Applying the Haddon Matrix in the context of work-related road safety

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Abstract

The Haddon Matrix was developed in the 1960s road safety arena, and has since been used in many public health settings. The literature and two specific case studies are reviewed to describe the background to the Haddon Matrix, identify how it has been critiqued and developed over time and practical applications in the work-related road safety context. Haddon's original focus on the road, vehicle and driver has been extended and applied to include organisational safety culture, journey management and wider issues in society that affect occupational drivers and the communities in which they work. The paper shows that the Haddon Matrix has been applied in many projects and contexts. Practical work-related road safety applications include providing a comprehensive systems-based safety management framework to inform strategy. It has also been used to structure the review or gap analysis of current programs and processes, identify and develop prevention measures and as a tool for effective post-event investigations.

Introduction, background and method

There is a body of research from around the world, summarised by Murray el al (2009a), showing that people driving for or to work make up a significant proportion (over 50%) of all road deaths and worker fatalities, at a very high cost to both society and organisations (NHTSA 2003, Davey & Banks 2005). For this reason increasing attention has focused on improving work-related road safety and developing models and frameworks for good practice (for examples see OGP 2011, Monclús 2010, Mooren & Grzebieta 2010, Newnam & Watson, 2011, Mitchell et al 2012). The focus of this paper is on the Haddon Matrix, which is one example of such a framework that has been widely used to guide research, policy and practice in the area of work-related road safety – allowing a systems-based approach to be adopted.

Against this background, four main aims are presented:

1. To describe some contextual background to the use of the Haddon Matrix, including research in public health, general road safety and work-related road safety arenas.

2. To set out how the Haddon Matrix has been reviewed, developed over time and critiqued as a systems-based road safety framework.

3. Two case studies are described in which the Haddon framework has been applied by organisations to help manage the safety of their drivers.

4. Several conclusions, recommendations and areas for further work are outlined with regards to utilisation of the Haddon Matrix as a tool for work-related road safety.

Background to the Haddon Matrix and its application in road safety

William Haddon was an American epidemiologist and a prominent advocate for collision prevention and injury control (Haddon 1968, 1970, 1972, 1980). He was instrumental in applying scientific methods to the study of motor vehicle injuries, seeking to identify the phases and factors related to each event. He identified three temporal phases which he called opportunity reduction (Pre-event phase), injury protection (Event phase) and the minimisation of adverse consequences (Post-event phase). These phases make up the rows of his two-dimensional Matrix in Figure 1. Three epidemiological factors make up the columns of the Matrix: Human, Vehicle/Equipment and Environment/Road-based. Haddon argued that together these phases and factors yield the first of a series of matrices of both practical and theoretical value in categorizing road-loss phenomena, knowledge, countermeasures and program efficacy. In accordance with the model, interventions for preventing crash and injury numbers and severity may involve changes in factors during any of the three phases.

	Human factors	**Vehicle/Equipment factors**	**Environment/Road factors**
Pre-event phase			
Event phase			
Post-event phase			

Figure 1 – Haddon Matrix framework showing phases and factors

Haddon (1972) asserted that road safety was no different to other forms of reduction of injurious energy exchange and that many general safety principles could be applied. He advocated for reducing losses caused by the energy exchange experienced by people and property to minimise damage. He focused particularly on countermeasures related to how much deceleration a 'properly packaged human adult' can tolerate without injury, arguing that a: *'Rationally selected set of pre-event, event and post-event countermeasures is commonly necessary to give maximum loss reduction'*.

In the same article, Haddon also suggested adapting and structuring his framework to meet the contextual needs of the situation and specific risk factors. He provided an example of a 3x10 matrix in which the Pre-event, Event and Post-event phases were maintained, but the Human factors were subdivided into six categories (Driver, Passenger, Pedestrian, Motorcyclist, Bicyclist and Other), the Vehicle and Equipment factor into two (Physical characteristics, and Movement/Location), and the Environment factor into two (Physical and Socio-cultural). This showed how his framework could be expanded and adapted as appropriate.

Since that time, the Haddon Matrix has been widely cited and utilised in road safety research, policy and practice. The World Health Organisation, for example, identified the Haddon Matrix as a dynamic systems-based framework for road safety (Peden et al 2004), with each cell allowing opportunities for intervention to reduce road crash injury. They suggested that Haddon's work led to substantial advances in the understanding of the behavioural, road and vehicle-related factors that affect the number and severity of casualties in road traffic collisions, providing a systems approach to identify and rectify the major sources of error or design weakness that contribute to fatal and severe injury crashes, as well as to mitigate the severity and consequences of injury. This included reducing exposure to risk, preventing road

traffic crashes, reducing the severity of injury and reducing the consequences of injury through improved post-collision care.

