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Fighting illicit trafficking of maps – The Methodology of the Enigma Project

Keywords: map heritage, illicit trafficking, digital archives, heritage provenance, heritage documentation

Summary: Historic maps can be considered a quasi-form between art, science, and technology. Cartographic artifacts are currently auctioned at prices ranging from a few hundred to hundreds of thousands of euros depending on their uniqueness, designer, age, and condition. Their value and unique characteristics have converted maps into objects sensitive to illicit trafficking, with many cases demonstrating their illegal seizure from G.L.A.M institutes (e.g. British Library, National Library of Spain, etc.). The Enigma Project, funded by the E.U, aims at developing a methodology for safeguarding, protecting, and managing the provenance of Cultural Heritage including cartographic documents (e.g. manuscript maps, atlases, etc.). The project's methodology focuses on three main concepts, the first of which is the development of a Unique Authenticity Identifier (UAI) that will create a virtual digital marking for each object to allow efficient tracking. The UAI has to be adaptive to each cultural heritage item's unique characteristics and concisely but efficiently answer the following question: which specific parameters should be defined for each object to uniquely document its characteristics and attributes? Existing databases that maintain cartographic and mapping artifacts (e.g Europeana) and also databases of stolen art (e.g. Lost-art database) will be studied to examine and assess the minimum metadata required to document a map's unique characteristics (e.g scale, designer, data, map location, projection, etc). This standardized documentation can be used for the project's second concept, which refers to stratification techniques that can assist in identifying similar maps in terms of reference location, designer, time period, thematic representation, and toponyms. Once the UAI and stratification methodologies have been completed, technologies such as crawlers in the dark web can be used to monitor any potential illegal activity regarding maps, and notify police authorities (e.g. Europol, Interpol), which can then intercept the transaction and return the artifact to its legal owner.

1. Introduction

Cultural objects provide a sense of identity, tradition and historical continuum to each place. The illicit trafficking of cultural objects has been an increasing concern for legislative, law enforcement agencies, customs, and international authorities which has been exacerbated by political unrest, armed conflicts, and of course through the increased options that technology and digital networks provide to the smugglers (Hulkevych, 2023, Votey, 2021, Blake, 2020, UNESCO, 2018, Hardy, 2015, Manacorda and Chappel, 2011). Illicit trafficking of cultural heritage items is a lucrative business established often over existing networks, transportation channels, and commerce practices of organized crime (Baranello, 2021, Chechi, 2019 Davis and Mackenzie, 2014, Van Duyne et al., 2014, Phelan and Roussinn, 2001). The internet in the form of social media networks or the so-called dark web has become the prime marketplace for advertising illegally seized objects and contacting potential buyers (Europol, 2021, Yates, 2015). This technological gateway has provided an

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additional market to illicit dealers who operate in small, decentralized groups, are not "professional" criminals per se, and usually act at a local level (European Commision, 2019, Nistri, 2009 , Sargent et al., 2020)

In that spectrum, the European Commission presented the EU action plan against the trafficking of cultural goods as part of its Security Union Strategy in December 2022. In this plan, cultural heritage trafficking crimes are identified as having some unique characteristics that distinguish them from other types of trafficking activities, including identity, authenticity, provenience, provenance, and legal status which often require an expert opinion. The plan states the importance of registering and documenting all cultural objects in databases to enhance their future traceability and identification in case of illegal seizure, and to increase their current visibility in the public. E.U legislation is also very strict concerning exporting cultural artifacts from its territory since an exporting license/permit is obligatory. The same holds true when importing such goods that have been illegally exported from third countries. However, some researchers estimate that Cultural Heritage related crimes are still not considered a serious crime and a cross-border threat to the E.U and are thus treated in a fragmented way and particularly as another means of money laundering (Cabana, 2024). Interpol's regular reports entitled "Assessing Crimes against Cultural Property" provide a vivid illustration of the nature, complexity, and spatial variability of the phenomenon (INTERPOL, 2022). As can be seen in Figure 1 , Europe appears to be the continent where the most recorded cultural object thefts occurred with approximately 18,000 items reported missing, followed by Asia (3,360 items). Most of the stolen objects (≈45%) regard numismatic items, followed by library materials (≈10%) and paintings or archaeological items (≈7%). The location where crimes against cultural property occur also presents variability per geographical area, e.g. in Europe there seems to be an even distribution of crime location per category except for paleontological sites which are very limited in number. On the contrary, Africa presents the largest variability per category with most of the crimes against cultural heritage being carried out in cemeteries or private homes. An interesting and at the same time alarming metric is that more than 60% of recorded crimes happen in locations where some level of security is expected to be present (e.g. Museums, Art Galleries, Archaeological Sites, etc.).

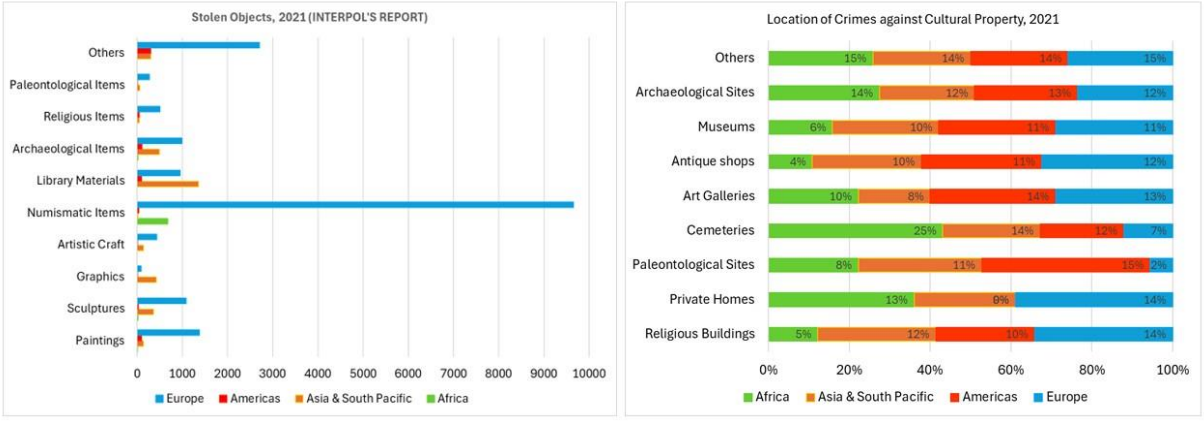

Figure 1. Statistics on Stolen Items and Location of Crimes against Cultural Property by Broader Geographic Area (INTERPOL, 2022).

The same report reveals that the authorities seize stolen cultural heritage objects mainly in Europe and Asia/South Pacific (Figure 2). Most of these objects in Europe are Archaeological Items (≈43%)

and Library Materials (≈31%) while in Asia/South Pacific are Numismatic Items (≈62%) and Archaeological Items (≈32%). This high geographic concentration of seized objects in specific areas could be attributed to the following two reasons:

i. increased custom security checks, particularly in the E.U 27 and the Schengen Area but also in the United States, the United Kingdom, Canada, etc. However, E.U's common border policy can be a liability in fighting the illicit trafficking of cultural objects inside the Union's territory,

ii. the majority of potential buyers/collectors of such illicit items are expected to be located in the richer parts of the world, so perhaps Europe, Asia, and the United States are expected to be end-destinations for these objects. In any case, these spatial patterns can assist in tracing the routes that trafficking networks use to import or export objects to different parts of the world. For example, perhaps it is no coincidence that in Europe Archaeological and Library Objects add to approximately 74% of seized objects as the area has a high concentration of renown libraries but also significant archaeological sites for example in Greece and Italy.

