through the UK by an international smuggling ring, and sold to the American antiquities dealer Ben Johnson roughly 6 months later (Kirkpatrick 1992). Bourne purchased the items from Johnson shortly after. Curiously, he claimed to the FBI that the pieces had originated in a *different* looted archaeological site in Peru, La Mina, which exempted the items from emergency

import restrictions that the US government had placed on artefacts from Sipán (Atwood 2003). Having acquired the objects before the formal imposition of import restrictions on Peruvian artefacts, and in the absence of proof that the objects originated in Sipán rather than La Mina, Bourne avoided charges, and the items returned to the museum (Constable 2008).

The New Mexico History Museum later announced that it would no longer welcome Bourne's anticipated donation of his personal collection of Mesoamerican artefacts. Bourne then turned instead to the Walters Art Museum, where he donated approximately 300 items from his collection and $4 million USD for a centre to focus on research of the ancient Americas (Yates 2014).

Further, Ron Messick, the New Mexico dealer from whom Bourne allegedly bought the earthenware sculpture under investigation, has also faced charges for trafficking artefacts that originated in looted Peruvian archaeological sites (The Washington Times 2005; Yates 2015, p. 41). The claim in the object's provenance field that Messick had acquired the items from an undisclosed "Arizona collection" is another example of a vague provenance that potentially covers up the object's illicit origins. The only publication provided to support the object's provenance is an overview of the John Bourne Collection, "Exploring Art of the Ancient Americas," published by the Walters Art Museum itself (Reents-Budet 2012).

While the earthenware figure at the centre of this study originated in Ecuador, not Peru, the actors involved in the object's historical chain of ownership are known to have participated in the trafficking of similar artefacts into the US and the fabrication of provenance to 'legitimise' these objects. Further, Bourne has participated in the laundering of items' provenance by donating them to museums (first the New Mexico History Museum and then the Walters Art Museum), the laundering of his own reputation through high-profile cash endowments, and the legitimisation of his collection through publishing activities, as demonstrated by the events related above. This object may not have drawn attention without being flagged by the NLP model currently in development, but research into this item and others like it have returned similar results that suggest the NLP model is able to predict promising opportunities for further research and investigation through the flagging of vague or deceptively worded object provenances.

5.2.1 The AAMD-Derived Network

This case study relies partly on analysis of the social networks that facilitated the circulation of these goods from their origins in Mesoamerican archaeological contexts, via trafficking networks which routed through Europe, to antiquities dealers and museums in the United States. Relationships among the actors involved can be studied further by conducting centrality analyses on the social network derived from the AAMD data to predict other opportunities for research into individuals and organisations who are closely related to those problematised above and/or that have significant influence in their networks.

After collecting data from the AAMD Object Registry using the automated web scraper described in the previous section, the refined NLP model was used to extract entities and relationships from all object provenances provided in the database. In the case of the provenance sample provided above, Table 2 lists the entities (and entity types) extracted, among which relationships were derived, for example that Ron Messick Fine Arts is located in Santa Fe, and that John G. Bourne gave the object to the Walters Art Museum in 2013. This procedure was repeated for all provenance samples in the database and resulted in a sprawling social network graph of 72,280 nodes (representing entities) and 111,863 edges (representing relationships among them) (Fig. 5). This method represents an innovative approach to enriching provenance data through the extraction of valuable data from unstructured texts (see also Giovanelli and Traviglia 2024).

Once this SNG is produced, different statistical analyses can be performed on the data to determine the centrality and influence of specific individuals, events, or organisations within the network. These results, in turn, can highlight opportunities for further research into those entities that have been central to the circulation of unprovenanced or under-provenanced objects. Notably, there are some limitations to this methodology which resulted from the nature of the source data; for example, 'private collection' (and variations, like 'collection', 'coll', and 'estate') is one of the most central entities in the network by most measures, reflecting the fact that many provenances have included an unspecified 'private collection' as one stop in their objects' ownership histories. However, this does not refer to the same private collection in every case; rather, dozens or even hundreds of unique private collections have been merged within a single node with the label 'private collection', reducing its value to the SNA of this graph.

