**NSF Report for the Workshop on Decision Analytics for Dynamic Policing**
**CMMI-1917624**

## 1. Introduction and Motivation

Strategic partnerships between officials in police agencies and criminologists in university settings, over time, have become quite routine. In fact, some federal funding agencies now require criminologists to partner with police agencies when they propose study of key policing issues, such as gun violence, intimate partner violence, drug abuse, and human trafficking. Two examples are The Boston Gun Project's Operation Ceasefire program [1] and the St. Louis Metropolitan Police Department's firearms suppression program [2]. These collaborations have greatly increased knowledge, from theoretical advancements to new police technologies and operational advances in police agencies.

The traditional research approach in law enforcement utilizes randomized experimental design (e.g., [3]). However, this approach does not take advantage of today's data collection capabilities. Hence, the next step in developing successful police agency-university partnerships expands the scope of involvement on the academic side to include researchers from engineering and mathematics with expertise in modeling data. Within the last decade, the concept of *predictive policing* was proposed by a RAND report [4], funded by the National Institute of Justice (NIJ), to categorize and encourage academic research developing machine learning and statistical modeling tools to accurately *predict* crime. Unfortunately, the real impact of predictive policing is reported to the public as negative (e.g., [5-8]). What these real-world cases expose is the blind "black-box" nature of prediction algorithms. While some might argue that the "blind" nature makes them "fair," one must be careful <u>not</u> to assume that a good prediction implies that an actionable causal effect has been discovered. Blindly implementing a machine learning algorithm on available data is flawed in four critical aspects:

1. It omits the human perspective, including human behavior, political biases, and community perception.
2. It assumes that the data include the necessary information for both prediction and action.
3. It assumes that the policing system is stationary.
4. It assumes unlimited police resources.

Ironically, while considered "old-fashioned," the randomized experimental design approach overcomes the first two flaws by identifying precisely what data need to be collected, accounting for social factors that can bias results, to answer specific research questions. The drawback to this traditional approach is the high expense to study a very limited set of issues. The third flaw motivates the concept of *dynamic policing*. While rarely studied for law enforcement applications, dynamic decision-making methods have been long-studied in operations research, dating back to Bellman [9]. Finally, the fourth flaw requires inclusion of constraints, which is not addressed in predictive modeling, but is a core consideration in operations research.

A key element in the RAND report that has yet to be acknowledged in the literature is the concept of *prediction-led policing*. For this concept, it is recognized that prediction alone, regardless of accuracy, is inadequate without connection to a policing strategy that identifies appropriate actions. By bringing together police departments (PDs) and academics with expertise in decision analytics and operations research (DA/OR) and criminal justice (CJ), this workshop facilitated a cross-disciplinary understanding of policing challenges that may be addressable by DA/OR approaches. DA/OR encompasses both randomized experimental design and machine

learning algorithms for big data, but additionally contributes expertise in decision-making and modeling of dynamic systems. The effective integration of policing knowledge and DA/OR is critical to forging research directions for new DA/OR methodologies.

## 2. Workshop Objectives

The objectives of the proposed workshop were:

1. Build an understanding of the dynamics of policing systems.
2. Build an understanding of the controllable decisions and uncertain elements in dynamic policing systems, for example, intervention teams, criminal responses to police actions, community outreach, interactions between PDs and disciplines related to policing (such as forensic science divisions), etc.
3. Create processes that facilitate research partnerships between DA/OR, CJ, and PDs to encourage the development of DA/OR methods for dynamic policing systems.
4. Identify critical research themes in dynamic policing that may be studied using DA/OR.
5. Identify methodological advancements needed in DA/OR to address the critical research themes in dynamic policing.

## 3. Workshop Organization and Participants

The workshop was organized by four core teams, located at the University of Texas (UT) at Arlington, Virginia Commonwealth University (VCU), Georgia Tech (GT), and the University of Alabama (UA) at Tuscaloosa. PI Victoria Chen led the team at UT Arlington with DA/OR colleague Yuan Zhou, CJ colleague Kent Kerley, and collaborators from Arlington, TX PD. Co-PI Paul Brooks and CJ expert Robyn McDougle led the team at VCU with statistics colleagues Ye Chen, David Edwards, and Yanjun Qian, and collaborators from PDs in Richmond, VA and other local municipalities. Co-PI Yao Chen led the team at GT with DA/OR colleague He Wang and collaborators from Atlanta, GA PD. Finally, Co-PI Burcu Keskin led the UA team with DA/OR colleague Matthew Hudnall, CJ colleague Diana Dolliver, and collaborators at Mobile, AL PD and the Alabama Law Enforcement Agency. NSF funding supported the organizers, conference facilities, and travel for some academic participants. PD representatives and several other participants were provided travel support from NIJ/U.S. Department of Justice (DoJ).

### 3.1 Workshop Participants

Based on advice from Senior Personnel Robyn McDougle, the workshop was structured around the formation of local teams, with each team ideally including DA/OR faculty, CJ faculty, and PDs. The purpose of this structure was not only to facilitate cross-disciplinary team conversations at the workshop, but also to increase the potential for continued interaction after the workshop. Given that the workshop organizers were predominantly based in the eastern and southern U.S., (Texas-TX, Virginia-VA, Georgia-GA, Alabama-AL), workshop participants were specifically targeted in the western and northern U.S., so that local teams in attendance would provide representation across the continental U.S. It was not required that participants have an existing policing research partnership. New local teams were formed in Arizona (AZ), California (CA), Illinois (IL), Massachusetts (MA), Oregon (OR), and Wisconsin (WI). Research collaborations are on-going with 7 out of the 10 local teams in TX, VA, GA, AL, IL, MA, and WI. Two additional local teams (AZ, CA) are still in contact, but are not yet pursuing research projects. The complete list of participants by local team is as follows:

| Team | Discipline | Name | Affiliation |
|------|-----------|------|-------------|
| TX | DA/OR | Tory Chen, Ph.D. | UT Arlington |
| TX | DA/OR | Yuan Zhou, Ph.D. | UT Arlington |
| TX | CJ | Kent Kerley, Ph.D. | UT Arlington |
| TX | PD | Patina Clements | Arlington, TX PD |
| TX | PD | Lt. Jason Rash | Arlington, TX PD |
| VA | DA/OR | Paul Brooks, Ph.D. | VCU |
| VA | DA/OR | Ye Chen, Ph.D. | VCU |
| VA | DA/OR | David Edwards, Ph.D. | VCU |
| VA | DA/OR | Yanjun Qian, Ph.D. | VCU |
| VA | CJ | Robyn McDougle, Ph.D. | VCU |
| VA | PD | Chief Scott Booth | Danville, VA PD |
| GA | DA/OR | Yao Xie Chen, Ph.D. | GT |
| GA | DA/OR | He Wang, Ph.D. | GT |
| GA | PD | Capt. Jacquelyn Gwinn-Villaroel | Atlanta, GA PD |
| AL | DA/OR | Burcu Keskin, Ph.D. | UA |
| AL | DA/OR | Kevin Curtin, Ph.D. | UA |
| AL | DA/OR | Matthew Hudnall, Ph.D. | UA |
| AL | CJ | Diana Dolliver, Ph.D. | UA |
| AL | PD | Chief James Barber | Mobile, AL PD |
| AL | PD | Maury Mitchell | Alabama Law Enforcement Agency |
| AZ | DA/OR | Ron Askin, Ph.D. | Arizona State University |
| AZ | DA/OR | Ross Maciejewski, Ph.D. | Arizona State University |
| AZ | DA/OR | Jorge Sefair, Ph.D. | Arizona State University |
| AZ | CJ | Mike White | Arizona State University |
| AZ | PD | Asst. Chief Brenda Buren | Tempe, AZ PD |
| AZ | PD | Carlena Orosco | Tempe, AZ PD |
| CA | DA/OR | Susan Martonosi, Ph.D. | Harvey Mudd College |
| CA | PD | Lt. Rachel Tobler | Redlands, CA PD |
| CA | PD | Amy Varela | Redlands, CA PD |
| IL | DA/OR | Kezban Yagci Sokat, Ph.D. | Northwestern University |
| IL | DA/OR | Nezih Altay, Ph.D. | DePaul University |
| IL | CJ | Doreen Salina, Ph.D. | Northwestern University |
| IL | PD | Marian Hatcher | Cook County Sheriff's Office |
| IL | PD | Cdr. William Leen | Cook County Sheriff's Office |
| IL | PD | Sgt. Stephen Moody | Cook County Sheriff's Office |
| MA | DA/OR | Renata Konrad, Ph.D. | Worcester Polytechnic Institute |
| MA | PD | Dep. Chief Sean Fleming | Worcester, MA PD |
| MA | PD | Supt. Daniel Wagner | Cambridge, MA PD |
| OR | DA/OR | Tim Anderson, Ph.D. | Portland State University |
| OR | CJ | Kris Henning, Ph.D. | Portland State University |
| OR | PD | Christian Peterson | Portland, OR Police Bureau |
| OR | PD | Lt. Nathan Voeller | Portland, OR Police Bureau |
| WI | DA/OR | Laura Albert, Ph.D. | University of Wisconsin-Madison |
| WI | DA/OR | Veronica White | University of Wisconsin-Madison |
| WI | CJ | Rebecca Konkel, Ph.D. | University of Wisconsin-Milwaukee |
| WI | PD | Sgt. Adam Grochowski | Milwaukee, WI PD |
| WI | PD | Stephanie Sikinger | Milwaukee, WI PD |

### 3.2 Workshop Agenda

The workshop took place on May 9-10, 2019 at the Renaissance Arlington Capital View Hotel in Arlington, VA. The schedule of events included four keynote presentations and five break-out discussion sessions. Information on the workshop was disseminated to workshop participants via the website: https://cosmos.uta.edu/workshop/. Information on the keynote presentations, including PDFs of the slides, are available from the workshop website. The agenda was as follows:

**Wednesday:**
- Participants arrive and check-in.

**Thursday:**
- 7:30–9:00 AM: Buffet breakfast.
- 8:15–8:30 AM: Welcome remarks by Irina Dolinskaya, NSF and Chris Tillery, NIJ.
- 8:30–9:00 AM: Introduction by Victoria Chen and Robyn McDougle.
- 9:00–9:45AM: Keynote by John Hollywood, RAND.
- 9:45–11:00 AM: Break-out session #1 by discipline (DA/OR, CJ, PD) – Obj. 1 & 2.
- 10:45–11:30 AM: Coffee and snacks.
- 11:15 AM–12:30 PM: Break-out session #2 across disciplines – Obj. 3.
- 12:30–2:00 PM: Lunch and open discussion.
- 2:00–3:00 PM: Keynote by Evan Levine & Lori Pollock, NYPD.
- 3:00–4:00 PM: Break-out session #3 in local teams – Obj. 2 & 4.
- 3:45–4:30 PM: Coffee and snacks.
- 4:15–5:15 PM: Break-out session #3 continued.
- 5:15–5:30 PM: Wrap-up and outline tasks for second day.
- 5:30–6:30 PM: Break.
- 6:30–8:30 PM: Dinner with keynote by Richard Larson, MIT.

