

University of Wollongong
Research Online

University of Wollongong Thesis Collection
1954-2016

University of Wollongong Thesis Collections

1998

Driving performance on an expressway under fog conditions and its improvement use of a fog warning system

Graham James Brisbane
University of Wollongong

Follow this and additional works at: <https://ro.uow.edu.au/theses>

University of Wollongong

Copyright Warning

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site.

You are reminded of the following: This work is copyright. Apart from any use permitted under the Copyright Act 1968, no part of this work may be reproduced by any process, nor may any other exclusive right be exercised, without the permission of the author. Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material.

Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

Unless otherwise indicated, the views expressed in this thesis are those of the author and do not necessarily represent the views of the University of Wollongong.

Recommended Citation

Brisbane, Graham James, Driving performance on an expressway under fog conditions and its improvement use of a fog warning system, Doctor of Philosophy thesis, Department of Civil, Mining and Environmental Engineering, University of Wollongong, 1998. <https://ro.uow.edu.au/theses/1283>

Research Online is the open access institutional repository for the University of Wollongong. For further information contact the UOW Library: research-pubs@uow.edu.au

NOTE

This online version of the thesis may have different page formatting and pagination from the paper copy held in the University of Wollongong Library.

UNIVERSITY OF WOLLONGONG

COPYRIGHT WARNING

You may print or download ONE copy of this document for the purpose of your own research or study. The University does not authorise you to copy, communicate or otherwise make available electronically to any other person any copyright material contained on this site. You are reminded of the following:

Copyright owners are entitled to take legal action against persons who infringe their copyright. A reproduction of material that is protected by copyright may be a copyright infringement. A court may impose penalties and award damages in relation to offences and infringements relating to copyright material. Higher penalties may apply, and higher damages may be awarded, for offences and infringements involving the conversion of material into digital or electronic form.

**DRIVING PERFORMANCE ON AN
EXPRESSWAY UNDER FOG CONDITIONS
AND ITS IMPROVEMENT BY USE OF A FOG
WARNING SYSTEM**

A Research Thesis Submitted To

The Department Of Civil, Mining And Environmental Engineering Of

The University Of Wollongong

By Graham James Beattie Brisbane

For The Degree Of Doctor Of Philosophy

February 1998

Acknowledgements

There are many people without whose support I would not have been able to complete this work. The list is lengthy and not able to be reproduced in full. However I would like to acknowledge and pay special thanks to the following:

My supervisors Associate Professor Denis Montgomery, Associate Professor Robin Chowdhury and in earlier days, Dr Yasmin Ashaari, without whose encouragement and advice there would have been no papers, no thesis and no Doctorate.

My family who have put up with the many tantrums and excuses to avoid work that occur often in a seven year period.

The Road and Traffic Authority for their support in both time and money and allowing personal research to be carried out on the project.

Andrew Vasiliou for his knowledge and commitment to the project.

Professor Ken Russell and Professor David Griffiths for their invaluable assistance in providing statistical support.

Neil Lamb for his encouragement and support in providing resources and time through work to ensure the project's completion.

Gareth Brisbane for his not inconsiderable support in statistics and computers without which the project would probably have taken another year.

THESIS ABSTRACT

DRIVING PERFORMANCE ON AN EXPRESSWAY UNDER FOG CONDITIONS AND ITS IMPROVEMENT BY USE OF A FOG WARNING SYSTEM

A Research Thesis Submitted To The University Of Wollongong By
Graham James Beattie Brisbane

Problem

Driving in any situation where the available sight distance is less than that appropriate for the travel speed of the vehicle will naturally present a problem when a hazard occurs. A motorist is often forced to take some emergency action to avoid a potential accident.

In most situations on the road there are many visual cues to give motorists an indication of an appropriate travel speed as well as conferring a perception of the speed actually being travelled. These may take the form of longitudinal lines on the road, warning signs or the general roadside landscaping.

However, in fog these cues cease to be visible and motorists commonly drive at speeds well in excess of the available stopping distance, frequently unaware they are doing so having lost the cues that help create the perception of speed. This problem is obviously

accentuated on higher speed roads such as divided carriageways where the only cues are to tell drivers they are on a high speed road and no apparent threats are available to prompt a lowering of speed.