One method for analysing influential entities is to calculate and compare each node's closeness centrality score; this reflects how close each is to the others in the network, and how many 'shortest paths' (the quickest way to move from one node to another within the system) pass through the entity. Unsurprisingly, the node with the highest closeness centrality score in the network is the auction house Sotheby's

Table 2 Entities extracted from the AAMD provenance sample by the NLP model fine-tuned for RITHMS project

Entity label	Entity type
John G. Bourne	Person
Ron Messick Fine Arts	Organisation
Walters Art Museum	Organisation
Santa Fe	Location
New Mexico	Location
October 3, 1998	Date
2013	Date

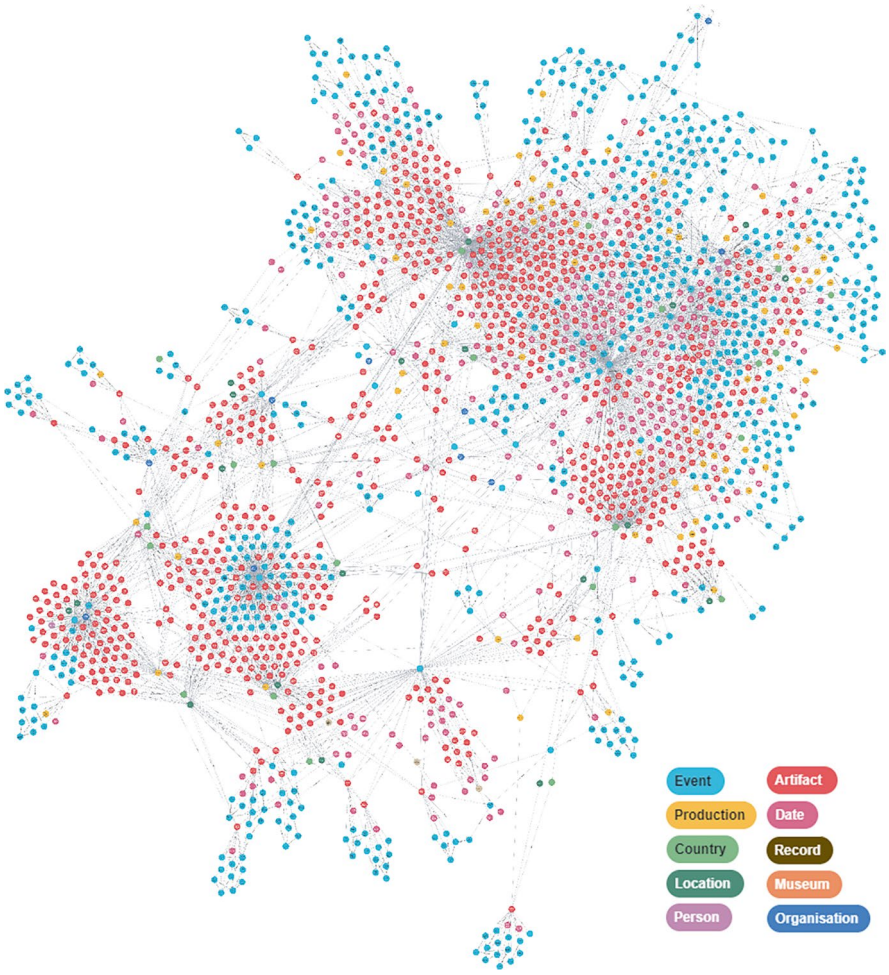

Fig. 5 SNG depicting a portion of the network derived from the AAMD dataset using the NLP model fine-tuned for RITHMS project, visualised in Neo4j

New York, which reflects its role as a broker and facilitator of a significant number of transactions in the cultural goods trade (Fabiani and Marrone 2021). Other nodes with an unsurprisingly high closeness centrality include Sotheby's London and Christie's auction house. More interesting is the fact that the former art dealer Nicolas Koutoulakis is within the top ten most central nodes according to this measure; Koutoulakis was named in the organigram of the Medici antiquities trafficking network and, along with his Paris-based gallery Segredakis, has been implicated in claims from Greece and Turkey for artefacts later determined to have been illegally removed from the countries and sold to the J. Paul Getty Museum in Los Angeles

(Watson and Todeschini 2007; Felch 2012). Through manual analysis of the nodes in Koutoulakis' immediate ego network (entities linked directly to him), Nanette B. Kelekian was identified as the most frequent buyer of his objects. According to the dataset, all the objects in the AAMD database that passed through Kelekian are now in the collection of the Metropolitan Museum of Art, which is known for its over-zealous acquisition practices, particularly in the 1970s (Hoving 1993; Watson and Todeschini 2007). Notably, the Kelekian objects were all acquired by the Met in either 2018 or 2020 from bequests expected before 2008, which permitted their acquisition according to the AAMD's most recent guidelines. Considering (i) Kelekian's proximity to Koutoulakis in the network, (ii) the fact that these objects all lack pre-1970 provenance and evidence of legal export from their countries of origin, and (iii) that she appears to be relatively unknown to scholarship on the illicit trade,[7] this is a promising lead for future research into objects believed to have entered the market illegally.

