

Structural Road Accident Models

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Structural Road Accident Models

The International DRAG Family

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INVESTOR IN PEOPLE

*“ Of making many books there is no end;
and much study is a weariness of the flesh. ”*

Ecclesiasticus, 12, 12.

To : André Viel
John Lawson
Claude Dussault
Michel Houée

*Alexander von Humboldt-Stiftung
Centre National de la Recherche Scientifique*

willing to take research funding risks,

Frank Haight

willing to wait for a manuscript of 1984,

sine quibus non.

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FOREWORD: ON A MANUSCRIPT OF 1984

Sylvain Lassarre

I became aware of the birth of the research stream presented in this book almost at the same time as Frank Haight, Editor-in-chief of *Accident Analysis and Prevention*, received the submitted manuscript describing the ancestor model, now called DRAG-1, in October¹ 1984.

That 220-page paper, written in French (Gaudry, 1984), formulated the road safety problem as a simultaneous equations model of demand for road use, safety and speed but, in the absence of data on speed, retained the reduced form equations of the system. These equations explained safety outcomes (victims injured and killed) through a multi-layer decomposition of the number of victims by category among exposure, frequency and severity effects. This innovative decomposition made it possible to test generally for the presence of risk substitution among the different dimensions of road safety, such as accidents of different categories and their severity. Substitution might occur if changes in some explanatory factor led to, say decreases in fatal accidents associated with increases in other accident severity categories, perhaps combined with partially offsetting changes in the severity (morbidity and mortality rates) of each accident category. *Patterns* of risk substitution explored in the original paper are analyzed further in this book, with the additional benefit of international comparisons, some of which are derived from second generation models obtained after painstaking improvements to first-cut data bases.

At the same time, the first use of Box-Cox transformations in road safety analysis made it possible for instance to test for, and in this case to reject, the proportionality of accidents to vehicle kilometrage and to remove many uncertainties associated with fixed-form results, along the lines previously demonstrated by Gaudry and Wills (1978).

In addition, the use of a multivariate monthly time series specification—with many interesting

¹ His letter of acknowledgement was received by Marc Gaudry, then on a sabbatical stay at the University of Karlsruhe, in November 1984.

graphs demonstrating the great variability of many series on a monthly basis—favoured the joint inclusion of variables belonging to different classes of determinants and yielded a number of interesting results linking for instance the state of the economy, fuel prices, automobile insurance regimes and various laws and regulations to safety outcomes *by category*. The paper also ventured unusual and challenging results and conjectures on the role of alcohol, hours worked and pregnancy that pointed to needed research using other data sets, including less aggregate data. Such models, some based on count and discrete data, are found here.

In his letter of October 2, 1985, accepting the paper for publication, Frank Haight stated: « Taking into consideration the length of the paper, which may run to as much as 150 printed pages, it may be necessary to publish it by sections in consecutive issues of the journal. » But it had to be translated first. And Marc Gaudry, named for a second time director of the Centre for Research on Transportation (CRT) of the University of Montreal, was immediately busy securing a large collective research grant for CRT and became somewhat overtaxed: he then failed to provide the necessary English translation of his manuscript and concentrated instead on algorithmic developments for the TRIO statistical software used by the growing number of colleagues, such as Ulrich Blum in Germany and Lasse Fridstrøm in Norway, who had almost immediately (well before 1989) started developing DRAG-type approaches of their own. The result of these diffusion efforts presented in this book allow, perhaps for the first time, a multinational comparison of road safety results obtained within similarly structured multivariate approaches.

This truly ambitious international activity, carried out within an active research network, has prompted great interest from the safety research and policy community, as indicated for instance by state-of-the-art analyses of DRAG network methodology and output by international committees (OECD, 1997; COST 329, 1999). But it is this book that provides the first thorough overview of the current state of the models (all of which being the object of ongoing work towards improved versions), of the estimation methods, as well as of the detailed results for the six models at the core of the network. The book also reports on other innovative models based on the DRAG-type structure and estimated with Box-Cox transformations on variables.

