Actuarial Research on the Effectiveness of Collision Avoidance Systems

FCW & LDW

A translation from Hebrew to English of a research paper prepared by

Ron Actuarial Intelligence LTD

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Chapter 1 - Introduction

Background on Ron Actuarial Intelligence LTD:

Following a bid issued by the insurance regulator at the end of 2009, Ron Actuarial Intelligence was chosen to maintain a market pool data of policies and claims related to Motor Bodily Injuries (MBI). The purpose of the pool data is to assist the regulator and the insurers with pricing of MBI policies. Ron Actuarial Intelligence has been operating the market pool data since April 2010.

The Statistical database gathers policies and claims data from all the insurance companies with compulsory insurance. The database is used to issue a risk-based price, and serves as a trust tool to ensure insurance companies' stability on one hand, and to determine a fair rate for policyholders on the other.

Introduction

In this study, we tested the influence of having a Forward Collision Warning (FCW) system and a Lane Departure Warning (LDW) system, developed by Mobileye (hereby "the system"), on the expected MBI claim cost in Israel.
Our work was performed on the frequency of claims only. However, our recommendation for premium rate discount also refers to the impact of the severity of the claim.

- This work was conducted at the request of the Capital Markets, Insurance & Savings Division and is based on the data analysis provided by Mobileye through the Ministry of Finance, statistical databases provided by Israeli Compulsory Insurance sector, which includes policies and claims data from all Israeli insurance companies since 1985. We will strive to conduct similar tests on other systems subject to the availability of data.
- The database of vehicles with Mobileye's systems installed included 6,190 policy years.
- The main guidelines we adopted when we built our model were:
  - Testing the impact of other parameters and controlling them, in order to establish the net impact of the system on claim frequency.
  - Building a professional model that would allow actuaries to price the risk premium for MBI policies, for vehicles that have LDW and FCW systems installed.

Purpose

The purpose of this paper is to examine, and recommend to the regulator, the level of discount to include in the estimate of the risk premium of MBI policies - for policies sold to policyholders that use vehicles with LDW and FCW systems installed.

Chapter 2 - Results and Work Method

Results:

1. Our calculations conclude that for privately owned passenger vehicles (automobile), the frequency of claims is reduced by 45% for vehicles with Mobileye LDW and FCW systems installed, compared to vehicles without the systems.
   For company owned passenger vehicles (automobile), there was a 47% reduction in claims.
   Although, the results are limited for company owned vehicles, as the level of exposure and number of claims for these vehicles was not statistically significant. However, the level of claim reduction among company owned passenger vehicles (automobile) strengthens the results regarding the claims for privately owned passenger vehicles (automobile).

   The results were estimated using a Generalized Linear Model.
   The explanatory variables were: driver's characteristics and vehicle's characteristics
   (as far as these were available).
   We assumed that claim counts distribution is either Poisson or Gamma.
   We want to state that there could be other explanatory variables which were not included in our model - such as road safety, traffic cameras etc.
   Therefore, there is a possibility that actual outcome could differ from our forecast.

2. We tested a large number of explanatory variables.
   For the **Poisson** distribution, below is a list of variables with statistical **significance lower than 5% :**

   2.1. Engine Size
   2.2. Age of the youngest driver who drives the car regularly
   2.3. Number of years the youngest driver has held a driving license
   2.4. Number of prior claims in the last three years
   2.5. Horsepower
   2.6. Existence of ESP system
   2.7. Type of usage for the vehicle
   2.8. Collection vehicle
   2.9. Manufacture year
   2.10. Having Mobileye's LDW and FCW systems installed

   Below is a list of only the variables with **statistical significance higher than 5%:**

   2.11. Gender of the youngest driver who drives the car regularly
   2.12. Family status

2.13. Conviction history which led to revocation of the license in the last three years
2.14. Airbags
2.15. Maximum number of passengers allowed
2.16. Type of ignition system
2.17. Ownership
2.18. ABS system
2.19. Type of gear system