Another similarly influential node according to closeness centrality is the New York-based Merrin Gallery, which has also been linked to the Medici trafficking network (Giovanelli 2021, 2024). Specifically, the gallery was implicated in an investigation by the Manhattan District Attorney's Office into a group of ten objects that had been looted from Egypt, as well as a fourth-century BCE Greek artefact that had been sold to the gallery by Giacomo Medici himself (Giovanelli 2021, 2024). By following the same procedure as above, 46 objects were identified that passed through the Merrin Gallery, 33 of which were then sold by the gallery to an anonymous 'private collection' (which, as outlined above, may refer to the same private collection or unique ones) before being donated or gifted to the Walters Art Museum. Recall that it was the Walters Art Museum that accepted John Bourne's donation of approximately 300 items (and $4 million USD) after these objects, problematised by their proximity to an international trafficking network of Mesoamerican objects, were refused by the New Mexico History Museum (Yates 2014).

This brief foray into SNA of the AAMD-derived network demonstrates that closeness centrality, which is just one among many centrality measures, is a promising method of statistical analysis for both identifying known trafficking networks and flagging new individuals and organisations for further research. While it is outside the scope of this chapter to investigate these opportunities further, this section has highlighted the promise of this method for research into cultural heritage crimes. During deployment in the final RITHMS platform, these mechanisms have the potential to produce actionable intelligence for law enforcement agents investigating and tackling the illicit trade of cultural goods.

[7] Nanette Kelekian has been named in some scholarship, including Decamargo (2012), Jenkins-Madina (2000), and Thum (2022), but these works have only mentioned her in passing and focused more on the activities of her grandfather, the prolific collector and dealer Dikran Kelekian. It appears that the connections between Nanette Kelekian and Nicolas Koutoulakis have not been explored.

5.3 WWII-Looted Databases

As RITHMS is concerned with building a social network graph of historic chains of ownership, databases of cultural goods looted during the Second World War are an important addition to the knowledgebase. Fourteen databases of WWII-looted cultural goods were identified for integration with RITHMS, as indicated in Table 3; of these, the first six will be discussed in this section.

Partway through the data collection phase, several inventory and numbering systems were identified in use by multiple databases, suggesting the potential to correlate data objects across repositories to consolidate the available information on each item. Of the fourteen databases investigated for the project, the first six listed in Table 3 were found to use common systems; Table 4 provides a list of the various inventories (left column) and the databases that use them (header row). This final case study outlines the methodology used to correlate data objects among databases, offering new possibilities for research into the provenance and recovery of WWII-looted cultural goods.

Six different inventory and numbering systems were identified. 'Munich numbers' represents a numbering system used by Allied forces to consolidate Nazi-looted collections for repatriation. Following the end of the war, cultural goods were brought *en masse* to the 'Central Collecting Point' in Munich to determine their country of origin and rightful heirs (Enderlein et al. n.d.). Many of the artworks

Table 3 Databases of WWII-looted cultural goods identified for RITHMS project

Database	Managing authority
Hermann Göring Art Collection ("Göring Collection")	[Germany] German Historical Museum
Reichskunstdepot Kremsmünster – Paintings ("K-List Database")	[Austria] Leonhard Weidinger
Linz Collection	[Germany] German Historical Museum
Rose Valland MNR	[France] Ministry of Culture
Einsatzstab Reichsleiter Rosenberg Collection ("Rosenberg Collection")	Claims Conference and the United States Holocaust Memorial Museum
Tableau et dessin database ("TED Database")	[France] Commission for the Compensation of Victims of Spoliation
Cultural Goods of the Second World War	[Netherlands] Cultural Heritage Agency
Lost Art Database	[Germany] German Lost Art Foundation
The Central Registry of Information on Looted Cultural Property, 1933–1945	Commission for Looted Art in Europe
Art Database	[Austria] National Fund of the Republic of Austria for Victims of National Socialism
Catalogue of Wartime Losses	[Poland] Ministry of Culture, Division for Looted Art
Max Stern Art Restitution Project	[Canada] Concordia University
Degenerate Art Database	[Germany] Free University of Berlin
Nazi-Era Provenance Internet Portal	[United States] American Alliance of Museums

Table 4 Databases of WWII-looted cultural goods that use common inventory systems

