

A complex network diagram with various sized nodes in black, blue, and grey, connected by thin grey lines. Some nodes are highlighted with larger circles.

TEMPORAL ANALYSIS AND FORECASTING

July 2024

ABOUT ME...

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Analyst since 2005; have worked at task forces, state fusion center, city and county law enforcement agencies

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TEMPORAL ANALYSIS AND NEXT EVENT PREDICTION



Day(s) of the Week

- Frequency
- Tempo
- Burn Rate



Hour(s) of the Day

- Midpoint
- Aoristic



Additional Methods

- Linear Regression
- Retrospective Temporal Approximation

REMINDERS

- These specific techniques are best applied to series predictions.
- We need to use the dates/times the incident **OCCURRED**, not when it was reported.
- Ranges of hours or days are expected in many property crimes and will be accounted for in our analysis.

BEHAVIOR

Humans are habitual creatures. We develop highly effective muscle memory and maintain routines of behavior to get through the mundane tasks in our lives.

Our repetitive and habitual nature also makes us very predictable. For instance, we tend to drive the same route to work or school, and prefer to shop and eat at our favorite places. This is also true for criminals, whether taking care of personal responsibilities or planning and executing their crimes.

This behavioral repetition is the foundation of tactical crime series analysis and next-event prediction.

PREDICTING THE NEXT HIT

DAYS OF THE WEEK



Frequency



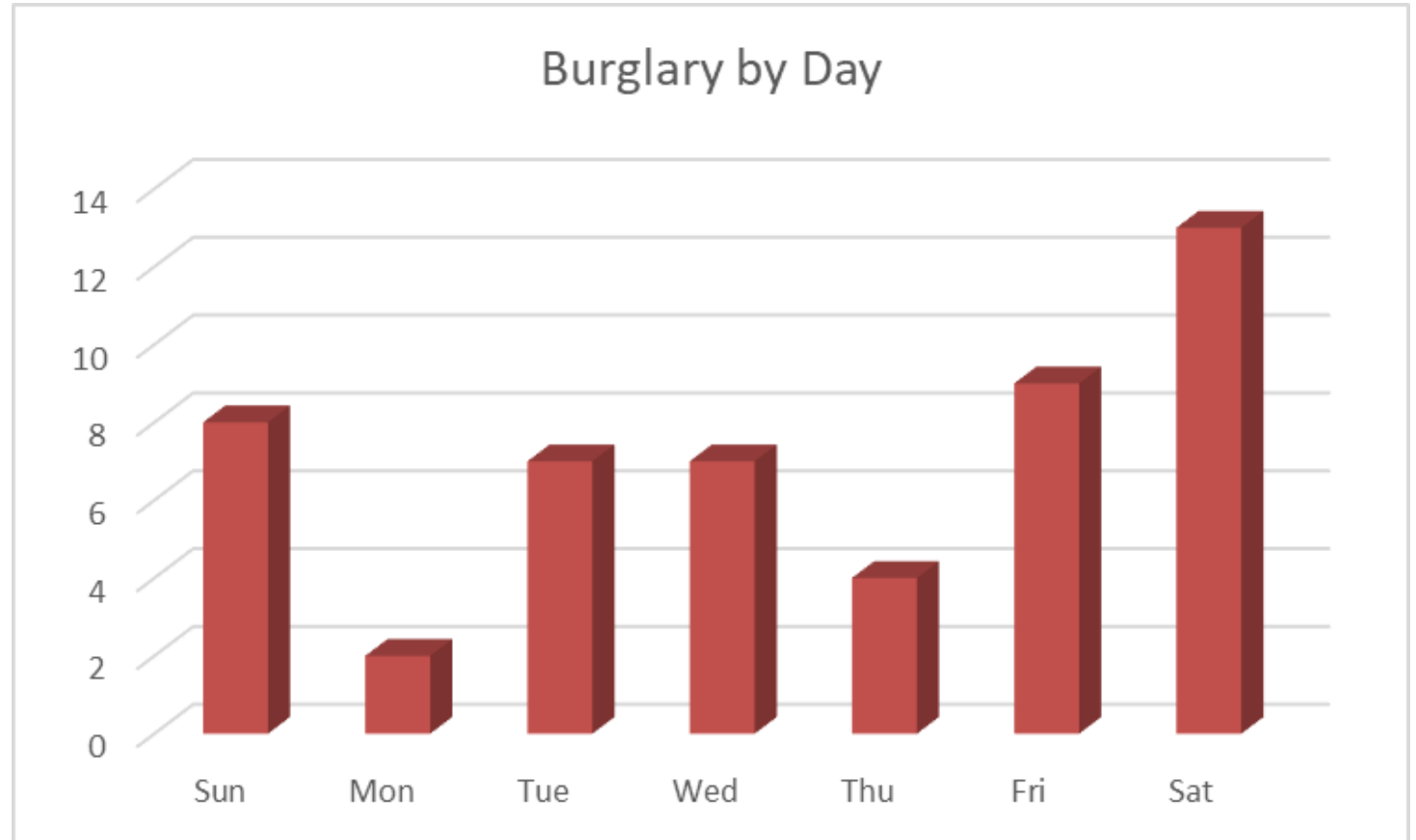
Tempo



Burn Rate

FREQUENCY

Count how many incidents occurred on each day



TEMPO

- Identify if there is a pattern
- Every three days, two days, four days, etc.

