

ORPS analysis using Generalized Linear Methods (binomial, multinomial logistic and Poisson regression)

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Outline

- Some Typical Results
 - Knowledge, Rule, Skill Based Errors
 - I&I, HEC, Near Miss Events
 - ISM2, ISM3, ISM4 Events
 - Environmental Events
 - Drill down on human performance factors
- More Detailed Description of Methodology
- Basis in Theory
- Other Possibilities

Analysis and Interpretation of Logistic Regression

- Compares two or more groups of data points.
- One group is designated the reference case.
- Predictor variables can be of any type.
- Easiest results to interpret are the “odds ratios,” $\exp(b)$ values.

Interpretation of $\exp(b)$

$$\text{odds} = \frac{P}{1 - P} = (\text{Probability of a group 1 event happening}) / (\text{probability of a group 1 event not happening})$$

$\text{Exp}(b)$ is the ratio of odds for two groups where the two groups have values of a variable which are one unit apart. An $\text{Exp}(b) > 1$ means the variable increases the odds(event). If $\text{Exp}(b) = 1.0$, the variable has no effect. If $\text{Exp}(b)$ is less than 1.0, then the variable decreases the odds(event).

Odds(a group 1 event) / odds(a group 2 event) = $\exp(b)$ or

Odds(a group 1 event) = odds(a group 2 event) X $\exp(b)$

Examples

- Knowledge, Rule, Skill Based Errors
- Environmental releases
- Comparison of Injury & Illnesses (I&I), Hazardous Energy Control (HEC), and Near Miss (NM)
- I&I, HEC, NM comparison in ops versus BOP facilities
- Events by ISM category
- Drill down example looking at human performance

What Causal Factors are most influential in Knowledge Based Errors?

- Consider only the I&I, HEC, NM, and Environmental events, SC2 and SC3, and only those involving knowledge based errors or no human performance issues (1027).
- Compare those events with knowledge based errors (439) with those events that involve no HP problems (588).
- What causal factors seem to contribute most to knowledge based errors?

Knowledge Based Errors

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1 ^a	Mmethods	.321	.101	9.994	1	.002	1.378
	ResM	-.188	.224	.700	1	.403	.829
	OrgPln	-.025	.098	.065	1	.799	.975
	FLS	.315	.160	3.844	1	.050	1.370
	ChngM	.374	.156	5.741	1	.017	1.453
	Wrcomm	-.098	.128	.582	1	.446	.907
	Vcomm	.415	.160	6.738	1	.009	1.515
	Engr	-.167	.124	1.821	1	.177	.846
	Training	.127	.155	.677	1	.411	1.136
	Constant	-.515	.092	31.156	1	.000	.597

a. Variable(s) entered on step 1: Mmethods, ResM, OrgPln, FLS, ChngM, Wrcomm, Vcomm, Engr, Training.

Interpretation: Factors related to management methods, supervisory methods, change methods, and verbal communications are most influential in knowledge based errors. The other factors listed, resource management, organization and planning, written communications, engineering and design, and training are not significant.



What Causal Factors are most influential in Rule Based Errors?

- Consider only the I&I, and NM events, SC2 and SC3.
- Compare those events with rule based errors (204) with those events that involve no HP problems (415).
- What causal factors seem to contribute most to rule based errors?

Rule Based Errors

Variables in the Equation

	B	S.E.	Wald	df	Sig.	Exp(B)
Step 1 ^a Mmethods	.323	.145	4.945	1	.026	1.381
ResM	-.083	.297	.079	1	.779	.920
OrgPln	-.351	.160	4.819	1	.028	.704
FLS	.460	.206	4.998	1	.025	1.584
ChngM	.483	.222	4.716	1	.030	1.620
Wrcomm	-.102	.186	.302	1	.583	.903
Vcomm	-.085	.255	.111	1	.739	.919
Engr	-.598	.205	8.498	1	.004	.550
Training	-.089	.218	.166	1	.684	.915
Constant	-.679	.121	31.376	1	.000	.507

a. Variable(s) entered on step 1: Mmethods, ResM, OrgPln, FLS, ChngM, Wrcomm, Vcomm, Engr, Training.