**Friday:**
- 7:30–9:00 AM: Buffet breakfast.
- 8:15–9:00 AM: Keynote by Sue Merchant, Blue Link Consulting, United Kingdom.
- 9:00–10:00 AM: Break-out session #4 in local teams – Obj. 4 & 5.
- 10:00–10:45 AM: Coffee and snacks.
- 10:15–11:15 AM: Break-out session #5 by discipline (DA/OR, CJ, PD) – Obj. 4 & 5.
- 11:15 AM–12:05 PM: Summaries.
- 12:05–1:00 PM: Lunch with closing remarks.
- Afternoon: Participants depart.

### 3.3 Keynote Presentations

As specified in the agenda, four keynote presentations were included in the workshop to provide additional information from experts to workshop participants. Speakers were also welcome to participate in break-out sessions. The presentations were as follows:

1. *Decision Analytics and Operations Research for Policing: Progress to Date and Needs for the Field*, John S. Hollywood, Ph.D., RAND Corporation.
2. *Detecting Crime Patterns*, Assistant Commissioner Evan S. Levine and Chief Lori Pollock, New York Police Department.

3. *O.R. and Policing – Looking Back, Looking Forward*, Richard C. Larson, Ph.D., Massachusetts Institute of Technology.
4. *Policing Applications in the United Kingdom*, Sue Merchant, Blue Link Consulting.

Dr. Hollywood was the lead contributor to the RAND report, and his presentation opened the workshop by presenting a broad view of DA/OR in policing. The intention of this presentation was to provide the appropriate scope to the participants. The second talk by the New York Police Department provided examples of real world applications of DA/OR, including work that was recognized by the Institute for Operations Research and the Management Sciences (INFORMS) as a finalist for the 2016 Franz Edelman Award. The role of this presentation was two-fold: (1) to connect more directly with PD representations in the audience and (2) to explain the complexities of policing to academic researchers. The third presentation was by Dr. Larson, who is a member of the National Academy of Engineering and an INFORMS Founding Fellow. As a dinner talk, his presentation gave an informal story of his path through policing research, including his seminal work in the 1970s. The fourth and final talk by Sue Merchant opened Friday events. Ms. Merchant has worked in the public sector in the United Kingdom (U.K.) for her entire career, including 28 years with the U.K. Ministry of Defence and the Metropolitan Police in London, England. Her presentation provided an important perspective from outside the U.S., emphasizing the U.K.'s long-standing use of DA/OR in policing.

## 4. Brief Literature Review

In order to properly position the objectives and scope of the proposed workshop, literature on predictive policing and policing strategy studies are described here. The predictive policing literature is focused on the prediction of crime, including perpetrators, victims of crime, and potential future offenders. Policing strategy studies include traditional randomized experimental design studies, optimization attempts, and simulation models. Participants were provided pre-workshop recommended reading via the website, which consisted of the 2013 RAND Report [4], Curtin et al. [10], Weisburd et al. [11], and Headley et al. [12]. Following the workshop, several other papers were added to the website, including a listing of Dr. Larson's work.

## 4.1 Predictive Policing

The RAND report [4] provides a taxonomy of different operational tools and techniques that appear promising and are used by police departments. Spatial prediction models are used to identify geographical areas with increased crime risk. Examples include crime mapping [13], hot spot analysis [14-16], risk terrain analysis [17-18], and near-repeat patterns [19-20]. To accommodate the temporal element of crime prediction, more sophisticated statistical methods for spatio-temporal modeling have been studied (e.g., [21-25]).

An alternative to predicting the location of crime is to predict individuals perpetrating or affected by crime. To identify the identity of a perpetrator for a specific crime, data from past similar crimes may be used to specify the characteristics of similar perpetrators. This literature is focused on specific crime types and perpetrator behaviors, for example, alcohol addiction [26], sexual assault [27], and violent behavior [28]. Victims of crime can be studied using similar data and analysis methods as above to identify potential future victims [29]. Finally, it is also desired to predict potential offenders with the hope of preventing a future crime. Again, the characteristics of past offenders can be analyzed to detect similar indicators in potential offenders [30-32].

## 4.2 Policing Strategy Studies

Studies of different policing strategies are most reliably investigated via randomized experimental design (e.g., [12, 33-36]). As in the medical world, this approach is the gold standard for identifying causal effects of specific actions. However, such studies are expensive and require collection of controlled data, as opposed to massive automated collection of observational data.

Optimization approaches have been attempted, including goal programming [37], location analysis [10, 38], linear and integer programming [39-42], and dynamic programming [43]. However, it should be noted that the derived optimal policies were static in nature (including the dynamic programming work). To better represent the dynamic nature of policing, simulation has been used in several studies. The advantage of simulation is the potential to study "what-if" scenarios [44]. In particular, agent-based simulation models [11, 45-46] and discrete-event simulation models [47-49] have been used to study policing strategies. However, while simulation is an appropriate tool for studying dynamic systems, a simulation model must be carefully calibrated using appropriate knowledge to enable results that resemble the real system.

## 5. Break-out Discussion Sessions

A key element in the organization of the workshop was to build in an evolution of the conceptual understanding of policing decisions. The ordering of the break-out discussion sessions was deliberately intended to gradually build on understanding that was gained in prior break-out sessions. In the midst of the workshop, many participants experienced an "a-ha" moment at which their understanding of policing decisions was clarified, opening their minds to alternate approaches for policing decision processes and further expanding the discussion for potential research directions.

## 5.1 Break-out Discussion #1

The purpose of this first break-out discussion session was to introduce the separate disciplines of DA/OR, CJ, and PD law enforcement to the concept of dynamic policing. The DA/OR researchers were divided into 2 sessions, the CJ researchers constituted one session, and the PD representatives were divided into 3 sessions. The discussion questions were focused on Objectives 1 and 2, especially around understanding the key terms "dynamic" systems, "controllable" decisions, and "uncertainties" in policing. Questions were customized for the three separate disciplines, so as to elicit separate perspectives.

For the DA/OR sessions, discussion questions were:

**Question 1: What are examples of dynamic systems or processes in policing?**
  (a) What are some common characteristics of these systems or processes?
  (b) Are these systems or processes currently modeled dynamically or statically?

**Question 2: What are examples of controllable decisions in policing?**
  (a) Which are dynamic versus static?
  (b) What factors might impact these decisions?
  (c) What policing or social outcomes might these decisions impact?

**Question 3: What are examples of uncertainties in policing?**
  (a) How might these uncertainties affect outcomes?
  (b) How might these uncertainties affect decisions?

(c) How might these uncertainties be modeled?

For the CJ session, discussion questions were:

**Question 1: What does the word "dynamic" mean to you?**
    (a) What are critical examples of dynamic systems or processes in policing?
    (b) How are these dynamic systems or processes modeled in current research?

**Question 2: What is controllable in policing?**
    (a) How are controllable decisions studied in current research?
    (b) Are these decisions considered as dynamic or static?
    (c) What policing and social outcomes might these decisions impact?
    (d) How can forecasting of outcomes be connected to controllable decisions?

**Question 3: What are examples of uncertainties in policing?**
    (a) How might these uncertainties affect outcomes?
    (b) How might these uncertainties affect decisions?
    (c) How is uncertainty represented in current research?

For the PD sessions, discussion questions were:

**Question 1: What does the word "dynamic" mean to you?**
    (a) What are critical examples of dynamic systems or processes in policing?
    (b) How are these dynamic systems or processes currently handled by law enforcement agencies?

**Question 2: What is controllable in policing?**
    (a) Are these decisions / actions considered as dynamic or static?
    (b) How are these decisions / actions currently made?
    (c) What are the major flaws in current approaches?
    (d) What policing or social outcomes might these decisions/actions impact?
    (e) How are forecasted/predicted outcomes connected to controllable decisions?

**Question 3: What are examples of uncertainties in policing?**
    (a) How might these uncertainties affect outcomes?
    (b) How might these uncertainties affect decisions/actions?
    (c) How are uncertainties currently considered in decision-making?

A *dynamic* system is one that is changing, possibly at varying rates. Tactical and strategic thinking to address dynamic situations are very different from those that handle static situations. Dynamic decision-making adaptively considers many moving parts, both micro and macro, including unforeseen circumstances and repercussions. Static decision-making is aggregate and considers few details. It was strongly agreed that the general policing environment is dynamic, including the following dynamic elements:

- Crime rates and types, which vary by location and over time.
- Human behaviors, including criminals, victims, officers, and bystanders.
- Officer performance and wellness.
- PD relationship with the community.

- PD relationship with District Attorney and the court.
- Law enforcement usage of technology.
- Online environment.
- Seasonal patterns and weather.
- Urban patterns, including transportation systems and available services.
- Regentrification and suburban sprawl.
- Social patterns and events, including holidays and attractions.
- Politics and laws.
- Media coverage of crime and PDs.
- Movements of people during protests.
- Human trafficking methods.

There are also elements of the policing environment that are mostly static or slow-changing, including:

- Total staffing and resources.
- Topology of the geographical region.
- Demographic characteristics.
- Urban infrastructure, including roadways, buildings, schools, hospitals, stadiums, etc.
- PD structures, including district maps, officer hierarchy, reporting systems.
- The law.
- Attitudes toward police – the level of public trust.
- Elected officials.

While police officers are trained to be able to act dynamically, departmental policies and decisions are typically modeled as static. This is mostly due to the annual planning habits of PDs and the aggregate nature of the available software planning tools. Dynamic aspects are not modeled formally, but some examples in which formal processes address dynamics include:

- Officer training, which has a process for presenting trainees with dynamic scenarios.
- Hot spot policing with randomization.
- Dispatching, which follows static rules for dynamically dispatching officers to calls for service.
- Task forces.

Processes that address dynamics are predominantly based on anecdotal evidence, and it is not explicitly known that these processes work. Specific examples of dynamic situations that were discussed include:

- A crime that is in progress (e.g., road rage situation, robbery that changes locations, mass shootings, vehicle pursuit).
- An officer that is hesitant to take a certain action because of potential media backlash.
- The use of force, including deadly force and the potential for excessive force.
- Laws that are unable to keep up with technology, such as data forensics on seized cell phones or usage standards on information from body-worn cameras.
- Juvenile exposure to criminal elements that ultimately leads a youth down criminal paths.
- Changes in law enforcement leadership or management.
- Public perception of law enforcement.

