An International Research Program Into The Vehicle/Pavement Interaction: OECD DIVINE Project

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ABSTRACT

In many OECD Member countries it has been estimated that one third to one half of all road maintenance is due to the effects of heavy truck axle loads. It has been suggested that 10% of these costs could be avoided through the design and use of more road-friendly vehicles. While it is essential to limit the national budgetary impacts of heavy vehicle effects, improved productivity in the movement of freight is also required. A major goal of road transport policy in OECD member countries is to strike an appropriate balance between vehicle weight limits, vehicle performance and road wear.

The OECD has undertaken the Dynamic Interaction between Vehicle and Infrastructure Experiment (DIVINE) in order to quantify the benefits of road-friendly vehicles and to provide means of assessing vehicles for road-friendliness. The goals of the research are to improve vehicle construction, pavement construction and pavement maintenance.

The research contributes to:

- encouragement of the design and use of road-friendly vehicles and procedures for the design and assessment of the road-friendliness of vehicles
- evaluation of the consequences for bridge design of introducing new vehicle technologies
- lessening of the deterioration of road networks
- evaluation of policy options pertaining to axle weights, axle configuration and number of axles
- a common international basis for future joint standards, testing procedures and policy initiatives for heavy freight vehicles.

Accelerated dynamic pavement testing, vehicle-pavement testing and vehicle-bridge testing explore the question of the effect of dynamic loading on pavement life and bridge behavior and essential tools are developed for measuring, understanding and predicting dynamic loading from heavy vehicles. An overview of the DIVINE research program and progress is presented and means of implementing the results of the research are discussed.

INTRODUCTION

The OECD has carried out a number of infrastructure research projects in recent years under its Road Transport Research (RTR) Program. In 1993, the OECD RTR initiated a major international infrastructure research project known as DIVINE (Dynamic Interaction of Vehicle and Infrastructure Experiment). This project follows a series of heavy vehicle and pavement-related OECD Expert Groups, including the FORCE Project and Expert Group IR2 (Dynamic Loading of Pavements).

DIVINE is truly international, has a budget administered under the OECD Road Transport Research Program, involves close interaction with national road and road research agencies and involves the private sector. The DIVINE research is being overseen by the OECD Expert Group IR6 (Dynamic Loading of Pavements). The DIVINE Co-operative International Research Program is due to be completed in 1995-1996.

DIVINE involves some 17 OECD member countries, and includes specialists in vehicles, pavements, bridges, road management and transport policy. Inter-linked research projects are being carried out in nine countries, with co-ordination centres in Paris and London.

The DIVINE program is broad and diverse and depends on clear identification of research plans, standardization of research techniques and good co-ordination. The DIVINE program is the result of a significant process of synthesis of national research programs, national road freight policy options and international needs for vehicle performance standards.

This paper presents an outline of the objectives, structure and research directions of DIVINE and the potential payoffs of the research.

BACKGROUND

World-wide experience is that there is a good return on infrastructure research and there are significant opportunities to increase road freight productivity and to reduce road maintenance costs. Previous OECD Expert Groups, including Impacts of Heavy Freight Vehicles [1]

and the FORCE Project [2] had focused on the emerging importance of scientific knowledge of the effects of heavy vehicles and associated regulatory policies, including axle weight limits.

For real change to occur, it was necessary to develop a new and common language for use by scientists from all disciplines and which could be used by policy-makers.

In 1988, the OECD initiated Expert Group IR2 to bring together vehicle, pavement and policy experts and produce a state-of-the-art assessment of the significance of dynamic road loading, to explain how the vehicle and pavement behave and interact dynamically, and to consider means of policy implementation to reduce road costs and improve productivity in road transport.

The Group held its first meeting in 1990 and moved to produce a review report which clarified many issues which were previously too complex to include in policy formulation. Due to the interdisciplinary nature of the group and the close involvement of vehicle manufacturers, the Group was able to identify priority research projects requiring international co-operation and the specialist expertise in the many disciplines represented on the Group.

These specialists include pavement and bridge researchers, pavement designers and managers, vehicle researchers, vehicle and suspension designers, road profile experts, weigh-in-motion experts, regulatory experts and policy experts. The interactions between these individuals resulted in significant technical growth and developed a partnership for charting the course for the future of heavy vehicles and pavements.

The DIVINE program is based on the work of Expert Group IR2, which published its scientific review of dynamic road loading [3] in October 1992. The IR2 report found that dynamic pavement loading is currently increasing in OECD member countries, leading to an increasing rate of road wear and to constraints on productivity improvements through liberalization of vehicle weight limits. The IR2 report concluded that this may be counteracted by a significant increase in the use of "road-friendly" vehicles and that policy initiatives could be developed to bring this about.

The IR2 report also found that, in general, the dynamic interaction between heavy vehicles and bridges is rather different from that between heavy vehicles and pavements and that it would be difficult to derive useful transport policy initiatives without giving specific consideration to bridge effects.

