TRANSPORT ENGINEERING RESEARCH NEW ZEALAND LIMITED

A Systems Approach to Making Safety Pay

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INTRODUCTION

Human error, rather than catastrophic vehicle or road failure, is the primary cause of most crashes. Vehicle and road failures are rarely the primary cause but are often major contributing factors that will determine whether a crash will occur if there is a human error, and the severity of the crash.

There are two ways of looking at human error, the person approach and the system approach (Reason 2000). The person approach focuses on unsafe acts committed by the people at the sharp end, the drivers. It views these unsafe acts as aberrant behaviour such as in-attention, carelessness and recklessness. The safety countermeasures that are adopted to reduce the level of aberrant behaviour include: increased Police enforcement, harsher penalties, advertising campaigns that try to change behaviour by focusing on fear, the threat of litigation, the imposition of stricter Rules and regulations, and retraining. It views drivers as being free agents capable of choosing between safe and unsafe practice. It is also an approach that is legally convenient.

The systems approach accepts that humans are fallible and errors are to be expected. It is often the best people who make mistakes – errors are not the monopoly of an unfortunate few. Similarly even the best equipment will break down and will deteriorate. What is important are the system defences, barriers and safeguards that are in place to minimise the risk of mistakes or failures causing or contributing to a crash. The systems approach to improving safety was developed in the aviation industry and is increasingly being applied to many other industries, including medicine and road transport.

We cannot change the human condition, but we can change the conditions under which humans work. The chances of making a error is very dependent on the road being driven on, the performance and condition of the vehicle, the safety systems employed by the operator and the pressures brought to bear by the users of the transport services. It is the management of the transport operation that can make the greatest difference to safety as they choose the drivers, provide training, set the standards of acceptable behaviour, select the vehicles, set the maintenance standards and set the schedules and rosters.

Another way of looking at it is that failures (including human errors) are like mosquitoes. You can swat them one by one, but they still keep coming. The best remedies are to create more effective defences and to drain the swamps in which they breed. The swamps in this case are the conditions that make it more likely that an error will occur.

As a measure of the importance of the operator in developing effective defence systems against errors occurring, Moses and Savage (1994) found that trucking firms that did not report crashes and took no steps to investigate them with the view to determining whether disciplinary, educational or other steps were required had crash rates nine times higher than firms that took the appropriate actions. They also found that operators who are unfamiliar with the hours of service requirements and do not keep records of driver duty have crash rates 30% higher than operators who do.

The primarily aim of the Operator Safety Rating Scheme (OSRS) is to improve safety by encouraging transport operators to take greater responsibility for safety. In my view the most important part of the scheme is in encouraging all operators to become good operators. Currently only a small proportion of transport operators, perhaps little more than 5 percent, have good management systems in place. It is important to give those companies some official recognition and incentives as a means of encouraging others to join their league. The incentives need to be sufficient to make it economically worthwhile to be among the best.

As a means of supporting the development of industry best-practice, the Road Transport Forum has commissioned TERNZ to develop a set of industry standards that will be used to help operators improve their safety management systems and as a means of auditing companies.

INDUSTRY STANDARDS

Essential to the safety management approach are inspection, monitoring and recording procedures that can demonstrate that potential safety hazards are identified and rectified. The obligations of being a transport operator include:

- Responsibility. An operator must ensure the vehicles are properly maintained and that competent, qualified drivers are behind the wheel.
- Education. Ensure that all people connected with the operation are trained or are receiving training for the task they are expected to undertake.
- Monitoring. Ensure vehicle maintenance, driver management and other safety policies are in place and monitored.
- Action. An operator must take immediate corrective action if the policies and procedures are not adequate or are not being followed.

The proposed industry standards will assist operators to meet those obligations by providing guidance with the setting up of the appropriate safety management systems. It will be based on world best-practice and will, where possible, include forms and other methods that can be used as the basis of a management system. The industry standards will include sections on:

1. The driver including on-road behaviour, traffic offences, health, fatigue, drug and alcohol use, licences, and training.