For the **Gamma** distribution, below is a list of only the variables with statistical **significance lower than 5%:**

2.20. Engine Size
2.21. Age of the youngest driver who drives the car regularly
2.22. Number of years the youngest driver has held a driving license
2.23. Number of prior claims in the last three years
2.24. Horsepower
2.25. ESP system
2.26. Type of usage for the vehicle
2.27. Collection vehicle
2.28. Manufacture year
2.29. Number of seats
2.30. Having Mobileye's LDW and FCW systems installed

Below is a list of only the variables with statistical **significance higher than 5%:**

2.31. Gender of the youngest driver who drives the car regularly
2.32. Family status
2.33. Conviction history which led to a revocation of the license in the last three years
2.34. Airbags
2.35. Type of ignition
2.36. ABS system
2.37. Type of the gearing system

Those variables which were not found to be significant – i.e. had significance level higher than 5%, were excluded from the analysis.

Please note, unlike the rate recommendation, this work is based on a different period of time than one published in for the rate recommendation- mainly due to medical expenses. Thus, the coefficients of the variables are different from those published in the rate recommendation.

Recommendations:

- We have found that vehicles with the Mobileye system installed had 45% less claims
- The impact of the system on claim severity is still unclear.
- Since the database we tested is not large, and claim frequency was small, the results may be deviated.
- In addition, the recommendation is relevant to other manufacturers in the market as well, who are also advised to offer a 15% discount on rate selection for vehicle holders with a similar safety system installed. In the next upcoming years we will follow the frequency and severity of claims in vehicles with the system installed. If any changes will arise in our estimates, we will update the relevant bodies accordingly.

Work Method:

- The database included 9,891 vehicles that had the system installed.

The data included the date of installation.
The data did not include date of removal of the system or date of test performed to verify that the system is installed or functional.
We received a letter from the company confirming that the vehicles listed above include the system, as reported by the distributors and sub-contractors. In addition, the company did not make any changes to the collected data.

- The database also included other types of vehicles, such as buses. However, the number of these vehicles was too small and statistically insignificant, hence, the impact of the system was not tested on these vehicles.

- The following table demonstrates different levels of claim frequencies, with and without the system:

	Exposure - policy Years 2009 -2012	Number of Claims	Claims Frequency
Privately owned passenger vehicle (automobile) w/o the system	6,486,415	161,973	2.5%
Privately owned passenger vehicle(automobile) with the system	5,366	55	1.02%
Company owned passenger vehicle (automobile) w/o the system	1,251,264	24,715	1.98%
Company owned passenger vehicle (automobile) with the system	824	8	0.97%

- Percentage of vehicles that have the system installed is only about 0.082%, (this allows us to provide a recommendation of reduction for vehicles with an installed system).

- The figures in the table above suggest that the system can reduce claim frequency by 59%. However, this result should be tested after the removal of confounders.
  Examples of confounders are anti-selection, such that a bigger group of younger drivers may choose vehicles with or without the system; or that the vehicles with the system are generally safer than the ones without the system.
  In the generalized linear model used, these confounders were removed.

- We have merged the database we received from the company, (that included the vehicles with the system) together with the database of the insurance companies- a database we already had as part of our regular market pool data analysis.
  The new merged database included reported claims in accident years 2009 -2012, and did not include IBNR addition.

- This database was transferred into the data mining system for completing missing data.
  This process was done using decision trees, after the system gathers the data into four homogenous groups, for each explanatory variable. This collection improves the goodness of fit of the explanatory variables.

- We have used SAS PROC GENMOD procedure.
  This procedure allows to model claim frequency using log linear regression model, assuming claims are distributed either Poisson or Gamma.

- We have tested the validity of the model, and only significant explanatory variables, those with level of significance lower than 5%, were kept in the model.

- As we didn't add IBNR estimate to the number of reported claims, the output from our model allows us to analyze the level of change of claim frequency, but doesn't provide the ultimate frequency.