DEVELOPMENT OF DIVINE PROGRAM

ROLE OF CO-OPERATIVE INTERNATIONAL PROGRAMS

The DIVINE Co-operative International Research Program differs from most research efforts of national research institutes, national co-operative programs and international standards organizations in that:

- it is truly multi-disciplinary and crosses the interface between vehicles, roads and bridges
- the close interaction between researchers improves scientific standards, and enhances parallel national research projects
- in-built peer review increases the credibility of results
- each element of research may be carried out using the most appropriate facilities and locations
- total costs, viewed in relation to outputs, are significantly reduced and efficient use of scarce research funds is enhanced.

ISSUES IN DEVELOPING THE DIVINE PROGRAM

In the case of the DIVINE Program, some difficulties were encountered with regard to:

- the wide scope, large number of interconnecting projects and significant total cost of the program may be viewed as ambitious
- even then, not all national objectives can be addressed fully
- trying to obtain funding from all available sources within each country; the need to seek industry support on a national rather than an international basis and difficulty of seeking industry support within some countries
- the high cost of transporting instrumented research vehicles between countries
- increasing commercial orientation of research institutes which restricts the travel of national experts and increases financial resources required by the project.

OUTLINE OF DIVINE PROJECT

OBJECTIVES

The scope of the research includes participation by vehicle, pavement and bridge experts as well as vehicle manufacturers. The main purpose of the research is to improve vehicle construction, pavement construction and pavement maintenance.

The research will contribute to:

- encouragement of the design and use of road-friendly vehicles and procedures for the design and assessment of the road-friendliness of vehicles
- evaluation of the consequences for bridge design of introducing new vehicle technologies
- lessening of the deterioration of road networks (including pavements and bridges)
- evaluation of policy options pertaining to axle weights, axle configuration and number of axles
- allocation procedures for road costs and maintenance planning related to truck weight

- common international basis for future joint standards, testing procedures and policy initiatives for heavy freight vehicles.

RESEARCH PROGRAM

Accelerated dynamic pavement testing, vehicle-pavement testing and vehicle-bridge testing are being used to explore the question of the effect of dynamic loading on pavement life and bridge behavior and essential tools are being developed for measuring, understanding and predicting dynamic loading from heavy vehicles.

The OECD DIVINE program consists of six inter-related Research Elements:

(1) Accelerated Dynamic Pavement Testing

The CAPTIF accelerated pavement testing facility at the University of Canterbury, New Zealand is being used to directly compare pavement distress under the dynamic behavior of "good" and "bad" suspensions.

A flexible test pavement was installed in CAPTIF's circular test track and contains primary response transducers. Two separate tracks of the test pavement are being trafficked simultaneously using 5 t test wheels - one fitted with a steel suspension and one fitted with an air spring. Measurements include the dynamic wheel load on each wheel, plus regular profile and distress measurements in each wheel track, plus primary pavement response measurements in each wheel track. Depending on the results of the first test, a possible second pavement may be constructed and trafficked in a similar manner.

This work is providing the first real insights into the extent of the effect of suspensions on pavement life and the mechanisms of pavement distress under dynamic loading.

Experts from FHWA US, VTT Finland, ARRB and Transit NZ are leading this work.

(2) Primary Pavement Response Testing

Measurement of pavement primary response to heavy vehicles provides a means of monitoring the likely damaging effects of heavy vehicles on pavements. This has been carried out under dynamic conditions. Existing strain-gauged test roads (in USA and Finland) have been used, in conjunction with three instrumented vehicles (operated by NRC, FHWA and TRL) to relate dynamic pavement responses to dynamic wheel loads and the pavement profile. This will provide comprehensive evidence of the effect of dynamic wheel loads on pavement primary response. The US Federal Highways Administration is leading this work.

(3) Road Simulator Testing Standard methods of measuring road-friendliness of vehicles are being developed. Canadian vehicle shaker (or "road simulator") facilities have been used to test the above three vehicles. The dynamic parameters of these vehicles have been measured and the vehicles have been tested on three pavements of varying unevenness and of measured profile characteristics. The test program has been designed to fully calibrate the test vehicles, to measure their dynamic parameters, to validate the road simulator in its ability to reproduce dynamic wheel loads in response to profile inputs and to develop validated vehicle tests of road-friendliness. The Canadian National Research Council is leading this work.

(4) Vehicle Simulation Comparison The ability of computer models to predict heavy vehicle dynamic loading is being evaluated. The owners of existing computer simulation models have been invited to participate in an exercise to compare the results of their models with actual test results, based on the same input information being supplied to all participants. Road profile and vehicle parameter data from the Road Simulator Testing Program is being packaged and provided to participants. The participants will then run their own models and provide the results to IR6 who will compare the results, provide feedback to participants and prepare a report with recommendations for validated and usable models. TNO Netherlands is leading this work.