March 2024						
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
25	26	27	28	29	1	2
3	4	5	6	7	8	9
				2	1	
10	11	12	13	14	15	16
2				4		2
17	18	19	20	21	22	23
1		2				
24	25	26	27	28	29	30
31	1	Notes				

TEMPO

Case Number	Date	Time	Interval	DOW
24-1234	3/5/2024	0100 - 0350		Tue
24-1235	3/7/2024	0130 - 0320	2	Thu
24-1236	3/8/2024	2315 - 0345	1	Fri
24-1237	3/10/2024	0210 - 0400	2	Sun
24-1238	3/14/2024	2215 - 0330	4	Thu
24-1239	3/16/2024	2330 - 0345	2	Sat
24-1240	3/17/2024	0200 - 0415	1	Sun
24-1241	3/19/2024		2	Tue

Average	2
Standard Dev	1
Median	2
Mode	2
Min	1
Max	4

BURN RATE

- When there is no discernable temporal pattern...
- Does the value of the stolen goods correlate with the frequency of their activity?

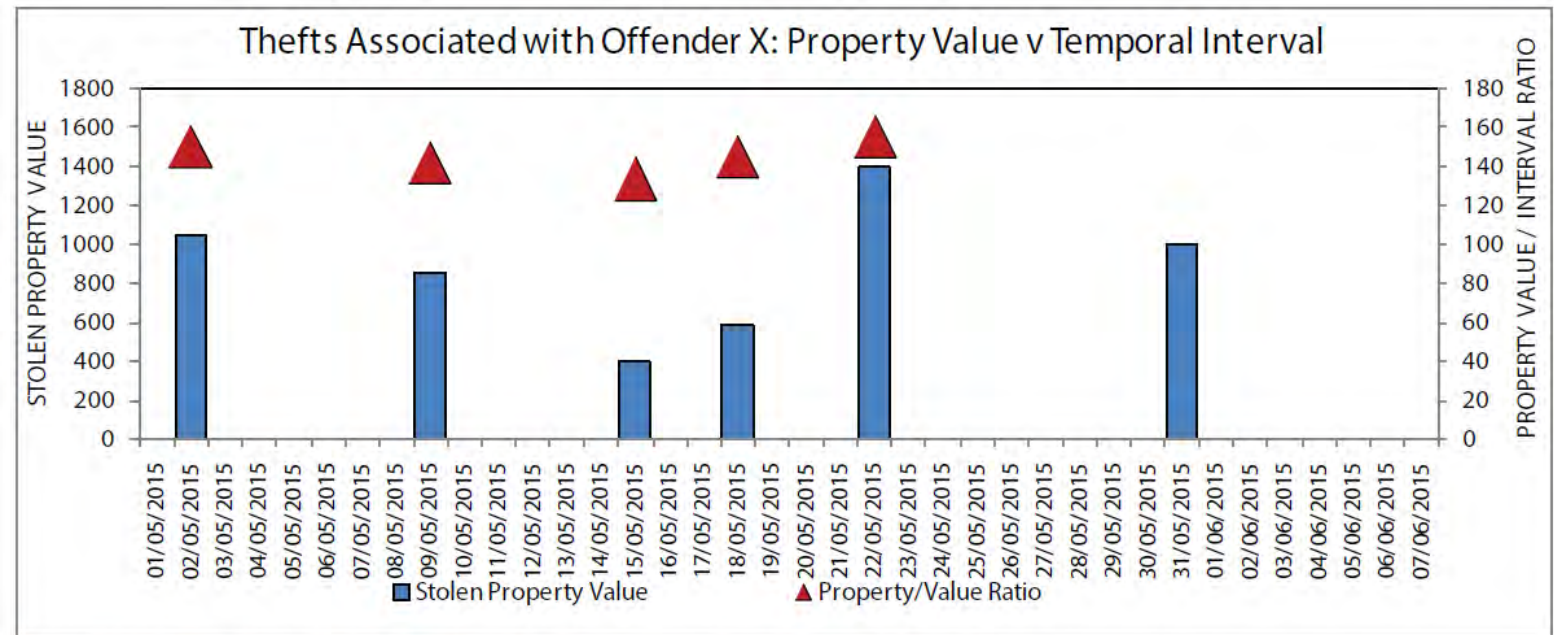


Figure 12-16: Timeline of crimes with ratio of property value stolen to interval.

