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Hostage Survival Probability Model

The National Tactical Officers Association (ntoa.org), the California Association of Tactical Officers (catonews.org), and Justice Academy (justiceacademy.org) recently joined together to conduct a national study regarding hostage survival rates, using Discriminant Function Analysis (DFA). The intention of the research study was geared toward surveying the national experience of such incidents with an eye on identifying the contributive factors associated with such special operations situations.

The Hostage Survival Probability Model (HSPM) project, as it was entitled, endeavored to isolate, quantify, and prioritize discriminant variables that possess a degree of influence over the outcome of such situations and then assemble these contributive factors into primary, secondary, and tertiary levels of influence in order to create a survivability equation that can be applied to future hostage situations.

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Hostage Survival Probability Model - Page 2

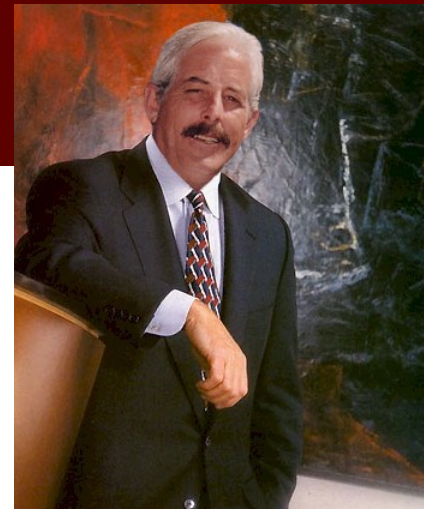
Predicated on the findings of a national survey of past incidents that occurred throughout the nation, the goal of the research team was to analyze the information provided by participating law enforcement agencies and, if practical, to use the findings of the DFA to (1) establish a listing of influential factors that contribute to the outcome of such situations, and (2) create a predictive algorithm that can be used by special operations units to help minimize the risk factors associated with direct enforcement actions, and in turn, enhance the likelihood of a positive outcome of future hostage situations based on historical trends. Discriminant Function Analysis is a powerful mathematical tool that is perfect for this type of study. It essentially allows the research team to create two groupings of potential outcomes or dependent variables (Hostage Killed or Hostage Not Killed), and then to compare the individual predictive power of each hypothesized independent variable contained within the study in determining the eventual outcome of such situations. Such a methodological approach also allows for the examination of the collective power of all of the variables included within the analysis in predicting the outcome. The final product looks like something you might expect to see on Einstein's chalkboard, but these equations really are quite simple to apply in real-world situations.

$$Y' = a + bX1 + bX2 + bX3 + bX4 \dots bX45$$

Fortunately, these statistical equations can also be programmed into a computer software application to take the math

out of it, so that tactical teams can use these tools more easily, while on scene. Such resources provide a mechanism for the team to ask "what - if" questions, in order to evaluate the dynamics of the situation and form judgments about the right balance of tactics required to resolve the situation, with the least amount of force and risk. Essentially the HSPM equation becomes another tool that can help decision makers in determining just the right amount of leverage to apply upon each variable in order to optimize the highest probability of a positive outcome. It's an oversimplification, but that's the best way to explain it. Each X factor (or variable) represents a value from the current incident (such as suspect has killed a hostage already or not). The [b] values in the equation are the standard discriminant values (or multipliers) that were derived from the national study. The [a] part of the equation is a static or constant value that never changes. Based on the findings of the national study that provides the (a) constant and the (b) multipliers for the equation, all that's required is to enter the values for each variable of the current situation into the standard equation in order to compute the risk potential for the current hostage crisis. The outcome of this research endeavor indicated that there were some very statistically significant findings, which consequently resulted in a potentially valuable tool that can be employed, along with the rest of the assets normally brought to bear on such an incident, to enhance the probability that the situation can be resolved peacefully.

About the Authors



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Hal Campbell currently serves as the Executive Director of JusticeAcademy.org. He also serves as a member of the teaching faculty for the University of Maryland. He was appointed to the bench by the Supreme Court of the State of Montana, Commission on Courts of Limited Jurisdiction.