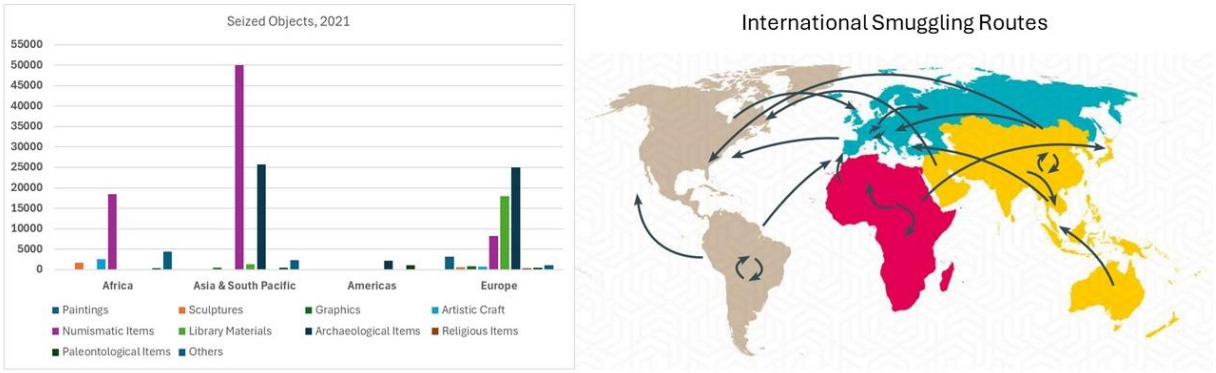

Figure 2. Seized Objects per Geographic Area and Category (on the left), and International Smuggling Routes (on the right, INTERPOL, 2022, pp.19)

In this framework, authorities combatting the illicit trafficking of cultural artifacts have taken limited advantage of new technologies (e.g remote sensing, UAVs, A.I, web crawlers, blockchain technology, etc) in their efforts to limit and intercept such activities (Spalazzi et al., 2021, Fincham, 2019, Tapete et al., 2016).

Cartographic objects, including manuscript and old maps, atlases, books, etc, can be considered as a quasi-form between art, science and a testimony of the technology that was used per time period for mapping and representing the earth's surface. Such artifacts are usually maintained in G.L.A.M (Galleries, Libraries, Archives, and Museums) institutions but also a significant number of objects are part of private collections that have not been documented or presented to the public. Cartographic artifacts are currently auctioned at prices ranging from a few thousand to hundreds of thousands of euros depending on their uniqueness, designer, age, and condition (Figure 3).

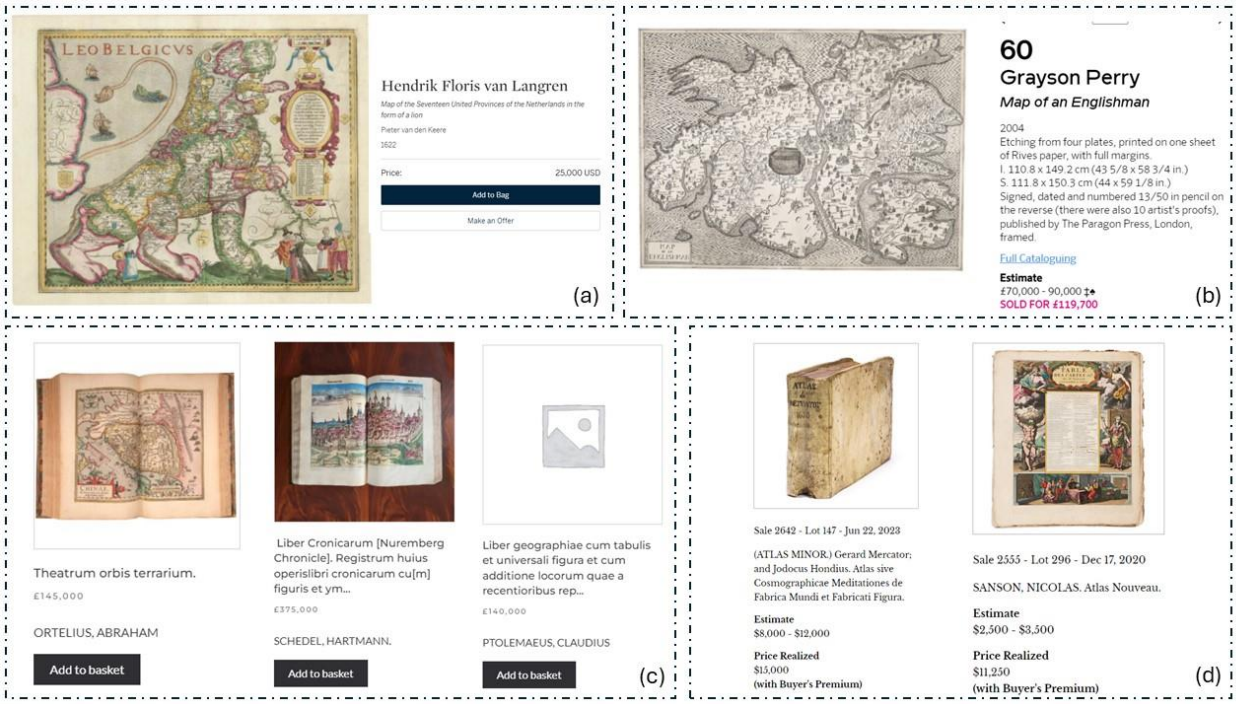

Figure 3. (a) Sotheby's Auctions, Map of the Seventeen United Provinces of the Netherlands in the form of a lion (46x37cm): estimated price $25,000, (b) Phillips Auctions, Map of an Englishman (111x150cm): sold for £119,700, (c) Marshall Rare Books (U.K), Theatrum orbis terranium by Abraham Ortelius: estimated price £145,000, Liber Cronicarum by Hartmann Schedel : estimated price £375,000 , Libre Geographiae by Claudius Ptolemaeus: estimated price £140,000 (d) Swan Galleries, N.Y, Atlas Minor by Gerard Mercator (sold for $15,000) & Atlas Nouveau by Nicolas, Sanson (sold for $11,250)