Part I. I have selected one feature drawn from each of the six models found in the first part of the book, both to whet the reader's appetite and to point to future research needs:

- Ch.1: a set of previously unpublished results on the shape of the curve linking (aggregate) alcohol consumption and accident frequency and severity by category raise the following question: would other less aggregate data sets exhibit such J-shaped effects if one looked for them instead of assuming monotonic shapes in tests? These results, determined within the multivariate structure of the DRAG-1 model, warrant urgent further examination;

- Ch. 2: the second generation model DRAG-2, developed by the Quebec Automobile Insurance Board (SAAQ) to make official analyses and policy evaluations—no other jurisdiction has an official model used, maintained and developed in such a continuous fashion—, produces forecasts of road fatalities using in particular an asymmetric (quasi-quadratic) relationship between vehicle kilometrage and fatal accident frequency and severity. This interesting device gets around the lack of observations on congestion;
- Ch. 3: the SNUS-2.5 model for Germany includes an original multimoment analysis of the empirical trade-offs among the first three moments of accident frequencies, with amazing similarities between Quebec and Germany. This occurs despite the fact—itself of certain interest for the understanding of safety behavior—that the frequency distributions of fatal accidents of these two jurisdictions are strongly asymmetric in opposite directions;
- Ch. 4: TRULS-1 results based on an extraordinary pooling of time series and cross sectional data for Norway (5016 observations!) include numerous interesting findings, for instance on the role of infrastructure or of pregnancy, the latter based on a comparison of subsets of drivers. These latter results have given rise to a multidisciplinary Norwegian research effort, starting in early 2000, to probe the issue further through an analysis of all road accidents by women in Norway over more than two decades;
- Ch. 5: the results for the DRAG-Stockholm-2 model for the County of Stockholm provide evidence of the countereffectiveness of certain safety measures, as well as complementary evidence on the unexpected effects of alcohol and pregnancy found in Ch. 1 and 4, respectively. A model for the City of Stockholm is under development;
- Ch. 6: the TAG-1 model for France, the only time series model presented that includes a speed equation, shows how speed on the intercity road network responds to various determinants, such as fuel prices;
- Ch. 7: the youngest of the models, TRACS-CA for California, contains explorations of quadratic effects for a number of variables that raise many unanswered questions.

The reader will find in Ch. 8 a comparison indicating closeness among many national results and pointing to new policy options: for instance, the important role of fuel prices as leading safety control variables, a result that should count as one of the important findings of this book.

Part II. The second section of the book does not contain complete regional models. However, it presents a number of safety research innovations. I would note the following:

- Ch. 9: in a simultaneous cross sectional analysis of safety outcomes and speed, the authors introduce Knight's famous distinction between (calculable) risk and (not calculable) uncertainty to test and account for functionally identifiable (non random) gaps between actual (realized) and controlled risk (represented by chosen speed). They also introduce a measure of expected risk based on random utility theory and isolate many fine effects of road design on safety and speed, with due regard to nonlinearities of the various

responses;

- Ch. 10: the analysis by type of road network presented for France, with Box-Cox transforms used on a subset of explanatory variables of a vector autoregressive (VAR) model, allows for a clear rejection of the popular linear VAR form and generally supports logarithmic (constant elasticity) forms but contains some evidence of finer (non constant) elasticities—implying the presence of saturation effects over time—for some individual variables.

Part III. Exacting researchers requiring complete descriptions of estimation methods and statistics obtained for the various models presented will be well served by the third part of the book, extracted from TRIO software documentation (Gaudry *et al.*, 1993). Also, Appendix 1 provides links to web sites presenting downloadable TRIO-generated TABLEX tables of results for those seeking to make comparisons with their own results, or simply wishing to analyze, for any equation, the exact elasticities for all variables of a model or, for any variable, the sign patterns found across all equations of a model. Readers should everywhere appreciate the use of elasticities to report on results for all variables, including qualitative (dummy) variables. One wishes that such standardized measures were used more frequently in order to empower readers to decide easily on the reasonableness of results.