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Hostage Survival Probability Model - Page 3

The HSPM model, if employed properly, can provide tactical teams with an ability to arrive at a scene, recon the situation, and then use the information they derive within the equation to provide a baseline assessment of current risk to the hostage. In other words, as it stands presently, there is an X% chance that the hostage will be killed. The question then becomes what does the tactical team need to do to lessen the likelihood of the hostage being killed, to regain control over the situation, ease tension, lower the probability of risk to the hostage, and resolve the situation with a minimum of force.

The HSPM Model can be utilized as a tool to aide in making judgments about potential risk. It is not a replacement for intuition, experience, or decisive action, but it may lessen the likelihood of harm to the hostage, based on a statistical probability, and predicated on an analysis of the cases that were made available by the national audience of tactical teams that contributed to the research endeavor. The illustration below represents the forty-five variables that were included within the study, their major category of hypothesized influence, and the suspected relevance to group association.

Regarding the interpretation of the discriminant functions associated with this study, it is first noted that an Eigenvalue of 11.93 was generated for the two sample groups examined. This relatively large Eigenvalue indicates that there exists a wide centroidal separation (geometrically) between the Hostage Killed and the Hostage Not Killed sample groups. More specifically, as applied to the predictor variables selected for inclusion within this examination and in consideration of the traits and values demonstrated by the participants within the two samples, it appears that the initially hypothesized expectations regarding group membership and causation were correct.

This finding leads to the next computation which measures the degree of association between the independent or predictor variable and the two sample groups. This statistic is identified as the canonical correlation coefficient and in this case was calculated at .96. This finding indicates that a very strong positive correlation exists between the predictor variables (collectively) and their ability to predict group membership. However, before it can be postulated with any degree of confidence that the aggregate HSPM model can correctly predict future group association for cases not contained within the sample, an additional statistic generated by the Discriminant Function Analysis program, referred to as the Wilk's Lambda must be evaluated.

As applied to this analysis the Wilk's Lambda is used to determine the collective degree of residual discrimination possessed by the predictor variables in determining group placement beyond the sample elements as is portrayed in inverse fashion. The Lambda statistic obtained in this study was computed at .0773 and, as such coincides with the canonical correlation coefficient previously achieved. This result indicates that the forthcoming regression formula should possess a high degree of accuracy in predicting group classifications for hostage survival. The level of significance for the Wilk's Lambda statistic achieved in this case can be determined by converting the Lambda coefficient into an approximation of a Chi-Square. The resulting Chi-Square achieved in this case was 106.23, $df=45$, which consequently provides statistical significance beyond the .00001 level.

Such a high level of significance suggests that the variables identified within the Hostage Survival Probability Model were, in fact, extremely strong predictors for determining group placement with the Hostage Killed or Hostage Not Killed categories and, as such, allow one to harbor a high degree of confidence in the ability of the model to predict future associations based on these selected empirical data elements.

Hostage Survival Probability Model - Page 4

Turning now to the order of relevancy of the predictor variables, it can be observed that of the variables examined, “Killed Hostage Already” was found to be the most discriminating characteristic for determining group placement and association based on a standard discriminant score of -1.6918. The second most powerful variable was discovered to be “Delusion” by the hostage taker with a discriminant score of -1.1841. For the remaining variables examined as part of this study, the descending order of contributive power and relevance for determining group association was as follows:

Standardized Discriminant Function Scores by Predictive Power Ranking

Killed Hostage	-1.6918	Incident Duration	.3840	Subject Hears Voices	.1807
Delusional	-1.1841	Subject Calls Friend	-.3813	Lessen Tension	-.1796
Authority Figure	-.9959	Hostage Provokes	-.3541	Subject IQ	.1613
Absence of Empathy	.9663	Subject Senses Doom	-.3468	Crime Incident	-.1531
Subject Suicidal	.8112	Hostage is Enemy	.3326	Hostage Gender	.1234
Verbal Threats	.7179	Restrained Hostage	.3213	Subject's Ethnicity	-.0989
Suicide History	.6137	Hostage is Co-Worker	.3137	Subject Ex-Con	-.0783
Dehumanize Hostage	-.5539	Calming Force	-.3136	Subject's Gender	.0775
Hostage is Stranger	.5379	Hostage Bravado	.3006	Terrorism	-.0649
Location Type	.5289	Disorganized Speech	.2825	Subject on Drugs	.0431
Subject on Alcohol	-.5039	Religious Motivation	.2785	Subject Fearless	.0416
Flight Desire	.4490	Hostage is Family	-.2419	Personalize Situation	.0278
Mental Impairment	-.4092	Stalls for Time	.2355	Subject's Maturity	.0109
Subject's Age	-.4007	Violence History	.2011	Separated Hostages	-.0076
Situational Control	-.3854	Revenge	.1891	Subject Gang Member	.0028

