Government Information Quarterly 30 (2013) 226–240

Contents lists available at SciVerse ScienceDirect

Government Information Quarterly

journal homepage: www.elsevier.com/locate/govinf

Spatiotemporal crime analysis in U.S. law enforcement agencies: Current practices and unmet needs

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ARTICLE INFO

Available online 30 May 2013

Keywords:
Law enforcement
Public safety
Crime analysis
Crime mapping
Geographic information systems (GIS)
Cartography
Spatiotemporal analysis

ABSTRACT

This article compares the current states of science and practice regarding spatiotemporal (space + time) crime analysis within intermediate- to large-size law enforcement agencies in the Northeastern United States. The contributions of the presented research are two-fold. First, a comprehensive literature review was completed spanning the domains of Criminology/Crime Analysis and GIScience/Cartography to establish the current state of *science* on spatiotemporal crime analysis. This background review then was complemented with a set of interviews with personnel from seven intermediate- to large-size law enforcement agencies in the United States in order to establish the current state of *practice* of spatiotemporal crime analysis. The comparison of science and practice revealed a variety of insights into the current practice of spatiotemporal crime analysis as well as identified four broad, currently unmet needs: (1) improve access to externally maintained government datasets and allow for flexible and dynamic combination of these datasets; (2) place an emphasis on user interface design in order to improve the usability of crime mapping and analysis tools, (3) integrate geographic and temporal representations and analyses methods to better unlock insight into spatiotemporal criminal activity, and (4) improve support for strategic crime analysis and, ultimately, public safety policymaking and administration. The results of the interview study ultimately were used to inform the design and development of a spatiotemporal crime mapping application called *GeoVISTA CrimeViz*.

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1. Introduction: the analysis of information on criminal activity

Crime analysis describes the systematic collection, preparation, interpretation, and dissemination of information about criminal activity to support the mission of law enforcement (Boba, 2005). The goal of crime analysis is the unlocking of valuable insights from the collected crime information in order to assist law enforcement with criminal apprehension and crime prevention, to the end of improving the overall quality of life for community residents (O'Shea & Nicholls, 2003). Ideally, crime analysis draws upon both quantitative and qualitative approaches in order to understand criminal activity fully, integrating descriptive and inferential statistical analyses of crime incidents with text reports, information graphics, and prior experience to determine the appropriate response tactics, strategies, and broader policies (Gottlieb, Arenberg, & Singh, 1994; Osborne & Wernicke, 2003). Influenced by the Digital Revolution and associated Information Age, research and development within crime analysis during the past two decades has emphasized the design of computer software that supports the assembly and interpretation of digitally-native crime information (Wilson, 2007). The research reported here focuses upon a critical subset of computing technologies designed to analyze the spatial and temporal (together *spatiotemporal*) components of crime information.

The field of *Geographic Information Science* (GIScience) and its technological counterpart *Geographic Information Systems* (GIS) describe the gamut of tools and techniques available to analyze geographically-referenced information (Goodchild, 1992). GIScience subsumes a variety of topics relevant to spatiotemporal crime analysis, which include geographic information collection (geocoding, GPS technology, remote sensing, and surveying), geographic information maintenance (geographic database management and multi-resolution databases), geographic information analysis (geocomputation, geographic data modeling, spatial analysis, and spatial statistics), geographic information representation (cartography and geographic visualization) and the use of geographic information and information products (geocollaboration, geovisual analytics, public participatory GIS, and spatial decision support systems) (for a general overview of these topics, see Longley, Goodchild, Maguire, & Rhind, 2005). The term *crime mapping* is used today to describe the

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0740-624X/$ – see front matter. Published by Elsevier Inc.
http://dx.doi.org/10.1016/j.giq.2013.02.001

application of all GIScience tools and techniques for crime analysis (Getis et al., 2000), although its original use focused on applications of Cartography only (i.e., the representation of geospatial crime information in map form).

There is a substantial volume of work within GIScience examining the treatment of spatial and temporal components of information in conjunction (e.g., Andrienko, Andrienko, & Gatalsky, 2003; Hägerstrand, 1970; Langran, 1992; Peuquet, 1994; Sinton, 1978). Despite this research, there is little implementation of temporal analytical functionality in popular GIS software. Perhaps as a direct result, the analysis of the temporal component of crime has been identified as an under-supported function of crime analysis, with Ratcliffe (2009: 12) stating in an overview of current challenges to crime analysis that "At present, the most under-researched area of spatial criminology is that of spatio-temporal crime patterns." Existing reports on crime analysis indicate that spatiotemporal analysis and visualization often is limited in practice to the generation of one-off, static maps showing crime over a small period of time, usually the past 7-to-30 days (Lodha & Verma, 1999). Thus, the possible use cases for advanced spatiotemporal crime analysis remain undetermined and therefore the positive impacts of spatiotemporal crime analysis remain unrealized.