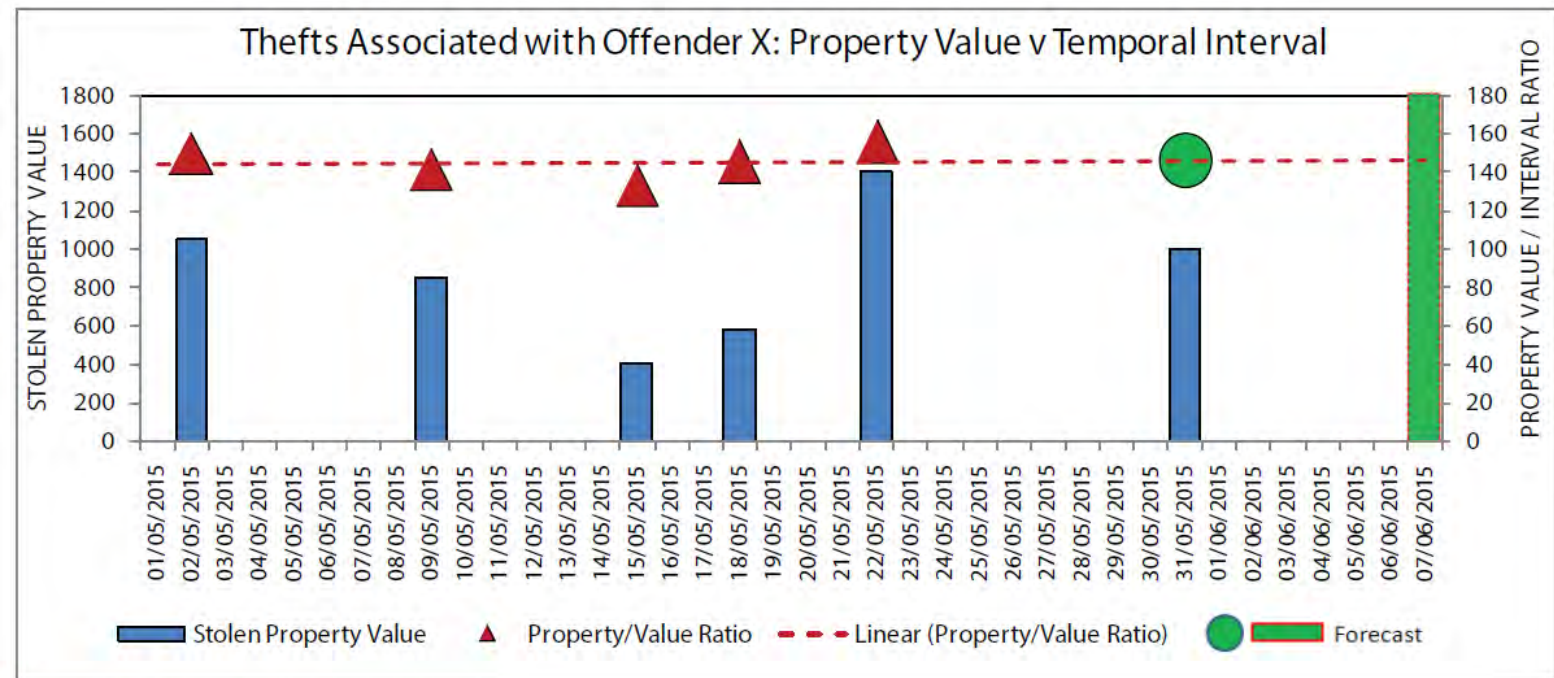


Figure 12-33: Leading indicator timeline.

Case Number	Date	Time	Interval	Property Value	Ratio \$ per Day	Prediction Days (with Avg)	Prediction Days (with Median)
24-1234	3/5/2024	0100 - 0350	0	\$300	150.00		
24-1235	3/7/2024	0130 - 0320	2	\$100	100.00		
24-1236	3/8/2024	2315 - 0345	1	\$350	175.00		
24-1237	3/10/2024	0210 - 0400	2	\$600	150.00		
24-1238	3/14/2024	2215 - 0330	4	\$325	162.50		
24-1239	3/16/2024	2330 - 0345	2	\$100	100.00		
24-1240	3/17/2024	0200 - 0415	1	\$300	150.00	2.15	2.1
24-1241	3/19/2024		2	\$700		5.01	4.7
		Average	2	\$ 353.57	\$ 139.58		
		Standard Dev	1	228.4132637	\$ 32.03		
		Median	2	\$ 325.00	\$ 150.00		
		Min	1	\$ 100.00	\$ 100.00		
		Max	4	\$ 700.00	\$ 175.00		
		Correlation Coefficient		0.981423606			

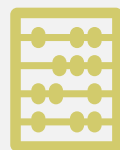
Positive correlation between the property value taken and the days between hits