- For this work we relied on the assumption that the system is effective for claims that amount to 100,000 NIS. However, this does not negate the effectiveness of the system for higher claims. An examination of the distribution of the claims suggest that the claims that sum up to 100,000 NIS constitute about 40% of the claims, Therefore, the effect of the system on all compulsory insurance claims is calculated by multiplying 40% by 45% , and the result is 18%. Based on this calculation, we recommended a 15% discount in risk selection for compulsory insurance, for vehicles with the system installed.

THE SYSTEM:

- The system is based on a camera with artificial vision technology.

The system provides safety alerts and offers a technological solution for avoiding traffic accidents, based on drivers' inattention or on an unexpected event. (There are additional technologies but were not tested in this work).

- LDW – Lane Departure Warning – when the driver unintentionally departs from the lane (without signaling)

- FCW – Forward Collision Warning – in case the vehicle faces a danger of collision with the vehicle in front, the system will provide a warning of up to 2.7 seconds before the crash.

Appendices

Appendix 1:

Results of the generalized linear model for privately owned passenger vehicles (automobile)

Based on a Poisson distribution when the target variable is claim frequency.

Analysis Of Maximum Likelihood Parameter Estimates								
Var. Name	Category	DF	estimate	S.E	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
Base		1	-5.2283	0.1832	-5.5873	-4.8692	814.46	<.0001
Car Usage	Other	1	-0.8263	0.0369	-0.8987	-0.7539	500.67	<.0001
Car Usage	Driving study	1	0.016	0.05	-0.0821	0.114	0.1	0.7498
Car Usage	Leasing	0	0	0	0	0	.	.
Engine Size CC	>1840	1	0.0559	0.0094	0.0374	0.0743	35.31	<.0001
Engine Size CC	1495-1596	1	0.0705	0.008	0.0548	0.0863	77.09	<.0001
Engine Size CC	1597-1839	1	0.1404	0.0082	0.1243	0.1566	290.47	<.0001
Engine Size CC	<1495	0	0	0	0	0	.	.
accident history	No claims	1	-0.4796	0.0121	-0.5033	-0.4559	1579.31	<.0001
accident history	At least 1 claim	0	0	0	0	0	.	.
age	25- 32	1	-0.2031	0.0073	-0.2175	-0.1887	767.69	<.0001

Analysis Of Maximum Likelihood Parameter Estimates								
Var. Name	Category	DF	estimate	S.E	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
age	33 -44	1	-0.2915	0.0091	-0.3093	-0.2738	1031.53	<.0001
age	+45	1	-0.3305	0.0104	-0.3508	-0.3101	1008.51	<.0001
age	-24	0	0	0	0	0	.	.
Prod. year	Before 1998	1	0.3378	0.0104	0.3174	0.3583	1047.92	<.0001
Prod. year	2001-1998	1	0.2472	0.0092	0.2291	0.2652	721.66	<.0001
Prod. year	2006-2002	1	0.1308	0.0086	0.1139	0.1476	231.06	<.0001
Prod. year	+2007	0	0	0	0	0	.	.
ESP	No	1	0.2475	0.0102	0.2275	0.2675	588.1	<.0001
ESP	Yes	0	0	0	0	0	.	.
License years	9-18	1	0.1969	0.0093	0.1788	0.2151	451.18	<.0001
License years	4-8	1	0.172	0.0103	0.1519	0.1922	279.3	<.0001
License years	-3	1	0.3356	0.0106	0.3148	0.3563	1003.42	<.0001
License years	+19	0	0	0	0	0	.	.
collection vehicle	Yes	1	1.7735	0.1162	1.5457	2.0012	232.87	<.0001
collection	No	0	0	0	0	0	.	.