Despite this helpful elasticity-based presentation, the research and policy communities still have much left to digest: to quote Frank Haight again, the heroic efforts made here “go beyond the well-known formula devised by Reuben Smeed over fifty years ago and challenge us all to understand and apply the models reported on”. As this occurs, I have no doubt that the approach to road safety documented in this book, with its emphasis on multiple-layer multivariate flexible-form specifications, will lead to an even larger family of DRAG-inspired models.

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RESEARCH SUPPORT, AND MORE

Marc Gaudry

Sylvain Lassarre

RESEARCH AND ITS IMPLEMENTATION

The long road to new states of the art. It is not possible to finance public interest research without backing from and some risk taking on the part of funding agencies, public agencies in particular. Indeed, some risk taking is necessarily involved in new methodologies producing new results, perhaps including unpopular results; also, significant amounts of money are necessary if modelling has to reach beyond the production of academically significant and publishable results to yield realistic and credible results, always including forecasts. This book is no exception.

Mixing colours. Although the Quebec Automobile Insurance Board (originally called RAAQ, now known as SAAQ¹) provided the original and principal funding of the Quebec models presented in this book, the research network itself could not have developed without direct contributions of network partners and their government agencies to the construction of their own models and to the sustainance of the TRIO software used by all. In addition, general purpose funding of our linkage activities provided continuity and greatly helped, notably for the joint international supervision of doctoral work. So we provide in these pages a few words about the intertwining of funding streams, in case minor lessons might be drawn by readers about the helter-skelter research and policy process, and to give some well deserved thanks².

¹ Established by the Quebec government since March 1, 1978, as a state-run monopoly insurance enterprise for bodily damage claims arising from road accidents, the *Régie* later became the *Société de l'assurance automobile du Québec*.

² In particular, Manuel Ramos and Annie Thuilot deserve our warmest thanks for the excellent job done in producing a first version of the camera-ready manuscript, finalized by Catherine

BACKGROUND SUPPORT AND RISK TAKING IN QUEBEC'S ROAD SAFETY RESEARCH FUNDING

Twelve years out of seventeen. During the last 17 years (1982-1999), the Quebec Automobile Insurance Board has provided a string of grants: firstly to the CRT³ university research project (1982-1984) towards the original DRAG-1 model, and then to implement it (1989-1991) and to insure in-house development of DRAG-2 at its Quebec City headquarters since 1991—where support for model development is now oriented towards the continued use of the model as an official policy evaluation and forecasting tool⁴. But the SAAQ has also contributed since 1991 to continuing methodological work on two-moment analysis⁵ at CRT through its common research program with the Quebec Ministry of transport (MTQ), jointly run by the Quebec government's research funding agency (FCAR). The SAAQ also stepped in to provide basic support (1996-1998) for the DRAG network proper when funding intended for this purpose suddenly vanished from the group grant where it had been embedded since 1991. But this list does not do justice to a particular person, André Viel, whose understanding of modelling, willingness to take risks and foresightedness effectively determined many crucial outcomes.

Risk taking by civil servants. In December 1982, André Viel, as head of research at RAAQ, accepted to fund an unsolicited research proposal. This proposal suggested to develop an approach inspired by the successful three-level system (Gaudry, 1980) of aggregate structural Demand, Performance and Supply equations implemented by the Montreal transit authorities⁶ to explain and forecast monthly transit ridership. It also stated that flexible (Box-Cox) mathematical forms should be applied to variables in order to obtain credible results. But it did not include a clear idea of how « safety performance » would be formulated in the new model—beyond noticing the availability of data on road victims by category—and certainly gave no inkling of the interest of using within the model a clear distinction between the frequency (accidents) and the severity (victims per event) of accidents; neither did it raise more complex issues about the nature of driving behaviour, such as later arose by viewing accidents in a multi-moment framework. In effect, the RAAQ just took a chance on something proposed

Laplante.