The European Commission (EU 2011) adopted a similar approach, identifying how a systems approach looks at the traffic system as a whole and at the interactions between roads, vehicles, and road users to identify where there is potential for intervention. The systems approach seeks to identify and rectify major sources of error or design weakness that contribute to fatal and severe injury crashes, recognising that people make errors which the traffic system needs to accommodate for. Similarly the '5 Pillars' safe systems model advocated by the United Nations Road Safety Collaboration and cited in the Challenge Bibendum White Paper (Michelin 2010) draws heavily on, although does not directly cite, the Haddon Matrix factors in focusing on: road safety management, safer road systems, safer vehicles, safe road users and improved post-collision care. More recently, the international standard on Road Traffic Safety, ISO39001, is shaped very much around such a systems-based approach with factors covering areas such as: leadership, route selection, journey management, driver management, vehicle management and post-event responses.

Despite this, the Haddon Matrix has its critics. Questions have focused on Haddon's approach favouring passive rather active safety features (Gladwell 2001, Robertson 2001) which may have delayed the implementation of seatbelt legislation while advocating for vehicle airbags. Other more recent criticisms by Mooren and Grzebieta (2010) focused on the problems of evaluating the impact of multiple simultaneous interventions and the value of the Haddon Matrix as a predictive tool. They also questioned the extent to which the Haddon Matrix can be defined as a systems-based model in line with current safe systems thinking in road safety. In this context, human error and frailty is placed at the centre of the system which is designed to accommodate these limitations to ensure safety, focusing particularly on the interactions between infrastructure, speed and physical vulnerability (OECD 2008).

While acknowledging such criticisms, the Haddon Matrix continues to be widely utilised as a systems-based framework in a range of public health and work-related road safety settings.

Applications of the Haddon Matrix beyond the road safety field – public health

Many researchers, policy makers and practitioners have extended beyond Haddon's original focuses on energy exchange events and how to address them. For example, Runyan (1998, 2003) described the Haddon Matrix as a compelling framework for understanding the origins of injury problems and for identifying multiple countermeasures to address them. Examples were given from fire prevention and firearm use in schools. A third dimension, incorporating the use of value criteria in the decision making process, was added including cost, freedom, equity, stigmatisation, participant preference and feasibility. Runyan (2003) surmised that the Matrix has been used both to conceptualize etiologic factors for injury and to identify potential preventive strategies. This makes the Haddon Matrix a useful tool not only for guiding epidemiologic research but also for developing interventions in a structured way.

Runyan and Yonas (2008) focused on the Haddon Matrix as a framework for analysis and preventative countermeasure development in public health and injury prevention. They argued that the Matrix was consistent with, and overlapped with, other public health models such as Bronfenbrenner's social-ecologic model, which focused on the individual in a broader context, citing teen driving as an example. Six factors were included: (1) Host – the injured teen; (2) Peers; (3) Parents; (4) Vehicles; (5) Institutions/organizations; and, (6) Sociocultural

practices and norms. They concluded that the Haddon Matrix provides a useful tool for policy development and implementation.

In total, Haddon (1972) has been cited in 130+ studies in areas as diverse as blunt thoracic injury in older adults (Hawk et al 2012), burns epidemiology (Deljavan et al 2012), obstetric fistulas (Wall & Lewis 2012), injury events in emergency medical services (Brice et al 2012), outpatient drug safety (Budnitz et al 2007), pesticide self-poisoning (Eddleston et al 2006), construction injuries (Bondy et al 2005, Glazner et al 2005), public health readiness (Barnett et al 2005), death investigations (Conroy & Fowler 2000), rape (Mantak 1995), electrocutions (Pineault & Barr 1994) and seatbelt usage (Robertson et al 1974).

The Haddon Matrix in the context of work-related road safety

Specifically in the field of work-related road safety, a number of researchers and practitioners have utilised and developed the Haddon Matrix. Faulks & Irwin (2002) identified it as a conceptual framework for the systematic exploration of injury countermeasures, providing an integrated approach to injury control and asset protection. They stated that the Haddon Matrix could be extended to consideration of the wider social-cultural-legal environment—legislation, standards, group norms, attitudes and beliefs. In an extension of this development, they proposed that the Haddon Matrix be further adapted to include explicit reference to, and consideration of, travel purpose when using the road transport system which is important when exploring new ways to exploit data to target risk-based interventions.

Edmonston and Sheehan (2001) developed a research tool conceptualising the diverse range of school transport risk factors and intervention strategies in Queensland using the Haddon Matrix as a framework. They argued that applying the Haddon Matrix in this way ensured the problem was examined in context and that feasibility and logistical concerns expressed by professionals in the field were given due consideration when prioritising recommendations. Swedish researchers Albertsson et al (2003) and Albertsson & Falkmer (2005) applied the Haddon Matrix as a tool for formally reviewing incidents, analysing data to inform countermeasures and taking corrective actions in the bus and coach sector. In particular, they focused on investigating whether seatbelts would have reduced injuries, and highlighted the triage problem in a severe mass casualty situation.