- Data issues, including data accuracy, data sharing, data needs, data retention, data misuse, and data overload.

Some flaws in current approaches were discussed as follows:

- Officers may not be kept up to date on changes in laws and best practices.
- Performance metrics do not match the desired behavior of officers. Quantities, such as number of tickets, number of stops, and time on a call, are measured while quality, such as following proper procedures, is not. Officers are penalized for not "performing" well based on these metrics, leading to behaviors that maximize quantity while minimizing quality.
- Information sharing is a challenge due to silos in specialties (e.g., intel officer, gang squad, patrol officers), incomplete communication processes that rely on human message passing, and information overload from technology.

With regard to what is *controllable* in the policing system, the variety of decisions that law enforcement agencies face is overwhelming, and often decisions must be made with little basis for evaluation. The policing system must determine how much and how often they should "turn the knobs" to make adjustments in dynamic situations. Dynamic decisions are prevalent in the policing system, and police officers undergo extensive training that seeks to prepare them for the variety of scenarios that they might encounter. However, this form of dynamic decision-making is ad hoc and highly dependent on the individual. There has been little examination of what decisions or interventions would more appropriately be modeled and controlled dynamically vs. statically. Examples of existing dynamic policing decisions include:

- Policies, procedures, and training on PD response to certain situations (e.g., hostage situations, use of force, mental health, violations of policies). These provide critical protocol for officers responding to a crime is in progress, but every situation is unique and every officer is unique.
- Patrol routing patterns. The intention is to catch crime in action, and each patrol officer is given total control of their approach based on their own preference.
- Technology options, including various forms of data recording. PDs have difficult choices on adopting or not adopting technology with little basis on making these decisions. The goal of vendors is to sell their product, rendering vendor information unreliable with regard to technology.
- Decisions to patrol or arrest that are affected by politics or the District Attorney's decision to prosecute, leading to the issue of wasting effort when a suspect is likely to be released immediately after arrest.
- Interactions with the public, including addressing confrontational "us v. them" environments.
- Implementation of change. This is often met with a lot of resistance by PDs because officers are humans that vary in their ability to adapt to change.
- Hot spot policing. This requires identifying hot spots and then appropriately deploying officers. While a post-hoc analysis is easy, these are typically too late to mitigate future hot spots. The current approach is reactive.
- Day-to-day assignment of officers to shifts and patrol regions to ensure adequate coverage with limited resources.
- Monitoring of video of public spaces.

A first step in determining whether to implement dynamic vs. static decision-making is to identify what decisions are truly controllable. It is a common misconception to interpret an outcome as controllable. PDs often want to "control" response time or "control" public perception, but these outcomes are not directly controllable. By clearly identifying what is directly controllable by PDs, the appropriate data can then be identified for determining the impacts of the controllable decisions. It is also a common misconception that all data are useful. By focusing on the controllable decisions and their impacts, superfluous data, which are ubiquitous, can be eliminated, subsequently eliminating numerous issues due to data overload. The discussion identified the following examples of controllable decisions:

- The order and mission of the law enforcement agency.
- Whether or not to be proactive or reactive. While it is commonly desired to be proactive, the ad hoc approach is reactive. Proactive decision-making is often misinterpreted as being predictive, such as predictive policing. The goal with proactive decision-making is to be prepared for the range of evolution of events.
- Technology usage. PDs struggle with the cost vs. benefit of various forms of technology, including GPS in vehicles, cameras, audio. Under the "no stone unturned" philosophy, it is easy to argue that all technology is beneficial. However, with limited resources, this philosophy is unrealistic and infeasible. Consequently, given the high cost, the benefits of technology must be viewed critically. More importantly, instead of technology pushing PDs, PDs should take control of what technology is needed and whether or not what is being offered is acceptable.
- University research collaborations. PDs can choose whether or not build collaborations with universities.
- Administrative processes, training, and policing duties. Some, but not all, of these are defined directly by PDs.
- Evidence collection. Laws control many aspects, but some elements may be directly controllable by PDs.
- Community interactions. The effectiveness of PDs is strongly impacted by community support. Communities that seek to undermine PDs create environments that waste precious resources. While PDs cannot directly control their public perception, they can control how they interact with the community.
- Quotas. These are used by PDs as incentives to, in theory, achieve desired outcomes, for example, stopping a specific number of vehicles exceeding the speed limit per month.
- Deployment of police. The traditional approach for deployment of regular patrol officers is based on a static district map that defines policing regions (a.k.a., sectors, beats). These regions are defined based on aggregate crime rates or response times such that the same (or similar) numbers of officers are deployed to each region. Traditionally, adjusting this deployment requires re-districting, which is costly and time-consuming.

In the above list, many of these controllable decisions are relatively static. The last three in the list are potentially appropriate for dynamic decisions since these decisions (interactions with the community, quotas, deployment) can vary over time more easily than the others in the list. For example, a PD should not invest in implementing a certain technology and then choose to not use it. Similarly, administrative processes and laws cannot change quickly. However, there are elements of these that may be dynamically adjusted, such as when and how to use technology, test new training processes, or modify duties.

In considering factors, decisions, and outcomes that may be relevant for conducting a rigorous DA/OR analysis and/or optimization, there are three general directions where more research is needed:

(1) There is a disconnect between outcomes and goals.
(2) There is a disconnect between outcomes and factors.
(3) There is a confounding of factors and decisions.

Current outcome metrics are chosen in practice because they are easy to measure, such as response time, and not because they are fundamentally related to policing goals. The focus by PDs on improving peripheral outcome metrics leads to decisions and expenses that do not address actual policing goals. Genuine policing goals include reducing crime, improving community relationships, maintaining officer wellness, and achieving resource efficiency. Consequently, creative research is needed to define goal-appropriate measurable outcomes, and data collection processes need to be developed to collect these measures.

Even if current outcome metrics were addressing genuine policing goals, current data collection processes do not enable an analysis that connects outcomes to causal factors. The data on outcomes lacks data on potentially related factors. One reason for this is because police departments commonly employ data that are provided by vendors. Another reason is that there are entities external to police departments that request various forms of data, which causes the data collection processes to be reactive instead of proactive. Typically, there is a focus on collecting outcomes for reporting to these entities. However, an understanding of these outcomes cannot be achieved unless there exist simultaneous data on factors potentially related to these outcomes.

The challenge with collecting data on potentially related factors is to clearly define these factors. In particular, if one wants to improve decisions, then it is of critical importance to distinguish factors that are controllable from those that are uncontrollable. This distinction is lost in the task of data collection. Recent capabilities to capture large quantities of data have pressured PDs to collect everything possible without considering relevance to policing goals or efficiency of resources. The consequence is an imbalance, with unmanageable quantities of unhelpful observational data, including camera footage that predominantly captures nothing of importance, and a lack of data on controllable factors, such as policing actions to deter speeders on roadways or burglaries around tourist attractions. For example, outcome data could show that the annual total of 911 calls was lower in the most recent year compared to the prior year. It might be anecdotally known that the police department did take some actions in the most recent year, such as signage to warn tourists to hide their belongings and lock their vehicles, but if there is no record of when and where such actions were taken, then any connection between these actions and outcomes cannot be explored, much less identified.

To distinguish controllable from uncontrollable factors, the discussion also considered uncertainties. Some of these are completely exogenous, and some are impacted by PD actions, but are not directly controllable. Example uncertainties that are essentially exogenous to PDs, but affect PD decisions include several dynamic elements listed earlier, such as the weather, the schedule of events and attractions, traffic patterns, social patterns, media coverage, laws, and politics. Example uncertainties that are impacted by PD actions include:

- Criminal response, from minor crimes and cybercrimes to active shooters and terrorist attacks.
- Human response, including PD officers and staff, criminals, victims, politicians, and the

community.
- Policing outcome measures, such as crime rates and response times.
- Data sources and discrepancies in data, including underreporting of crimes.
- Budgets and resources, including insufficient resources for randomized controlled trials.
- Unintended consequences.

Overall, the above discussion emphasizes that a major obstacle to DA/OR is policing data. Existing data are insufficient for existing DA/OR approaches. However, new approaches are needed for both data collection and DA/OR tools. Specifically, while data collection could be enhanced, coordination is needed between data collection processes and the development of new DA/OR tools in order to realize a successful solution approach. Creativity is needed both in defining outcome metrics and in defining potential policing decisions or interventions that balance both efficacy and cost. DA/OR approaches must be developed to appropriately coordinate data collection plans with innovative data-driven decision-making methods, so as to achieve actionable decisions connected to genuine policing goals.

## 5.2 Break-out Discussion #2

For the second break-out discussion session, participants were organized into a mix of disciplines, such that every group had representation from each of the three disciplines, DA/OR, CJ, and PD law enforcement. The purpose of this break-out session was to learn how existing research partnerships between PDs and universities had been established, and to uncover obstacles and different perspectives on the roles of these partnerships. To facilitate this discussion, workshop organizers and their PD partners were assigned across the six groups. Specifically, Group 1 included organizers from TX and AL, and PD from GA; Group 2 had organizers from VA and PD from TX; Group 3 had organizers from VA, AL, and GA; Group 4 had organizers from TX, AL, and GA, and PD from VA; Group 5 had organizers from TX and VA; and Group 6 had organizers from VA and AL, and PD from TX. The discussion questions were focused on Objective 3, pertaining to the creation of research partnerships between DA/OR, CJ, and PDs. The discussion questions were:

**Question 1: How were the research partnerships by members in your group created?**

**Question 2: What were potential obstacles?**

**Question 3: What elements of the partnership are most attractive to PDs? to CJ? To DA?**

**Question 4: What are key terminology to facilitate communication?**

**Question 5: Can these research partnerships lead to actual change in policing?**

Building the right team of collaborators requires team members that are open-minded enough to learn what other team members can contribute and determined enough to figure out how these contributions can work together to generate new ideas and tangible solutions. Some obstacles to forming appropriate partnerships include:

- PD leadership with an "old school" mentality because they may be dismissive of research findings that are contrary to their existing beliefs.

- PD leadership with a "what can you do for me?" attitude because they may be too impatient for the pace of academic research.
- Team members with vendor affiliations because they may have biased perspectives.
- Self-interested academic researchers that seek to push projects in which they can apply their desired methodology because they will not be sufficiently focused on the benefits to policing.
- Overly confident academic researchers that promise to solve more problems than is realistic because they will not be able to deliver on their promises.
- Team members with political agendas because they will attempt to lead the research to support their biases.