Interpretation: Factors related to management methods, supervisory methods, and change management are most influential in rule based errors. Engineering/Design and Organization/Planning factors decrease to odds of rule based errors. The other factors listed, resource management, written communications, and training are not significant.

What Causal Factors are most influential in Skill Based Errors?

- Consider only the I&I, HEC, NM, and Environmental events, SC2 and SC3, and only those involving skill based errors or no human performance issues (1038).
- Compare those events with skill based errors (468) with those events that involve no HP problems (570).
- What causal factors seem to contribute most to skill based errors?

Skill Based Errors

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1 ^a	Mmethods	.061	.110	.310	1	.578	1.063
	ResM	-.099	.229	.187	1	.665	.906
	OrgPln	-.324	.115	7.923	1	.005	.723
	FLS	.485	.161	9.055	1	.003	1.625
	ChngM	-.377	.213	3.125	1	.077	.686
	Wrcomm	-.166	.146	1.301	1	.254	.847
	Vcomm	.056	.184	.092	1	.761	1.058
	Engr	-.463	.136	11.636	1	.001	.629
	Training	-.053	.172	.094	1	.760	.949
	Constant	.001	.087	.000	1	.988	1.001

a. Variable(s) entered on step 1: Mmethods, ResM, OrgPln, FLS, ChngM, Wrcomm, Vcomm, Engr, Training.

Interpretation: Factors related to supervisory methods are most influential in skill based errors. Engineering/Design and Organization/Planning factors decrease to odds of skill based errors. The other factors listed are not significant.

Summary Comparison

FACTORS	Knowledge	Rule	Skill
Management Methods	1.378	1.381	X
Resource Management	X	X	X
Organization and Planning	X	0.704	0.723
Supervisory Methods	1.37	1.584	1.625
Change Management	1.453	1.62	X
Written Communications	X	X	X
Verbal Communications	1.515	X	X
Design and Engineering	X	0.55	0.629
Training	X	X	X

Interpretation: Values shown are the odds ratios ($\exp(b)$ values) for the significant factors in the analyses.

Values > 1 increases the odds of the event type being studied over the reference case. Values < 1 decrease the odds.

Each value is an estimate within a range (confidence interval). Additional tests required to draw conclusions about relative size of the numbers.

What differences in causal factors best distinguish between SC2 and SC4 Environmental Events?

Parameter Estimates							
Sig ^a		B	Std. Error	Wald	df	Sig.	Exp(B)
2	Intercept	-.904	.432	4.383	1	.036	
	Eqfailure	-1.036	.613	2.857	1	.091	.355
	Mmethods	1.473	.730	4.074	1	.044	4.363
	Wrcomm	2.140	.919	5.423	1	.020	8.501
	Vcomm	1.699	1.013	2.815	1	.093	5.467

Interpretation: Given there is an environmental release, for a single causal factor increase in either Management Methods, or Written or Verbal Communications, the odds of it being Significance Category 2 (SC2) are approximately 4.3-8.5 times the odds of it being Significance Category 4 (SC4). (A unit increase in an Equipment Failure causal factor indicates that the odds of the event are ~3 times more likely to be SC4 versus SC2.)

Summary Comparison of Three Event Types

FACTORS	I&I	HEC	NM
	Exp(B)	Exp(B)	Exp(B)
Mmethods	3.230	X	1.349
ResM	4.264	X	X
OrgPln	X	X	X
FLS	X	X	X
ChngM	X	X	X
Wrcomm	X	X	1.699
Vcomm	X	X	1.684
Engr	X	1.603	X
Training	X	X	X
Maint	X	2.698	1.692
Prmatl	X	X	X
Eqfailure	X	6.407	2.108
Skill	X	X	X
Rule	3.747	X	1.925
Knowledge	X	X	X

The groups being compared are all I&I events with all non-I&I events; all HEC events with all non-HEC events...etc.