In two comprehensive reviews of work-related road safety practice (Murray et al 2003, Murray et al 2009a) it was noted that traditional fleet safety interventions in many organisations typically focused on driver behaviour and training. The research, however, identified the need for a more systematic or holistic occupational safety and health (OHS) based approach to road safety in organisations led by multi-disciplinary stakeholder groups. Although several theoretical frameworks were discussed, the Haddon Matrix was identified as and expanded into a comprehensive systems-based framework for piloting, implementing, structuring and embedding good practice, policy and interventions in organisations. Haddon's original three phases (Pre-event, At-scene and Post-event) were retained, but the factors have been expanded to include five categories: Management culture; Journeys, Road/site environment; People - drivers and managers; Vehicles and External/societal/community/ brand. These studies focused on how, in addition to being a strategic framework for generating and categorising work-related road safety countermeasures, the Haddon Matrix could be used to structure fleet gap analysis reviews, employee safety culture surveys, post event investigations and program evaluations. Over time the approach has evolved and been applied in a range of organisations.

Two peer reviewed case studies of driver safety improvement programs, implemented by cross organisational multi-functional committees led by OHS professions, are described. Both programs, undertaken by Wolseley (Murray et al 2009b) and British Telecommunications (BT) (Wallington et al 2014), involved the extended Haddon Matrix. In each case sustained long-term improvements in their road safety performance and costs were achieved. Wolseley used the Haddon Matrix to help shape its management policies and practices supported by an insurance-led road safety gap analysis (Figure 2). It contained 14 separate elements each with approximately 30 questions. As an example, a typical Policy question would be: 'My organisation has a comprehensive written, dated and published 'fleet safety, health and environmental policy' signed by the Chief Executive Officer (or equivalent)'. The percentage data in Figure 2 summarise the results of the responses 'No', 'Moving Towards' and 'Yes'.

Area of work-related road safety	2004 %	2006 %	2009 %	All fleets %
Road safety policy	39	84	95	73
OHS policy and risk assessment	47	78	90	68
Legal compliance	60	88	98	76
Organisational leadership/culture	48	81	94	72
Journey/mobility planning	62	72	90	77
Driver recruitment/induction	74	86	92	70
Driver management	61	80	94	65
Driver wellbeing	42	73	90	62
Vehicle management	58	83	95	76
Claims reporting/investigation	43	69	92	64
Community involvement	36	82	93	46
Reversing	49	70	92	64
Cash for cars	60	80	91	62
Agency drivers	50	60	70	73
Overall	53	78	91	68
Annual third party claims rate	60	49	32	-

Figure 2 - Work-related road safety process gap analysis and compliance

The gap analysis was undertaken by one of the insurer's fleet risk engineers. It set an objective baseline for benchmarking processes, both internally and against industry good practice, leading to recommendations covering safety policy, driver risk assessment and management leadership. Work-related road safety was identified as the biggest risk factor for asset damage and human harm faced by the company. One of the first initiatives was for the organisation's new OHS Manager to take over the running of the Fleet Safety Steering Group (FSSG), with key stakeholders from across the organisation, which was set up to implement the recommendations from the initial gap analysis.

As well as for framing its gap analysis, Wolseley used the Haddon Matrix to extend its post collision investigation processes beyond the typical focus on 'driver error' to include organisational, management and journey-based risks. Like BT (below), Wolseley has extended its influence beyond the workforce to focus on community road safety initiatives.

During the timeframe of the published case study the insurer gap analysis was repeated twice. This is reflected in Figure 2. Based on the compliance in each section (0 = no items in place, 100 = all items fully implemented), the company benchmarked poorly against the 'All fleet'

industry average in 2004. By 2006, and again in 2009, it had improved to be above the industry average on 13 of the 14 indicators. These independent measures of success, framed by the Haddon Matrix, helped with setting, refining, developing, reviewing, evaluating, evolving, incrementally improving and sustaining the company's policies, planning, procedures and processes. Over the same time period, Wolseley cut its annual third party claims rate per vehicle from 60% to 32%, avoiding over 1,000 claims per year. It also achieved significant cost savings through injury and asset damage prevention and gained a number of wider 'reputational' and 'industry leadership' benefits. Despite changes to the business, the company continues to focus attention on road safety.