To address this there have been many attempts to provide Driver Aid Systems to warn motorists of the hazards they face. One such system was provided on the Waterfall - Bulli section of the F6 in 1974. However the continued occurrences of multiple vehicle accidents culminating in a 66 vehicle event in 1986 suggested that the system may no longer be as effective as was originally intended. (No research was ever undertaken to assess whether the system actually met its objectives although this was unlikely, given the nature of the fog in the Bulli Tops area, the way the system operated and the fact a number of features of the original proposal were never actually installed).

Proposed Solution

Rather than simply replace a system which was no longer maintainable or visible in bad fog conditions with a similar system, a research project was proposed to examine changes in technology which had become available since the 70s and to determine whether these could be used to develop a workable system.

The new solution proposed a dynamic, site independent system which could monitor both the fog and the motorists and provide real-time advice to the motorist if vehicle speed was inappropriate to the conditions.

Research

Before developing a new system based purely on the theory, a trial site was selected and research undertaken to assess the effectiveness of the arrangement outlined.

Over a three year period studies were undertaken on the characteristics of vehicles when travelling in various fog visibilities ranging from 250 m to under 50 m.

The research was undertaken in three discrete stages:

April - December, 1992, - characteristics of vehicles unaffected by any sign display

January - April, 1993, - evaluation of the 1974 sign system modified to provide some limited dynamic information

May, 1993 - December, 1994, - evaluation of an improved sign arrangement with full dynamic information provided on fog and speed where appropriate.

The results showed that an independent dynamic sign display could be used which would be effective in modifying vehicle speed characteristics, particularly at times when the speeds were highest without the use of such a sign.

Outcome

As a result of the results of this research project, the RTA proceeded with the design and construction of a new Driver Aid System for the F6 Waterfall-Bulli Freeway. The work involved a \$3.5m contract with Telstra and was commissioned in 1996.

A number a factors in the design were directly attributable to the findings of the research including:

- the use of dynamic independent sites
- incorporation into each site of fog detection equipment, speed detection and warning signs capable of displaying appropriate warning messages for individual motorists relative to the situation
- location of the appropriate areas for the system to be located
- use of flashing warning lights in association with each sign display

Papers Published

The following papers on this research have been published at various major

Conferences:

BRISBANE G.J.B. (1992) *Driver Behaviour During Periods of Restricted Visibility*. 16th ARRB Conference, Perth, Australia. November, 1992. Proceedings Part 4, pps 313-329.

BRISBANE G.J.B. (1993) *Driver Response to Fog Conditions: An Intelligent Approach*. Pacific Rim Transtech Conference, American Society of Civil Engineers, Seattle, USA. July 1993. Proceedings Volume 1, pps 347-353.

LEVERENZ A.J & BRISBANE G.J.B. (1993) '*Proposed Fog Detection and Speed Advisory System*.' 26th International Symposium Automotive Technology and Automation (ISATA), Aachen, Germany. September, 1993. Proceedings from Dedicated Conference on Advanced Transport Telematics/Intelligent Vehicle Highway Systems - Towards Development And Implementation. Pps nk.

BRISBANE G.J.B. (1994) *Speed modification - Intelligent signs for the future?*.

Proceedings 17th ARRB Conference, Gold Coast, Australia. August 1994. Proceedings Part 5, pps 149-163.

BRISBANE G.J.B. (1996) *Driving in Fog - Putting Research into Practice*.

Proceedings 18th ARRB Conference, Christchurch, New Zealand. September 1996. Proceedings Volume 5, pps 283-298.

**DRIVING PERFORMANCE ON AN EXPRESSWAY
UNDER FOG CONDITIONS AND ITS IMPROVEMENT
BY USE OF A FOG WARNING SYSTEM**

**A CASE STUDY OF THE F6 SOUTHERN EXPRESSWAY AT
BULLI TOPS.**

CONTENTS

1 Introduction	1
1.1 Background	1
1.2 Aims	3
1.3 Scope of Study	4
2 Background	7
2.1 Accidents	7
2.1.1 Accidents in Fog	7
2.1.2 F6 Fog Accidents	9
2.2 Fog Formation	15
2.3 Measurement of Visibility	19
2.3.1 General	19
2.3.2 Daytime	23
2.3.3 Night-time	30