The question being asked in each case is how are the I&I or HEC or NM events uniquely different from all other events?



Parameter Estimates

sig3201 ^a	B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp (B)	
							Lower Bound	Upper Bound
1 Intercept	-5.734	.639	80.629	1	.000			
Rule	1.352	.451	8.973	1	.003	3.864	1.596	9.359
ResM	2.623	.745	12.409	1	.000	13.777	3.201	59.287
Mmethods	1.692	.373	20.593	1	.000	5.432	2.615	11.283
Wrcomm	.706	.510	1.917	1	.166	2.025	.746	5.500
ResM * Rule	-2.045	1.445	2.004	1	.157	.129	.008	2.196
Mmethods * ResM	-.770	.427	3.252	1	.071	.463	.201	1.069
ResM * Wrcomm	2.827	1.277	4.896	1	.027	16.888	1.381	206.520

Exploratory Techniques
Significance Level 2-3, n=572
Injuries Only

a. The reference category is: 0.

Parameter Estimates

sig3201 ^a	B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp (B)	
							Lower Bound	Upper Bound
1 Intercept	-2.008	.161	155.668	1	.000			
Engr	.479	.177	7.356	1	.007	1.615	1.142	2.282
Maint	.884	.344	6.618	1	.010	2.420	1.234	4.745
Eqfailure	1.622	.341	22.582	1	.000	5.062	2.593	9.882

Significance Level 2-3, n=481
HEC Only

a. The reference category is: 0.

Parameter Estimates

sig3201 ^a	B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp (B)	
							Lower Bound	Upper Bound
1 Intercept	-2.845	.217	172.508	1	.000			
Vcomm	.092	.332	.077	1	.781	1.097	.572	2.104
Mmethods	.432	.148	8.480	1	.004	1.541	1.152	2.061
Eqfailure	.658	.316	4.331	1	.037	1.931	1.039	3.590
Rule	.344	.282	1.489	1	.222	1.411	.812	2.453
Wrcomm	.583	.185	9.941	1	.002	1.791	1.247	2.572
Rule * Vcomm	.879	.448	3.841	1	.050	2.408	1.000	5.796

Significance Level 2-3, n=604
Near Miss Only

a. The reference category is: 0.

Comparison of HEC events in Production versus BOP Facilities

Parameter Estimates

sig3201 ^a	B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp (B)	
							Lower Bound	Upper Bound
1	Intercept	-2.387	.310	59.480	1	.000		
	Eqfailure	2.399	.717	11.196	1	.001	11.009	2.701 44.867
	Engr	.583	.282	4.278	1	.039	1.792	1.031 3.115

a. The reference category is: 0.

Significance Level 2-3, n=165 Production Facilities (ORPS types1-13)