Partnerships need to think long-term. Patience will be required on both the academic and the PD sides. From the academic side, understanding the complexities and nuances of policing is challenging, and oversimplifying the problem may not yield helpful results. From the PD side, the time-scale in universities follows semesters and involves the training of students, which typically does not match with the time-scale of PDs. Approaches for developing projects in forging DA/OR, CJ, and PD partnerships include:

- Focusing on a specific issue/problem, such as licit and illicit drug issues, human trafficking, and prostitution.
- Focusing on policing operations, including strategic resource allocations, shift assignments, and analysis of crime data.
- Participatory action research in which research can be conducted using activities and data that are already part of regular PD processes.

It was recommended to start with smaller projects and small "wins" to build trust and confidence towards a long-term partnership. It is important for academic team members to contribute expertise and knowledge that are currently unavailable to their PD partner. These will vary for individual PD agencies, so academic team members must take time to understand the capabilities of their PD partner. In addition, PDs should consider nominating their mid-career officers for NIJ Law Enforcement Advancing Data and Science (LEADS) Scholarships.

Connections with local campus police, former students, or current students on PD internships can facilitate building teams. It is critical that partnerships identify benefits for all team members. Specifically, academics need funding to support their research and publications to demonstrate progress, while PDs need tangible results. These are often non-overlapping, which means that the team members need to think creatively and collaboratively to ensure the desired benefits are achieved. In addition, the projects pursued must be identified collaboratively. Not all issues that PDs want solved will be of interest to academic researchers and vice versa. The opinions on important policing issues vary across PDs, academics, and the general public.

The challenge of bringing the right people together is compounded by the somewhat high turnover of staff at PDs. For example, the Arlington, TX PD liaison for the UT Arlington team changed four times during their partnership, or approximately once every 1.5 years, including a time period for which there was no assigned liaison. Two elements were critical in maintaining the continuation of the partnership:

1) Continual support by PD leadership ("champion").

2) Inclusion of CJ team members, including adjunct professors with careers in law enforcement.

Larger organizations, like the Alabama Law Enforcement Agency (ALEA) and the Metropolitan Police in London, England, have had structured processes that enable more stability in university partnerships.

The recommended first step of a partnership between a university and a PD partner is to establish a memorandum of understanding (MOU) that specifies the agreement between the two entities, including processes that enable the partnership to continue even with PD staff turnover. The MOU is important in order to establish clear lines of trust. Some PDs had experiences in which they shared data with a university, and the university used that data against the PD. One purpose of the MOU is to prevent such acts of mistrust in the partnership, while still allowing universities to publish research based on shared PD data. Some PDs have formal organizational structures that enable funded research contracts with universities. Formal contracts will include stricter agreements than an MOU. Examples within the workshop were the Atlanta, GA Police Foundation, which directly funds research conducted by universities, and ALEA, which already has agreements in place with local universities to enable support of policing research. PDs that want to encourage research should consider establishing pathways to working with academics.

Without an existing local structure for funding research, it is necessary for the academic team members to jointly pursue funding opportunities with PD partners. Several NSF and U.S. Department of Justice (DOJ) program directors were present at the workshop and provided advice on grant funding opportunities. In particular, NSF program directors from CMMI/ENG and SES/SBE and DOJ program directors from NIJ and the Bureau of Justice Assistance (BJA) voiced interest in funding DA/OR research for policing. However, funding from federal agencies typically leads to more fundamental and methodological findings that are publishable, but perhaps not necessarily yielding tangible benefits for local PDs. Local funding structures are still needed to support research results that are directly beneficial for local PDs. In order to respond quickly to calls for grant proposals, it is recommended that team members stay in regular contact.

The partnership benefits for PDs include gaining access to the skill set of the academic partners and enabling the claim of university research collaborations and state-of-the-art analytics to improve policing and the PD public image. Partnerships can also facilitate PD staff attaining more education with the university partner. DA/OR academic members benefit from a plethora of interesting and challenging applications, access to real data, and real-world analytics examples for training students. CJ academic members benefit by connecting PD knowledge and data with DA/OR methods to identifying new findings and perspectives in CJ research. CJ team members have the critical role of translating the benefits of DA/OR to PD leadership and explaining the structure of PD processes, reports, and data to DA/OR team members.

The issue of terminology is a continual challenge. For example, the word "probability" has a clear definition in DA/OR terminology, but in the policing world is confused with the term "probable cause," which has a distinct meaning from probability. Academics must be prepared to explain or illustrate their concepts multiple ways because the description that will be understood cannot be easily predicted in advance. Freedom to ask "stupid questions" must be widely accepted to minimize misunderstandings. Academics that are good teachers will likely have more success since they will have a stronger ability to explain concepts multiple ways and better instinct when interpreting misunderstandings or confusion. It is recommended to avoid the use of acronyms, abbreviations, and unnecessary jargon. In order to provide some background

on terminology to workshop participants, two sets of terminology were included in the workshop program.  The first set included DA/OR terms, and the second set included policing terms [50-54].  Neither set was intended to be comprehensive.  Rather, the intention was to introduce participants to the need to translate terminology when building partnerships.  Both terminology sets are included at the end of this subsection.

Finally, the workshop participants discussed the potential for these partnership to create actual change in policing.  PDs can be steeped in tradition, so any proposed change must be evaluated carefully in order to generate buy-in and alleviate concerns.  Real change may require formal processes to implement change and facilitate accountability, such as a project management manual or a steering committee.  To influence the policing community, presentations at law enforcement conferences, police chiefs, and policymakers will have more impact that presentations at research conferences.  Academic researchers will need to learn to effectively present their work to policing audiences by considering short videos or demonstrations and "elevator pitches."  Ultimately, the larger mission is not research, but to improve the community and keep people safe.


**The What is Decision Analytics?**  Here is an evolution.

**Operations Research** gained popularity in military operations in World War II, and afterward became a more general field focused on developing methods to optimize decisions.

**Statistics** is the original data analysis field and is the foundation of many current data analysis techniques.  Statistical methods are typically based on mathematical foundations that guide the proper collection and analysis of data.  However, these mathematical foundations have been seen by some to limit the applicability of statistical methods.

The term **Stochastic** refers to elements that are uncertain or have random behavior.  Stochastic behavior is most commonly represented using **Probability Modeling** (not to be confused with "probable cause"), but an alternative is **Fuzzy Logic**.

The term **Deterministic** refers to entities that are not Stochastic.  Methods in **Operations Research** originated in the **Deterministic** realm, for which all values were considered known with certainty.  The most popular of these methods is **Linear Programming**.  More recent methods seek to address **Stochastic** behavior.

**Simulation** is a computer modeling approach that seeks to mimic the behavior of a real world system.  These are useful for studying complex systems that cannot be easily manipulated in the real world, such as flight simulators, vehicle crash simulators, air quality simulators, traffic simulators, etc. Many Simulation models are **Deterministic**, meaning that the same input into the computer model will yield exactly the same output.  A **Stochastic** Simulation model explicitly represents uncertain behavior, so that the output has realistic variation, even when given the same input.

**Variability** exists when more than one value can be realized.  The field of **Statistics** is intended for the study of variability in data.  Variability can exist due to both **Deterministic** sources (such as the laws of physics underlying the movement of objects) and **Stochastic** sources (typically uncertain elements).

**Experimental Design** is a classical field of statistics that guides a controlled data collection approach, so as to enable unbiased study of how input factors affect a numerical target/response/output variable. This is an appropriate approach for studying how controllable decision variables (e.g., interventions) influence performance, but can be expensive to implement.

**Regression** is a statistical modeling approach that uses numerical explanatory factors to predict a numerical target/response/output variable. The most common method is **Linear Regression**, but other more general forms exist.

**Classification** is a statistical modeling approach that uses numerical explanatory factors to predict a binary target/output variable. For example, the output variable could be the presence or absence of a disease. Extensions to more than two categories do exist.

**Data Mining** arose in the 1990s as a response to the rise in available data, especially large streams of automatically collected data. Most of these new data were unable to satisfy statistical modeling assumptions, and hence new ad hoc approaches were created to seek patterns in these data. The emphasis was no longer on the correctness of the modeling, but rather on the speed and ability to detect potential anomalies, such as credit card fraud detection.

**Prediction** or **Predictive Modeling** refers to the modeling case in which there is a target/response/output variable that is desired to be predicted in the future. Statistical and data mining approaches based on Regression or Classification are Predictive Modeling approaches.

**Learning** refers to the fitting of a model or algorithm to data. In most statistical modeling approaches, the learning process is well understood and tractable, but in some data mining approaches, the learning process can be highly computational and intractable. **Neural networks**, for example, have a complex, nonlinear learning process. Recent work in **Deep Learning** has sought to overcome this issue by enabling a much more intensive search process for structuring and fitting a neural network model, so as to produce improved predictive performance.

**Machine Learning** refers to computer algorithms that conduct the complex learning process of data mining methods. The terms data mining and machine learning are sometimes used interchangeably.

**Supervised Learning** is a term that encompasses both Regression and Classification, i.e., when there is a specified target/output variable.

**Unsupervised Learning** explores multi-dimensional data that do not have a specified target/output variable.

The concept of **Analytics** arose about a decade ago with a desire for businesses to connect data to better decisions. The analytics process was originally intended to follow four stages:
> Stage 1) **Descriptive Analytics** follows the same concept of Descriptive Statistics, which simply seeks to summarize data using calculated metrics and graphical methods.
> Stage 2) **Diagnostics Analytics** is intended to answer specific questions using methods as simple as drilling down into the data or more complicated data mining methods.
> Stage 3) **Predictive Analytics** is mostly the same as Predictive Modeling.
> Stage 4) **Prescriptive Analytics** is akin to Operations Research, except, in theory, the optimization decision process is based on the prior three stages and is, thus, data-driven.

The reality of Analytics is that these are now seen as different types of analytics instead of four parts of one process. The predominant analytics type is Predictive Analytics, a.k.a., Predictive Modeling, Data Mining, Machine Learning, etc. While analyses from the first two stages can seamlessly feed into stage 3, there remains a disconnect between stage 3 and the desire to make good decisions in stage 4. This is because Predictive Models are not intended to study controllable decision variables that would be necessary to conduct an optimization.

The term **Decision Analytics** is intended to bridge the gap between stages 3 and 4, so as to fulfill the original intention of Analytics. The future of decision analytics is yet to be written.

## Policing Terms

**Broken Windows Theory**: A theory that posits minor incidents of disorder lead to fear among the populace that keeps citizens from interacting with each other, which in turn leads to a reduction in the fear of apprehension among criminals.

**Call Priority:** A system in which a faster response and more resources are given to more critical calls for service.

**COMPSTAT:** A management process that involves the analysis of data to identify problems and the assignment of responsibility to police personnel for the resolution of those problems.