	Göring Collection	K-List Database	Linz Collection	Rose Valland MNR	Rosenberg Collection	TED Database
Munich number	X	X	X		X	X
Linz number		X	X		X	
Aussee number		X			X	
Lv number		X				
ERR number					X	X
MNR number				X		X

confiscated by the Nazis during the war were intended for an unrealised 'Führermuseum' in Linz, Austria; these works were acquired by the 'Linz Special Commission' (*Sonderauftrag Linz*), which was established in June 1939 (Commission for Looted Art in Europe n.d.; Enderlein et al. n.d.; Leonhard Weidinger n.d.). Consequently, 'Linz numbers' represent the numbering system used for the full collection of these objects. Many of the items acquired for the Linz collection were, at various points during the war, stored at the Altaussee salt mine in Austria; these objects were inventoried using 'Altaussee' or 'Aussee' numbers (Leonhard Weidinger n.d.; Monuments Men and Women Foundation 2022). An alternate numbering system for objects stored in the mine is that of 'Lv numbers'; these were recorded by US soldiers upon reaching Altaussee, so it is possible they differentiate between objects originally brought to the mine for storage (the Aussee number) and those still in the mine when the Allies arrived (Lv number). Another department responsible for the acquisition of objects for the proposed museum in Linz was the *Einsatzstab Reichsleiter Rosenberg* (Special Purposes Reich Leader Rosenberg, ERR) office, which purchased and confiscated objects specifically from France; these items are identified by their 'ERR number.' Lastly, 'MNR numbers' refer to an inventory system for looted objects that could not, for various reasons, be returned to their rightful owners following the war and were entrusted to the care of French national museums (Ministère de la culture n.d.).

The databases used for this analysis are the Göring Collection, Linz Collection, Rose Valland MNR database, the so-called 'K-List' of looted works temporarily stored at the Kremsmünster Benedictine monastery, the Rosenberg Collection of works acquired by the *Einsatzstab Reichsleiter Rosenberg* task force, and the Tableau et Dessin database of claims for WWII-era compensation. It should be noted that data used for this research were collected between 12 February and 8 March 2024. Data were gathered using similar Python-based modules as those used for the Securius and AAMD databases. Following data collection, rule-based

classification techniques were implemented using the *Pandas* package to normalise the data records and standardise inventory numbers; this enabled correlation across the six datasets as well as the identification of the most frequent values (e.g., most common artist or country-of-origin).

This approach identified hundreds of cases where records on the same object were provided by multiple databases. These examples were found by correlating the shared inventory numbers shown in Table 4, with the initial aim of consolidating all available information on each item. This mechanism provides additional opportunities for provenance research to leverage the consolidated open dataset of RITHMS by eliminating data silos and creating a central repository (Leeson et al. 2025). However, this approach found that many databases provided different data on the same item; inconsistencies ranged from minor variations in dimensions to significant discrepancies in title, provenance, materials, and other fields. Correlation of this data provides additional unforeseen advantages for research into looted goods, as indicated in the following example: a painting by the Dutch artist Pieter Aertsen, which is included in four databases with Munich number 11795.

Table 5 consolidates the different pieces of information provided by each database for this object, sourced from the Göring Collection, K-List database, Linz Collection, and Rosenberg Collection (ERR Project n.d.; German Historical Museum n.d.-a, n.d.-b; Leonhard Weidinger n.d.). It is outside the scope of the present study to determine the accuracy of the information provided by each database. Rather, this example shows that correlation of data between multiple sources can be used for two main purposes: to validate (or call into question) object data, and to improve the scope of object records by aggregating existing data. Consolidating all available information on this piece enables the reconstruction of the history of an extremely interesting object—something that would not be possible if provenance research relied on one database alone.

Jacques Goudstikker was a Jewish art dealer who owned and lived in the estate of Nyenrode Castle in Breukelen, the Netherlands. Following the German occupation of the Netherlands, which began in May 1940, Hermann Göring (one of the senior Nazi officers who oversaw the confiscation of thousands of artworks during the war) immediately acquired the full inventory of Goudstikker Gallery and integrated about 300 of the 800 paintings into his own personal collection (Köhler 2019). Those he did not retain (including the Aertsen painting), he consigned at various auction houses in Germany (German Historical Museum, n.d.-a, n.d.-b). The painting, which was taken from the Netherlands to Germany in July 1940, was consigned that same month to art dealer and director of the Göring Collection, Walter Andreas Hofer. It went unsold, however, and was later moved to the Altaussee salt mine to protect it from Allied bombing. In 1943 the work was consigned again to the Munich-based Galerie Marie Almas-Dietrich, where it again failed to sell. In February 1944, Göring used the painting (and 49 others) to barter for a highly sought-after Vermeer—a more desirable work, but one which was later found to be a forgery (Köhler 2019). The Aertsen was confiscated again, this time joining the Linz Collection of works intended to fill the anticipated 'Führermuseum' in Hitler's hometown of Linz, Austria. In 1945, however, following the end of the war, the