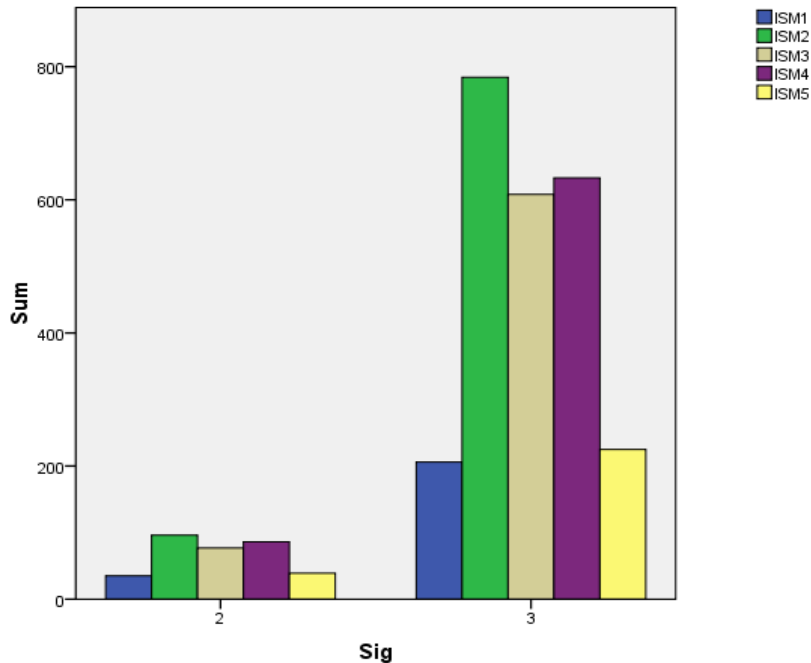
Parameter Estimates

sig3201 ^a	B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp (B)	
							Lower Bound	Upper Bound
1	Intercept	-1.592	.185	73.721	1	.000		
	Eqfailure	1.843	.537	11.785	1	.001	6.318	2.206 18.100

a. The reference category is: 0.

Significance Level 2-3, n=223 BOP (ORPS type 99)

Summary Comparison of ISM2, 3, 4 Events



Factors	ISM2	ISM3	ISM4
Mmethods	X	1.351	1.165
ResM	X	X	X
OrgPln	1.645	1.653	X
FLS	X	X	1.869
ChngM	1.355	1.346	X
Wrcomm	X	1.776	X
Vcomm	X	X	1.475
Engr	1.450	1.200	.801
Training	1.396	X	1.369
Maint	X	X	X
Prmatl	X	1.620	X
Eqfailure	1.398	X	.666
Skill	X	.786	2.158
Rule	X	X	1.820
Knowledge	1.437	X	1.279

Note: Some model fit issues to be resolved.

Drill down example

- What causal factors are most associated with human performance errors?
- Can use previous methods, but there are other useful GLM tools.
- Using Poisson Regression – looking at the # of HP factors identified per event
 - Coefficients $\exp(b)$ interpreted differently, but relative significance easily seen looking at other information.

A Level Causal Factors

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-.736	.0284	-.791	-.680	671.146	1	.000
Engr	-.076	.0368	-.149	-.004	4.299	1	.038
Eqpmatl	-.356	.0396	-.434	-.279	81.179	1	.000
Mngt	.157	.0113	.135	.179	192.695	1	.000
Commun	.187	.0210	.146	.228	78.801	1	.000
Training	.202	.0378	.128	.276	28.542	1	.000
ExPhen	-.763	.1216	-1.002	-.525	39.380	1	.000
(Scale)	1 ^a						

Dependent Variable: HuPerf

Model: (Intercept), Engr, Eqpmatl, Mngt, Commun, Training, ExPhen

a. Fixed at the displayed value.

- This analysis looks at all 2003-2008 ORPS events, analyzing the significance of causal factors relative to the number of HP errors identified, 0-6, per event.
- Look at “Sig.” column first to see if factor is significant; then look at Wald Chi-Square column to see relative significance with respect to other factors.

Consider B level factors of top 3 A factors: Management, Equipment/Materials, Communications

Parameter Estimates

Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-.743	.0270	-.796	-.690	758.444	1	.000
Prmatl	.126	.0547	.019	.233	5.314	1	.021
Eqfailure	-.871	.0729	-1.014	-.728	142.958	1	.000
Mmethods	.174	.0223	.130	.218	60.659	1	.000
OrgPln	.129	.0279	.074	.184	21.330	1	.000
FLS	.274	.0372	.201	.347	54.389	1	.000
ChngM	.119	.0341	.052	.186	12.093	1	.001
Wrcomm	.093	.0273	.040	.146	11.646	1	.001
Vcomm	.319	.0384	.243	.394	68.711	1	.000
A6B2	.219	.0747	.073	.366	8.618	1	.003
A6B3	.396	.0758	.247	.544	27.239	1	.000
ExPhen	-.754	.1216	-.992	-.515	38.411	1	.000
(Scale)	1 ^a						

Dependent Variable: HuPerf

Model: (Intercept), Prmatl, Eqfailure, Mmethods, OrgPln, FLS, ChngM, Wrcomm, Vcomm, A6B2, A6B3, ExPhen

a. Fixed at the displayed value.