Analysis Of Maximum Likelihood Parameter Estimates								
Var. Name	**Category**	**DF**	**estimate**	**S.E**	**Wald 95% Confidence Limits**		**Wald Chi-Square**	**Pr > ChiSq**
vehicle								
horsepower	100- 114	1	0.0209	0.0082	0.0049	0.037	6.53	0.0106
horsepower	58-99	1	0.0206	0.0086	0.0037	0.0376	5.69	0.017
horsepower	Less than 57 and more than 115	0	0	0	0	0	.	.
LDW & FCW	No	1	0.5662	0.1358	0.3	0.8325	17.37	<.0001
LDW & FCW	Yes	0	0	0	0	0	.	.

<u>The following table is a conversion of the estimates from a log scale</u>

increasing by the power of 2.718

Variable Name	Category	Estimate	e^estimate
Base		-5.2283	0.01
Car Usage	Other	-0.8263	0.44
Car Usage	Driving study	0.016	1.02
Car Usage	Leasing	0	1.00
Engine Size CC	More than 1840	0.0559	1.06
Engine Size	1495- 1596	0.0705	1.07

Variable Name	Category	Estimate	e^estimate
CC			
Engine Size CC	1839 1597	0.1404	1.15
Engine Size CC	Less than 1495	0	1.00
accident history	No claims	-0.4796	0.62
accident history	At least 1 claim	0	1.00
age	25- 32	-0.2031	0.82
age	33 -44	-0.2915	0.75
age	+45	-0.3305	0.72
age	-24	0	1.00
Prod. year	Before 1998	0.3378	1.40
Prod. year	2001-1998	0.2472	1.28
Prod. year	2006-2002	0.1308	1.14
Prod. year	+2007	0	1.00
ESP	No	0.2475	1.28
ESP	Yes	0	1.00
License Years	9-18	0.1969	1.22
License Years	4-8	0.172	1.19

Variable Name	Category	Estimate	e^estimate
License Years	-3	0.3356	1.40
License Years	+19	0	1.00
collection vehicle	Yes	1.7735	5.89
collection vehicle	No	0	1.00
horsepower	100- 114	0.0209	1.02
horsepower	58-99	0.0206	1.02
horsepower	Less than 57 and over than 115	0	1.00
LDW & FCW	No	0.5662	1.76
LDW & FCW	Yes	0	1.00

The following table includes a list of all the significant explanatory variables :

Source	DF	Chi-Square	Pr > ChiSq
Car Usage	2	862.6	<.0001
Engine Size CC	3	314.6	<.0001
accident history	1	1372.6	<.0001
age	3	1386.3	<.0001
Production Year	3	1223.5	<.0001
ESP	1	591.6	<.0001
License Years	3	1180.5	<.0001

collection vehicle	1	458.4	<.0001
horsepower	2	8.1	0.0172
LDW & FCW	1	21.2	<.0001

Criteria for the goodness of fit of the model:

Criterion	DF	Value	Value/DF
Deviance	4338	5724.5	1.32
Scaled Deviance	4338	5724.5	1.32
Pearson Chi-Square	4338	8511.9	1.96
Scaled Pearson X2	4338	8511.9	1.96
Log Likelihood		-716879.7	
Full Log Likelihood		-631608.6	
AIC (smaller is better)		1263259.1	
AICC (smaller is better)		1263259.3	
BIC (smaller is better)		1263393.1	

APPENDIX 2:

Results of the generalized linear model for privately owned passenger vehicles (automobile)

Based on a Gamma distribution when the target variable is claim frequency.