As observed in the table above, whether or not a hostage had already been killed during the incident, and whether the subject was delusional served as the dominant factors in the equation, and were closely followed by whether or not the hostage was perceived as an authority figure by the hostage taker, along with a demonstrated absence of empathy for the hostage, a detectible suicidal level by the subject, verbal threats made to kill the hostage, and a history of suicidal threats by the subject. The remaining variables that were examined within the study, in descending order of relative discriminating power to the outcome, are profiled within the table, along with their standardized discriminant function score. These values are based on the discriminant analysis of the information provided by the law enforcement agencies participating in the study, and the quantifications they provided for each factor, for each incident reported.

Hostage Survival Probability Model - Page 5

The next step in the discriminant analysis process is to convert the standardized discriminant scores to unstandardized discriminant function scores so that they can be used within the regression equation. The Constant that was computed for the probability equation equaled 11.34. The unstandardized discriminant function scores for all variables within the study are provided within the table below.

Unstandardized Discriminant Function Scores

Flight Desire	.9094	Killed Hostage	-11.0514	Authority Figure	-3.4146
Situational Control	-.7237	Verbal Threats	1.2792	Hostage is Stranger	1.0765
Subject Fearless	.0703	Restrained Hostage	.6403	Subject on Drugs	.0514
Subject Senses Doom	-.4642	Hostage Bravado	.4983	Subject on Alcohol	-.5934
Subject Suicidal	1.119	Calming Force	-.4069	Subject's Maturity	.0197
Delusional	-1.678	Subject's Ethnicity	-.1956	Disorganized Speech	.4400
Subject Hears Voices	.2191	Subject's Gender	.6259	Separated Hostages	-.0150
Mental Impairment	-.4881	Hostage Gender	.1447	Location Type	.8934
Hostage Provokes	-.8838	Subject's Age	-.0348	Incident Duration	.0238
Violence History	-.3635	Subject's IQ	.2665	Stalls for Time	.3588
Suicide History	.6364	Subject Ex-Con	-.1089	Subject Calls Friend	-.5309
Religious Motivation	.3310	Subject Gang Member	.0036	Dehumanize Hostage	-.7554
Crime Incident	-.3265	Hostage Co-Worker	1.1404	Absence of Empathy	1.1554
Terrorism	-.3737	Hostage is Family	-.4839	Personalize Situation	.0329
Revenge	.2770	Hostage is Enemy	.7889	Lessen Tension	-.2525

Concerning the objective of using the results of the HSPM study to create a predictive equation that can be used to assess the statistical probability of hostage survival, the regression equation for the forty-five variables contained within the study is as follows:

$$\begin{aligned}
 Y' = & 11.34 + .9094x_1 - .7237x_2 + .0703x_3 - .4642x_4 + 1.119x_5 - 1.678x_6 + .2191x_7 - .4881x_8 \\
 & + .8838x_9 - .3635x_{10} + .6364x_{11} + .3310x_{12} - .3265x_{13} - .3737x_{14} + .2770x_{15} \\
 & + 11.0514x_{16} + 1.2792x_{17} + .6403x_{18} + .4983x_{19} - .4069x_{20} - .1956x_{21} + .6259x_{22} \\
 & + .1447x_{23} - .0348x_{24} + .2665x_{25} - .1089x_{26} + .0036x_{27} + 1.1404x_{28} - .4839x_{29} \\
 & + .7889x_{30} - 3.4146x_{31} + 1.0765x_{32} + .0514x_{33} - .5934x_{34} + .0197x_{35} + .4400x_{36} \\
 & + .0150x_{37} + .8934x_{38} + .0238x_{39} + .3588x_{40} - .5309x_{41} - .7554x_{42} + 1.1554x_{43} \\
 & + .0329x_{44} - .2525x_{45}
 \end{aligned}$$

Hostage Survival Probability Model - Page 6

As applied to the entire sample of hostage incidents reviewed as part of this discriminant analysis, it was discovered that the resultant regression equation possesses an extremely high level of accuracy with regard to correctly classifying grouping classifications. In fact, not one case contained within the national sampling was misclassified by the regression equation relative to its placement.