Table 5 Information provided on Aertsen's "Outdoor Kitchen" by each of the databases under examination

	Göring Collection	K-List Database	Linz Collection	Rosenberg Collection
Image	Yes		Yes	
Inventory numbers	Munich, Linz, and RM	Munich and Aussee	Munich and Linz	Munich and Goudstikker
Artist name	Pieter Aertsen	Pieter Aertsen	Pieter Aertsen	Pieter Aertsen
Artist lifespan	1508–1575		1508–1575	
Artwork title	Küche im Freien (Outdoor Kitchen)	Küche im Freien (Outdoor Kitchen)	Küche und Bereitung eines Mahles im Freien (Cooking and Preparing an Outdoor Meal)	Keukenstuk (Kitchen Piece)
Date			1533 (around)	
Material/ technique	Wood	Oil on wood	Wood	Painting Oil on Panel
Dimensions	59 × 137.5	59/138	59.5 × 138	59.5 × 138 cm
Previous owner	Collection Goudstikker		Jacques Goudstikker Collection/ Amsterdam 1940 (private collection Netherlands)	Jacques Goudstiker – Amsterdam, Netherlands
Previous location	Nyenrode Castle 1513			Nyenrode Castle, Breukelen, The Netherlands
Transfer type	Forced Sale		Forced Sale	
Consignment	Hofer, Walter Andreas/ Berlin, July 13, 1940		Galerie Maria Almas - Dietrich/ Munich 1943	
Transfer date		17 January 1941		
Transfer destination		Aussee		
Restitution	Netherlands		Netherlands	
Other notes	Delivery of Vermeer exchange on February 9, 1944 to Goudstikker-Miedl/Amsterdam, from there to the special order Linz (Linz 3031)		Acquired for Hermann Göring (RM 406)	

painting was brought to Munich where it was inventoried by Allied troops at the Central Collecting Point and where the decision was made to repatriate the piece back to the Netherlands (German Lost Art Foundation, n.d.-b).

The story does not end there. From the safekeeping of the Dutch government, one might assume the painting should have been restituted to Desirée Goudstikker, widow of Jacques and the major shareholder of the looted Goudstikker Gallery. However, the piece (and others repatriated like it) were instead sold at various auctions across the Netherlands in the 1950s (Köhler 2019). While it is known that the Aertsen painting was sold at Van Marle, de Sille and Baan auction house in Rotterdam between 20 and 22 December 1950, the buyer and subsequent provenance are unknown (German Lost Art Foundation n.d.-b). The painting, having survived so much during the war and having been repatriated to its country-of-origin, was returned to the market and its whereabouts are currently unknown.

This history could not have been reconstructed in such detail if provenance research had relied on just one of the databases mentioned above or was conducted without proper mechanisms to correlate data from different sources. In fact, additional context included here but not integrated in Table 5 was found in the Lost Art Database, yet another repository of WWII-looted cultural goods that could only be correlated with the others through manual analysis (German Lost Art Foundation n.d.-b; Köhler 2019). One limitation of this method—correlating objects using common inventory numbers—is that it does occasionally face collisions, where the same identifier has been assigned to multiple objects. While this can be resolved by comparing other object data to determine whether it is the same object, it means that the inventory code for these two items can no longer be used for correlation as it has been proven to not be unique. However, this still represents an opportunity for manual investigation to reconcile these errors, validate correct information, and further examine promising leads.

5.3.1 Network Analysis of WWII Data

Using the same methodology as that applied to the AAMD database, namely the automated extraction of entities using a fine-tuned NLP model, a similarly enriched network graph was generated that visualises the relationships among individuals, organisations, events, and other entities involved in the circulation of cultural goods during and after the Second World War. This builds on previous work, which has highlighted the ways in which looted and trafficking of cultural goods during the period relied on the same networks that enabled other war crimes (Giovanelli et al. 2025). In this study, one key individual, Walter Neuling, was found to serve as a bridge between Nazi looting activities and the mass confiscations of cultural goods realised by the German Democratic Republic in the 1960s, well after the close of the war. Neuling was found to be a crucial cut-point linking the two mass confiscations, both of which constituted nationwide appropriations of cultural goods (many of which in both cases were sold abroad to raise state funds) and were largescale

examples of state crime disguised as actions in the national interest (Förster 2016; Giovanelli et al. 2025).