PREDICTING THE NEXT HIT

HOURS OF THE DAY



Midpoint



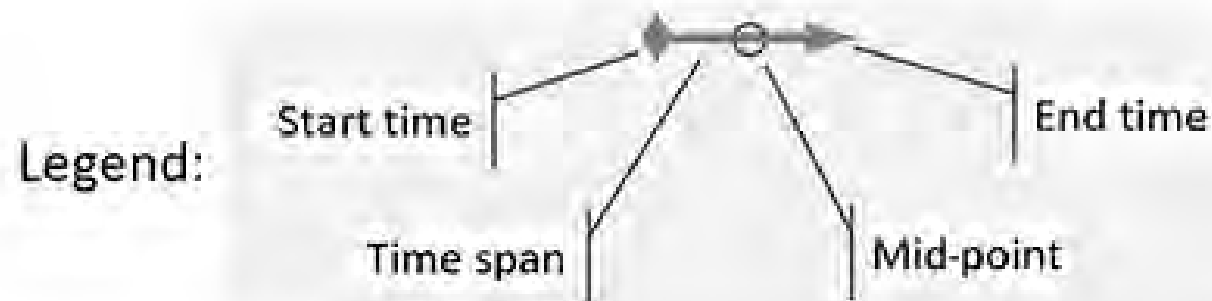
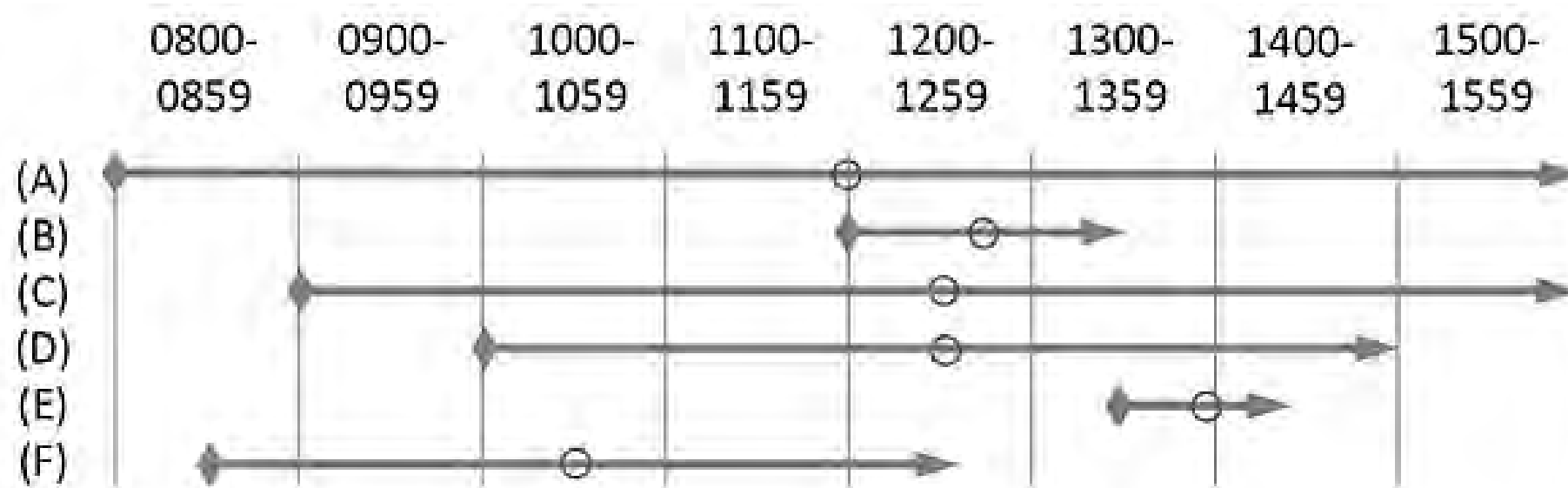
Aoristic

MIDPOINT ANALYSIS

Basic analytic method to deal with uncertain temporal data is to calculate the midpoint of the timeframe of an incident. In essence – calculating the median of the incidents' time to find frequency and make a prediction.

The downside to this method is that it assigns an artificially high probability to an arbitrary median in the data, so while simple, it is not the most reliable.

MIDPOINT ANALYSIS



AORISTIC ANALYSIS

Aoristic analysis addresses a temporal problem common with some types of recorded crime. In many cases, police know exactly when a crime occurred.

When victims of crime are unable to say when the event occurred, many police departments record a crime event as having a ‘*start*’ date and time, and an ‘*end*’ date and time. These dates/times can also be referred to as the ‘from’ and ‘to’ date and time. The start date-time usually references when the person left their house (or parked their car), and the end date-time records when they first discovered their property missing. The period between the start date-time and end date-time is referred to as the event’s *time span*. Incidents that have an undetermined event time are described as ‘aoristic’.

Hours	Case Numbers							Total	Percentage
	24-1234	24-1235	24-1236	24-1237	24-1238	24-1239	24-1240		
2100									
2200					1			1	4%
2300			1		1	1		3	11%
0000			1		1	1		3	11%
0100	1	1	1		1	1		5	19%
0200	1	1	1	1	1	1	1	7	26%
0300	1	1	1	1	1	1	1	7	26%
0400							1	1	4%
0500								0	0%
0600								0	0%
0700								0	0%
0800								0	0%
								27	