³ DRAG-type safety research is now carried out at the Agora Jules Dupuit (AJD) of the Center for Research on Transportation (CRT), a joint research centre of *Université de Montréal*, *École polytechnique* and *École des hautes études commerciales*, all located in Montreal.

⁴ In 1999, the administrative basis for development of DRAG-3 has effectively been set.

⁵ See Ch. 1 and 3 for details.

⁶ And, to a lesser extent by those of Toronto as well.

from outside, a form of risk taking ruled out in practice by the new system⁷ of mandated research topics applied since 1998 under the revised terms of the SAAQ-MTQ-FCAR program, or for that matter by the « tasks » under the various Fourth and Fifth Framework programme calls of the European Commission.

But André Viel took other risks without which this research stream might have ended in a trickle: when RAAQ authorities ordered a reorientation of their 1985 joint research program with the Quebec government's FCAR research fund, with a view to excluding from it DRAG-type research because they disliked some of the results found in the report they had just received (Gaudry, 1984), he maintained a strict scientific and professional neutrality until these authorities changed their mind and decided five years later to implement the model in house. Fortunately, John Lawson, then director of road safety research at Transport Canada, had stepped in to provide minimal « survival » funding in the meantime. More recently, Claude Dussault, current head of research at SAAQ, similarly supported DRAG network activities when amounts intended for this purpose were arbitrarily « reassigned » within a multi-project group grant. This decision made a very large difference to the vitality of the international network.

OTHER SPECIFIC, JOINT AND COMMON FUNDING OF A RESEARCH NETWORK

National databases. After 1984, it took about three years before the elaboration of two new models started at Karlsruhe and Oslo. Ulrich Blum and Lasse Fridstrøm then funded the construction of national databases from local sources, as did leaders of other modelling efforts more than six years later: Sylvain Lassarre in Paris, Göran Tegnér in Stockholm and Patrick McCarthy in West Lafayette. Graduate students at the Master's (*Diplomarbeit*) and Ph. D. levels were involved in Canada, Germany and France. In all cases, high quality fully documented databases, like the DRAG-I database (Gaudry *et al.*, 1984), were constructed progressively over a period of years, allowing for successive generations of models.

It is generally very difficult and expensive to finance work on new high quality national time

⁷ Although mandated research topics make it impossible for managers of large multi-project research grants subjected to inadequate supervision within the university to redistribute funds to the advantage of their personal projects after these funds have been procured globally for a group of projects, one wishes that it had been possible to close the door to such « larceny » within universities without mandating topics. Project-specific funding approval would have sufficed to reestablish honesty by forbidding « redistribution » among projects.

series: for instance, derivation of monthly vehicle kilometrage from motor vehicle fuel sales and other indicators took more than one person-year for France—it is therefore gratifying that the resulting series and its methodology will become a permanent feature of the French national accounts in 2000, an outcome greatly facilitated by Michel Houée's encouragement. In Germany, the construction of vacation calendars by province required one man-year of work and the numerous statistical issues related to unification since 1989 still constrain the credible available data set. The youngest of the databases, for California, was constructed on a shoestring budget.

In Belgium, The Netherlands and Israël it has not yet been possible to fund the construction of a database, despite the interest and availability of research team leaders at Louvain, Delft and Ben-Gurion universities. Vested interests, often using only individual data of a cross-sectional nature, have objections to time series analysis and do not share our catholic perspective on the comparative advantages of different types of data. At other times, evaluators used to bivariate, or even to multivariate, linear relationships shy away from relationships determined without the comfortable straightjacket of fixed functional forms.