2. Company management including training, dealing with crashes and complaints, subcontractors and systems management.
3. Use of the vehicle including: scheduling, load securing, and mass and dimensions.
4. Vehicle condition including roadworthiness and design
5. Crash investigation as a means of learning from what has happened and to make changes to the safety management system to reduce the possibility of similar crashes occurring in the future.

The following section describes some of the issues surrounding roadworthiness and how they will impact on the Industry Standards as an illustration of how the Industry Standards will work.

ROADWORTHINESS

Safety risk

Vehicle defects cause, or contribute to, crashes in a variety of different ways. Some crashes are due to the catastrophic failure of components such as tyre blowouts and driveline failures. Depending on traffic density, most of these crashes tend to be single vehicle crashes. More common are defects that reduce the performance of the vehicle and hence the inability to take evasive action to avoid a crash. If a crash is unavoidable, reduced performance can increase the severity of the crash. As an example, poorly adjusted brakes can limit the ability of the vehicle to stop quickly enough in an emergency. If a crash is unavoidable, impact speeds will be higher if the brakes are poor. Similarly, badly worn steering or suspension components can affect the ability of the vehicle to stay on its wheels during an evasive manoeuvre in an emergency situation. There are also cases where a component will fail catastrophically while under pressure during an evasive manoeuvre and thereby contribute to the crash.

When investigating crashes it is often very difficult to determine whether a mechanical defect contributed to the crash and to what extent. A failed component may have been present before the crash, or may have failed as a result of the crash. Similarly a downhill run-away crash may be due to poor driver control of the descent rather than the performance of the brakes.

The proportion of crashes where vehicle factors have been found to play a significant role is very dependent on the depth of the investigation and the expertise of the crash investigators. Police crash investigations typically report mechanical defects as being a factor in 3% to 8% of crashes (Baas and Oliver 2001). In-depth investigations undertaken by specialist crash investigators on the other hand have reported that mechanical defects cause or significantly contribute to approximately 13% of crashes involving heavy vehicles. This includes crashes where error on the part of a third party caused the crash but defects in the heavy vehicle were such that, had the defects not been there, the crash could have been avoided or at least its severity significantly reduced. In the in-depth investigations, brake defects accounted for over half of the mechanical defect related crashes, or approximately 6% of all heavy vehicle related crashes. This was followed by tyres (2%), chassis (1.5%) lights and signals (1%) steering (0.7%) and cab components (0.7%). The primary brake problems were air-brake system failures and improper brake chamber push-rod adjustments.

Time to failure

Components can fail at any time and numerous studies have shown that without intervention it is almost certain that a typical heavy vehicle will develop a red-sticker or out-of service level defect within three to six months of a CoF or maintenance inspection. While the probability is relatively low immediately after an inspection, it is never zero and begins to grow as soon as the vehicle is put back into service.

The following table from a study undertaken by UMTRI (Gillespie and Kostyniuk 1991) shows the probability of a vehicle having an out-of-service level fault since the last time it was inspected or repaired (i.e. when it was last found to have no defects). The average distance travelled by tractors in the survey was approximately 65,000km per year. The study estimated that 1/3rd of the total defects found were severe enough to be at the out-of-service level.

Table 1: Probability of an out-of-service level fault since last repair

(Gillespie and Kostyniuk 1991).

	Time since last repair (months)									
Vehicle type	1	2	3	4	5	6	7	8	9	10
Tractors	0.22	0.42	0.60	0.77	0.92	1	1	1	1	1
Semitrailers	0.08	0.15	0.21	0.26	0.30	0.34	0.37	0.39	0.41	0.43
Dollies	0.07	0.13	0.19	0.24	0.29	0.33	0.36	0.40	0.43	0.45

Taking tractors as an example, the table indicates that within the first month after being inspected and repaired the average tractor will have a 22% chance of developing an out-of-service level failure. At 6 months one failure will occur on average. The above results were combined to provide the probability of combination vehicles having faults. This is shown in table 2.