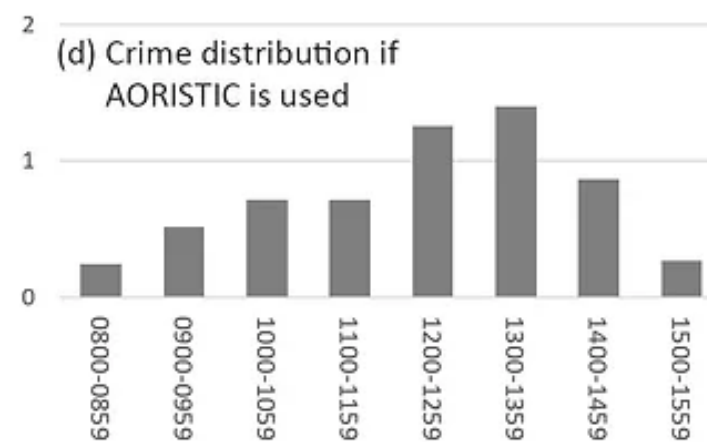
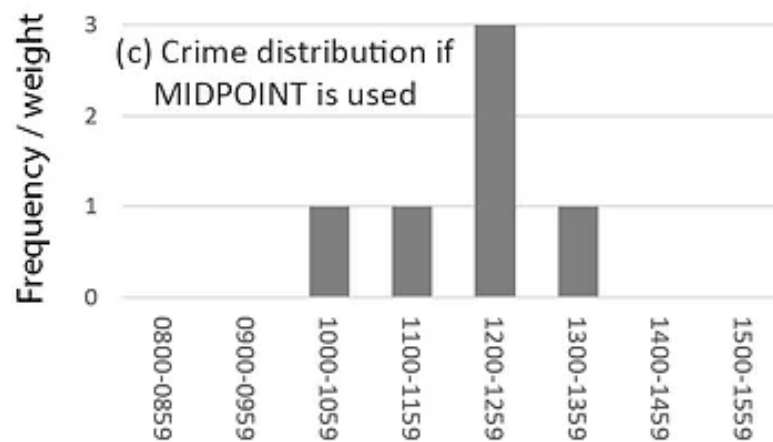
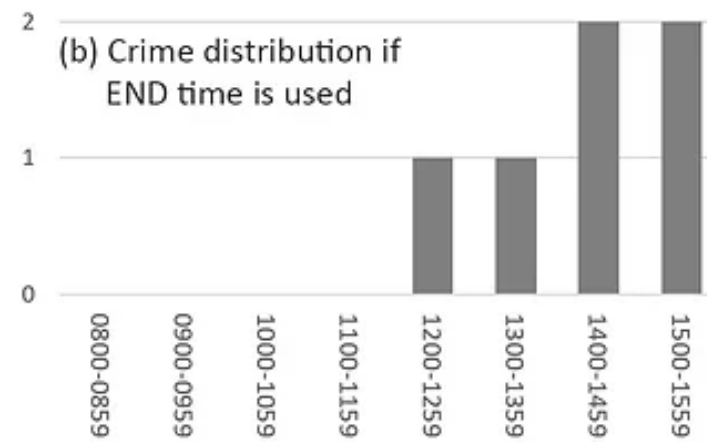
A proportional probability distribution is the aoristic approach, which distributes the relative probability of the time event across each hour.

	B1	B2	B3	B4	B6	B9	B11	B13	B15	B16	B17	B18	B19	Total	%	
2100														0	0	
2200			X		X						X			3	5	
2300			X	X	X	X			X		X	X		7	11	74%
0000			X	X	X	X			X		X	X		7	11	
0100			X	X	X	X	X	X	X		X	X		9	14	
0200	X		X	X	X	X	X	X	X	X	X	X	X	12	19	
0300	X		X	X	X	X	X	X	X	X	X	X	X	12	19	
0400		X	X	X	X							X		5	8	
0500		X	X	X	X									4	6	
0600			X	X	X									3	5	
0700			X											1	2	
0800														0	0	
														63		

Calculate the time frame by making a grid for the hours of the day, add up the incidents in each hour block and calculate the percentage for the ranges.

Count the incidents per hour, calculate the percentage and concentrate on the highest frequency times.