2.3.4 Daytime with Lights-on	33
2.4 Visibility in Fog	34
2.5 F6 - Southern Expressway	38
2.6 Driving Performance in Restricted Visibility	43
2.6.1 Speed	43
2.6.2 Headway	49
2.7 Visibility Measuring Devices	52
2.7.1 General Background	52
2.7.2 Transmissometers	53
2.7.3 Scatter Devices	54
2.8 Driver Aid Systems	57
3 Analysis Arrangements	62
3.1 Experimental Proposal	62
3.1.1 Proposal	62
3.1.2 Variables	63
i) Visibility	64
ii) Speed	67
iii) Headways	68
iv) Vehicle Length	71
v) Travel Lane	71
vi) Time of Day	72

vii) Day of Week	72
viii) Wet and Dry Conditions	73
3.2 Site Selection	73
3.2.1 Assessment Criteria	73
3.2.2 Site Analysis	78
i) Fog Frequency	78
ii) Level of Service	82
iii) Lane Discipline	82
iv) Accessibility	83
v) Freedom from Outside Influence	83
vi) Future Options	83
vii) Maximised Traffic Volumes	83
3.2.3 Selection	84
3.3 Equipment	85
3.3.1 Visibility Measurement Devices	85
3.3.2 Speed Measurement Devices	89
i) Options	89
ii) Selection	93
3.4 Stage 2 Proposal	96
3.5 Stage 3 Proposal	97
3.5.1 Type of sign	98

3.5.2 Letter Size and Colouring	99
3.5.3 Variable Vs Fixed Message	101
3.6 Final Sign Development	102
3.7 Costing	103
4 Normal Speed Characteristics	105
4.1 Data Arrangements	105
4.1.1 Fog Data (*.FOG)	106
4.1.2 General Vehicle Data in Fog (*.CMB)	108
4.1.3 Normal Speed Characteristics (*.CNT)	109
4.2 Data Collection in Fog	112
4.3 Data Aggregation	115
4.3.1 Data Selected	115
4.3.2 Outputs	116
i) Average Speeds and 85th Percentiles	117
ii) Coefficient of Variation	117
iii) Free Speed Comparisons	119
4.4 Results	124
4.4.1 Speed Comparisons	124
4.4.2 Headways	152
5 Analysis of Vehicle Characteristics with No Sign Display	154
5.1 Variables	154

5.1.1 Speed Analysis	154
5.1.2 Headways	155
5.2 Speed Analysis	156
5.2.1 Methodology	156
5.2.2 Regression Analysis	156
5.3 Comments on Speed Results	159
5.3.1 Visibilities 250 - 1000 m	159
5.3.2 Visibilities below 250 m	160
i) All Conditions	160
ii) Speed Variations	162
iii) Night Vs Day	164
iv) Dawn and Dusk Vs Day	165
v) Day of week	166
vi) Rain	168
vii) Heavy Vehicles	170
5.4 Headways	173
5.4.1 Results	174
i) Daytime	177
ii) Dusk	179
iii) Night	180
iv) Dawn	180

5.5 Conclusions	181
5.5.1 Mean and 85th Percentiles	181
5.5.2 Coefficient of Variation	185
5.5.3 Headways	186
6 Existing Driver Aid System	188
6.1 Introduction	188
6.2 Stage 2 Proposals	191
6.3 Results	191
6.3.1 Visibility	191
6.3.2 Vehicle Data	193
6.4 Speeds	193
6.4.1 Results	193
6.4.2 Analysis	196
6.5 Headways	201
6.6 Summary	204
7 New Sign Characteristics	206
7.1 Introduction	206
7.1.1 Sign Construction	206
7.1.2 Software	208
7.2 Site Changes	216
7.3 Sign Effectiveness	219

7.3.1 Speed Modification Trial	219
7.3.2 Modification Results	220
7.4 Results of Vehicle Speed and Headway Changes in Fog when using New Sign	221
7.4.1 Data Collection	221
7.4.2 Visibility	224
7.4.3 Speed At Central Site	226
7.4.4 Speed Through Test Length	236
7.4.5 Headways	242
7.5 Summary	250
8 Summary and Conclusions	252
8.1 Project Summary	252
8.2 Results Summary	254
8.2.1 Accidents	254
8.2.2 Visibility	255
8.2.3 Trial Details	256
8.2.4 Speed And Headways In Fog Conditions Without Modification	257
8.2.5 Effectiveness of Existing System	261
8.2.6 Speed And Headways Using Dynamic Warning Sign	263
8.3 Main Conclusion	265