Their value and unique characteristics have converted maps into objects sensitive to illicit trafficking, with many cases demonstrating their illegal seizure from G.L.A.M institutes, not by members of organized crime but rather from map experts who knew exactly what to look for in high-security chambers of libraries and archives. In 2005 the F.B.I issued a request upon all GLAMs holding rare manuscript maps to audit their collections after a series of recorded such thefts in public and university libraries including the British Library, Boston Library, Yale Library, etc (Jury, 2005). Authorities identified that their thief must be someone aware not only of the uniqueness and rarity but also of the existing demand for them, i.e. someone who probably is a map dealer or a map expert. The National Library of Spain was a victim of a similar crime when two engraved and illustrated cosmographic maps from Ptolemy's "Geography" were stolen from a limited access room in 2007. The robber was of Uruguayan origin posing as a researcher to gain access to the valuable manuscripts. The maps were eventually seized by the F.B.I in the United States and returned to the library. Sweden's National Library personnel also identified a rare atlas of 1597 by Cornelis Wytfliet depicting the New World, belonging to their collections being offered for sale by an American Map dealer named W. Graham Arader III. Arader had acquired the map from Sotheby's auction house without being aware of its illegal provenance. Investigations led to the conclusion that the atlas along with at least other 55 objects were illegally seized from the Kungliga Library by a senior librarian who was very thorough in also destroying the related catalogue cards to cover his traces (Cohen, 2012). In the case of the Carnegie Library in Pittsburgh, PA (U.S.A), a standard audit performed by external officers in 2017 revealed that the library was missing artifacts of some $8 million dollars' worth, including the Bleaeu Atlas (1644) containing 276 manuscript maps and Ptolemy's Geography from which all maps had been cut off. These artifacts were stolen from the Oliver Room, a maximum-security location with only one point of entry and 24h video surveillance com-

bined with an advanced security system. Inspections by police and district attorney authorities revealed that the Carnegie Library Robbery was an inside job performed by a librarian who was reselling them to a reputable bookseller after marking them with a "Withdrawn from Library" stamp to lift any suspicion of them being stolen. One of the most notorious map thefts was the American map dealer E.Forbes Smiley III who was able to steal valuable maps from various GLAM institutions including the British Library, Harvard's Houghton Library. Smiley was eventually arrested at Yale University and was charged with stealing maps worth around $3,000,000 from major libraries. Other libraries that have reported similar incidents are the Library of Copenhagen, Aberystwyth, Helsinki, the Hague et al.

Considering all the above examples, it could be argued that the illicit trafficking of cultural objects is a very complex problem since it regards very diverse items. Moreover, there is a chain of people that can be involved in the trafficking process that can either have some expert knowledge in the field or simply act on an opportunistic profit basis (e.g. robbers, looters). New technologies also facilitate trafficking by individuals and not necessarily through organized crime networks. Another problem lies in the different legal protection status of cultural heritage objects at a national and international level which can lead to confusion and legal gaps in the transportation procedure of such items. More importantly, there is still an issue with documenting all known cultural objects using common standards and common databases, something that would require both time and significant resources. Finally, one should also consider the time factor divided into two components: firstly, the time that it usually takes to apprehend a theft of a collection item which can vary significantly from the crime date itself. Secondly is the very limited time that a Law Enforcement Agency (L.E.A) officer has at his disposal before deciding on whether to confiscate an item or not.

In that framework, the ENIGMA project (2023-2026, funded by the E.U, grant number 101094237) brings together 12 partners from 7 countries to improve existing research on the identification, traceability, and provenance research of cultural objects as well as on safeguarding and monitoring endangered heritage sites. The goal is to develop a toolkit that will assist all involved stakeholders in responding more adequately and on time to this very complex problem, which includes interlinked databases maintained by various authorities at a national and global level. The present research showcases how the proposed ENIGMA methodology can assist and be utilized to also protect cartographic heritage assets from robbery or illicit trafficking.

2. Existing Databases for Documenting Cultural Objects

2.1 Databases of Stolen Cultural Objects

Several independent database infrastructure systems exist to record stolen or looted cultural objects. Access to these databases is usually upon registration by authorities who can claim their legal interest in monitoring stolen property. Each database keeps different metadata on the artifacts and their study can facilitate the discussion on the necessary information that should be recorded for each cultural object per category.

The Regional Intelligence Liaison Office (RILO) of the World Customs Organization (WCO) in Western Europe developed the electronic information exchange platform known as *Archeo*. By making it easier to facilitate potentially fraudulent artifacts, Archeo seeks to limit cultural heritage fraud and maximize effective and efficient law enforcement in this field. It is a real-time communication tool that uses data from customs seizures as recorded in the Customs Enforcement Network database. It brings together stakeholders including Ministry of Culture Experts and academics, and

custom authorities who are usually the ones to decide whether an object will be released or hold in the border controls. Archeo's access is therefore limited to these two categories of end-users.

The *Art Loss Register* (ALR) was established in London in 1990 by a non-profit organisation named The International Foundation for Art Research (IFAR). It currently holds the largest private database of lost cultural objects with more than 700,000 recorded items. Items are uploaded in the ALR by law enforcement agencies, insurance companies, victims of theft, etc. to deter illicit trafficking and sales by providing a guarantee to art market clients that they are dealing with non-claimable objects. Search in the database can be provided upon registration and with a fee of approximately £80 per search.

The *Lost Art Database* (https://www.lostart.de/en/start) is another privately developed and maintained database procured by the German Lost Art Foundation. Its main goal is to document cultural objects that were seized between 1933 and 1945, as a result of the Nazi persecution, also known as "trophy art". Currently, the online database holds more than 180,000 records, including library objects, paintings, numismatic artefacts, etc. The database also contains approximately 645 records regarding maps that were either Nazi-confiscated or looted including Map Germaniae by Pieter Schenk (Time Period: 1707), Reyamann's Special Map (Time Period:1806), and several maps of the General Karte von Mitteleuropa (Time Period: 1937).

Interpol's *Database of Stolen Works of Art* (https://www.interpol.int/Crimes/Cultural-heritage-crime/Stolen-Works-of-Art-Database) is a database that contains all officially reported stolen cultural objects (currently more than 52,000 records). Their documentation includes metadata and photographic documentation where applicable. More specifically the database records are organized around the international standard used for cultural objects, i.e. Object ID, provided by the International Council of Museums, which organises information in nine categories, i.e. Type of Object, Materials, and Techniques, Measurement, Inscriptions and markings, distinguishing features, title, subject, date or period, and maker. The database can be used upon request and is also accompanied by a mobile application (ID-Art mobile app) that can be used to access the database records, report an item as stolen and also report sites at risk of robbery or illegal excavations.

The *National Stolen Art File* (NSAF) (https://artcrimes.fbi.gov/) is a database of stolen cultural objects developed by the F.B.I. Stolen object records can be submitted by law enforcement agencies either in the United States or Internationally. The NSAF keeps a central repository of data and photographic documentation of stolen art that can be used by law enforcement agencies. The NSAF can also be used via desktop or mobile applications with a free search option. In the summer of 2024, one record in the NSAF regards a map, more specifically described as Middlesex Described with the Most Famous Cities of London and Westminster (dimensions: 36x60in) and 7 records regard atlases including two versions of Atlas Minor of Gerard Mercator (Time Period: 1621, a copy of Novus Atlas Sinensis was sold at an auction at Swann Auction Galleries for a price around £15,000), Novus Atlas Sinensis by Martino Martini (Time Period: 1655, a copy of Novus Atlas Sinensis was sold at an auction at Marshall's Rare Books for a price around £18,500), Le Grand Atlas by J.Blaeu (Timer Period: 1663)

art and cultural property. Stolen objects are submitted for entry to the NSAF by law enforcement agencies in the U.S. and abroad. When an object is recovered, it is removed from the database. It can also be used by applications on the mobile phone» [FBI, 2022].

Another important and thorough database is LEONARDO (The Stolen Works of Art Database System), maintained by the Command for the Protection of Cultural Heritage of the Italian Carabinieri (Carabinieri, 2017). Initially established in 1980, it currently records 1,285,765 stolen objects, 810,423 images, and 65,970 theft cases. All the material is digitised in image and text formats.