Analysis Of Maximum Likelihood Parameter Estimates								
Var name	**Category**	**DF**	**Estimate**	**Standard Error**	**Wald 95% Confidence Limits**		**Wald Chi-Square**	**Pr > ChiSq**
Base		1	-5.2153	0.1475	-5.5044	-4.9263	1250.98	<.0001
Car Usage	Other	1	-0.7037	0.0721	-0.845	-0.5624	95.27	<.0001
Car Usage	Study driving	1	0.1956	0.0931	0.0131	0.378	4.41	0.0357
Car Usage	Leasing	0	0	0	0	0	.	.
No. of seats	4	1	-0.1902	0.0118	-0.2134	-0.167	258.62	<.0001
No. of seats	+ 5	1	-0.3089	0.0122	-0.3328	-0.285	641.57	<.0001
No. of seats	-3	0	0	0	0	0	.	.
Engine size CC	More than 1840	1	0.0512	0.0117	0.0282	0.0742	19.06	<.0001
Engine size CC	1495- 1596	1	0.0635	0.0101	0.0437	0.0833	39.46	<.0001
Engine size CC	1839 1597	1	0.1347	0.0105	0.1142	0.1552	165.73	<.0001
Engine size CC	Less than 1495	0	0	0	0	0	.	.
accident history	No claims	1	-0.4814	0.0185	-0.5177	-0.4451	677.07	<.0001
accident history	At least 1 claim	0	0	0	0	0	.	.
age	25- 32	1	-0.1772	0.0101	-0.1969	-0.1574	308.9	<.0001
age	33 -44	1	-0.257	0.0118	-0.2801	-0.2338	472.99	<.0001
age	+45	1	-0.2868	0.0131	-0.3124	-0.2612	481.93	<.0001

Analysis Of Maximum Likelihood Parameter Estimates								
Var name	**Category**	**DF**	**Estimate**	**Standard Error**	**Wald 95% Confidence Limits**		**Wald Chi-Square**	**Pr > ChiSq**
age	-24	0	0	0	0	0	.	.
Production year	Before 1998	1	0.3302	0.0128	0.3052	0.3553	668.3	<.0001
Production year	2001- 1998	1	0.2479	0.0111	0.2262	0.2697	499.89	<.0001
Production year	2006- 2002	1	0.1409	0.0099	0.1214	0.1603	200.91	<.0001
Production year	+2007	0	0	0	0	0	.	.
ESP	No	1	0.2475	0.0111	0.2258	0.2692	500	<.0001
ESP	Yes	0	0	0	0	0	.	.
License Years	9-18	1	0.1958	0.0105	0.1751	0.2164	345.21	<.0001
License Years	4-8	1	0.181	0.012	0.1576	0.2044	229.25	<.0001
License Years	-3	1	0.3229	0.0131	0.2972	0.3485	607.52	<.0001
License Years	+19	0	0	0	0	0	.	.
collection vehicle	Yes	1	1.7795	0.0636	1.6548	1.9042	782.38	<.0001
collection vehicle	No	0	0	0	0	0	.	.
horsepower	100- 114	1	0.0299	0.0101	0.0101	0.0498	8.75	0.0031
horsepower	58-99	1	0.0234	0.011	0.0019	0.0449	4.55	0.0329
horsepower	Less than 57 and more than 115	0	0	0	0	0	.	.
LDW & FCW	No	1	0.6155	0.1096	0.4008	0.8303	31.55	<.0001
LDW & FCW	Yes	0	0	0	0	0	.	.

The following table is a conversion of the estimates from a log scale

Var name	Category	Estimate	E^estimate
Base		-5.2153	0.01
Car Usage	Other	-0.7037	0.49
Car Usage	Study driving	0.1956	1.22
Car Usage	Leasing	0	1.00
No. of seats	4	-0.1902	0.83
No. of seats	+ 5	-0.3089	0.73
No. of seats	-3	0	1.00
Engine size CC	More than 1840	0.0512	1.05
Engine size CC	1495- 1596	0.0635	1.07
Engine size CC	1839 1597	0.1347	1.14
Engine size CC	Less than 1495	0	1.00
accident history	No claims	-0.4814	0.62
accident history	At least 1 claim	0	1.00
age	25- 32	-0.1772	0.84
age	33 -44	-0.257	0.77
age	+45	-0.2868	0.75
age	-24	0	1.00
Production year	Before 1998	0.3302	1.39
Production year	2001- 1998	0.2479	1.28
Production year	2006- 2002	0.1409	1.15