**Computer Aided Dispatch (CAD):** A computer system and database that tracks calls for service as they are received, monitors the status of patrol units, and provides various reports relating to calls for service, the activities of officers, and the calls to which officers respond.

**Crime Displacement:** The shift of crime either in terms of space, time, or type of offending from the original targets of crime prevention interventions.

**Crime Hot Spots:** Small geographic areas with a high concentration of crime.

**Crime Maps:** Maps that display where various crimes have occurred in a particular jurisdiction over a particular period of time.

**Crime Scene Profile:** Information about an offender that includes such details as race, age (or age range), employment status, type of employment, marital status, level of education, and location of residence.

**Data-driven policing:** Policing that occurs when leaders collect and analyze departmental data to make informed decisions about how their departments should best operate, particularly with regard to policies and strategies.

**Deterrence:** Making someone decide not to do something.

**Diffusion of Crime Control Benefits:** The spread of the beneficial influence of an intervention beyond the places which are directly targeted, the individuals who are the target of control, the crimes which are the focus of intervention or the time periods in which an intervention is brought.

**Directed Patrol:** Involves assigning officers to intensively patrol particular areas at particular times (while often freeing them from answering calls-for-service).

**Discretion:** A police officer's personal judgment of how best to handle a situation.

**Evidence-based Policing:** Policing that involves the use of research findings to inform policies and strategies.

**Hot Spot Policing:** Concentrating police in areas where crime is most likely to occur.

**Intelligence-led Policing:** An approach to policing that involves the collection and analysis of information on likely offenders and their methods of operation.

**Overpolicing:** The perception of too much police presence and action in a neighborhood.

**Police Intervention:** The physical involvement of police officers in an incident, especially where officers use force to control public disorder.

**Predictive Policing:** Policing strategy that uses data to try to predict and prevent crime.

**Probable Cause:** A standard of proof that is generally required in order for police to justify a search or arrest.

**Problem Oriented Policing (POP):** A type of policing that attempts to address specific problems that affect quality of life of residents in a community.

**Residual Deterrence Decay:** Decay that occurs when a residual deterrent effect dissipates, and the normal level of crime resumes.

**Response Time:** the amount of time that elapses between when a crime occurs and when officers arrive at the scene. It includes both citizen reporting time and police response time.

**SARA (Scanning, Analysis, Response, and Assessment) Model:** A method of problem solving that involves identifying a problem, researching what is known about the problem, developing solutions to the problem, and then evaluating the success of the solution.

**Uniform Crime Reporting (UCR):** The Uniform Crime Reporting (UCR) program compiles official data on crime in the United States, published by the Federal Bureau of Investigation (FBI). The UCR Program's primary objective is to generate reliable information for use in law enforcement administration, operation, and management.

**UCR Part I Offenses:** For reporting purposes, criminal offenses are divided into two major groups: Part I offenses and Part II offenses. In the Part I offenses, there are eight crimes, (murder and nonnegligent homicide, rape (legacy & revised), robbery, aggravated assault, burglary, motor vehicle theft, larceny-theft, and arson) to be reported to the UCR Program. These offenses were chosen because they are serious crimes, they occur with regularity in all areas of the country, and they are likely to be reported to police.

**UCR Part II Offenses**: In Part II, the following categories are tracked: simple assault, curfew offenses and loitering, embezzlement, forgery and counterfeiting, disorderly conduct, driving under the influence, drug offenses, fraud, gambling, liquor offenses, offenses against the family, prostitution, public drunkenness, runaways, sex offenses, stolen property, vandalism, vagrancy, and weapons offenses.

**Underpolicing**: The perception of too little police presence and action in a neighborhood.

**5.3 Break-out Discussion #3**

The third break-out discussion spanned two sessions and was the primary break-out for the local teams of DA/OR, CJ, and PD participants. The goal of this break-out was to explore potential research topics, and there were general themes across all the teams, as well as specific challenges for individual teams. As stated earlier, there were ten local teams representing different regions across the continental U.S. New local teams, with participants that had not met prior to this workshop, were grouped with those that were already building collaborations. Group 1 consisted of TX and WI; Group 2 had VA and CA; Group 3 had AL and OR; Group 4 had GA and IL; and Group 5 had an AL organizer with AZ and MA. Although not all local teams included a CJ member, the groups were organized such that at least one CJ member was present in each group. The discussion questions were focused on Objective 4, but referred back to Objective 2, which was discussed in the first break-out. The discussion questions for the third break-out were:

**Question 1: What are hot topics in policing that are of interest to your teams (e.g., opioids, use of force, mental health, community relationships, forensic science)?**
   (a) What are the dynamic systems or processes for these topics?
   (b) What are controllable decisions for these topics?
   (c) What are uncertain elements for these topics?

**Question 2: What aspects of these systems or processes need improvement?**
   (a) What are the relevant policing and social outcomes?
   (b) What would be considered optimal?
   (c) How might improvement in performance be measured?

**For each topic from above:**

**Question 3: How might DA/OR approaches be appropriate?**
   (a) What is the dynamic structure, if any?
   (b) What uncertain elements need to be modeled?
   (c) What are objectives and constraints?
   (d) What relationships are unknown and would need to be modeled?

**Question 4: What are funding opportunities?**

The discussion on questions 3 and 4 will be combined with Break-out Discussion #4 in Section 5.4. The topics discussed by the different groups covered issues pertaining to PDs/officers, offenders, the community, and the use of technology, science, and data. The list of topics, given below, is denoted by the break-out groups that discussed them:

   1) PD: Officer training (MA/AZ)
   2) PD: Officers' mental health and wellness issues (TX/WI, VA/CA)
   3) PD: Role in social services (MA/AZ)
   4) PD: Threat negation (MA/AZ)
   5) PD: Resource limitations (VA/CA, MA/AZ)
   6) Offenders: Mental health issues (TX/WI, VA/CA, GA/IL, MA/AZ)
   7) Offenders: Recidivism, opioids and drug-related issues (TX/WI, VA/CA, GA/IL)
   8) Offenders: Gun violence (TX/WI, GA/IL)
   9) Community: Hate incidents (TX/WI)
   10) Community: Homeless people (VA/CA, MA/AZ)

11) Community: Relationships and community-based policing (TX/WI, VA/CA, AL/OR, GA/IL, MA/AZ)
12) Community: Police legitimacy, public perception, lack of trust (AL/OR, MA/AZ)
13) Technology/Science/Data: Quality and Value (TX/WI, VA/CA, AL/OR, GA/IL)
14) Technology/Science/Data: Use and expense (TX/WI, VA/CA, MA/AZ)
15) Technology/Science/Data: Forensics (VA/CA)
16) Technology/Science/Data: Outcome measures (TX/WI, AL/OR, GA/IL)

A summary of the discussion of the topics in each category is provided next.

### 5.3.1 PDs/Officers

The research topics in this category are broadly relevant to PDs, as opposed to focused on specific types of incidents or crimes. A well-established topic is the training of officers. While many components of police training have a long-standing history, there are still challenges in preparing officers for the uncertainty of policing. One critical example is use of force and de-escalation training. Simulated scenarios are a standard approach to train officers. More interactive simulations and clear training protocols, including the mandated amount of training time for different types of scenarios. are needed. Further, police training must adapt to the demands for policing. In order to be more proactive with police training, an ability to forecast policing demands is needed.

Police training has a potential link to the mental health and wellness of officers. The level of preparedness can reduce stress. However, in addition to rigorous training, there is a need to regularly monitor officers' wellness. Currently, there is no formal mechanism. Human resources has been informally involved in stress management by providing resources, if consulted by an officer that has suffered emotional trauma. The wellness of officers affects the resource level of PDs and the performance quality of the police force. Without adequate monitoring, officers may "burn-out" at a high rate, exacerbating an existing shortage of officers and degrading the effectiveness of PDs. The worst case is when an officer commits suicide.

In general, the policing environment is highly resource-limited. It is a continual challenge to appropriately direct resources and utilize available resources efficiently and effectively. In addition, PDs must continue to perform under dynamically changing political climates that affect everything from the budgets to laws to trends in prosecution to public perception. The hope that predictive policing and sophisticated technology would help PDs focus their efforts has not been realized, and in some cases, has created new problems. For example, the excessive use of technology has led to massive amounts of useless data that PDs must somehow maintain and store. The complexity of the policing environment must be respected instead of oversimplified when considering the optimization of police resources. Some example topics that planning and operations should consider are officer workload, officer training, matching dynamic staffing needs and staff availability, forecasts for demands on facilities, dynamic zoning of beats, and optimized dispatching rules.

Adding to the core policing mission of public safety are research topics that could be considered peripheral, but may be critical to improving the efficient use of resources. One of these is threat negation. The goal for this is to identify persons in advance who may be a threat to the community. Policing is primarily reactive in nature because the system is structured around responding to calls for service. However, crime prevention requires proactive interventions, the impact of which are difficult to measure. Since a crime is being prevented, one can never be certain if the person of interest would have perpetrated a crime, without police intervention.

A second peripheral topic is the role of PDs in social services. Social services exist to assist the community [55]. While social service programs do not directly address crime, offenders are born of the community, and programs or interventions that can provide non-criminal pathways to at-risk persons would potentially reduce the population of criminals. The role of PDs in creating and supporting social service programs is unclear, especially given the already limited availability of PD resources.

### 5.3.2 Offenders

One of the most challenging issues for PDs is recidivism or chronic offenders. These cases are commonly associated with mental illness and/or drug addiction and are complicated because they are influenced by both criminal and medical/psychological issues. Opioids, in particular, have received significant attention recently. Resources are limited both for PDs and for the health care system. If either of these resources is insufficient, then the challenge of recidivism continues to cycle, creating inefficient use of both resources. Coordinating interventions and proper care of these offenders requires collaborations with health care entities (e.g., hospitals), such as having police officers visit hospitals on a regular basis and sharing offender medical records. However, there are challenges in current practice, including, but not limited to:

- Police officers are not designated or trained for hospital visits.
- Decisions on health care resources and police resources, such as the availability of mental health facilities and police staffing, are made independently.
- Data that are meant to track chronic offenders are not well maintained, and patient medical records are not integrated with police data.
- Different data sources can yield different interpretations.
- Measurement of the effectiveness of hospital visits is lacking.
- The effectiveness of crisis intervention teams (CITs) is unclear, especially since offenders may choose to reject help.

Recidivism also involves crimes like human trafficking, where the victims are those that require medical or psychological care. Given limited facilities and personnel resources, PD collaborations with social services, as mentioned earlier, could potentially yield more resource-efficient approaches to break the cycle of recidivism, such as the use of Narcan to reverse opioid overdoses.