When consolidating data from multiple databases for SNA, an important consideration is the merging or linking of entities across sources. This would enable, for example, the linking of 'Walter Neuling' and 'Neuling, Walter' as the same individual. For this purpose, the CCHT developed a Python function for consolidating variations on individual names, factoring in string case, punctuation, and name order. This allowed for the merging of the following possible variations: 'Walter Neuling', 'walter neuling', 'NEULING, Walter', 'Neuling, Walter', 'WALTER NEULING', and so on. After implementing this function on the dataset collected from the *Proveana* database of WWII-era entities (including individuals, dates, and artworks), managed by the German Lost Art Foundation, an individual was identified who is also referenced in the AAMD database. This represents an insight that was largely unexpected and resulted from the unique combination of techniques and methods implemented for data processing within the RITHMS project: web scraping, consolidation of data from isolated sources, node linking, manual provenance research, and social network analysis (particularly centrality analyses).

The individual, Giorgio Sangiorgi, was a Rome-based art dealer and collector who mainly operated in the first half of the twentieth century (Dumbarton Oaks n.d.). To start, Giovanelli and Traviglia (2024) have reported that he has a relatively high closeness centrality score in a social network graph derived from auction house data, emphasising his efficient connections to other influential nodes in the network, including auction houses themselves as well as key individuals in the WWII-era trade of cultural goods. As a result, it is unsurprising that Sangiorgi also appears in the Office of Strategic Services (OSS) Art Looting Investigation Unit's (ALIU) final report on individuals implicated in the agency's investigations into Nazi-led confiscations (NARA 2016). The OSS was a special unit of the United States government tasked with researching looted art and identifying the individuals responsible who should be prioritised in postwar legal proceedings (Salter 2015). Sangiorgi was flagged because he, in his capacity as an art and antiquities dealer, regularly sold pieces to Walter Andreas Hofer, the primary agent of Hermann Göring (NARA 2016). Sangiorgi is also named in the AAMD dataset in the provenance of a first-century Roman marble urn currently in the collection of the Metropolitan Museum of Art, which was purchased by John J. Medveckis from Sangiorgi's son through Christie's auction house (AAMD n.d.-a). In sum, Sangiorgi is an important, influential node who links together multiple seemingly isolated datasets.

Rather than displaying evidence of wrongdoing, this analysis sheds light on the overlaps among diverse datasets and the value of consolidating seemingly unrelated open data—in this case, auction house records, databases of WWII-looted objects, OSS reports, and a North American registry of unprovenanced archaeological objects. This has provided unexpected insights into the ways in which networks extend across space and time and are rarely bounded by the constraints imposed upon them in typical social network analyses. The consolidation of data across multiple databases also offers other prospects for the recovery of WWII-looted objects. The Aertsen painting, for example, has been recorded with multiple titles, all of

which can be used as possible aliases of the piece should it go back on the market. Similarly, the various repositories provide us with multiple different materials and slightly different dimensions, which allow the casting of a wider net when mining data from online auction houses or marketplaces for the painting. Interdisciplinary techniques and methods contribute to the further enrichment of the data and enable its reconstruction in a social network graph, allowing the visualisation of the network of actors and events around each item and providing additional prospects for correlation and investigation.

6 Discussion: Opportunities, Limitations, and Ethical Considerations

The case studies provided above offer initial insights gleaned from analysis of some of the databases integrated in the open dataset from which the RITHMS social network graph is derived. As indicated by the example of the WWII databases, the consolidation and correlation of data from multiple sources provides even greater opportunities for the provisioning of intelligence on looted goods. Other open sources include social media, news, and websites, each of which contributes further source layers to the network under examination.

Following the construction of the network, deep learning algorithms for link prediction can be leveraged to suggest connections that are likely to exist in the real world but are not present in the collected data. Yates and Graham (2023) have used a KG embedding model to suggest new relationships based on the known nodes and edges of a specific network: in their case, the organigram depicting the organisational structure of the Medici antiquities trafficking network. The model they used predicted a relationship between the notorious art dealer Leonardo Patterson and the Brooklyn Museum which, upon further investigation, turned out to be a promising lead for two objects connected to a known trafficking network. Crucially, the impact of this lead relied largely on the domain expertise of the authors, who leveraged their extensive knowledge of actors, events, and networks in the art trade to validate predictions made by the model. This experience reinforces the importance of interdisciplinary collaboration for intelligence-led policing to combine the domain-specific knowledge of researchers, the on-the-ground experience of LEAs, and the increasingly promising potential of new tools for machine learning, network analysis, and data mining.