Table 2: Failure Probabilities for Various Vehicle Combinations

(Gillespie and Kostyniuk 1991).

	Time since last repair (months)									
Combination	1	2	3	4	5	6	7	8	9	10
Trucks	0.22	0.42	0.60	0.77	0.92	1	1	1	1	1
Tractor-Semitrailers	0.29	0.57	0.80	1	1	1	1	1	1	1
Doubles	0.44	0.84	1	1	1	1	1	1	1	1

Passing an inspection is no guarantee that a vehicle will be defect-free once it is put back into service. As Gillespie and Kostyniuk (1991) points out "The inspection only provides assurance that the probability of a defect is lower on an inspected vehicle than on vehicles that have not been inspected".

The graphs in figure 1 show the proportion of tractors that survived without developing out-of-service level defects for different types of defects. Of note is the relatively short time in which air systems and lights develop faults.

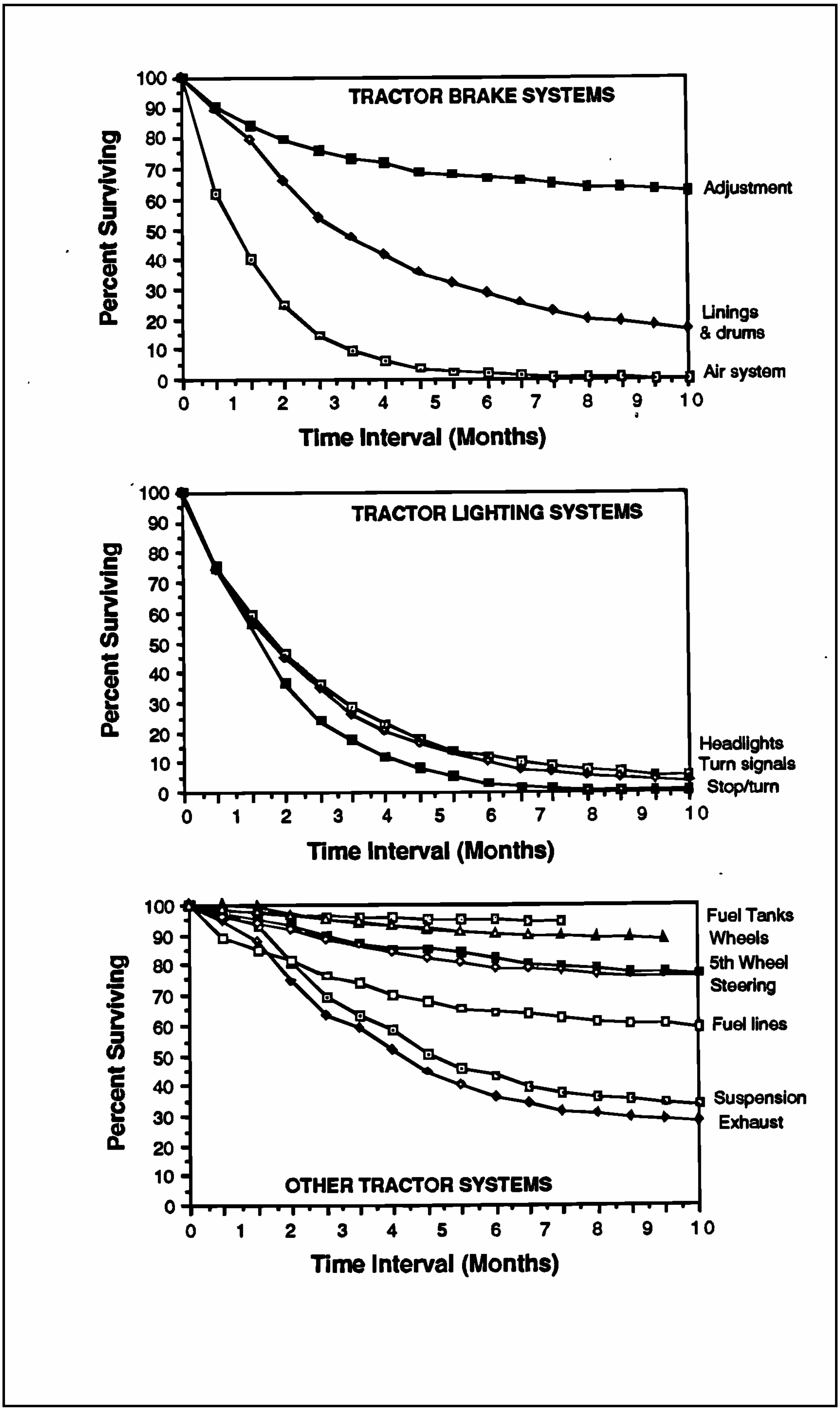

Figure 1: Proportion of tractors that survived without developing various different types of out-of-service defects (Gillespie and Kostyniuk 1991).

The following extract from Gou, Clement et al. (1999) reporting on a Quebec in-depth crash investigation study noted that:

(a) there is a very high correlation between vehicle age and mechanical condition (Figure 2);