Gun violence is another important issue. With gun violence, the police must investigate the causes, such as the relationship between the shooter and victim, and victims must be hospitalized while also being interrogated. Simply responding to incidents of gun violence is not enough, so there is a movement to engage the community to identify and alter behaviors that are affiliated with gun violence. However, one challenge is identifying the appropriate community stakeholders. A community based defender approach involves attorneys connecting with the community to gain a better understanding of their clients' environment and potentially improve future outcomes for clients.

### 5.3.3 Community

As already mentioned, the community is a major player in the formation and mitigation of behaviors that could lead to crimes. Many behaviors are not necessarily criminal, but create incidents that require police intervention. For example, hate incidents, such as sending "anti" flyers to the community, are not crimes. Often, these incidents are associated with bias (e.g.,

against different races).  Homelessness is not a crime, but the relocation of homeless individuals requires police intervention, often with no effect on the actual problem of homelessness.

In general, a PD's relationship with the community and local government is critical for the effectiveness of PDs.  These are partners in the mission of policing, and if there is conflict between any of these three (PDs, community, local government), then the mission fails.  In particular, poor public perception undermines PD efforts and negatively impacts officer morale.  The policing environment is driven by humans, consequently involving human error and environments that are emotionally and politically charged.  Research is needed to help PDs improve trust with communities, obtain feedback in non-traditional ways, and communicate how PDs are working to improve the community.  Some PDs conduct surveys and seek to ensure good representation of their community's demographics.  Unfortunately, some communities find these surveys intrusive, so responses are difficult to acquire.  Most importantly, the community needs to see the impact of their feedback or they will no longer bother to provide it.  Research that studies the public perception of different policing communities could identify patterns that lead to new approaches for building community trust.

Community-based policing is a positive approach to connect with the community. Frequent and regular contact between PDs and the community is necessary to build partnerships. Data and information from neighborhoods and local businesses may be potentially of higher benefit towards both effectiveness and efficiency than PD implementation of surveillance technology.  While obtaining information from the community is not a new practice for officers, the formal integration of information and feedback from the community into PD decision-making still needs development.

### 5.3.4 Technology/Science/Data

With continued advancements in technology (e.g., body-worn cameras, surveillance, social media, crowd-sourced information), PDs have been pressured to purchase and implement more and more technology without clear benefits.  The vast majority of data collected by technology goes unused, sometimes due to regulatory restrictions, but more often due to the sheer volume of data, rendering that technology both inefficient and ineffective.   Further, technology is expensive and should be better justified before purchase.  The belief that more data is better is false.  Rather, the decision-making process must connect all components from problem statements to data collection to analysis to decisions to potential consequences.  Unfortunately, most PDs are dependent on vendors to supply technology and software, and do not have direct control of this process.  By building PD-university partnerships, researchers can provide an unbiased analysis of technology and software to advise PDs in their technology choices and how best to use technology.  For example, comprehensive placement of surveillance cameras is an inefficient use of technology, under limited resources.  Fixing cameras in places that can be memorized by criminals may be an ineffective use of technology.  Cost-effective solutions are needed pertaining to the use of technology and its affiliated data, including hardware, software, social media, and crowd-sourced information.

While the quantity of data is not lacking, the quality, in the sense of utility, is lacking.  In addition, the recent focus on the analysis of data from technology has taken some focus away from other potentially more fruitful and established data for criminal investigation, such as police radio recordings, 911 call data, crime lab data and forensic science, and GPS patrol car data.  Research is needed to study what data are needed to improve decision-making, develop appropriate data collection mechanisms, and create ways to coordinate or share data sources, such as across

jurisdictions or between organizations (e.g., PDs, emergency services, drug enforcement, hospitals), so that an integrated analysis is possible. The National Incident-Based Reporting System (NIBRS) is an example of a data source that was not effectively shared with local PDs. Even when data are found to be useful, additional problems arise, including:

- Quality of the analysis, such as skewing it to fit a specific political agenda.
- Different data retention policies for different organizations.
- Inefficient data collection procedures that are a burden on officers.
- Uneasiness with admitting uncertainty.
- Focus on a single "worst-case" scenario, without consideration of other scenarios.

Of critical importance for decision-making is the specification of appropriate performance outcomes. Current performance metrics for policing are based more on what is easy to measure, such as PD response time to calls for service and time on call, than what really matters. The primary reason for this is because many desired metrics are difficult to quantify. For example, if robberies by migrants have decreased, is it because crimes being committed by migrants are being underreported due to national headlines regarding immigration? Care must be taken in both quantifying and interpreting data, so as to avoid unintended consequences. Even more problematic is when performance metrics are derived from predictive models that are not rigorously developed for uncovering causal effects. For example, a predictive model could leverage a negative correlation pattern between the number of traffic stops and the number of crime incidents. This does not mean that the number of traffic stops is an appropriate performance metric for crime. PDs know what is genuinely important. Research on performance metrics is needed.

Complicating any policing decision is the myriad of potential performance metrics, of which some examples are:

- Crime rate
- Reduction in fatalities
- Unintended consequences
- Community trust
- Rate of recidivism
- Opioid or other drug addiction rate

While individual decision problems might pertain to only a few performance metrics, the interconnectedness of the policing system is a cause of unintended consequences. All topics are hot topics for policing, and they are interrelated. Dealing with people with mental health is tied to community relations and use of force training, such as communications about ongoing problems and initiatives (e.g., de-escalation training). There are problems of perceptions by the community and how lawful members view the actions of police. Policing is not elegant. Research developing performance metrics must be integrated within the decision-making process of the policing system.

## 5.4 Break-out Discussion #4

The fourth break-out discussion re-mixed the local teams of DA/OR, CJ, and PD participants, and focused on DA/OR research themes for policing. Some of the discussion that was initiated in the third break-out discussion is included in this section. By re-mixing the local teams, perspectives from the earlier discussion could be shared across the fourth break-out session. The goal of this break-out was to explore research directions in DA/OR appropriate for the policing topics raised in the third break-out. Group 1 consisted of TX and OR; Group 2 had VA and WI;

Group 3 had AL and MA; Group 4 had GA and AZ; and Group 5 had a VA organizer with CA and IL.  Although not all local teams included a CJ member, the groups were organized such that at least one CJ member was present in each group.  The discussion questions were focused on Objectives 4 and 5, which focused on DA/OR policing research themes and methodologies.  The discussion questions for the fourth break-out were:

**Question 1: What are the research themes that your teams identified in Break-out #3 that may be studied using DA/OR?**

**For each research theme:**

**Question 2: What types of DA/OR methodologies could be employed?**
    (a) What aspects could be easily addressed with existing DA/OR methodologies?
    (b) What aspects are challenging to address with existing DA/OR methodologies?

**Question 3: What information is needed to measure relevant policing and social outcomes?**
    (a) What information or data might be available?
    (b) What information or data would need to be collected?

**Question 4: What information is needed to study the controllable decisions?**
    (a) What information or data might be available?
    (b) What information or data would need to be collected?

**Question 5: What information is needed to study the uncertain elements?**
    (a) What information or data might be available?
    (b) What information or data would need to be collected?

    In DA/OR, there are three basic categories of methodologies:

    (1) Optimization, more formally referred to as Mathematical Programming, e.g., linear and nonlinear programming, combinatorial optimization, and dynamic programming.
    (2) Uncertainty representation, more formally referred to as Stochastic Modeling, e.g., probability modeling, stochastic processes, and stochastic simulation modeling.
    (3) Empirical or data-based approaches, more formally referred to as Statistics, e.g., regression, classification, data mining, machine learning, and design of experiments.

In real world decision-making applications, the methods from these categories are used in various combinations.  The simplest implementation is a static optimization using linear programming in which the parameters of the optimization that specify objective functions and constraints are taken from real data or experience.  This would be a combination of categories (1) and (3) above.  The limitations of the resulting optimal solution would be that the solution is only valid for the specified parameters and does not account for any uncertainty.  However, given that linear programs are fast to solve, one can easily re-solve with different parameters to gain more information.  A stochastic optimization, such as a two-stage stochastic program, can be computationally intensive to solve, but reasonable approximations or bounds on the stochastic programming solution may be achieved by solving related linear programming formulations.  The challenge for applying DA/OR to policing is to identify the appropriate scope for a particular problem and reasonable assumptions to enable a practical solution.  The interwoven complexity and human aspect of policing creates a highly non-separable family of problems and care must be taken to track unintended consequences.

As cited in Section 4, the policing literature relevant to DA/OR is dominated by two separate types of methodologies. Using the design of experiments methodology, there are many studies implementing randomized controlled trials to study the impact of specific strategies. Using a predictive modeling methodology, such as statistical modeling or machine learning, there is significant recent research conducting predictive policing. Interestingly, research that conducts design of experiments _with_ predictive modeling is lacking. The general argument with the advent of "big data" is that design of experiments is not needed because data are plentiful. However, based on the workshop discussions, only certain types of data are plentiful, such as excessive quantities of camera recordings; it is not clear that what is being collected is useful; and, most importantly, PDs need help identifying what data should be collected. This aspect is where DA/OR expertise will be essential. For a given problem, the DA/OR expert can assess what information are available, what is needed to strengthen decision-making, and how the additional information can be affordably obtained. For the various policing research topics mentioned in earlier sections, none of them currently have the necessary information for good decisions.

The issue of data is a major concern on many levels, and while access to more data was seen as a need, there is limited assistance that DA/OR could provide to directly facilitate the sharing of data across different confidential sources. However, advice based on DA/OR analyses would benefit the decision to seek data-sharing between agencies. The idea of making more effective and efficient use of data is very attractive to PDs. Hence, PDs would greatly benefit from research that studies the cost effectiveness of currently collected data and proposes potentially more cost-effective data collection plans. This includes the cost of relevant technology and cost of PD personnel effort. Defining what is actually needed for data collection would reduce the required effort and more clearly justify technology decisions. PDs are continually pressured to purchase new technology by both vendors and the need to attain a positive public image. However, given limited budgets, the purchase of technology is often an extravagant expense for PDs and should be carefully assessed. Research that studies data collection plans could simultaneously assess related technology and provide more general guidance to PDs on the purchasing and use of technology. Finally, given the various forms of data, research that seeks to synthesize results from multiple types and sources of data could provide additional guidance for complex decisions, for example, involving 911 call information, police reports, camera recordings from various locations, audio recordings, crowdsourced information, criminal history, and medical (mental health) history.