Obviously, similarity in the quantification strategy used for each case (See Regression Equation Quantification Guide) is a critically important aspect to the outcome of the equation's predictive accuracy for future incidents, but it seems safe to infer from the results of this study that it is possible to use the variables identified and the regression equation derived from the study as a means of assessing hostage peril, and perhaps as a mechanism to manipulate the "controllable" variables of the greater equation in order to lessen the statistical probability that the hostage will be harmed.

Toward this goal, it is important to recognize several aspects of the model which include; (1) the relative discriminating power that each predictor variable possesses within the equation, (2) the controllable versus non-controllable nature of these factors, and (3) the aggregate effect possessed by the entire equation as applied to the manipulation of lesser factors to achieve the desired outcome. For example, although it may not be practical to expect to have any control whatsoever over the variable "delusion" in the equation, it may prove advantageous to seek to affect changes in the subtle level variables associated with the major category of Survival Disposition in order to alleviate the subject's level of fear, perceived expectation of doom, and predisposition toward suicide. By affecting changes in those three variables (for example), the outcome might be altered even though "delusion" remained a consideration in the crisis equation.

Similarly, endeavoring to counteract non-controllable factors in the equation that combine to present a highly charged and potentially lethal scenario might be achieved by manipulating controllable influences within the Situational Specifics category, along with some of the Negotiation Effectiveness variables. More specifically it might prove advantageous when faced with an overwhelming statistical likelihood of lethal action by the subject because of dominant values within the Situational Disposition and Situational Violence columns, to counteract the aggregate effect they possess by manipulating (repeatedly) the influence that not allowing the subject to have outside communication to contact friends has on the situation, and/or by not allowing the situation to go beyond a pre-determined duration, combined with continually reframing the subject's demands, and perhaps through repeated efforts to humanize the hostage to the subject. Again, there are many potential combinations that may influence the outcome of such situations. The important thing to remember is that each variable in the hostage survival equation possesses a level of influence over the outcome of the situation, and by strategically changing the value of each specific X factor; it may prove possible to lessen the probability of an undesirable outcome. Manipulation of the situation to achieve a positive outcome isn't a new concept. We have employed such tactics for years through qualitative means, but having a statistical probability model that articulates the realm of influential variables in such an incident and knowing their relative strength (individually and collectively) facilitates a broader view of the situation and provides a mechanism for anticipating potential scenarios before deciding on a tactical strategy.