(b) time elapsed since the last annual inspection appears to have no influence on older vehicle mechanical condition (Figure 3);

(c) most major defects (53%) affect the braking system;

(d) when older vehicles are put aside, the inspection program appears to have a preventative effect for accidents caused by mechanical defects over a period of up to 3 months after its application.

The first finding indicates that the inspection program does not fulfill its mandate, which is to attenuate the effect of vehicle age on mechanical condition. The finding suggests that the program needs to be adapted to vehicle age in particular. The second finding indicates the importance of a continuous maintenance program by owners because a single inspection per year is not enough to ensure good mechanical condition. The third finding confirms the need for a preventative maintenance program targeting components of the brake system in particular. This maintenance program should be carried out following manufacturer's recommendations, every 300 hours of service or 12,000km of mileage (approximately 3 months of service)".

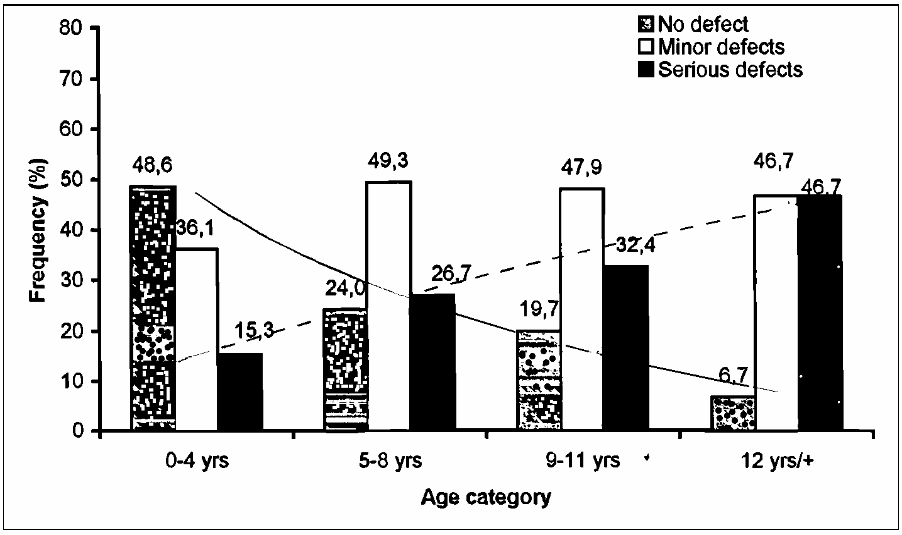

Figure 2: Mechanical condition as a function of age for vehicles subjected to annual inspections.