Here, we describe research to address directly this challenge of spatiotemporal crime analysis. The aim of our research was the identification of gaps between the spatiotemporal crime analysis techniques reported in the literature and the actual use of these techniques by law enforcement to combat crime. The primary contributions of the research are two-fold. We first completed a comprehensive background review to understand the current state of *science* in spatiotemporal crime analysis, disambiguating and synthesizing relevant research from the knowledge domains of Criminology/Crime Analysis and GIScience/Cartography. We then conducted a set of interviews with experts from seven intermediate- to large-size law enforcement agencies in the United States (daytime service populations of 125,000 to many millions) in order to compare the current state of *practice* in spatiotemporal crime analysis to the previously reviewed state of science. Such a critical comparison of science and practice is relevant to detectives, officers, and decision makers working in law enforcement as well as municipal, state, and federal administrators and policymakers working broadly in public safety. The interview study also served as the needs assessment stage for the design of a spatiotemporal crime mapping application called *GeoVISTA CrimeViz* (http://www.geovista.psu.edu/CrimeViz) developed in collaboration between the Penn State GeoVISTA Center and the Harrisburg (PA, USA) Bureau of Police (for details on the application, see Roth, 2011; Roth & Ross, 2009; Roth, Ross, Finch, Luo, & MacEachren, 2010). Therefore, we were interested in identifying the key crime analysis needs of law enforcement agencies that the *GeoVISTA CrimeViz* application must support, with a particular emphasis on those needs not currently supported by readily available spatiotemporal crime analysis software.

The article proceeds in four sections. In the following section, we synthesize background material from the domains of Criminology/Crime Analysis and GIScience/Cartography to establish the current state of science on spatiotemporal crime analysis. In the third section, our interview protocol and qualitative data analysis approach is described. We present the results and discuss the key findings of the interviews in the fourth section, providing an overview of the current state of practice to contrast with the background review. The fourth section is organized according to six key crime analysis needs identified from the background review: (1) geographic information, (2) cartographic representation, (3) cartographic interaction, (4) spatial analysis, (5) temporal analysis, and (6) map and analysis use. The fifth and final section contains our concluding remarks and lists several broad spatiotemporal crime analysis needs that currently are not fully support.

2. Background review: current state of science on crime analysis

A comprehensive review of existing literature was completed prior to the interview study in order to characterize the current state of science on crime analysis. The following review is organized into three sections: (1) a summary of the origins and purpose of crime analysis from the discipline of Criminology, with an emphasis on the types of crime analysis; (2) a summary of the different kinds of geographic information that may be collected to support crime analysis and the ways to represent this information cartographically (i.e., in map form); and (3) advanced statistical and computation techniques to analyze the spatial and temporal components of these information.

2.1. Origins and purpose of crime analysis

Crime analysis has its roots in 19th century London, where the first modern police department was established (Boba, 2005). August Vollmer, Police Chief of Berkeley (CA, USA) and founding professor of the UC-Berkeley School of Criminology, often is credited with the first application of crime analysis in the United States in the early 20th century, with other important early U.S. work conducted by the 'Chicago School' of sociologists (e.g., Shaw & McKay, 1942; Sutherland, 1934). Vollmer's student, O.W. Wilson, first defined the term 'crime analysis' in his recommendation of information analysis techniques to police departments in the 1950s and 1960s (Wilson & McLaren, 1977). The crime analysis capabilities of law enforcement agencies expanded through the 1970s and 1980s (Emig, Heck, & Kravitz, 1980), due in part to federal grants provided through the National Institute of Justice, a program of the United States Department of Justice. There also was increased interest at this time in crime analysis in academia; a review of this research is provided in Harries (1999).

Crime analysis therefore is informed by the discipline of *Criminology*, or the scientific study of the causes and control of crime and delinquent behavior, with the goal of understanding criminal activity, rehabilitating convicted criminals, and improving the quality of life within a community (Sutherland, Cressey, & Luckenbill, 1992). There are two popular criminological theories that emphasize the importance of spatiotemporal pattern and process (Cahill & Mulligan, 2007). Under *routine activity theory*, an individual criminal incident requires three conditions to occur concurrently in place: (1) presence of a motivated offender, (2) presence of a suitable target, and (3) absence of a proper guardian, law enforcement or otherwise (Cohen & Felson, 1979). The spatiotemporal dynamics of these three components can be analyzed both to identify locations of elevated crime risk and to prescribe the appropriate policing tactics to attenuate this crime risk (Bruce, 2008). In contrast, *social-disorganization theory* evaluates the ability of a community, or homogenous geographic unit, to combat negative community-level changes and enforce positive ones (Shaw & McKay, 1942). By analyzing the spatial and temporal differences in demographic and environment characteristics between stable and disrupted neighborhoods, long-term policing strategies can be developed and absent public policies can be established to prevent criminal activity in blighted communities (Sampson & Groves, 1989). Together, these two theories reveal the importance of spatial and temporal context during crime analysis (Wilcox, Land, & Hunt, 2003).

Boba (2005) describes five types of crime analyses, or the general applications of criminological theory and crime analysis techniques in support of the functions of law enforcement:

(1) *Criminal investigative analysis* describes the process of collecting and analyzing information about a criminal offender. Criminal investigative analysis often involves the construction of offender profiles from known information, which then allows for the inference of offender characteristics (e.g., personality type, social habits, and work habits) based on those profiles (Jackson & Bekerian, 1997); journey-to-crime analysis, described below, is