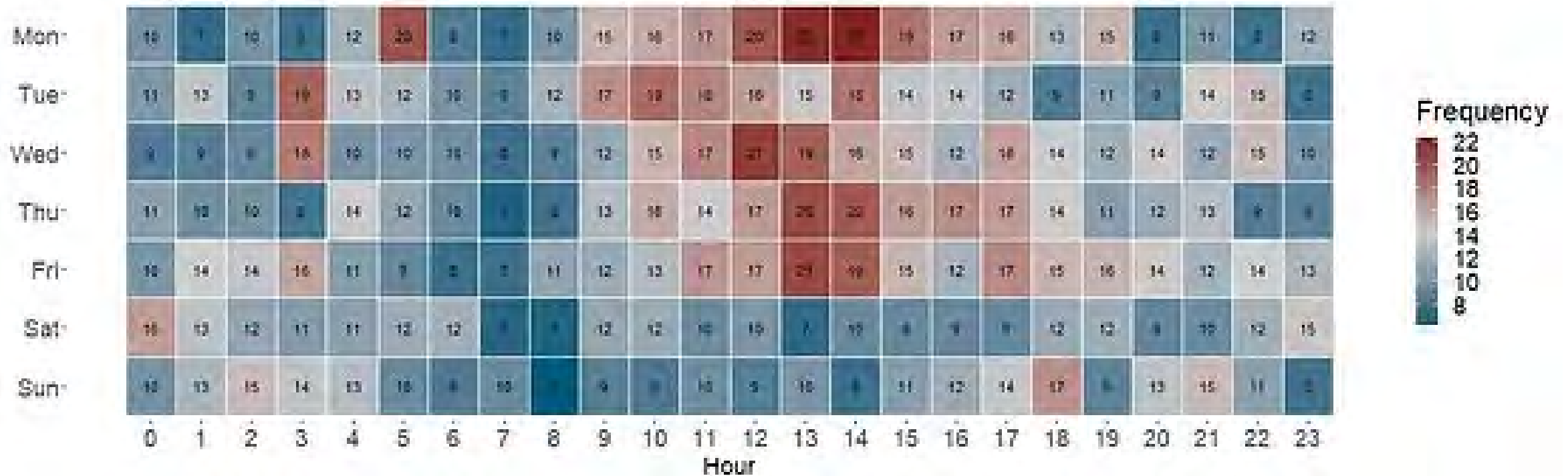
COMPARISON



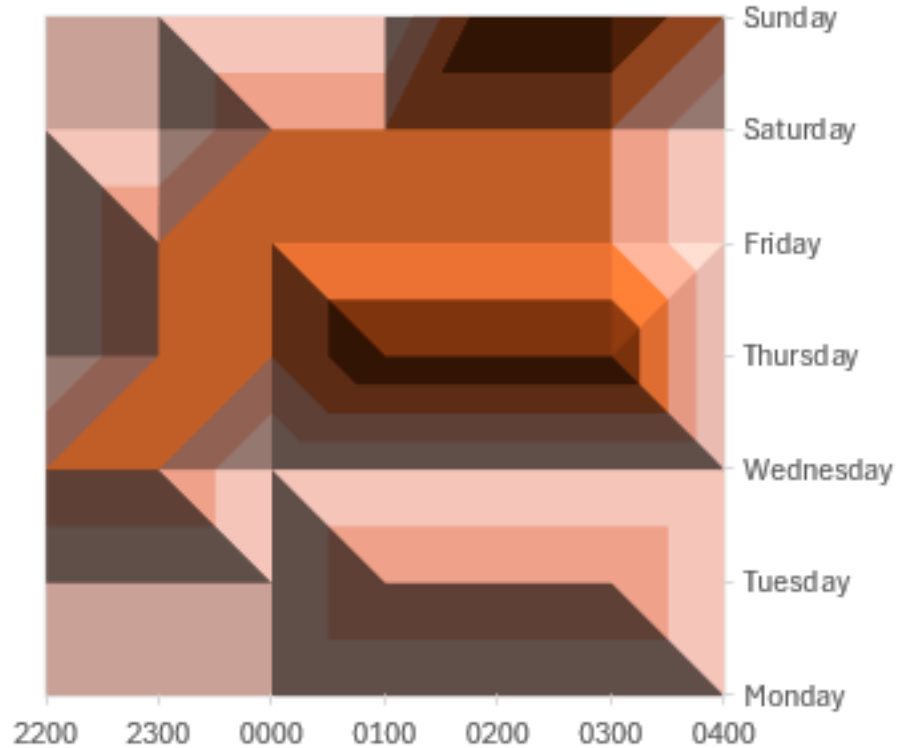
Hour block

Hour block

REMINDER



Temporal Topography



USING OUR EXAMPLE NUMBERS FROM EARLIER:

If the suspects continue to act as they have in the past, anticipate our next hit being on Saturday March 23, most likely between 0200 and 0400 hours.

CONSIDERATIONS

- If all known timeframes are over 24 hours, you cannot reliably predict the anticipated time of the next hit.
- If most incidents could have occurred over multiple days (*e.g., vacation burglary*), you *could* conduct a midpoint analysis of the days or, better yet, a similar calculation to the aoristic analysis of days of the week – noting that the reliability of the prediction will be reduced due to the lack of specific temporal data.

TEMPORAL PROGRESSION

- Times changing throughout the series
- Correlation to geographic/spatial pattern

Example – Incidents are progressively occurring later in the night (or earlier the next morning) as the incidents get further away from their central node of activity (*residence*).

ADDITIONAL METHODS

LINEAR REGRESSION

If there is a strong correlation of your incidents over time (either increasing or decreasing in frequency somewhat consistently) you can use Linear Regression to forecast the next interval.

Date	Interval Days	DOW	Series Item
1/1/2024		Mon	1
1/11/2024	10	Thu	2
1/19/2024	8	Fri	3
1/27/2024	8	Sat	4
2/3/2024	7	Sat	5
2/10/2024	7	Sat	6
2/14/2024	4	Wed	7
2/17/2024	3	Sat	8
Next Hit	2.428571429		9
<i>Corr Coef</i>	-0.952500953		