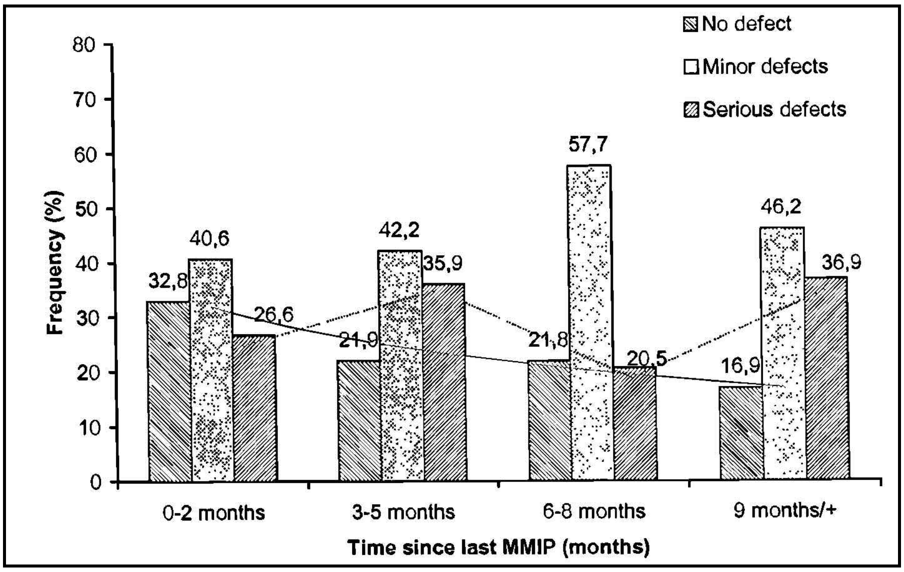

Figure 3: Mechanical condition as a function of time since last annual inspection.

Surveys undertaken by LTSA and CVIU confirm that there a significant proportion of the heavy vehicles out on the road that have major defects.

CoF and roadside inspections

The primary aim of CoF inspections is to ensure that at least once every 6 months vehicles are repaired to a minimum standard of roadworthiness. It is maintenance by regulation.

Many in the transport industry prefer mandatory periodic inspections, as they do not want to lose a system under which Government effectively takes responsibility for the safety of their vehicles (McInnes 1991). The transport companies surveyed by McInnes were not concerned about the cost of compliance, only that the cost should be the same for all.

The purpose of random roadside inspections on the other hand is primarily to remove unsafe vehicles from the road and to act as a deterrent to using unsafe vehicles. The greatest benefit from roadside inspections comes from the threat of removal of vehicles from the road for repair (Evanco 1997). This can be very disruptive to schedules and fleet operations, and operators will try to minimise this risk by improving their maintenance systems. Roadworthiness inspections are being introduced across Europe because the regulated annual roadworthiness test for commercial vehicles is considered not to be sufficient to guarantee the roadworthy of heavy vehicles. In the US the emphasis is already on roadside inspection.

Alternative Compliance in Australia, the Compliance Review approach in North America and the proposed safety rating scheme in New Zealand take the systems approach with the expectation that the operator will have systems in place that ensure its vehicles are in a safe condition. An integral part of this approach is ensuring vehicles are inspected daily and that predictive or preventative maintenance is part of the system. Moses and Savage (1995) found that the benefits of the US safety management compliance review program outweighed the costs by 4.2:1 compared to

1.6:1 at best for roadside inspections. Periodic inspections are less cost effective than roadside inspections because of their reduced deterrent effect.

In a statistical analysis of heavy vehicle fatal crash involvement and out-of-service violations in the US, Evanco (1997) found that while out-of-service orders directly improve safety by removing defective vehicles from the road, it is the threat of inspection and the possibility of being declared out-of-service (OOS) that is the major driving force in reducing the number of fatal crashes.