LEONARDO database is the reference point for the Italian and foreign LEAs. It allows for a careful analysis of criminal phenomena concerning the illicit trafficking of cultural property. Recently, thanks to the SWOADS Project (Stolen Works Of Art Detection System), the software components of the LEONARDO database were enhanced and expanded in technological (i.e., big data, machine learning) and architectural terms.
The main entities recorded in the above-mentioned databases can be found in Figure 4.

ObjectID	Lost Art Database	Interpol's Stolen Works of Art	F.B.I's NSAF	Art Loss Database
Description	Object Report	Information		Information
ID	Lost-Art ID	ID	ID	ID
Image	Image	Image	Image	Image
Maker	Author	Artist	Maker	Artist
	Editor			
Title	Title	Title	Title	Title
	Place of Publication			Publication History
Date/Period	Document Date	Period	Period	Date
Object Type	Object Type	Object Type	Object Type	
	Group of Reported Objects			
Material/Technique	Material/Technique	Material/Technique	Materials	Medium
Measurements	Dimensions	Dimensions	Measurements	Dimensions
	Circumstances of loss		Incident Type	
	Provenance			Provenance (Historic and Current)
Subject	Description	Description	Description	Description
Inscriptions & Markings / Distinguishing Features	Signature	Signature/Markings (State/Position)		Signature/Markings
	Published Since			
	Contact	Country		
		Shape		

Figure 4. Information/Entities Recorded in Databases of Stolen Cultural Objects

2.2 Documenting the Cartographic Heritage

2.2.1 The Object ID Paradigm

Object Identification (Object ID), initiated by the J.Paul Getty Trust in 1993, is an international standard for documenting cultural objects promoted by major law enforcement agencies, including the FBI, Scotland Yard and Interpol, UNESCO, museums, cultural heritage organizations, art trade and art appraisal organizations, and insurance companies (Thornes et al. 1999). The goal of this initiative is to create a more consistent framework for documenting diverse cultural heritage objects and provide a universally accepted proof of provenance that can be easily and rapidly distributed among the various GLAM institutions (Yasaitis, 2005).

Object ID is essentially a checklist containing a minimal level of nine descriptive categories to adequately document each object. More specifically, the recorder needs to answer the following questions (ICOM, 2020) :

i. Type of Object (e.g. painting, sculpture, etc.)
ii. Materials and Techniques (e.g. paper, brass, wood, etc.)
iii. Measurement (e.g. dimensions and/or weight)
iv. Inscriptions and Markings (e.g. signature, property marks, etc.)
v. Distinguishing Features (e.g. damage, repairs)
vi. Title
vii. Subject (e.g. landscape)
viii. Date or Period
ix. Maker (e.g. painter's name, cultural group, etc.)

The process of documenting a cultural artifact using Object ID involves a four-step process as follows:

i. Take high-resolution images of the object.
ii. Identify and record the information of the above-mentioned nine thematic categories
iii. Provide a short description of the object with any necessary additional information in free text.
iv. Keep the Object ID documentation secure.

Object ID provides increased flexibility in documenting heritage items through its rather limited but essential list of fields and can be easily apprehended by specialists and not specialists in the art field (Yasaitis, 2005). However, its implementation requires significant funding and human resources, particularly in the case of countries and organisations that do not already maintain some form of digital inventory of their collections.

2.2.2 Europeana Database

Europeana is a digital platform that allows access to significant collections of cultural heritage objects belonging to GLAM institutes worldwide. The cultural content in Europeana's database includes more than 50 million images, works of art, books, manuscripts, videos, etc (Purday, 2009). By defining a European way of dealing with digital heritage, Europeana has become an instrument of European digital cultural policy (Capurro and Plets, 2020). The goal of the platform is to make European Cultural Heritage accessible to a global audience by including a wide range of cultural objects, providing free access to the data and metadata of the digital collections, collecting the necessary data from the various GLAM institutes, providing a multi-language interface, supporting research on the field of culture, ensure copywrite protection of the artifacts, building a collaborative network between the institutes, and, use the recorded data for innovative projects that promote the notion of digital cultural heritage and digital humanities.

The Europeana Data Model (EDM) is the digital framework that underpins one of the most comprehensive cultural heritage databases in the world. It forms the backbone of an organization with a structure and transparent access to the rich treasures of European culture. More specifically the EDM is an interoperable framework that allows Europeana infrastructure to collect, connect, and enrich cultural heritage metadata. The EDM's schema includes the following short list of entities:

i. ProvidedCHO (Provided Cultural Heritage Object): The main entity that represents cultural heritage objects provided by institutions

ii. Proxy: A resource representing a ProvidedCHO in a specific context or language allowing for different representations of the same object.
iii. Aggregation: A group of ProvidedCHO that are brought together, often by a cultural institution, for a specific purpose.
iv. WebResource: Represents the digital resources associated with cultural heritage objects, such as images, audio, or text.
v. Agent: Represents people or organisations involved in the creation, curation, or management of cultural heritage objects
vi. Concept: Represents abstract ideas, subjects, or terms used to describe cultural heritage objects.
vii. TimeSpan: Represents time-related information, such as dates associated with cultural heritage objects.
viii. Place: Represents geographical locations associated with cultural heritage objects.
ix. Rights: Contains information about copyright and usage rights of cultural heritage objects.

Europeana offers several APIs (e.g. Search API, Record API, Entity API, etc.) that can be used to access the data and metadata but also contribute back. It also has a dedicated Python library that can be used to access the datasets and perform analyses and queries after registering for an API key.

2.2.2.1 Europeana and Cartographic Heritage Objects.

In the context of the present research, we used Europeana's API capabilities to discover and analyze cultural heritage objects and collections related to cartography and maps. Four keywords or concepts were used to perform the research, namely "Atlas" (concept code:2826), "Manuscript Map" (concept code: 2916), "Map" (concept code: 43), and "Cartography" (concept code: 2971). A total of approximately 298,000 records were retrieved presenting, however, a very uneven distribution among the 4 categories (Figure 5). The digital documentation of the dataset provides the following basic information: europeana_id, uri, type, image_url, country, description, title, creator, language, rights, provider, dataset_name, concept, concept_lang, description_land, title_lang. i.e pretty similar fields to Object ID's specifications.