Following a detailed collision analysis undertaken in 2003, BT implemented an OHS-led program, utilising the Haddon Matrix to inform, structure and target a long term work-related road safety initiative. The program focused on risk assessing and managing BT's safety culture and leadership, journeys, people, vehicles and role in society. It has led to significant reductions in claims, collisions and costs over the intervening time period. The specific program elements and interventions are listed in Figure 3. The community aspects of the extended Haddon Matrix helped BT to engage key stakeholders in widening its program to include family members and friends (Murray & Watson 2010). It also identified the reputational, good practice and other benefits of participating in external industry shaping initiatives, such as the Fleet Safety Benchmarking project, European Road Safety Charter, the Driving for Better Business program and work with the European Transport Safety Council.

Both cases, and many similar but as yet unpublished projects, suggest that the Haddon Matrix can be effectively applied in the work-related road safety context for a range of purposes.

	Management culture & leadership	**Journey/Site/ Mobility management**	**People**	**Vehicle**	**Society/Community**
Pre-event or pre-drive	- Business case - Risk analysis - Engagement with researchers & experts - Pilot & evaluate policy & process - OHS-led approach & steering committee - Management communication, coaching & data - Process & outcomes targets - Online data-warehouse & tools for decision making - Unique identifiers for data integration	- Risk assessment - Work allocation & scheduling - Reducing need to travel - Journey planning & route selection - Fatigue management - Vehicle utilisation to reduce exposures Safe and Fuel Efficient - Driver coaching (SaFED) - Use of alternative means of communications such as remote, online and tele-conferencing	- Induction process - Policy and handbook - Online program: a. Privacy & data protection b. Driver undertaking c. Assessment d. Targeted coaching based on risks - Face to face coaching - Encouragement - Communication - Monitoring - OneToOne - Eyesight checks	- Selection - Specification - Safety features - Standards - Supplier engagement - Maintenance - Checking - Telemetry to manage and monitor use -Vehicle utilisation	-Engagement with research community - Marketing program - Family members program - Community involvement - Safety groups - Road Safety Week - Conference circuit - Media/outreach - Safety awards - Benchmarking - Regulator briefings & involvement - Corporate Social Responsibility (CSR)
At scene	- Reporting process & support to driver	- Manage scene	- Clear process to manage scene & report events	- Crashworthy - Telemetry to capture data	- Escalation process

Post-event	- Event investigation - On-going evaluation - Change management - Program renewal	- Debrief & review - Investigate & improve	- Driver debrief - Counselling, support & rehabilitation - Reassessment & coaching	- Investigate vehicle and telemetry data - Vehicle inspection & repair	- Manage reputation & community learning process

Figure 3 - Summary of BT countermeasures in the adapted Haddon Matrix framework

Discussion, conclusions and areas for further study

From the contextual background described, it can be seen that the Haddon Matrix has evolved into a framework for informing strategy, structuring the review and gap analysis of current processes, identifying and developing new prevention measures and post event interventions in the public health and road safety arenas. Despite the criticisms described above, the adapted Haddon Matrix provides a holistic, OHS-led, systems-based, framework for identifying and structuring risk factors and interventions for work-related road safety reviews, program development, targeted interventions and post event investigations.

Based on the literature, and the cases presented, the Haddon Matrix provides a framework and structure for analysis to assist with developing potential objectives or courses of action. It has been utilised in a range of public health, injury prevention and safety management settings. In reality, in organisations decisions about which interventions to pursue depend on a range of factors including: major events, competing business priorities, budget, management capability, lines of least resistance and the actual risks faced by the organisation at any given time. Organisations such as BT and Wolseley have applied the Haddon Matrix in an on-going manner as a holistic, OHS-led, systems-based framework to risk assess, structure, benchmark and monitor the implementation of work-related road safety improvement programs. The matrix has also been utilised as a structure for reviews of policy, process and performance in organisations, as well as a broad framework to enhance the breadth and depth of incident investigations, to structure data collection practices and ensure all potential risk factors are identified and considered, rather than just focusing on driver behaviour. This approach is very much in line with the safe systems approach to road safety.

No model or framework (Haddon or otherwise) is without limitations. For this reason further discussion, debate and research is encouraged. Leading organisations adopt a comprehensive OHS-led approach to road safety, focusing on managing their drivers, vehicles, journeys and role in society. This means that that a key area requiring further attention is how the impact of individual interventions can be teased out when adopting such a systems-based approach to work-related road safety. Another is the relationship between separate interventions and the extent to which they affect other areas of road safety through positive or negative spreads of effect. This suggests that there is a need for detailed research to develop more sophisticated approaches for estimating and evaluating the causal chains and combined effects of work-related road safety countermeasures being implemented simultaneously. This requires detailed evaluation-based research, using complex statistical models, some of which is on-going in the BT case described. To date, however, such research has been beyond most individual organisations, and may require government supported academic input to become a reality.

Overall, the Haddon Matrix continues to provide a structured, holistic systems-based, OHS-led framework for research, policy and practice in in the work-related road safety arena.

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