Parameter Estimates

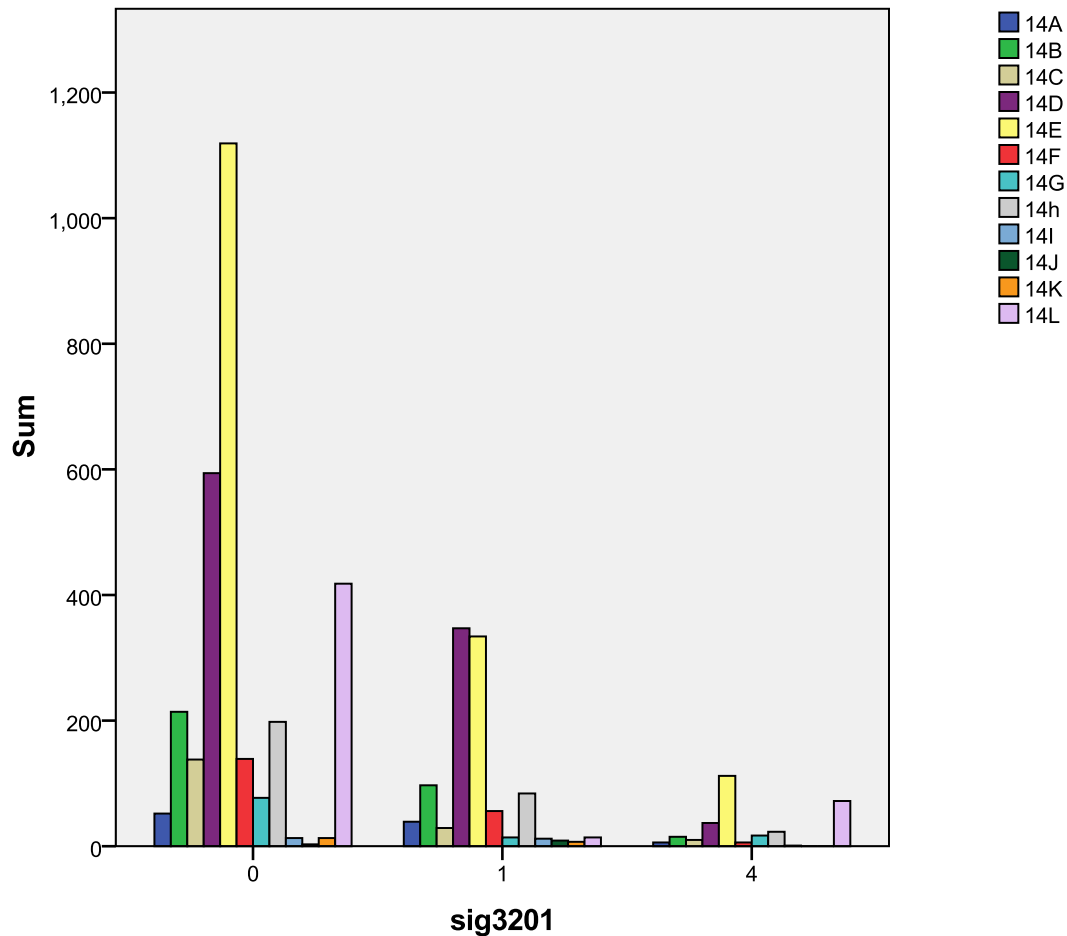
Parameter	B	Std. Error	95% Wald Confidence Interval		Hypothesis Test		
			Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	-.794	.0298	-.853	-.736	712.199	1	.000
Eqfailure	-1.164	.0911	-1.342	-.985	163.138	1	.000
Mmethods	.193	.0260	.142	.244	55.299	1	.000
OrgPln	.263	.0387	.187	.339	46.222	1	.000
FLS	.611	.0576	.498	.723	112.400	1	.000
ChngM	.089	.0356	.020	.159	6.298	1	.012
Wrcomm	.138	.0313	.077	.199	19.462	1	.000
Vcomm	.334	.0442	.247	.421	57.112	1	.000
A6B2	.335	.0848	.169	.501	15.590	1	.000
A6B3	.505	.0770	.354	.656	43.038	1	.000
ExPhen	-.836	.1353	-1.102	-.571	38.221	1	.000
Eqfailure * Mmethods	.294	.0743	.148	.440	15.644	1	.000
Eqfailure * ChngM	.249	.1202	.014	.485	4.299	1	.038
Eqfailure * Wrcomm	.332	.0902	.156	.509	13.581	1	.000
Eqfailure * Vcomm	.434	.1372	.165	.703	10.015	1	.002
Mmethods * FLS	-.132	.0340	-.199	-.065	15.072	1	.000
OrgPln * FLS	-.134	.0440	-.220	-.047	9.215	1	.002
OrgPln * Wrcomm	-.132	.0346	-.199	-.064	14.481	1	.000
OrgPln * ExPhen	.499	.1850	.136	.862	7.270	1	.007
FLS * Vcomm	-.148	.0579	-.261	-.034	6.512	1	.011
FLS * A6B2	-.242	.1060	-.450	-.034	5.207	1	.022
(Scale)	1 ^a						