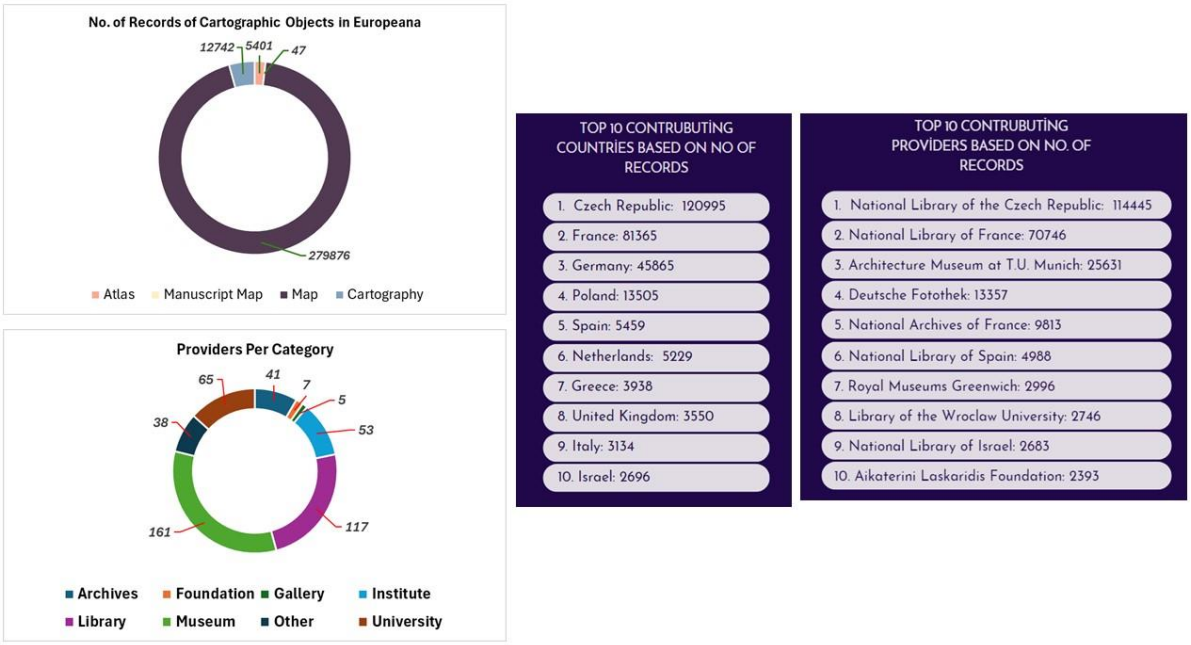

Figure 5. Basic Statistic Metrics on the Europeana Platform records regarding cartographic heritage objects.

Python data analysis libraries (e.g Pandas, GeoPandas) were used to further explore the retrieved datasets. 487 unique providers have uploaded cultural heritage content regarding Cartography and Maps in the Europeana Platform, most of which are either Libraries or Museums. These providers are located in 41 countries, with an extreme concentration in Central and Northern Europe but also in the United States, the United Kingdom, Greece, Spain, etc (Figure 6). Regarding the number of records per country the Czech Republic, France, Germany, and Poland have the most contributions to the Europeana Platform with the National Library of the Czech Republic and the National Library of France having a combined sum of more than 185,000 records (Figure 5). Some cartographers/geographers appear to be the designers of a significant number of records, such as Jean-Baptiste Bourguignon d'Anville (1388), Th. Fischer (1776), Nicolas Sanson (1094), Jacques-Nicolas Bellin (851), Guillaume Delisle (589), Joan Blaeu (585), Guillaume Sanson (527), Nicolas de Fer (456) and others.

The data and metadata recorded for each cartographic object vary between providers. For example, in the case of Nicola de Fer's map "Carte de Californie et du Nouveau Mexique" (https://www.europeana.eu/en/item/9200517/ark__12148_btv1b84917809) the metadata recorded in Europeana's platform include a unique id, a url address to the online record and the photographic documentation, the country of origin, the creator's name, a collection id, the provider's title, year of design, scale, map language, dimensions, etc.

Although Europeana is the first large-scale systematic effort to document cultural objects, it is evident that there are still some discrepancies in the recording of C.O metadata. For example, Blaeu's name exists in several different versions (e.g Blaeu, Joan, Blaeu, Joan (1596-1673), Blaeu, Johann) and is not a unique record that could facilitate data research. In the "Coverage" metadata field, it should be expected that the providers would record the geographic location that each cartographic object covers, however in most cases this field is empty and the information can be extracted by the title or description field of the map. The scale factor, which is essential in maps, is not a separate documentation field but is also included in the description of the object often in languages other than English.

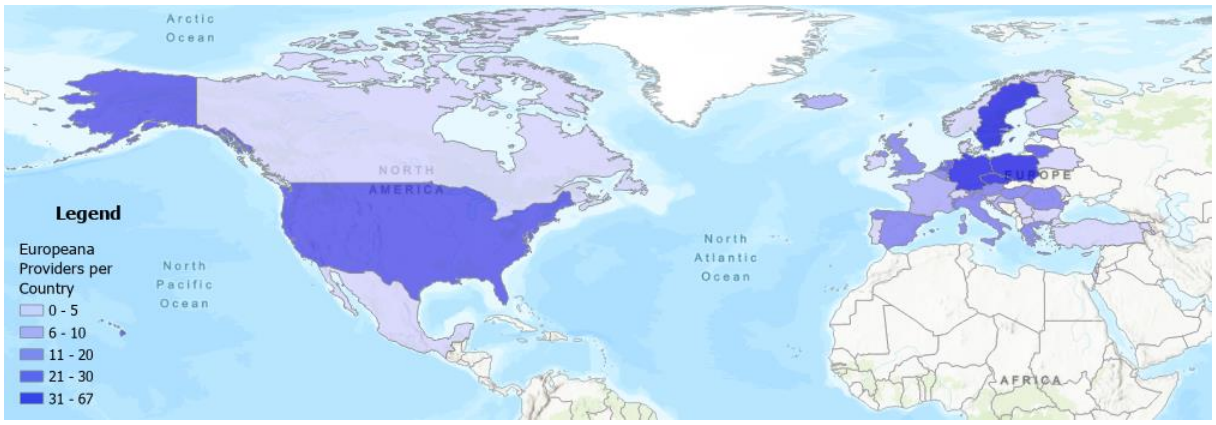

Figure 6. Thematic Representation of the Number of Europeana Providers per Country

3. The ENIGMA Approach to a Complex Problem

3.1 Project Goal and Structure

Enigma's mission against the illicit trafficking of cultural objects evolves around three categories of objectives, namely Scientific and Innovation objectives, technical objectives, and demonstration, dissemination, and exploitation objectives (Patias and Georgiadis, 2023). The Scientific and Innovation objectives include the design of a Unique Authenticity Identifier (UAI) as a composite index for each object, the integration of Earth Observation and G.I.S analysis techniques for monitoring illegal excavation sites, and the development of a novel decision support and communication platform that will facilitate ENIGMA's research. The Technical Objectives include the development and testing of UAI tools, the use and customization of machine-learning algorithms for object clustering, and an advanced metadata analysis to identify potential links between different data sources and objects. All new tools and methods developed under the Enigma Project will be tested and validated through diverse pilot scenarios. Finally, the demonstration, dissemination, and exploitation objectives involve the drafting of an effective communication strategy between stakeholders across the wider community involved in cultural heritage protection and the drafting of policy recommendations based on the findings of the performed research. The organization of the projects in Work Packages can be found in Figure 7.