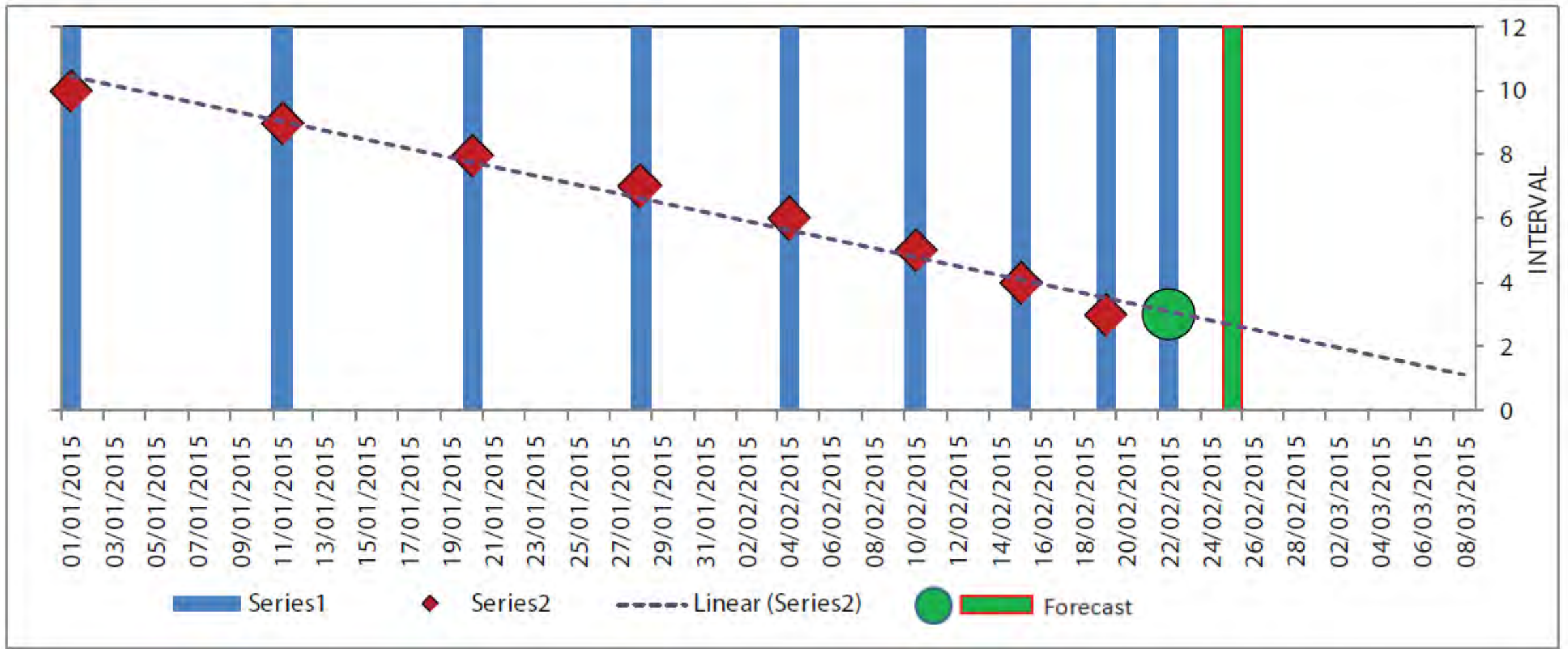
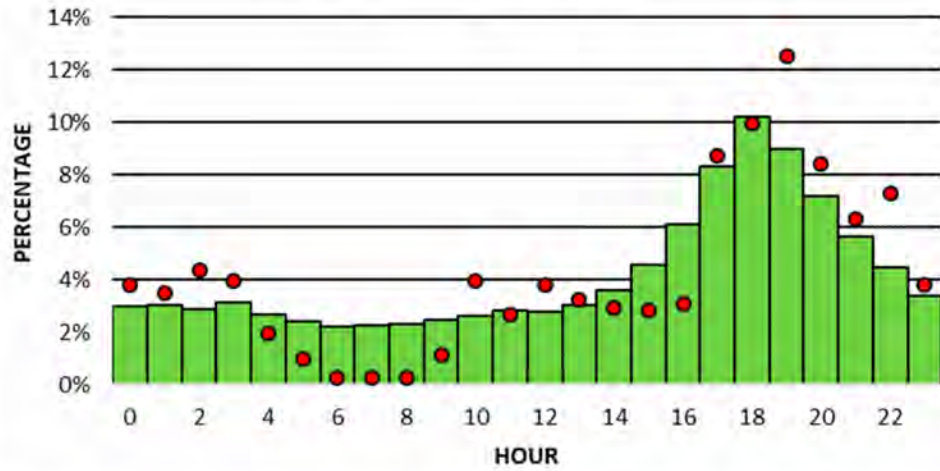


Figure 12-31: Accelerating tempogram including trendline & forecast.

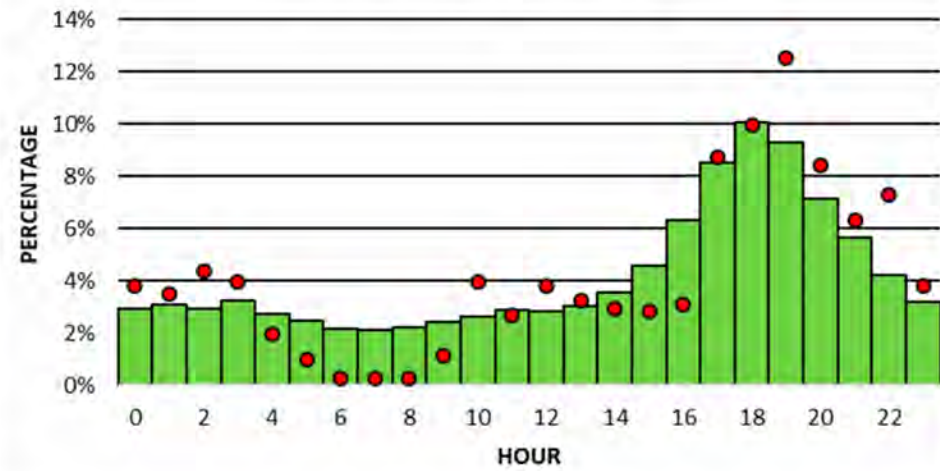
TEMPORAL APPROXIMATION METHOD

- Estimates the probability that a specific type of crime will occur at any given hour of the day based on the current series and past incidents.
- Including in our analysis the historical crimes that we have precise KNOWN times for of similar crime type.