While the opportunities for data-driven insights on the flow of cultural goods are promising, there are also some limitations to this research which should be noted. Certain constraints exist on all research that relies on OSINT sources and open data, some of which have already been acknowledged in this chapter. For example, in the case of the Securius database of police-confiscated objects, the extent of data coverage relies entirely on the diligence of police to voluntarily enter data on their confiscations. Consequently, a hotspot of seizures must be examined in relation to other

sources of data to provide additional context on the confiscations and determine whether they truly reflect an increased number of looted or trafficked goods. Similarly, the AAMD database consists of information provided by the museums themselves, and OSINT research on this source depends largely on the willingness of museums to provide comprehensive provenance voluntarily. In this context, it is also critical to keep in mind that an item's or organisation's inclusion in the consolidated dataset or the RITHMS platform does not inherently imply misconduct or criminal activity, but rather serves as a mechanism for examining the routes through which cultural objects flow.

Similarly, while SNA offers some exciting opportunities for tracking and tackling the illicit trade of cultural goods, it has some limitations as an analytical tool that should be considered and mitigated, where possible, in scientific research and investigations. First, KGs and social network graphs inescapably oversimplify relationships among actors, which are significantly more complicated than what is drawn from SNA-based research. On the one hand, this is deliberate, as it allows for a macroscopic appreciation of the network, which can provide valuable context on the overall flow of goods and information. However, this also necessarily simplifies very complex relationships, the impact of which cannot be underestimated. As a result, SNA-based research should incorporate a range of data sources to examine both the characteristics of the network as a whole and the specificities of individual nodes or relationships that have been flagged by initial, macroscopic analysis. A similar challenge is the inability to accurately define the boundaries of a social network, so it must be recognised that the network constructed by the collected data only reflects a subset of the real-world interactions among actors, many of which do not leave a documentary record.

There are also several ethical considerations that must be kept in mind when conducting OSINT research in general, particularly in support of law enforcement efforts. First, results and insights should be discussed as such: they are not 'evidence' or 'proof' of wrongdoing until the appropriate investigations have occurred and a judicial authority has accepted that such intelligence constitutes evidence, in compliance with the relevant legal and ethical constraints. Similarly, research should be careful to not use dehumanising language when describing specific individuals, such as 'criminal' or other reductionist language that draws pre-emptive or unsupported conclusions. Ultimately, the RITHMS platform is intended as a tool for data management that has the potential to support law enforcement activities, but it does not create or generate evidence, and it does not make decisions or solve problems autonomously. Further, the platform will not be delivered with data and will only begin data processing after it has been installed within the secured premises of the implementing law enforcement agencies. A set of legal and ethical requirements for the project were also defined early in the development process and concern the assurance of security and best practices for the platform's use as well as the ethical and legal considerations of leveraging AI tools in the investigation of cultural goods trafficking (Díaz Castaño and Faraldo Cabana 2023; Faraldo Cabana et al. 2023a, b; García Adán and Fuentes Loureiro 2023).

The final challenge facing this research, and the RITHMS platform specifically, is the importance of ensuring end-users thoroughly understand and regularly use every available function. If officers and analysts were to not appreciate the full potential of the tools provided, or they were to fall into a routine of consistently relying on only one or two main functions, the impact of the project would be similarly limited. With this challenge in mind, a comprehensive plan for testing, validation, and training will allow LEAs to familiarise themselves with all the functions of the tool and promote understanding of how it can enable intelligence-led policing of trafficking networks. Conversely, enhanced collaboration between law enforcement and technical partners will ensure that the platform leverages systems of data classification and processes of knowledge discovery that LEAs already use in their real-world investigations of illicit activity. This safeguards the effectiveness of the tool and amplifies its relevance to end-users.