Figure 7. Structure of the ENIGMA Project

3.2 Identifying the Key Stakeholders – Record User Requirements

The design of the ENIGMA platform was initiated with the recording of user requirements and a gap analysis of the existing and implemented processes in combatting illicit trafficking. The key stakeholders were identified as follows:

i. Law Enforcement Agencies (L.E.A) involving both national and international authorities whose prime goal is to investigate and prevent theft, recover stolen items, protect cultural heritage sites, assist in increasing public awareness on security issues and assist in the prosecution of the offenders.
ii. Ministry of Culture officials, who are entrusted with the task of protecting cultural property by proposing legislative acts in that direction. Besides the legislative task, these officials also have to efficiently document the cultural heritage of the country, educate the public in the field of heritage protection and preservation and promote international cooperation in this domain.
iii. Customs and Border Control Agencies are on the frontline of preventing illicit trafficking at the entrance/exit points of each country by inspecting and seizing suspicious shipments or objects, inspecting and verifying the validity of the relevant documentation, and also collaborating with law enforcement agencies and cultural heritage experts.
iv. Museums are key institutes in preserving and recording our cultural heritage for the benefit of future generations. Their tasks include the collection of CH objects (even through their acquisition and repatriation), the collaboration with other relevant institutes or archives, and the provision of their expertise and scientific knowledge to the community.
v. Finally, auction houses are pivotal in the trade of cultural goods in a global market. As such, they should exercise due diligence on the provenance and legal status of the objects presented to them, comply with the existing national and international legislation on Cultural Heritage Protection, and assist in repatriating illegally seized objects.

The process of performing checks at the entry points of each country is fairly simple. An individual who has transferred a C.H item is requested by the police and customs officials to demonstrate any relevant documentation that proves its legal status, authenticity, and provenance. If such documentation doesn't exist or the customs services can prove relatively fast that this item was stolen, then the individual is arrested and the object confiscated, according to the provisions of the national legislation. If the item's provenance and legal status seem dubious then again it can be temporarily confiscated for further research. This simple process, however, hides several pitfalls. For example, no common traveling document exists for cultural objects, although UNESCO and the World Customs Organisation (WCO) have proposed the so-called Model Export Certificate for Cultural Objects in 2005 which contains essential information on the item but also a photographic documentation (Mödinger, 2016). In addition to that, the officers performing the document and object verification are not experts in the very diverse field of cultural heritage, so they typically limit themselves to the strict bureaucratic and still non-automated process of customs control where again there might be insufficient knowledge about the legal protection status of each item per country. These officers, who are essentially the frontline defense against illicit trafficking, also face the problem of insufficient and high-resolution documentation of declared stolen items, the lack of a common platform where all lost-items databases can communicate with each other and the lack of desktop or mobile applications that will facilitate the documentation of the imported or exported object and will contribute in limiting the time needed to perform the necessary controls. In the case of items stolen from official institutions such as GLAMs there is also a significant time gap between the actual

robbery and its apprehension by the authorities, which usually takes place during an audit. That time gap provides the opportunity for smugglers to transport the object out of the country to its final buyer before it is even reported as stolen. Based on the identified gaps by the projects' partners and an extensive questionnaire designed to record user requirements, the following toolkit is proposed to combat illicit trafficking of cultural heritage objects.

i. Cultural Good transfer pre-registration tool: this tool will be used to pre-register the intention to transport a Cultural Object (C.O) in both the source and destination country. The responsible authority will issue a digitally signed or digitally verifiable certificate and the application will be stored in an online database.
ii. Unique Authenticity Identifier (U.A.I) based query and similarity scoring tool: this tool will provide a similarity composite index of similar Cultural Objects (found in museums, galleries, online databases, websites, etc.) to a given C.O to assist experts and law enforcement agencies in providing a fast identification of the object.
iii. Fast on-site documentation tool: this tool will provide a user-friendly interface to non-experts (i.e. police, customs authorities) for documenting the C.O. It will include basic information regarding the C.O based on existing standards, images, and a high-resolution 3D model (where applicable).
iv. Documented Cultural Objects database: The information collected on-site will be stored in a database that can be accessed by all relevant authorities fighting against illicit trafficking.
v. C.O spatial connection tool: this tool will be able to record and track a C.O that travels through various nodes.
vi. Crowd Sourcing Database and Management Tools: this tool will be used to search and find similar C.O in a crowd-sourcing database.
vii. Internet and Social Media crawler: this will crawl webpages and social media to find and store in a database C.O and relevant information about them.
viii. C.O origin detection: this tool will provide the similarity between a given C.O and C.O that have already been recorded to various databases or various databases to identify -if possible- its origin and communicate with the proper authority, GLAM institute, etc.
ix. Global L.E.A open access database: create the structure for a global LEA open access database that can integrate data for already existing platforms.
x. Hot Spot Satellite Monitoring: this tool will monitor hotspots of potential illegal excavations using open-access satellite imagery (e.g. Sentinel, Landsat) and provide alerts in the case of change detections.

3.3 Building the Unique Authentication Identifier

The development of a Unique Authentication Identifier (U.A.I) for each cultural object is one of the core concepts of the ENIGMA project. The U.A.I will be essentially, a composite index based on the holistic documentation of the Cultural Objects. The parameters that will be included in the U.A.I should adhere to the following two major constraints: they should exist in the stakeholders' (museums, galleries, etc.) databases and they should be easily identified, defined, and described on the spot by L.E.A officers. In that spectrum, the following three categories of parameters have been defined: primary, secondary, and optimum. The primary parameters are the ones that already exist in most databases and are easy to identify and report (e.g. subject, type of object, materials and techniques, dimensions/weight, inscriptions/markings, distinguishing features, object photos). The

secondary parameters are the ones that can be either documented by experts or retrieved from existing databases (e.g. content semantics, textual content, historical context, spatial/location associations). The optimum parameters have been identified as an object's 3D characteristics (e.g. structure/volume) and surface/texture characteristics (e.g. resolution, complexity, opacity, clarity).
The U.A.I will not be a static index that will be calculated once but a dynamic metric used to estimate the similarity between the C.O under examination with other registered objects that have been reported as stolen or under threat. In that sense, the identifier not only encapsulates the distinctiveness of each C.O but also delineates its position within a dataspace from which similarity distances are computed. To calculate the U.A.I three separate categories of data are needed:

i. Feature Data: attributes that describe the inherent and unique characteristics of each object.
ii. Timestamp Data: refers to the temporal aspect of the dataset marking the exact time when the record was created or last modified. The inclusion of a timestamp ensures that the U.A.I reflects not only static features but also the dynamic aspect of data.
iii. Position Data: delineated the spatial or contextual location of the record within the data space. This component is crucial for calculating similarity distances since it indicates the record's relative position to other C.O.

A Similarity Calculation Subsystem will be developed to ensure the effectiveness of the proposed methodology incorporating techniques such as Dimensionality Reduction, Feature Importance Calculation, and Distance Calculation. Dimensionality reduction techniques are employed to simplify the dataset while retaining essential information. Methods such as Principal Components Analysis (PCA) reduce the number of variables, making the data more manageable and improving the efficiency and accuracy of similarity calculations. Feature importance calculation is used to prioritize more influential variables, thereby enhancing the accuracy of identifying similar C.O. The final step involves calculating the distances between objects in the existing databases to determine their similarity. Various distance metrics, such as Euclidean distance, cosine similarity, or Jaccard index, are applied depending on the nature of the data. This calculation is pivotal in identifying and quantifying the similarity between C.O, allowing for the discovery of meaningful contextual relationships.

3.4 ENIGMA's Platform Architecture and Early Demonstrator

ENIGMA's system -currently under development- is based on a 3-tier architecture having as its main components a Web Application Tier Server, a Database Tier Server, and a presentation tier of the data to be managed. This architecture provides increased capabilities for storing and querying data and for developing interfaces that can be utilized for analysing and reporting descriptive and spatio-temporal data. This architecture in terms of functional modules can be broken down as demonstrated in Figure 8.