8.4 Replacement System	267
8.5 Future Work	271

BIBLIOGRAPHY

Bibliography	273
--------------	-----

APPENDICES

Appendix A Usage of F6 Driver Aid System 1985-1990	281
Appendix B Analysis of Accidents In Fog And All Other Conditions In The Vicinity Of Bulli Tops	289
Appendix C Analysis of Deceleration Sight Distances	297
Appendix D Speed Correlation	302
Appendix E Level of Service	310
Appendix F Statistical Analysis Inputs and Outputs	311
Appendix G Catalogue of Known Driver Aid Systems	318
Appendix H Site Plan	324
Appendix I Data Files	325

LIST OF FIGURES

Fig 2.01 Comparison Of Accidents In Clear & Fog Conditions 1987 - 1990	10
Fig 2.02 Comparison Of Vehicles In Accidents In Clear & Fog Conditions, 1987 - 1990	11
Fig 2.03 Percentage Of Vehicles In Accidents By Time Of Day 1987 - 1990	14
Fig 2.04 Upslope Fog Caused By Escarpment Forcing Up Air Flow	18
Fig 2.05 Average Annual Hours Of Fog At Site 64N By Time Of Day	19
Fig 2.06 Comparison Of Vehicle Observation With Distance (after Behrendt, 1978)	21
Fig 2.07 Comparison Of Approaching Vehicle With Headlights On And Departing Vehicle With No Lights (MOR 130 m)	22
Fig 2.08 Comparison Of Approaching Truck And Departing Car (MOR 130 m)	23
Fig 2.09 Veiling Luminance Due To Headlight Backscatter (Allen et al 1977)	26
Fig 2.10 Scattering Function (Spencer 1960)	26
Fig 2.11 Extinction Coefficient From Various Atmospheric Conditions (Allen et al, 1977)	30
Fig 2.12 Variation Of Visual Range With Extinction Coefficient (White & Jeffery, 1980)	31
Fig 2.13 Relation Between Intensity Of Light Source And Visibility Distance In Various Daylight Fogs (Moore & Cooper, 1972)	32
Fig 2.14 Control Sites On Existing Driver Aid System	39

Fig 2.15 Advisory Message Sign On F6 (DMR, 1975)	40
Fig 2.16 Mean Speed & Visibility In Fog M4 Winter 75/76 (Sumner et al, 1976)	45
Fig 2.17 Close-up Of Oregon Advisory Sign Installation (George et al, 1979)	58
Fig 2.18 M25 Trial Sign (Traffic Engineering & Control, 1991)	60
Fig 2.19 European Style Fog Warning Sign	61
Fig 3.01 Trial Site	63
Fig 3.02 Visibility - 0800-1900, 26 March 1992	64
Fig 3.03 Visibility - 1230-1330, 13 September 1993	65
Fig 3.04 Traffic Lane Proportions Through Test Site	70
Fig 3.05 Stopping Distances For Different Countries (after Hawkins 1984)	76
Fig 3.06 Deceleration Sight Distance - Daytime	77
Fig 3.07 Fog Occurrence At Northbound Sites: 1985 - 1990	79
Fig 3.08 Monthly Fog Occurrences (Days) At Site 64N: 1985-1990	80
Fig 3.09 Hours Of Fog Occurrences Per Month At Site 64N 1985 - 1990	80
Fig 3.10 Physical Layout Of FD12	86
Fig 3.11 FD 12 Relative To Roadway	88
Fig 3.12 Detector Siting	89
Fig 3.13 Loop Layout	94
Fig 3.14 Traffic Signal Control Box With Equipment	95