Hostage Survival Probability Model - Page 7

Z	Situational Outcome	(1 – Hostage Survived, 2 – Hostage Died)	Revision Date Jan 25,2014
bX1	Survival Disposition of the Subject (1-Low, 2 - High)		
	bX1a	Flight – No expressed desire to escape (1 – False, 2 – True)	
	bX1b	Control – Subject appears to enjoy the situational control (1 – False, 2 - True)	
	bX1c	Fear – Subject appears fearless (1 – Fearful, 2 – Fearless)	
	bX1d	Doom – Expression of impending doom (1 – False, 2 – True)	
	bX1e	Suicidal – Subject has expressed a suicidal tendency (1 – False, 2 - True)	
bX2	Mental Illness (1 – Not Impaired, 2 – Impaired)		
	bX2a	Delusion – Subject displays a level of delusion that impacts reasoning (1 – No, 2 – Yes)	
	bX2b	Voices – Subject hears voices guiding their actions (1 – No, 2 – Yes)	
	bX2c	Severity – On scene judgment re: mental impairment (1 – Not Severe, 2 – Severe)	
	bX2d	Aggressive – Hostile and aggressive behavior toward hostage or police (1 – No, 2 – Yes)	
	bX2e	Violence History – Does the subject have a history of violent tendencies (1 – No, 2 – Yes)	
	bX2f	Suicidal History – Has the subject tried to commit suicide previously(1 – No, 2 – Yes)	
bX3	Subject's Violence Motivation (1 – Low, 2 – High)		
	bX3a	Religious – Is the subject motivated by religious beliefs (1 – No, 2 – Yes)	
	bX3b	Criminal – Was the situation that perpetuated the incident a criminal act (1 – No, 2 – Yes)	
	bX3c	Terrorism – Is the subject a terrorist (1 – No, 2 – Yes)	
	bX3d	Revenge – Is the incident predicated on revenge (1 – No, 2 – Yes)	
bX4	Situation Violence (1 – Low, 2 – High)		
	bX4a	Killed Hostage – Has the subject killed a hostage already (1 – No, 2 – Yes)	
	bX4b	Verbal Threats – Has the subject made verbal threats to kill the hostage (1 – No, 2 – Yes)	
	bX4c	Restrained Hostage – Have the hostages been neutralized by restraint devices (1 – No, 2 – Yes)	
	bX4d	Hostage Bravado – Hostage demonstrating a threat to the subject (1 – No, 2 – Yes)	
	bX4e	Calming Force – A calming force is involved in the situation (1 – True, 2 – False)	
bX5	Situational Demography (1 – Not Influential, 2 – Influential)		
	bX5a	Subject's Ethnicity (1 – Caucasian, 2 – Minority)	
	bX5b	Subject's Gender (1 – Female, 2 – Male)	
	bX5c	Hostage Gender (1 – Female, 2 – Male)	
	bX5d	Subject's Age (Age in Years)	
	bX5e	Subject's Intellect Level (1 – Normal, 2 – Diminished)	
	bX5f	Ex-Con – Does the subject have a criminal history with time spent in prison (1 – No, 2 – Yes)	
	bX5g	Gang Member – Is the subject a member of a street or prison gang (1 – No, 2 – Yes)	
bX6	Participant Relation (1 - Not Influential, 2 – Influential)		
	bX6a	Co-Worker (1 – No, 2 – Yes)	
	bX6b	Family (1 – No, 2 – Yes)	
	bX6c	Enemy (1 – No, 2 – Yes)	
	bX6d	Authority Figure – Is the hostage an authority figure to the subject (1 – No, 2 – Yes)	
	bX6e	Stranger – The hostage is a stranger to the subject (1 – True, 2 – False)	
bX7	Cognitive Impairment (1 – Not Influential, 2 – Influential)		
	bX7a	Drugs – Is the subject under the influence of drugs (1 – No, 2 – Yes)	
	bX7b	Alcohol – Is the subject under the influence of alcohol (1 – No, 2 – Yes)	
	bX7c	Maturity – Does the subject's maturity level influence their ability to be rational (1 – No, 2 – Yes)	
	bX7d	Disorganized Speech – Is impairment effecting speech ability (1 – No, 2 – Yes)	
bX8	Situational Specifics (1 – Not Influential, 2 – Influential)		
	bX8a	Separation of Hostages – Have the hostages been separated by the subject (1 – No, 2 – Yes)	
	bX8b	Location Type –Was the hostage relocated to an interior area (1 – No, 2 – Yes)	
	bX8c	Incident duration – Duration of the incident at its conclusion in hours	
	bX8d	Stalls for Time – Is the subject stalling for time (1 – No, 2 – Yes)	
	bX8e	Subject Calls Friends/Relatives during the incident (1 – No, 2 – Yes)	
bX9	Negotiation Effectiveness (1 – Low, 2 - High)		
	bX9a	Dehumanize Hostage – Subject values life of the hostage's life (1 –True, 2 – False)	
	bX9b	Absence of Empathy – Subject displays empathy for the hostage (1 –True, 2 – False)	
	bX9c	Personalize Situation – Subject rejected efforts to personalize the situation (1 –No, 2 – Yes)	
	bX9d	Lesson Tension – Subject rejected efforts lesson the tension (1 –No 2 – Yes)	
	bX9e	Reframe Demands - Subject resisted efforts to reframe demands (1 –No, 2 – Yes)	



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