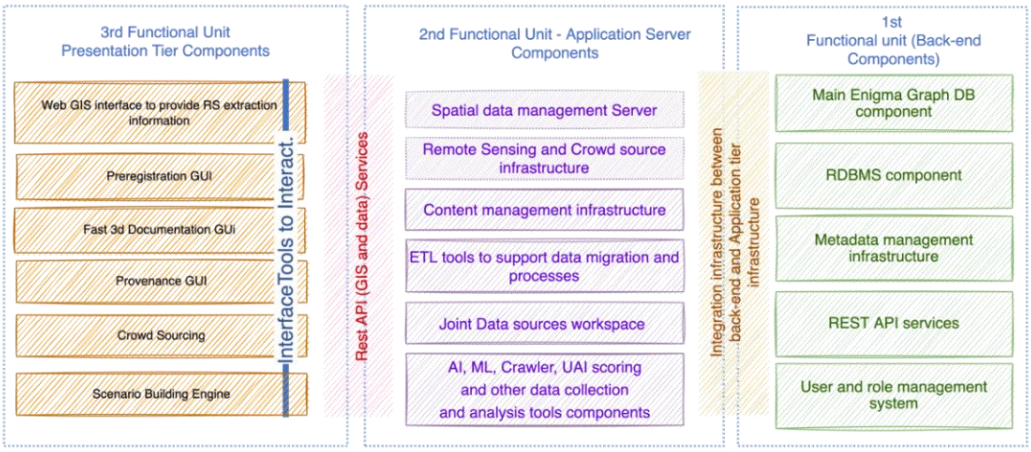

Figure 8. Functional Components and Subsystems

The early demonstrator of the ENIGMA toolkit emphasizes the need to integrate the tools described in paragraph 3.2 into a unified decision support system. Several components have already been integrated into the system including User Management and Permissions, Web Crawler, Registration and Authentication, and Scenario Building Engine. The integration of these components ensures a smooth and efficient data exchange between each component, user interface effectiveness, and workflow coherence. The User Interface of some components, including the pre-registration tool for issuing a travel document can be found in Figure 9. The individual carrying the C.O is expected to pre-register the upcoming transportation by describing and geographically declaring the travel's starting and destination point, as well as his personal information. The user can then upload any documentation accompanying the C.O, including authenticity and provenance information, etc. as well as images of the object or even 3D documentation if possible. As soon as the corresponding authority approves the request, a QR code is generated to provide access to the approval documentation. In this way, once the C.O reaches its point of exit/entry the officers checking for any potential illicit trafficking can verify the transportation request and the authenticity of the item itself.

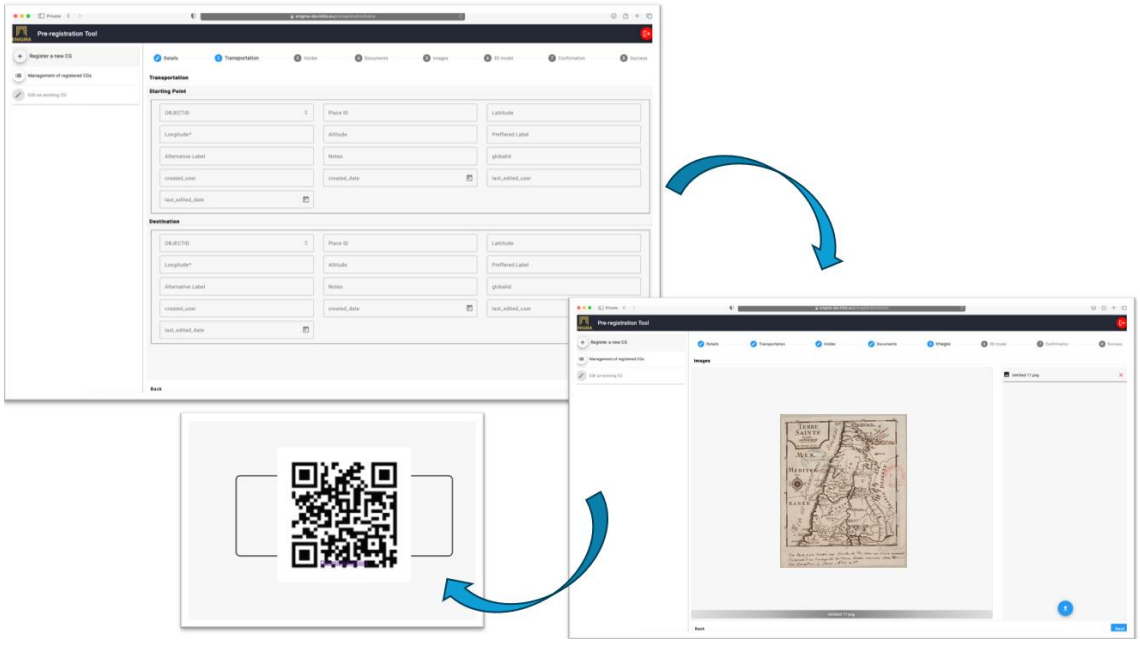

Figure 9. Web GUI to support pre-registration and searching of Cultural Objects.

3.5 Building an Operational Scenario

The following story presents an operational scenario where a L.E.A officer finds an object at an entry point. In the case that the object is missing the pre-registration documentation presented in the previous paragraph or the officer suspects that the documented object differs from the one that was described or is overall suspicious he should follow the following procedure:

i. Use the primary parameters and search in the existing stolen/looted/lost art databases by performing a query using images and textual data describing the object.
ii. The search findings will be presented in the form of a similarity score based on weight assignment at each parameter.
iii. If the search returns positive results, then the officers should follow their standard operational procedures.

The primary parameters are used to initiate a search in the stakeholders' database and the Web to retrieve -if possible- the secondary parameters through the existing databases' documentation. The results of the initial query are refined and used to provide a similarity score to the existing documented C.O. The final result will be an alert with a possibility score. If an alert is issued, then the officers should continue with the operational procedures.

For example, an individual arrives at a custom service with a map entitled "*Oost-Frise, ou le comté d'Embden subdivisé en ses principals jurisdiction*[6]". The officer can initiate a search using the fast on-site C.O documentation toolkit in the stolen art databases based on the name of the map, the cartographer's name (Sr.Sanson), the design year (1709), the dimensions (56.5x43cm), and the scale (transcribed as Escelle and followed by a graphic scale) (Figure 10). The map also has an inscription marking "est. 1512 (205)", a stamp entitled "Biblioteque de l'Arsenale" and is partially colored.