Fig 3.15 Schematic Layout Showing Display Options for Each Panel (Brisbane 1994)	102
Fig 4.01 Speed Vs Visibility For Cars - Visibility 251 - 1000m	126
Fig 4.02 Speed Vs Visibility for Cars During Day In Slow Lane- Vis 251 - 1000m	127
Fig 4.03 Speed Vs Visibility For Cars At Night In Slow Lane Vis 251:1000m	128
Fig 4.04 Speed Vs Visibility For Both Lanes In All Conditions - Vis <250m	129
Fig 4.05 Speed Vs Visibility For All Cars In Fast Lane - Vis <250m	130
Fig 4.06 Speed Vs Visibility For All Cars In Slow Lane - Vis <250m	131
Fig 4.07 Speed Vs Visibility For Cars In Fast Lane During Day Vis <250m	132
Fig 4.08 Speed Vs Visibility For Cars In Slow Lane During Day Vis <250m	133
Fig 4.09 Speed Vs Visibility For Cars In Fast Lane At Night Vis <250m	134
Fig 4.10 Speed Vs Visibility For Cars In Slow Lane At Night Vis <250m	135
Fig 4.11 Speed Vs Visibility For Cars In Fast Lane At Dawn Vis <250m	136
Fig 4.12 Speed Vs Visibility For Cars In Slow Lane At Dawn Vis <250m	137
Fig 4.13 Speed Vs Visibility For Cars In Fast Lane At Dusk Vis < 250m	138
Fig 4.14 Speed Vs Visibility For Cars In Slow Lane At Dusk Vis <250m	139
Fig 4.15 Speed Vs Visibility For Cars In Fast Lane In Dry Vis <250m	140
Fig 4.16 Speed Vs Visibility For Cars In Slow Lane In Dry Vis <250m	141
Fig 4.17 Speed Vs Visibility For Cars In Fast Lane In Rain Vis <250m	142
Fig 4.18 Speed Vs Visibility For Cars In Slow Lane In Rain Vis <250m	143

Fig 4.19 Speed Vs Visibility For Cars In Fast Lane On Weekdays Vis <250m	144
Fig 4.20 Speed Vs Visibility For Cars In Slow Lane On Weekdays Vis <250m	145
Fig 4.21 Speed Vs Visibility For Cars In Fast Lane On Saturdays Vis <250m	146
Fig 4.22 Speed Vs Visibility For Cars In Slow Lane On Saturdays Vis <250m	147
Fig 4.23 Speed Vs Visibility For Cars In Fast Lane On Sundays Vis <250m	148
Fig 4.24 Speed Vs Visibility For Cars In Slow Lane On Sundays Vis <250m	149
Fig 4.25 Speed Vs Visibility For Heavy Vehicles In Fast Lane Vis <250m	150
Fig 4.26 Speed Vs Visibility For Heavy Vehicles In Slow Lane Vis <250m	151
Fig 5.01 Speed Vs Visibility For Cars In Slow Lane During Day & Night - Visibility 251 - 1000m	160
Fig 5.02 Average & 85th Percentile Speeds For All Conditions	161
Fig 5.03 Coefficient Of Variation For All Conditions	162
Fig 5.04 Coefficient Of Variation In Slow Lane By Time Of Day	163
Fig 5.05 Coefficient Of Variation In Fast Lane By Time Of Day	164
Fig 5.06 Speed Differences By Lane For Night & Day Conditions	165
Fig 5.07 Speed Differences In Slow Lane For Dawn, Dusk & Day Conditions	166
Fig 5.08 Speed Differences For Sundays & Weekdays	167

Fig 5.09 Speed Differences For Saturdays & Weekdays	167
Fig 5.10 Coefficient Of Variation During Week & Weekends	168
Fig 5.11 Speed Reduction In Dry & Rain Conditions	169
Fig 5.12 Coefficient Of Variation In Dry & Wet Conditions	170
Fig 5.13 Average & 85th Percentiles For Heavy Vehicles In Slow Lane All Conditions	171
Fig 5.14 Coefficient Of Variation For Heavy Vehicles In Slow Lane All Conditions	172
Fig 5.15 Headway Distribution By Time Of Day - Vis < 150m	174
Fig 5.16 Comparison Of Headway Distributions In slow lane- Day	177
Fig 5.17 Comparison Of Headway Distributions In slow lane- Dusk	179
Fig 5.18 Comparison Of Headway Distributions In Slow Lane- Night	180
Fig 5.19 Comparison Of Headway Distributions In Slow Lane - Dawn	181
Fig 5.20 Increasing Coefficient Of Variations	185
Fig 5.21 Coefficient Of Variations Without Change	186
Fig 6.01 Original Fibre-optic Sign From 130m With MOR 130m	190
Fig 6.02 Original Fibre-optic Sign From 70 m With MOR 130m	190
Fig 6.03 Speed Vs Visibility During Day VIS <250 m (7577 Cars)	194
Fig 6.04 Speed Vs Visibility During Dusk VIS <250 m (448 Cars)	194
Fig 6.05 Speed Vs Visibility At Night VIS <250 m (3498 Cars)	195
Fig 6.06 Speed Vs Visibility At Dawn VIS <250 m (822 Cars)	195