As mentioned earlier, it is critically important, and also a major challenge, to collect data on relevant outcomes for PD decision-making. For example, the crime count on robberies is based only on reported crimes, so if this count decreases, it could be because robberies are down or it could be because reporting is down. Because desired outcomes can be difficult to measure, PDs are often evaluated based on outcome metrics that are easy to calculate, but less relevant to the mission of PDs. The metrics "response time" and "time on call" were frequently mentioned in discussions. Response time measures the time it takes for an officer to respond to a specific call for service, and time on call measures how long the officer spends handling the call for service. However, in reality, only high priority calls must maintain faster times; hence, the objective to minimize all times is misguided in the larger objective of public safety, given limited resources. The lesson here is that any DA/OR researcher should ensure that the objectives being optimized for decision-making are appropriate, and, further, any constraints being specified are genuine. A classic example of a potentially misguided optimization is the task of redistricting. PD service areas are hierarchically partitioned into regions, such as districts to beats to smaller sectors. Redistricting redefines the boundaries of these regions, and because these boundaries affect all

aspects of PD operations, the cost of redistricting is high. The purpose of redistricting is to create partitions, such that the required level of service is uniform for all partitions. This is a straightforward static optimization problem, but the larger goal of balancing service is actually a dynamic problem that varies both spatially and temporally, so research that enables PDs to optimize their service goals from a dynamic perspective without redistricting is potentially more cost-effective.

In general, the policing environment is dynamic. This does not exclude the use of static decision-making tools, but understanding the dynamics that affect the specific decision(s) of interest are critical in creating a useful result. Given the dynamic nature of policing, advancements in dynamic or multi-stage optimization methods would be of potential benefit. The major hindrance is the development of state transition and outcome relationships. In order to conduct dynamic optimization, it is essential to model unknown and uncertain relationships involving relevant state, outcome, and decision variables. These relationships could potentially be derived from data, such as building a black-box machine learning model; however, care must be taken when opening the black box and interpreting the incorporated features. As is well known, correlation does not imply causal impact, so features selected by predictive models, such as machine learning models, do not imply a causal impact on the predicted outcome. Research incorporating causal modeling from the statistics literature could be relevant here. In addition, design of experiments is the gold standard for studying causal impacts. This leads back to the issue of data. The available data must provide a sufficient representation of scenarios to build state transition and outcome relationships.

In cases where streams of data are readily available, there is a need for innovation beyond predictive policing. While crimes, perpetrators, and victims are clearly relevant to predict, the dynamic nature of policing makes it difficult to promise predictions that will be helpful. One must assess what is genuinely "predictable" with the available data. For example, are there elements of the system that are well understood and can form a basis for "normal" conditions? If so, then a quality control or statistical process monitoring approach, possibly involving machine learning methods, could be appropriate for separating "normal" from "abnormal" conditions. This approach does not require directly predicting every possible abnormal condition, such as a specific crime caught on video. In reality, there are insufficient data on abnormal cases and too many abnormal conditions to yield good predictions. Rather, the quality control approach focuses on normal observations and generates a system alert when a new observation deviates from normal. It is more common for data and knowledge on normal conditions to be plentiful.

In DA/OR research, the study of many scenarios is achieved via simulation. Simulation is also a common tool for acquiring information on relationships for dynamic optimization, so research on simulation-based optimization and surrogate optimization is relevant here. As cited earlier in Section 4, there are some simulation studies in the policing literature. While simulations require data collection, they additionally employ structural knowledge of the dynamic system, which enables them to study "what-if" scenarios. In the case of policing, behavioral knowledge will also be relevant. The most appropriate simulation methods are discrete-event simulation models and agent-based models, for which examples of both are cited in Section 4.

The addition of behavioral information raises the most difficult aspect of policing, which is the human aspect. Police officers are human, criminals are human, bystanders are human. The most complex issues involve the human aspect, including mental health, drug addiction, and use of force. Incorporating the human behavior aspect into DA/OR methodologies is possibly the most important research direction and will require collaborative efforts between DA/OR experts and

social scientists, including CJ experts.  The DA/OR toolbox contains a wealth of methods that can address highly complex problems, if data and knowledge are available to appropriately calibrate methods.  What is lacking in the DA/OR toolbox is the human aspect.  For example, one could use social media buzz to estimate a potential issue.  However, the sheer presence of buzz builds on itself, like a rumor, distorting its meaning and rendering it no longer a reliable data source.  This is due to the human element.

Finally, uncertainty clouds all policing decisions.  This is in large part due to the human element, but in general there is more unknown about the policing system than known.  The availability of data itself is an uncertain problem.  From a public image perspective, it is undesirable to project an image of uncertainty.  Worst case scenarios are considered by PDs, but these are essentially considering only one scenario.  Assisting PDs to find robust decisions under uncertainty would be extremely valuable because such decisions would provide a forward direction without ignoring the uncertainty.  Fortunately, this is already a prolific area for DA/OR researchers, and many already existing methodologies may be adaptable to the policing domain.  What is missing is a basis for what methodologies are appropriate for which problems and which methodologies can be adapted to represent the human element.  A fundamental research problem is creating this basis of methodologies and formulations.  DA/OR research in the policing literature predominantly addresses individual problems without providing a more general basis for others to follow.

As an example that incorporates aspects of everything discussed above is the important issue of recidivism that was mentioned in Section 3.  The relevant outcome is rate of recidivism among the population of interest. The definition of recidivism changes for different agencies, police departments and service providers. For some agencies, it might include only re-arrest for a different charge, while other agencies might also be interested in the violation of probation.  Another important factor is the length of time between a current crime and any subsequent crime.  These differ across researchers and studies.  Optimal interventions would need to provide tailored and measurable services to a victim/offender that successfully integrates that person into the community.  That includes customized assistance on their most immediate needs, such as obtaining a job, finding stable housing, etc.  However, it is difficult to track outcomes because the people involved are often very transient and have fears, feelings and concerns about accepting help and changing behavioral patterns.  A comprehensive communication technique would need to be built into the approach to continue contact with individuals that we hope will lead to a reduction in the recidivism rate.  The aim is to reduce their risk factors that are known to strongly influence recidivism and relapse.  Adding to the complexity is the fact that problems are interconnected.  Mental health and substance abuse are related to recidivism, prostitution, and human trafficking, just to name a few.

DA/OR experts can work with PD crisis intervention training (CIT) to study the potential of intervention strategies by identifying characteristics of individuals susceptible to recidivism, identifying features of interventions, creating customized interventions based on these characteristics and features, and making efficient use of PD resources to implement interventions.  Given the human element, characteristics and features may be qualitative, such as an individual's ability to accept help or the presence of an advocate with life experience that can build a rapport with victims or offenders.  A major issue in this vulnerable population is the willingness to admit that one has serious problems that impact all aspects of life.  Victims and offenders might have been impacted by traumatic events which prevents them from trusting or seeing a pathway to safety.  Even after an individual accepts help, there is uncertainty in whether they show up for

treatment, how long they persist in treatment programs, and whether or not the treatment yields success. Every individual's case has unique attributes, so success requires a course of action that captures the perspective of victims/offenders that do not understand their own needs.

Grant opportunities that support such collaborations will encourage progress in this direction. In particular, academic partners will seek external grant funding to support research efforts. While NSF can support fundamental methodological research that would benefit policing, there is a need for funding to support the adaptation of existing methods to build a foundation for DA/OR in policing. Some funding opportunities for applied work may be available via the National Institute of Justice, the Department of Homeland Security, local governments, or foundations. For applied efforts, it will be important for DA/OR researchers to articulate the practicality of their ideas in a proposal.

**5.5 Break-out Discussion #5**

The fifth and final break-out discussion returned back to separate disciplines of DA/OR, CJ, and PD law enforcement, as in Break-out #1, so that the discipline experts could share and summarize what they have learned. Like the first break-out, there were 6 groups with 2 DA/OR, 1 CJ, and 3 PD. The discussion questions were focused on Objectives 4 and 5, which was the same as Break-out #4, but this time the discussion was within each discipline instead of across local teams with all disciplines. The discussion questions for this final break-out were:

**Question 1: What are the research themes that your teams identified in Break-outs #3 and #4 that may be studied using DA/OR?**

**Question 2: What are structural commonalities for these themes?**
    (a) Dynamics?
    (b) Controllable decisions?
    (c) Uncertain elements?
    (d) Performance objectives?
    (e) System constraints?

**Question 3: What aspects could be easily addressed with existing DA methodologies?**

**Question 4: What aspects are challenging to address with existing DA methodologies?**
    (a) What makes them challenging?
    (b) What methodological advancements in DA/OR are needed?

In this section, policing research themes are organized by a DA/OR approach and prioritized based on the workshop discussion. In Section 5.4, the listing of DA/OR basic categories provided a set of existing methods. Relatively easy problems are those that can be formulated using existing methods. An important first task for DA/OR policing research is to build a basis in the literature of DA/OR formulations for policing problems using existing methods. This would form a foundation of DA/OR in policing research. This foundation will be essential in guiding the community of DA/OR researchers to avoid "re-inventing the wheel." Further, DA/OR policing research projects must be collaborative efforts with a PD law enforcement agency and CJ experts. There is a lack of operative use of DA/OR in PD practice, so this foundation also needs to demonstrate the effectiveness of DA/OR methods in order to gain the "buy-in" of PDs. Consequently, the first challenge is building relationships with PDs. DA/OR researchers must be prepared for skepticism from PDs and will need to establish a sequence of

small victories to build trust.  PD participants emphasized an ability to communicate to practitioners and the need for "boots on the ground" to gain the necessary perspective on policing.  If DA/OR solutions fail once, there may not be a second chance.  As mentioned in Section 1, the predictive policing movement promised great progress for predicting crime, and, unfortunately, the failures are remembered over the successes.  The pressure to collect "big data" has created new problems for PDs instead of solutions.

The efficiencies of DA/OR approaches have the potential to uncover what information is important for improving decision-making.  While academic researchers are not typically rewarded for applications of existing methods, this foundation can still be part of a larger project that addresses a challenging decision-making problem, and there is no shortage of challenging problems in law enforcement.  The discussion in this last break-out reprised potential research topics from Section 5.3, but attempted to bring these into better focus through a DA/OR lens.  Each potential project requires careful consideration of each of the following phases:

A.  Problem definition
B.  DA/OR formulation
C.  Data collection
D.  Estimation/Learning
E.  Decision-making
F.  Evaluation

The research challenges within each of these phases are discussed next for topics identified as high priority by PDs.  Ideally, projects should plan for deliverables that are frequent enough to maintain the engagement of PDs.  The patience of PDs will depend on their leadership, where more research-friendly PDs will likely be those that support officers and staff to participate in the NIJ LEADS Scholars Program.