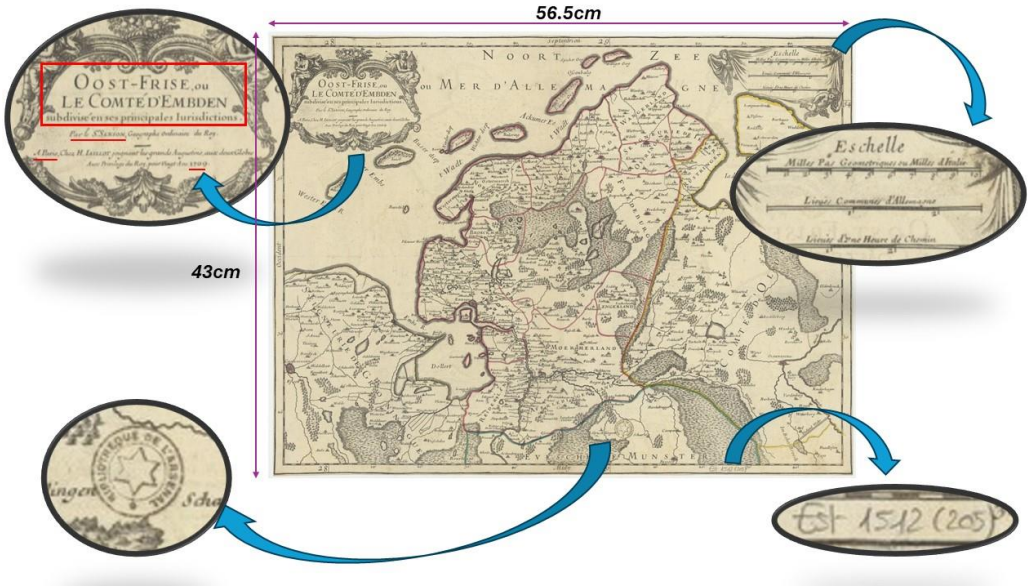

Figure 10. Guillaume Sanson's Map entitled "Oost-Frise, ou le comté d'Embden subdivisé en ses principals jurisdiction"

The Lost-Art Database of the German Lost Art Foundation returns a finding of a similarly entitled map, reported as Nazi-confiscated property (https://www.lostart.de/en/Fund/598215). The dimensions however of the map are different, i.e 62.80x54.10cm instead of 56.5x43cm. The stolen map

[6] . East Frisia or the County of Emden, divided into six judicial districts

also has water stains and heavily worn edges, follows a different coloring pattern, and is reported as having several distinct handwritten markings across its surface, i.e under the right cartouche in pencil: "27 [in a circle]", on the right margin of the sheet in pencil: "around 1600" (Figure 11). Finally, the stolen map is missing the “Biblioteque de l’Arsenale” stamp and the “Est. 1512 (205) marking. In that sense the U.A.I’s of the two objects will have a low similarity score, indicating that the object transported has not been reported as stolen.

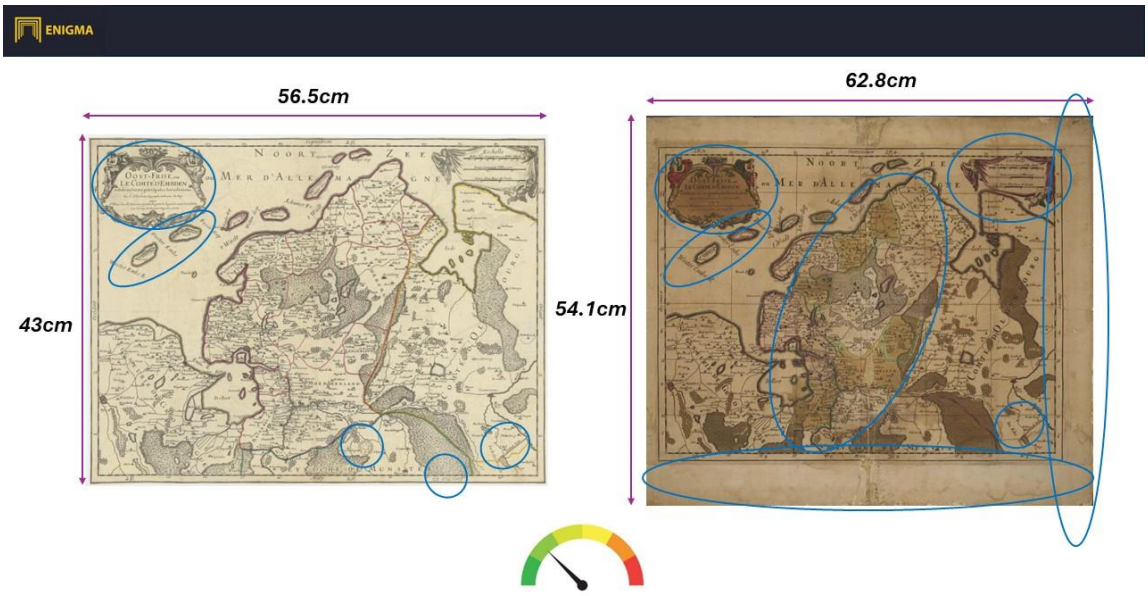

Figure 11. Differences between the original Oost-Frise map presented at the customs service and the recorded stolen item at the Lost-Art Database.

4. Discussion

The present research tried to illustrate the very complex nature of fighting against the illicit trafficking of cultural goods. This particular category of crime -up until recently considered purely a white-collar crime- has been the epicenter of many security calls over the last years by the European Union or other international organisations. The very diverse characteristics of heritage objects (either numismatic, sculpture, paintings, maps, etc.) increase the difficulty in drafting a common standard of metadata documentation that can be implemented by all G.L.A.M institutes or individuals. Furthermore, the unique documentation of each unique object requires considerable effort and resources. Even in this best-case scenario where all known C.O. objects were documented, there would still be an undefined number of objects that can be traded without being recorded in any official database. The problem is aggravated by the fact that in most cases the first line of defense against the illicit trafficking of cultural goods are the officers of Law Enforcement Agencies, i.e. non expert personnel in the field of cultural heritage. These officers have to check if all the necessary procedural steps were followed to export or import a C.O., verify that the object is not in a protected legal status in its country of origin or destination, decide on its authenticity, and verify that it has not been reported as stolen in any national or international database. These actions also have to be performed in a very limited time frame and usually on the spot.

The ENIGMA project aims at developing a toolkit that can assist in the fight against the illicit trafficking of Cultural Objects by introducing new core concepts such as the Unique Object Identi-

fier (U.A.I) and incorporating state-of-the-art equipment and algorithms regarding earth observation, machine learning, web crawlers, 3D scanning, 3D reconstruction, etc. The Unique Object Identifier is a new dynamic composite index based on the holistic documentation of each object. The UAI allows for the calculation of comparison metrics between objects examined by L.E.As and objects reported as stolen. In that sense, the official authorities can evolve from a simple stolen/not stolen classification to a calculated possibility factor. The success of the proposed ENIGMA platform lies in several key points, the first of which refers to the need to promote the detailed documentation of C.O. based on common standards and using databases that can communicate with each other. This documentation has to be performed by experts working in G.L.A.M institutes who can assess the unique characteristics of each object. Once a C.O. reaches an exit/entry point, it must be accompanied by all the necessary documentation which can be uploaded in advance using the ENIGMA pre-registration tool. In the case of a suspicious item, the L.E.A officer can use the platform's fast on-site documentation tool to record the main characteristics that he can visually identify (e.g. category, title, dimensions, markings, etc.) and initiate a search -using the U.A.I index- in databases of stolen C.O to verify if this or a rather similar object has been recorded as missing. In any case, although the ENIGMA platform aims at introducing new concepts and technologies in the fight against illicit trafficking of C.O. based on documented user requirements it should be reminded that the uniqueness of each tangible heritage item -including maps- will always create barriers in their efficient documentation through international database systems. Perhaps more worryingly, it has been proven that crime networks demonstrate exceptional resilience and adaptability to L.E.As deterrent measurements, and in this spectrum, the ENIGMA effort has to constantly evolve and adapt by incorporating new technologies and new algorithms.

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