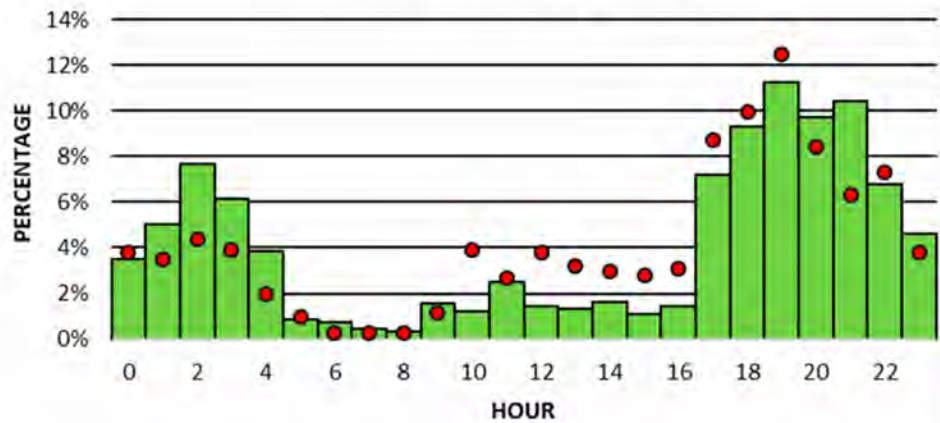
AORISTIC METHOD



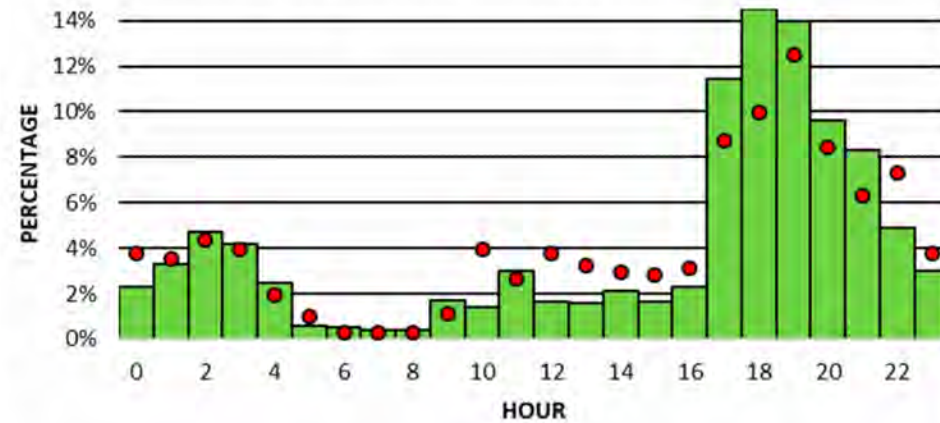
AORISTICext METHOD



RETROSPECTIVE TEMPORAL APPROXIMATION METHOD



EXTENDED RETROSPECTIVE TEMPORAL APPROXIMATION METHOD



KEEP IN MIND

We are dealing with humans, and many factors are at play in every person's life, including suspects. Even the best, most accurate predictions can still be thwarted by a suspect who changes their pattern of behavior or an outside factor or influence that changes the 'game'.

Don't fret if your forecast/prediction does not come to fruition, go back and reassess with this new information and try again.

REFERENCES

Jerry Ratcliffe:

<https://www.jratcliffe.net/aoristic-analysis#:~:text=What%20is%20aoristic%20analysis%3F,or%20when%20they%20were%20assaulted>

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<https://andrewpwheeler.com/2018/09/03/aoristic-analysis-for-hour-of-day-and-day-of-week-in-excel/>

Oswald, L., & Leitner, M. (2020). Evaluating temporal approximation methods using burglary data. *ISPRS International Journal of Geo-Information*, 9(6), 386.

IACA (2017). *Exploring Crime Analysis: Readings on Essential Skills* (3rd ed.). International Association of Crime Analysts.

FUTURE CLASSES IN THE TACTICAL SERIES



SPATIAL ANALYSIS



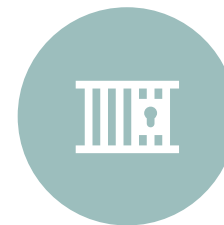
CRIMINAL BEHAVIOR
AND TACTICAL
PROFILING



PRODUCTS AND
DISSEMINATION



EFFECTIVE RESPONSE



AFTER THE ARREST



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QUESTIONS?