Exploratory look at interactions among B level factors, next steps might include looking at the most significant down to the C level

Dependent Variable: HuPerf

Model: (Intercept), Eqfailure, Mmethods, OrgPln, FLS, ChngM, Wrcomm, Vcomm, A6B2, A6B3, ExPhen, Eqfailure * Mmethods, Eqfailure * ChngM, Eqfailure * Wrcomm, Eqfailure * Vcomm, Mmethods * FLS, OrgPln * FLS, OrgPln * Wrcomm, OrgPln * ExPhen, FLS * Vcomm, FLS * A6B2

a. Fixed at the displayed value.



DOE Key Word analysis associated with QA, 14A-L, suggests D, E, and L should be studied, (and maybe B, C, F, and H).

Comparison Options

- Any categorical variable: event, facility, activity, field office, contractor, ISM, key word, person, place, type...
- Any ordinal variable: time, date, ...
- Any binomial variable: yes-no, dayshift-backshift...
- Any count variable: number of causal factors, events, times on day-shift versus off-shift...

Micro-Exploratory Analysis of Data

- From Macro-view explore more detailed relationships and effects of context.
 - May only use subsets of events
- Must continually evaluate model fit and validity, significance of predictors, and refine the model.
- Analysis goal is to identify significant causal factors at the lowest interpretable levels.
- Next step TBD: Sort, extract, and study events indicated by analysis to gain further understanding.
- Benefit: may result in focal areas for assessments and corrective actions.

Next Steps?

- Many more questions can be explored in ORPS.
 - Investigate effectiveness of corrective actions over time?
 - Attempt to compare sites and identify best practices?
 - With each run, can specifically identify key events for more thorough case study of causes and corrective actions.
 - Adjust priorities in assessment and corrective action processes?
- Methods applicable to other databases
- Future upgrades of ORPS or other systems should be based on theory, keeping analysis methods in mind

More Detailed Description of the Methodology

- Data Characteristics
- Formatting for Analysis
- Defining and Coding Variables
- Analysis Techniques
- Limitations and Cautions
- Interpretation of Results

Data Characteristics: 2003-2008

- This data base has recorded 1000+ events per year for the last five years covering safety and operational events in administrative, common industrial to high hazard facilities. Each event is consistently evaluated and reported on based on a common set of procedures and classification criteria led by trained professionals.
- 41 fields of data are captured, including Facility Function (27 types), Significance Category (6 levels), Activity Category (14 types), Causal Factors (167 in 3 level event tree format), Reporting Codes (81 in 3 tier format), Corrective Actions, and other event details including dates, times, conditions, and personnel involvement.
- Content analysis and event study methodology are used to extract metrics suitable for statistical analysis. Since almost all of the information extracted is categorical, and mostly binomial, significant challenges exist in application of statistical analytic methods.