Collaboration. Perhaps more difficult still is the financing of international collaboration. In this case, Marc Gaudry was fortunate to benefit from three sources of flexible funds. Firstly, throughout the whole 17-year period, from the Natural Sciences and Engineering Research Council of Canada (NSERCC): their program evaluates individual researchers every three years, with the emphasis on their output rather than on the contents of their proposals. They do not assume that, if you need a portable PC or a 24-hour trip to Karlsruhe in the middle of July for a thesis defence, they are a better judge of relevance than you are. It would be surprising if there were worldwide a more productive and cheaper to manage funding program than this Canadian NSERCC program.

Secondly, since 1984, from the Alexander von Humboldt Foundation of Germany: in particular, the ability to spend over many short stays in Germany his 1990 research prize award (*Forschungspreis*), and to combine it with a DFG guest professorship at Karlsruhe in 1993, was extremely helpful, in view of the long-term nature of the DRAG collaboration projects. Thirdly, support in 1998 from the French National Centre for Scientific Research (CNRS⁸) through the tenure of a research position at BETA⁹ in Strasbourg was helpful in the same way: the great freedom associated with this position made a crucial difference to the coordination of activities necessary for this book, in particular those linked to the doctoral

⁸ *Centre national de la recherche scientifique.*

⁹ *Bureau d'économie théorique et appliquée, Université Louis Pasteur and UMR CNRS 7522.*

theses of Laurence Jaeger and Karine Vernier.

Collaboration was also greatly helped by the membership of Lasse Fridstrøm and Sylvain Lassarre in the road safety methodology committees of the OECD (1997) and the European Commission (COST 329, 1999).

Conferences. Many researchers organized useful full day seminars on the DRAG approach: Roger Marche (at IRT/ONSER, in Arcueil, 1985), Sylvain Lassarre (in Strasbourg, 1993), François-Pierre Dussault (at IRRST in Montreal, 1993) and Göran Tegnér (in Borlänge, 1996). Also, the series of well attended INRETS¹⁰ road safety modelling seminars in Paris, financed by the Directorate for Safety and Circulation on Roads (DSCR¹¹) of the French ministry of transport (MELTT) since 1992 and organized by Sylvain Lassarre, provided salutary collaboration opportunities, as well as chances to expound upon work-in-progress and to produce proceedings¹².

These seminars culminated in the international conference on DRAG-type models held in November 1998 in Paris, where first versions of the papers found in this book were presented, thanks to joint financial support from the DSCR, the SAAQ and the DFK (Swedish Foundation for Transportation Research). In view of the complexity and limited availability in English of most models, it was then decided to obtain better-coordinated second versions of all papers even if this certainly slowed down publication of the book.

Common tools. All but one of the models presented here rely on some of the algorithms implemented within the fully documented TRIO software¹³. It has been possible to finish Version 2 of this program in 1993 (Gaudry *et al.*, 1993) with a large TRIO-DRAG contract funded by Transport Canada (1991-1993). Since then, all DRAG network participants have made important contributions to its maintenance, much larger than those made by other users¹⁴. However, one member, Ulrich Blum, made exceptional financial contributions to the maintenance of the program and even funded in 1998-1999, through a grant from the German

¹⁰ *Institut national de la recherche sur les transports et leur sécurité*, in Arcueil.

¹¹ *Direction de la sécurité et de la circulation routières, Ministère de l'équipement, du logement, du tourisme et des transports (MELTT)*.

¹² The series starts with Paradigme (1993).

¹³ See Part III of this book, where two of these algorithms are partially documented.

¹⁴ The TRIO user network currently has about 100 registered members worldwide.

Research Foundation (DFG¹⁵) at Dresden University, the extension to the third moment (see Ch. 3 and Ch. 12) of the two-moment analysis available in the LEVEL-1.4 algorithm¹⁶ since 1991.

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¹⁵ *Deutsche Forschungsgemeinschaft*.

¹⁶ See the updated description in Ch. 12 and the application in Ch. 3.