Var name	Category	Estimate	E^estimate
Production year	+2007	0	1.00
ESP	No	0.2475	1.28
ESP	Yes	0	1.00
License years	9-18	0.1958	1.22
License years	4-8	0.181	1.20
License years	-3	0.3229	1.38
License years	+19	0	1.00
collection vehicle	Yes	1.7795	5.93
collection vehicle	No	0	1.00
horsepower	100- 114	0.0299	1.03
horsepower	58-99	0.0234	1.02
horsepower	Less than 57 and more than 115	0	1.00
LDW & FCW	No	0.6155	1.85
LDW & FCW	Yes	0	1.00

The following table includes a list of all the significant explanatory variables:

Source	DF	Chi-Square	Pr > ChiSq
Car Usage	2	431.27	<.0001
No. of seats	2	726.75	<.0001
Engine Size CC	3	182.83	<.0001
accident history	1	768.68	<.0001
age	3	565.92	<.0001
Production Year	3	732.13	<.0001
ESP	1	490.79	<.0001
License Years	3	658.38	<.0001
collection vehicle	1	465.9	<.0001
horsepower	2	9.29	0.0096
LDW & FCW	1	25.97	<.0001

The following table includes criterions for the goodness of fit of the model

Criterion	DF	Value	Value/DF
Deviance	9485	894253.88	94.2809
Scaled Deviance	9485	14108.842	1.4875
Pearson Chi-Square	9485	951919.89	100.3606
Scaled Pearson X2	9485	15018.651	1.5834
Log Likelihood		35650.454	
Full Log Likelihood		35650.454	
AIC (smaller is better)		-71252.909	
AICC (smaller is better)		-71252.782	
BIC (smaller is better)		-71081.071	

Appendix 3:

Results of the generalized linear model for company owned passenger vehicles (automobile)

Based on a Poisson distribution when the target variable is claim frequency.

Analysis Of Maximum Likelihood Parameter Estimates								
Var Name	Category	DF	Estimate	Standard Error	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
Base		1	-4.4071	0.3538	-5.1005	-3.7136	155.16	<.0001
Engine Size CC	>1999	1	-0.5236	0.0284	-0.5792	-0.4679	339.74	<.0001
Engine Size CC	1498 - 1598	1	-0.1538	0.0148	-0.1829	-0.1247	107.45	<.0001
Engine Size CC	- 1599 1998	1	-0.1715	0.0249	-0.2203	-0.1227	47.41	<.0001
Engine Size CC	<1497	0	0.0000	0.0000	0.0000	0.0000	.	.
FCW & LDW	No	1	0.6272	0.3536	-0.0659	1.3203	3.15	0.0761
FCW & LDW	Yes	0	0.0000	0.0000	0.0000	0.0000	.	.

The following table is a conversion of the estimates from a log scale

Var Name	Category	Estimate	e^estimate
Base		-4.4071	0.01219
Engine Size CC	>1999	-0.5236	0.592384
Engine Size CC	1498 -1598	-0.1538	0.857443
Engine Size CC	1998 - 1599	-0.1715	0.8424
Engine Size CC	<1497	0.0000	1
FCW & LDW	No	0.6272	1.872361
FCW & LDW	Yes	0.0000	1

Following is a list of the significant explanatory variables:

Var Name	DF	Chi-Square	Pr > ChiSq
Engine size CC	3	384.28	<.0001
LDW& FCW	1	3.92	0.0477

Results of the Criterions for goodness of fit of the model

Criterion	DF	Value	Value/DF
Deviance	3	1.5484	0.5161
Scaled Deviance	3	1.5484	0.5161
Pearson Chi-Square	3	1.5645	0.5215
Scaled Pearson X2	3	1.5645	0.5215
Log Likelihood		-121558.0298	
Full Log Likelihood		-107691.5795	
AIC (smaller is better)		215393.1590	
AICC (smaller is better)		215423.1590	
BIC (smaller is better)		215393.5562	

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