Fig 6.07 Coefficient Of Variation When Using Existing Sign (Slow Lane)	196
Fig 6.08 Speed Differences During Day When Using Existing Sign	98
Fig 6.09 Speed Differences At Dusk When Using Existing Sign	199
Fig 6.10 Speed Differences At Night When Using Existing Sign	200
Fig 6.11 Speed Differences At Dawn When Using Existing Sign	200
Fig 6.12 Comparison Of Headway Distributions In Slow Lane- Night	203
Fig 6.13 Comparison Of Headway Distributions In Slow Lane- Dawn	203
Fig 7.01 Demonstration Of Sign At RTA Granville Workshops (From 150 m)	207
Fig 7.02 Example Of Warning Circle In Operation (From 150 m)	208
Fig 7.03 Maximum Differential Velocities	09
Fig 7.04 Relationship Of high & Low Speed Vehicles With Maximum Differential Speeds - Slow Lane In Day	210
Fig 7.05 Display Of 'YOUR SPEED' (50 m)	211
Fig 7.06 Display Of 'SAFER SPEED' (20 m)	212
Fig 7.07 Flowchart For Selection Of Messages Generated By Site Computer Based On Site Conditions	214
Fig 7.08 Insertion Of New Message Into Sign Queue For Display	215
Fig 7.09 Sign Erection	217
Fig 7.10 Sign Warning Motorists Of Speeding Behaviour (Brisbane, 1994)	219
Fig 7.11 Q. Why Use A Variable Message Sign?	220
A. Because It's there ??? (Brisbane, 1995)	

Fig 7.12 New Fibre-optic Sign From 130 m With MOR 80m	222
Fig 7.13 New Fibre-optic Sign From 70 m With MOR 80m	222
Fig 7.14 New Fibre-optic Sign From 30 m With MOR 80m	223
Fig 7.15 Speed Vs Visibility During Day With New Sign Vis <250 m (16678 Cars)	226
Fig 7.16 Speed Vs Visibility During Night With New Sign Vis <250 m (6460 Cars)	227
Fig 7.17 Coefficient Of Variation With New Sign (Slow Lane)	227
Fig 7.18 Comparison Of Average Speeds With and Without New Sign During Day Vis <250m	228
Fig 7.19 Average Speeds For Heavy Vehicles With And Without New Sign In Slow Lane Vis <250m	229
Fig 7.20 Comparison Of Average Speeds With And Without New Sign At Night Vis <250m	229
Fig 7.21 Coefficient Of Variation Comparison In Day (Slow Lane)	230
Fig 7.21 Coefficient Of Variation Comparison In Day (Slow Lane)	231
Fig 7.23 Distribution Of Time Of Day Samples	232
Fig 7.24 Distribution Of Day Of Week Samples	232
Fig 7.25 Distribution Of Samples By Visibility (Mar 1992 - Dec 1994)	235
Fig 7.26 Speed Changes At Site A - Slow Lane	237
Fig 7.27 Speed Changes At Site A - Fast Lane	238
Fig 7.28 Speed Changes Through Sites During Day	241

Fig 7.29 Speed Changes Through Sites During Night	241
Fig 7.30 Headway With & Without Sign (Site C)	242
Fig 7.31 Headways With & Without Sign At Night (Site C)	244
Fig 7.32 Headways With & Without Sign At Dawn (Site C)	245
Fig 7.33 Headways With & Without Sign At Dusk (Site C)	245
Fig 7.34 Headways With & Without Sign At Night (Site D)	249
Fig 7.35 Headways With & Without Sign At Dusk (Site E)	250
Fig 8.01 New Sign In Operation	268
Fig 8.02 New Sign Providing Advance Warning Of Fog	269
Fig 8.03 Mobile Warning Sign In Operation	271