(5) Spatial Repeatability Testing The damaging effect of heavy vehicle dynamic loading depends critically on the tendency of such loads to repeat at particular points of the pavement. Two high-speed highway sections of flexible pavements have been fitted with load sensing devices and dynamic loadings as a function of distance along the pavement have been recorded for a significant time period at each site. This work is being carried out in the UK and France, and additional results are being provided by NRC Canada. Data will be analyzed for variations in the accumulated dynamic loading at each load sensor. Experts from TRL UK and LCPC France are leading this work.

(6) Dynamic Bridge Loading It is by no means certain that pavement-friendly vehicles will also prove to be bridge-friendly. Three bridges in Switzerland with varying fundamental frequencies have been load tested dynamically using the Canadian NRC instrumented vehicle. Tests were carried out with both leaf-spring and air suspensions. The Swiss EMPA is leading this work. In addition, a related study involving short-span, high-frequency bridges has been carried out in Australia. The Queensland University of Technology is leading this work.

BENEFITS OF THE RESEARCH

RESEARCH OUTPUTS

The research will provide information on the magnitude of the effect of dynamic loading on the life of the infrastructure and on means of increasing the road-friendliness of heavy vehicles. Direct outputs will include:

- new insights for pavement engineers into the design and maintenance of pavements for increased life.
- a method for rating the road-friendliness of vehicles
- a proven and generally usable computer model of heavy vehicle dynamic loading
- information on the dynamic bridge loading as influenced by the vehicle suspension type
- policy options contributing to improved road freight industry productivity.

POTENTIAL PAYOFFS

Reduced Road Costs Total road funding currently runs at 0.2 - 1.9% of Gross National Product [4] and OECD member countries have different criteria and policies in allocating funds to new construction, rehabilitation, periodic maintenance and routine maintenance. Routine maintenance is a significant component of road expenditure in all countries and is the dominant component in some countries [4].

Road managers in all countries face the dilemma of increasing truck traffic, economic growth, increasing

consumer expectations of traffic safety and road condition and reducing road budgets [4]. The DIVINE project's discoveries with regard to ways of reducing road wear are expected to provide a much-needed tool in managing this difficult equation of truck traffic, road condition and maintenance funding.

Improved Road Freight Productivity While the DIVINE project will address means of reducing road maintenance costs, even greater benefits may be possible in some countries through improved productivity of road freight operations. World-wide, the annual costs of operating freight vehicles exceeds the costs of building and maintaining roads (vehicle operating costs have been estimated to be up to approximately 30 times road costs [5]). By way of example in the Australian context (1989-90), the average annual operating cost of a 6-axle vehicle was US$175,000, compared to average annual road track costs, attributed to the same vehicle, of $11,300 [6].

There is a world-wide emphasis on productivity. Improvements in road freight productivity - through potentially higher payloads - have a large potential payoff in reducing total vehicle operating costs and reducing transport costs, which - according to World Bank estimates - typically represent 10% of Gross National Product in high-income countries. Experience in many countries has shown that these reduced transport costs tend to be passed on to consumers in the form of lower prices for goods.

The implementation of such productivity improvements clearly depends on national policies with regard to road funding, road user charges, size-and-weight limits and vehicle regulations. Three types of policy objective could arise from the DIVINE Project:

- reduce road wear (and hence road maintenance costs)
- improve productivity while avoiding increases in road costs
- reduce road costs and increase productivity

and the DIVINE Project is strongly oriented to working towards the latter objective.

Increased payloads and productivity could be brought about by a mix of transport policy options selected to best suit the regulatory and economic environment in each country. Components of these policy options could include:

- the possibility of higher gross weights for road-friendly vehicles, perhaps brought about by additional axles rather than higher individual axle weights; this may involve increased use of tridem groups in place of tandem groups
- consideration of increased axle group weight on proven road-friendly tandem and tridem groups
- scientifically-based means for measuring and assessing the road-friendliness of heavy vehicle suspensions (including the dynamic and load-sharing performance of suspensions).

Such vehicle-related options could be supported by new strategies for pavement design, reconstruction and maintenance which is less likely to produce, and is less sensitive to, dynamic loading and perhaps stronger, more even pavements on designated freight routes. These outcomes of the DIVINE project are expected to bolster the characterization and measurement of highway condition and to enhance the Pavement Management Systems on which all OECD countries are increasingly reliant.

REFERENCES

[1] OECD (1983) Impacts of Heavy Freight Vehicles. Paris.

[2] OECD (1991) OECD Full-Scale Pavement Test. Paris.

[3] OECD (1992) Dynamic Loading of Pavements. Paris.

[4] OECD (1994) Road maintenance and rehabilitation: funding and allocation strategies. Paris.

[5] NEWLAND, DE (1992) Technical issues - the way forward. Closing Address, Third International Symposium on Heavy Vehicle Weights and Dimensions. Heavy Vehicles and Roads: Technology, Safety & Policy. Thomas Telford, London.

[6] INTER-STATE COMMISSION (1990) Road use charges and vehicle registration: a national scheme. Australian Government Publishing Service, Canberra