7 Conclusion

Cultural goods trafficking is a complex criminal activity that transcends national borders, increasingly exploits new technologies, leverages existing and clandestine transit routes, and overlaps with other typologies of both licit and illicit activities. The investigation and tackling of illicit trade and trafficking networks thus depend on the aggregation of expertise from a diverse range of stakeholders: domain experts, data analysts and technicians, law enforcement agencies, and actors from civil society. Research on the trade and trafficking of cultural goods must necessarily integrate data from similarly diverse sources and leverage new and promising technologies for data mining, analysis, and knowledge discovery. As the case studies in this chapter have demonstrated, open-source and publicly available data represent an increasingly valuable resource for the research of these activities.

The RITHMS project has already produced actionable insights on the movement of cultural goods through its leveraging of OSINT sources, SNA, NLP, and interdisciplinary methods of data analysis. This research emphasises an interconnected analysis of isolated databases and encourages a broader approach to studying the circulation of cultural goods using open sources. The platform developed by the Consortium is projected to provide further actionable intelligence on trafficking routes and, ideally, enable the dismantling of networks which have facilitated the illicit trade. Building on this project and the many opportunities presented by the integration of new technologies in cultural goods crime research, intelligence-led policing derived from analyses of open data offers promising opportunities for a network-focused approach to confronting trafficking and illicit trade.

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Michela De Bernardin is an ancient historian and classical archaeologist with honours from the University of Pisa and the Scuola Normale Superiore, where she also obtained her PhD in Ancient History and Archaeology within a joint program with the Ruprecht-Karls-Universität Heidelberg.

After a specialised postgraduate course at the Centro Studi Criminologici in Viterbo, she completed a two-year postgraduate program at the University of Roma Tre addressing the illicit trade of Palmyrene funerary portraits and the impact of numismatic forgery on the art market. She co-founded and is now the secretary of the Art Crime Project APS organisation. Since 2020, she has been collaborating with the Centre for Cultural Heritage Technology (CCHT) of the Italian Institute of Technology (IIT). Her research stretches from provenance, looting, and forgery studies to the dynamics of illicit trafficking. Currently, she is a Postdoctoral Research Fellow at the CCHT and the Scientific Project Manager of the HE RITHMS project.

Riccardo Giovanelli an archaeologist specialising in Egyptology and Roman Provinces, directed his research towards investigating the looting and illicit trafficking of cultural artefacts in 2011, prompted by the widespread looting of museums and archaeological sites in Egypt during the Arab Spring. He is now a Postdoctoral Researcher at the Center for Cultural Heritage Technology (CCHT) in Venice. He researches practical application of advanced digital methods and Knowledge Graph frameworks towards the challenges associated with preserving cultural heritage and curbing the trade of looted artefacts. He is the President of the civil society organisation 'Art Crime Project', and actively engages in initiatives aimed at raising awareness, involving the broader public and fostering collective action to prevent and counter art-related crimes across various dimensions.

Sara Ferro a Control and Automation Engineer specialising in Machine Learning and Deep Learning models applied to sequential data, focused her research on developing innovative models for the automatic digitalisation of historical documents written in Western Latin-based languages. She earned her PhD in Computer Science from Ca' Foscari University of Venice, where her doctoral program was conducted in collaboration with the Center for Cultural Heritage Technology (CCHT) of the Italian Institute of Technology, based in Venice, Italy. Her thesis introduced new procedures, methods, and models to accurately transcribe historical texts by leveraging contextual information within the data, an important concept in Computer Vision and Natural Language Processing research. She is a Postdoctoral Researcher at CCHT, working under the EU Project RITHMS to utilise and define new Natural Language Processing models for extracting information from online sources to help create a Knowledge Graph database for the RITHMS platform.

Arianna Traviglia is the Director of the Centre for Cultural Heritage Technology (CCHT) at the Italian Institute of Technology (IIT). Her work focuses on integrating advanced technologies into the study, protection, and conservation of cultural heritage. With expertise in archaeology and imaging technologies, she leads interdisciplinary research in Artificial Intelligence, Nanotechnologies, and Robotics for material culture and ancient landscape studies. Over the past decade, Dr. Traviglia has led or contributed to numerous EU-funded projects on cultural heritage preservation. Currently, she coordinates the RITHMS project, which uses social network analysis and knowledge graphs, in collaboration with seven European police forces, to combat cultural property trafficking. She also leads the ALCEO project, funded by the European Space Agency (ESA), employing satellite imagery to detect archaeological looting. Dr. Traviglia has held academic positions in Italy (University of Venice) and Australia (University of Sydney, Macquarie University) and collaborates with the Council of Europe, contributing to the upcoming guidelines on AI for cultural heritage. Recognised with several awards, she also serves as Chair of the technical-scientific committee for the Cassa Depositi e Prestiti Foundation.