APPENDICES

Fig A.1 Fog Usage Of F6 Southbound Sites: 1985 - 1990	283
Fig A.2 Fog Usage Of F6 Northbound Sites: 1985 - 1990	284
Fig A.3 Fog Usage Of Other Sites: 1985 1990	285
Fig A.4 Days Usage At Site 64N: 1985 - 1990	286
Fig A.5 Monthly (Hours) Usage At Site 64N: 1985 - 1990	287
Fig A.6 Hourly Usage At Site 64N: 1985 - 1990	288
Fig B.1 Accident Occurrences By Units Numbers Involved Per Accident	294
Fig B.2 Unit Involvement By Units Numbers Involved Per Accident	294
Fig B.3 Percentage Of Vehicle Accidents By Time Of Day	296

Fig B.4 Percentage Of Units In Fog Accidents By Time Of Day	296
Fig D.1 Scatter Plot & Linear Regression Line For Loop 3 - 5th August 1992	303
Fig D.2 Scatter Plot & Linear Regression Line For All Loops - 5th August 1992	303
Fig D.3 Scatter Plot Of Speed Difference Against Loop Speeds	306
Fig D.4 Scatter Plot & Linear Regression Line For All Loops - 27 November 1993	307

LIST OF TABLES

Table 2.01 Accident Severity: 1987 - 1990	12
Table 2.02 Vehicles Involved In Accidents On F6/Bulli Tops By Time Of Day: 1987 - 1990	13
Table 2.03 Relationship Between Standard Visual Ranges & Actual Visibility Distances In Fog (Behrendt, 1978)	20
Table 2.04 Decrease In Lateral Vision With Speed (after Etienne 1991)	37
Table 3.01 Kepner-Tregoe Analysis For Site Selection	84
Table 3.02 Kepner-Tregoe Analysis For Speed Detection Selection	93
Table 3.03 Character Heights For Light Emitting Signs	100
Table 4.01 Sample Output From 260392.FOG File	107
Table 4.02 Sample Output From 050492.CMB File	108
Table 4.03 Sample Output from 010492.CNT File	110
Table 4.04 Selected Days For Normal Behaviour	111
Table 4.05 Average Speeds For Days Of Week & Time Of Day	111
Table 4.06 Statistical Results For Normal Speed Characteristics	112
Table 4.07 Minimum MOR For 16th March - 31st December 1992	113
Table 4.08 Comparison Of Visibility With Precipitation	115
Table 4.09 Typical Sorted Data	116
Table 4.10 Coefficient O Variation Trough Site By Time Of Day	118

Table 4.11 Comparison Of Speeds & 85th Percentiles For Lead Vehicles & All Vehicles During Daylight	122
Table 4.12 Comparison Of Speeds & 85th Percentiles For Lead Vehicles & all Vehicles During Night	123
Table 4.13 Summary Of Results	125
Table 4.14 Speed Vs Visibility For Cars - Vis 251 - 1000m	126
Table 4.15 Speed Vs Visibility For Cars During Day In Slow Lane- Vis 251:1000m	127
Table 4.16 Speed Vs Visibility For Cars At Night In Slow Lane Vis 251:1000m	128
Table 4.17 Speed Vs Visibility For Both Lanes In All Conditions - Vis <250m	129
Table 4.18 Speed Vs Visibility For Cars In Fast Lane - Vis <250m	130
Table 4.19 Speed Vs Visibility For Cars In Slow Lane - Vis <250m	131
Table 4.20 Speed Vs Visibility For Cars In Fast Lane During Day Vis <250m	132
Table 4.21 Speed Vs Visibility For Cars In Slow Lane During Day Vis <250m	133
Table 4.22 Speed Vs Visibility For Cars In Fast Lane At Night Vis <250m	134
Table 4.23 Speed Vs Visibility For Cars In Slow Lane At Night Vis <250m	135
Table 4.24 Speed Vs Visibility For Cars In Fast Lane At Dawn Vis <250m	136
Table 4.25 Speed Vs Visibility For Cars In Slow Lane At Dawn Vis <250m	137
Table 4.26 Speed Vs Visibility For Cars In Fast Lane At Dusk Vis <250m	138
Table 4.27 Speed Vs Visibility For Cars In Slow Lane At Dusk Vis <250m	139
Table 4.28 Speed Vs Visibility For Cars In Fast Lane In Dry Vis <250m	140
Table 4.29 Speed Vs Visibility For Cars In Slow Lane In Dry Vis <250m	141