**5.5.1 Problem Definition**

Defining the problem scope is arguably the most difficult phase given the lack of literature on a DA/OR foundation in law enforcement and the interconnections between all aspects of policing.  The most universal issue in policing is resource limitations, which is a classic DA/OR problem.  A common frustration about consulting firms that analyze PDs is their recommendation that PDs need more resources, such as more officers, more staff, and more technology.  These recommendations are impractical and, instead, what is needed are approaches that help PDs to succeed given their constraints.  For example, if more personnel are not possible, then how can PDs be more efficient with their existing personnel?  Or if hiring is possible, but retention is a problem, then how can PDs enable better retention?  Several suggestions on resource allocation raised the desire to incorporate officer preferences and reduce the number of "hats" that officers must wear.  Every officer is different and a smooth running team requires leveraging their individual skills.

Officer retention is connected to officer safety, wellness, and training.  Personalized approaches are needed to monitor officers' workload and mental status.  Dynamic decision-making is also relevant to adjust their assigned tasks, so as to mitigate stresses on the job.  Continuous improvement in officer training, could also be advised to better prepare officers to achieve de-escalation with dangerous or mentally unstable offenders.  Improving officer safety with any means, including monitoring, training, workload adjustment, technology, and tele-policing, would be worthwhile to study.

Some frequently mentioned causes of officer and PD stresses are not criminal in nature,

but community-related. A constant battle for some regions is the public image of PDs. It is an unfortunate irony that the community that PDs have sworn to protect and serve is also a significant source of conflict. Stresses come from government officials with specific political agendas, the District Attorney's office that controls which cases to prosecute, unions that use their leverage only for their benefit, and the public that expects perfection from police. Finding innovative ways to uncover the constraints implied by these exogenous influences would enable PDs to maximize cooperation and build more productive community relationships. PD participants suggested prioritizing the response to certain crimes, engaging with community leaders, understanding political agendas, and perhaps focusing on areas of public interest, such as opioid addiction and gun violence. Finally, there is a desire for PDs to better publicize the caring aspects of law enforcement. In summary, a dual objective would be the prevention of crime while simultaneously improving the relationship between PDs and the community. These are not necessarily conflicting objectives, so there is hope of a "win-win" situation.

The area in which PDs have the most expertise and confidence is the criminal aspect. Officer training emphasizes this preparation. This is not to imply that officers react perfectly in every situation, but frustration arises from forces mentioned earlier that render PD efforts futile. The most commonly mentioned examples are recidivism and mental health, which are often linked. It is the duty of the PDs to arrest offenders, but they do not control the rehabilitation of offenders, so when the system fails, these offenders return to the same crimes, and PDs must arrest them again and again in a never-ending cycle of seemingly wasted effort. PDs have a strong interest in studying interventions that could potentially break this cycle.

Finally, there is the use of technology, including surveillance cameras, body-worn cameras, audio recording, and GPS tracking. The volume of data collected automatically by technology is beyond what PDs are able to manage. While some researchers seek to analyze these data in the hope of finding useful clues, the truth is that most of these data are not useful and, instead, create the new problem of storage. An easy DA/OR problem to solve would be a camera location problem. However, the more important problem is to identify how to make efficient and effective use of technology.

**5.5.2 DA/OR Formulation**

Several aspects of an appropriate DA/OR formulation were discussed throughout the workshop, including dynamic vs. static structures, controllable decisions, uncertain elements, performance objectives, and system constraints. By the end of the workshop, PD participants were better able to articulate the decisions that PDs control versus the uncertainty that they cannot control. The majority of the discussion in this last break-out that was relevant to formulation was the definition of performance objectives. PD participants recognized that DA/OR solutions would only work well if PDs identified the right question to study. For example, an outcome measure that tracks arrests might seem reasonable, but arrest numbers are not satisfying if they don't result in convictions and ultimately greater community safety. More importantly, there are many intangibles that are not easily quantified, such as politics, unions, public image, trust, mental health, legitimacy, fear of crime, social efficacy, officer wellness, officer buy-in, officer instincts.

Collaboration with CJ experts and social scientists will be essential for identifying appropriate objectives for a DA/OR formulation. To address the human element, it is important to include latent constructs in the modeling. Data analysts have the reputation of preferring simple metrics, such as the number of police vehicles, location, or response time. The individual

characteristics of officers and criminals cannot be incorporated with these simple metrics. DA/OR researchers must not make this mistake, if they want to gain the trust of PDs. CJ expertise should be incorporated to represent difficult latent constructs in DA/OR modeling. One interesting example is optimizing the mix of one-person versus two-person patrol cars, optimizing personality types of two-person assignments, and how best to mix younger officers with more experienced ones. By considering the social and behavioral aspects in a DA/OR formulation, the decision-making outcomes could not only impact crime metrics, but could improve staff recruitment and retention issues. Modeling and concepts from behavioral economics could have a potential benefit in formulating DA/OR objectives. Further, because policing problems will have multiple objectives, the social science perspective will be needed to understand trade-offs between the objectives. While economic cost is certainly an objective to be considered, social costs could yield more severe negative impacts. One major mistake can cause cascading negative perceptions and consequences for years.

With regard to constraints, the many exogenous pressures on PDs cannot be ignored when mapping out constraints. These also require social and behavioral representations. In order to avoid an overly myopic solution, the DA/OR formulation should consider constraints that connect the specific problem at hand to these exogenous influences. DA/OR researchers must be careful to develop a deep enough understanding of the problem to identify genuine constraints as opposed to constraints that PDs have imposed upon themselves. A classic example is the beat structure that PDs employ to allocate officers. Over time, PDs have developed rules on officer allocation that are dependent on the district/beat structure. While the beat structure is fine to maintain in a DA/OR model, the allocation of officers to beats is not genuinely dependent on shifting the boundaries of beats in a redistricting optimization. In other words, the allocation constraints based on beat boundaries are not genuine constraints in the problem of patrol officer allocation.

### 5.5.3 Data Collection

There are two main findings regarding data. First, there is a lot of data being collected by many disconnected sources. Second, there is very little data on controllable decision variables. Most data related to decisions or interventions are studied via randomized controlled trials. While rigorous controlled studies will continue to be an important component in policing research, PD decision-making cannot depend solely on such studies. Consequently, the desire to make use of existing data remains a priority for PDs. However, care must be made to understand policing issues beyond a data set, in particular, to ensure that the available data are sufficient for answering the question at hand, and to identify what other data would be helpful to collect. Surveys developed in collaboration with CJ and social science researchers will likely be an essential element to gain understanding. For example, when seeking to prioritize crimes, surveys of all stakeholders would uncover issues that are important to government leaders, unions, citizens, etc.

Returning back to the first issue of disconnected sources, relevant data systems are currently siloed in multiple areas of expertise. Medical databases are separate from criminal databases, making it difficult to analyze problems involving drug addiction and mental health. Confidential and sensitive data could be extremely helpful, but difficult to acquire. Video and audio data cannot be easily linked to each other. In some cases, there could also be missing or incorrect data due to human errors. Workshop participants also discussed the use of data from the community via crowdsourcing applications.

### 5.5.4 Estimation/Learning

The primary concern in learning from data pertains to interpretation and not methodology. A common failure by data analysts is misunderstanding the role of the collected data. An elegant spatial process based on historical location data could be developed to model, in theory, where crime is more likely to occur. However, the model assumes the system is stationary, and ultimately becomes obsolete as soon as PDs intervene with crime prevention strategies, or perpetrators change behavior, or political agendas shift. Here again is where CJ expertise is required to appropriately interpret data, so that it can be converted into information that will enable effective decision-making.

### 5.5.5 Decision-making

Teams of DA/OR researchers will be needed to address the various challenging aspects of optimizing decisions in policing. Assuming that the challenges of objectives, constraints, and data can be overcome, it may seem that solution algorithms from dynamic programming, stochastic programming, and Markov decision processes would be appropriate. However, the underlying relationships that are needed to guide decisions in these algorithms are unknown and subject to uncertainty. An obvious approach is to employ data to estimate these unknown relationships. However, basing decisions purely on the prediction from a machine learning algorithm does not encourage robust decisions under uncertainty. Furthermore, as pointed out in Section 4, predictive models are not causal models and cannot be directly employed to direct an optimization. Making appropriate use of data, not necessarily via predictive models, to guide policing decisions is where DA/OR research should focus its innovation.

### 5.5.6 Evaluation

The typical approach for evaluation is a randomized controlled trial. In engineering research, a less invasive approach is the use of computer simulation models. In particular, the use of stochastic simulation models, as suggested in Section 4, could become essential to the foundation of DA/OR policing research. While real data are still needed for calibration and validation, computer simulations provide an alternate form of data generation that does not require direct manipulation of the real environment. Simulations enable study of hypothetical scenarios, under uncertainty, including worst case scenarios that prepare decision-makers for both typical and extremely rare events. Furthermore, the use of computer simulations can be incorporated within a DA/OR decision-making framework.

      The rigorous design of experiments concept underlying controlled experiments is still relevant when employing simulation models for evaluation. In policing, the term "simulation" refers to officer training exercises. These same training tools, such as scenario cities or virtual reality simulations, could potentially be employed with design of experiments to test strategies. Experimental designs can be derived to handle both quantitative and qualitative decision structures. Finally, results could then highlight which strategies could be fully tested via a randomized controlled trial.

### 6. Closing Remarks

One of the most serious challenges facing police departments is the effective utilization of resources to address calls for service, especially when responding to serious crimes. This issue was addressed quite clearly in the report from the President's Task Force on 21st Century

Policing ([56], p. 19), as the authors noted that "data collection, supervision, and accountability are also part of a comprehensive systemic approach to keeping everyone safe and protecting the rights of all involved during police encounters." Reviewing current PD practices with a DA/OR framework could yield reforms across many operational aspects, including data collection, data analysis, resource allocation, planning, police training, and crime investigation.

DA/OR as a discipline is not well known within the law enforcement context. Towards filling this gap, this workshop identified and recommended specific research directions and challenges for developing DA/OR approaches to enable policing strategies that are cost-effective, consider social influences, identify the appropriate data, address policing dynamics and uncertainty, and utilize existing knowledge from PD/CJ expertise. This workshop additionally provided guidance on building collaborations with PDs. Workshop participants were diverse and open to listening to each other. Out of 47 workshop attendees, 21 were women and 6 were under-represented minorities. Out of the 5 keynote speakers, 2 were women. The implemented workshop structure is recommended as a model for future workshops and research partnerships in other complex cross-disciplinary application domains.

In order for a DA/OR approach to yield useful results, care must be taken to select genuinely relevant performance objectives. One of the primary findings was the need for DA/OR researchers to work closely with CJ experts and other social scientists to ensure understanding of behavioral and social influences and impacts. A second important finding was that DA/OR researchers should tread carefully in developing approaches and solutions, so as not to follow the mistakes of the predictive policing movement. PD participants emphasized that if DA/OR solutions fail once, there may not be a second chance. Overall, the potential impact of DA/OR research in law enforcement is extremely high, but progress will require care, collaboration, persistence, and an open mind.

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