Vaughan (1993) noted that vehicle inspection has gone through several distinct stages in NSW since the late 1970s. Initially heavy vehicles were only subjected to annual inspections at licensed garages. Spot monitoring found that 1 in 4 had defects. Random roadside inspections introduced to supplement the annual inspections resulted in a reduction in major defects to about 8 to 10 percent. The later transfer of annual inspections from licensed garages to a government inspection regime resulted in a further fall to about 6% of heavy vehicles having major defects. Vaughan (1993) found that on a cost-benefit basis the greatest benefits were derived from the introduction roadside inspections.

Industry Roadworthiness Standard

As mentioned above a set of industry standards are being developed by TERNZ for RTF as part of the Operator Safety Rating Scheme.

The roadworthiness industry standard will be based on the best of the systems that other countries have developed and will include items such as:

- Daily checks undertaken by the driver
- Fault recording and reporting
- Fault repair
- Periodic maintenance scheduling and reporting
- Responsibilities (driver, manager, in-house and out-sourced maintenance workshops)
- Record keeping
- Monitoring and auditing
- Training and education

CONCLUSION

In New Zealand a significant proportion of the heavy vehicle safety related compliance and enforcement resources are devoted to Police enforcement activities that lead to the issuing of infringement notices and the to six monthly CoF vehicle inspections. While these activities, especially Police enforcement, are important, there has been a major shift overseas and in other industries towards a safety management approach. With the safety management approach it is accepted that humans will make errors. What is important is reducing the chance of making errors. An important part of that approach is encouraging transport operators to have in place good systems to manage safety, and a set of industry standards and guidelines are being developed to assist with this.

This paper has specifically looked at roadworthiness as an example of the need for industry standards. While few crashes are caused by catastrophic vehicle failure, vehicle defects have been estimated to be a significant contributing factor in over 13 percent of crashes involving heavy vehicles (including those not caused by the heavy vehicle).

Overseas studies and maintenance records have found that the time elapsed since the last periodic inspection has little influence on mechanical condition for older vehicles as these vehicles are likely to develop faults soon after the inspection. Over half of the major defects are brake system related, and when older vehicles are put aside, any preventative effect from a periodic inspection disappears within 3 months. The only way to ensure vehicles are roadworthy is by ensuring transport operators take responsibility for the condition of their vehicles. The CoF inspection regime enables the less scrupulous operators to abrogate their responsibility by claiming that the vehicle has a current Certificate of Fitness, which by its very name implies the vehicle is fit to be on the road.

REFERENCES

Baas, P. H. and R. Oliver (2001). Review of Heavy Vehicle Inspection Arrangements, TERNZ: 46.

Evanco, W. M. (1997). The Impact on Fatal Involvements of Commercial Vehicle Operation ITS User Services. Mobility for Everyone. 4th World Congress on Intelligent Transport Systems, Berlin, ITS Congress Association.

Gillespie, T. D. and L. P. Kostyniuk (1991). A Rationale for Establishing the Period of Validity for CVSA Truck Inspection Decals, UMTRI.

Gou, M., B. Clement, et al. (1999). "Effects of Heavy-Vehicle Mechanical Condition on Road Safety in Quebec." Transportation Research Record 1686 99-0166.

McInnes (1991). Quality Assurance and Heavy Vehicle Fitness, Land Transport Division, NZ Ministry of Transport.

Moses, L. N. and I. Savage (1994). "The Effect of Firm Characteristics on Truck Accidents." Accident, Analysis and Prevention 26(2): 173-179.

Moses, L. N. and I. Savage (1995). A Cost -Benefit Analysis of United States Motor Carrier Safety Programs. Evanston, Il, Northwestern University.

Reason, J. (2000). "Human error: models and management." British Medical Journal 320(18 March 2000): 768-770.

Vaughan, R. G. (1993). "Safety Maintenance of Road Vehicles." IMechE(C444/007/93): 127-133.