Table 4.30	Speed Vs Visibility For Cars In Fast Lane In Rain Vis <250m	142
Table 4.31	Speed Vs Visibility For Cars In Slow Lane In Rain Vis <250m	143
Table 4.32	Speed Vs Visibility For Cars In Fast Lane On Weekdays Vis <250m	144
Table 4.33	Speed Vs Visibility For Cars In Slow Lane On Weekdays Vis <250m	145
Table 4.34	Speed Vs Visibility For Cars In Fast Lane On Saturdays Vis <250m	146
Table 4.35	Speed Vs Visibility For Cars In Slow Lane On Saturdays Vis <250m	147
Table 4.36	Speed Vs Visibility For Cars In Fast Lane On Sundays Vis <250m	148
Table 4.37	Speed Vs Visibility For Cars In Slow Lane On Sundays Vis <250m	149
Table 4.38	Speed Vs Visibility For Heavy Vehicles In Fast Lane Vis <250m	150
Table 4.39	Speed Vs Visibility For Heavy Vehicles In Slow Lane Vis <250m	151
Table 5.01	Average Speed Differentials For Variables (Slow Lane)	157
Table 5.02	Average Speed Differentials For Variables (Fast Lane)	158
Table 5.03	Kolmogorov-Smirnov Test On Cumulative Distributions In Fog By Time Of Day	175
Table 5.04	Kolmogorov-Smirnov Test On Cumulative Distributions With Normal & Fog Conditions	176
Table 5.05	Kolmogorov-Smirnov Test On Cumulative Distributions With Fog Conditions Below 150m During Day	178
Table 6.01	Minimum MOR For 17th January -23rd April 1993	192
Table 6.02	Kolmogorov-Smirnov Test On Cumulative Distributions With No Sign & Existing Sign	202

Table 7.01 Comparison Of Normal Speeds In Clear Conditions 1992/1993	216
Table 7.02 Comparison Of Normal Speeds In Clear Conditions 1992/1994	218
Table 7.03 Minimum MOR For 21st July 1993 -31st December 1994	225
Table 7.04 Speed Changes At Site C - Slow Lane	233
Table 7.05 Speed Changes At Site C - Fast Lane	234
Table 7.06 Speed Changes At Site A	236
Table 7.07 Speed Changes At Site D	239
Table 7.08 Speed Changes At Site E	240
Table 7.09 Kolmogorov-Smirnov Test On Cumulative Distributions With No Sign & New Sign At Site C	243
Table 7.10 Kolmogorov-Smirnov Test On Cumulative Distributions With No Sign & New Sign At Site D	247
Table 7.11 Kolmogorov-Smirnov Test On Cumulative Distributions With No Sign & New Sign At Site E	248

APPENDICES

Table A.1 Fog Usage Of F6 Southbound Sites: 1985 - 1990	283
Table A.2 Fog Usage Of F6 Northbound Sites: 1985 - 1990	284
Table A.3 Fog Usage Of Other Sites: 1985 1990	285
Table A.4 Days Usage At Site 64N: 1985 - 1990	286
Table A.5 Monthly (Hours) Usage At Site 64N: 1985 - 1990	287
Table A.6 Hourly Usage At Site 64N: 1985 - 1990	288
Table B.1 Accidents In Fog Around Bulli Tops 1987-1990 (From RTA Accident Data Base)	289
Table B.2 Accidents By Number Of Units In Accident	293
Table B.3 Accident Severity	295
Table B.4 Accidents By Time Of Day	295
Table C.1 Stopping Distances	298
Table C.2 Deceleration Sight Distances	299
Table C.3 Maximum Differential Velocities For MOR	301
Table D.1 Results Of Speeds By Radar & Loops Taken 5/8/92	304
Table D.2 Correlation & Standard Deviations Of Errors - 5/8/92	305
Table D.3 Speeds Loops 1 - 5 By Radar & Loops Taken 27/11/93	308
Table D.4 Speeds Loops 6 - 10 By Radar & Loops Taken 27/11/93	309
Table D.5 Correlation & Standard Deviations Of Errors 27/11/93	309