Formatting for Analysis and Coding of Variables

- Download to Excel; numerically code data
- Categorical, count, and binomial variable format
 - Mostly Poisson distributions (not meet OLS criteria)
- Import to SPSS for statistical analysis

Analysis Techniques

- Binomial / Multinomial logistic regression
 - Maximum Likelihood Estimation (MLE)
 - Data considerations:
 - Generally a very robust analytical process with almost any form of predictor variables.
 - The dependent variable of interest must be binomial or categorical- you are making a comparison between two or more different categorical values of the variable.
 - The independent predictors (indicators) can be continuous or categorical with almost any distribution.

Logistic Regression- Overview

- *Binary (or binomial) logistic regression* is a form of regression which is used when the dependent variable is a dichotomy and the independents are of any type. *Multinomial logistic regression* exists to handle the case of dependents with more classes than two, though it is sometimes used for binary dependents also since it generates somewhat different output. Logistic regression can be used to predict a dependent variable on the basis of continuous and/or categorical independents and to determine the percent of variance in the dependent variable explained by the independents; to rank the relative importance of independents; to assess interaction effects. The impact of predictor variables is usually explained in terms of odds ratios.

Logistic Regression- Meaning

- Logistic regression applies maximum likelihood estimation after transforming the dependent into a logit variable (the natural log of the odds of the dependent occurring or the alternative occurring). In this way, logistic regression estimates the odds of a certain event occurring instead of another event. Note that logistic regression calculates changes in the log odds of the dependent, not changes in the dependent itself as ordinary least squares (OLS) regression does.

Analytical Limitations and Cautions

- Issues: variable definitions, usually need large sample size, lots of “0”s in the data set, frame of reference in analysis.
- Only makes comparisons / contrasts with a reference level, no “accident/no accident” or frequency analysis.
- Interpretation is challenging: Results are in $\log(\text{likelihood})$'s, and likelihood ratios- can be converted to probabilities.

Interpretation of Results

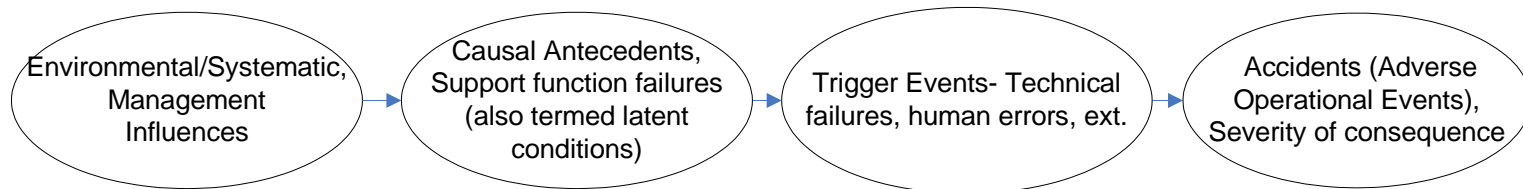
- The “b” coefficients
 - For a one unit increase in an independent predictor variable, the log odds of dependent variable level (versus the dependent variable reference level) increases by “b.”
- The $\text{Exp}(b)$ values.
 - For this reason, many researchers prefer to exponentiate the coefficients and interpret them as odds-ratios. For example, we can say that for a one unit increase in an IV, the odds of the specific level of the DV (versus the reference level) increased by a factor of $\text{exp}(\text{betta})$. Also called odds ratios.

Macro-Testing of Theory

- Determining Causality
 - Statistical correlation, temporal precedence, lack of other plausible explanations
- Research interests
 - Identifying major causal factors and relative importance
 - Evaluating context (3 each): facility type, activity type, and reporting type
 - Special focus on reasons/causes for human error

Macro-Testing of Theory

- A systems view of accident causality



- Importance of Tests and Results
 - Validate theory: suggest major directions for improvement.

Examples Models of Evaluation

