

SURVIVAL OF THE FITTEST: USING EVOLUTION THEORY TO EXAMINE THE IMPACT OF REGULATION ON INNOVATION IN AUSTRALIAN AND CANADIAN TRUCKING



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Abstract

This paper examines the impact of regulation on trucking in Australia and Canada by applying evolution theory. By drawing an analogy between regulatory environments and animal habitats, and another between animal species and truck configurations, the examination focuses on how changes to the regulatory ‘habitat’ can figuratively lead to the evolution of more productive truck ‘species’. Evidence of such ‘evolution’ in trucking is presented using three case studies. These case studies demonstrate: (a) the evolution of a single truck species (the truck and dog) in response to the introduction of performance-based standards in Australia; (b) evolution within a regional Canadian trucking fleet as truck species flourish or become extinct in response to changing size and weight limits; and (c) the proliferation of longer combination vehicles in Canada as a result of an expanded highway network (or habitat). Examination of the evidence leads to the development of a number of guiding principles for trucking regulation.

Keywords: productivity, length, mass, configuration, regulation, road network, evolution

1. Introduction

In his book *On the Origin of Species*, Charles Darwin (1859) advanced the theory of evolution by natural selection. Darwin used the phrase “survival of the fittest” to describe the natural selection process. This phrase can be interpreted not only in the sense that only the strongest or most agile of a species can survive long enough to reproduce and pass on their genes, leading to gradual improvement in the species over many generations, but also in the sense that only those species most able to adapt in this way to rapid changes in their habitat will be able to flourish under those changing conditions and develop distinct new features (sometimes referred to as *punctuated equilibrium*). The theory of punctuated equilibrium, which was initially proposed in the 1970s (Eldredge and Gould, 1972), calls into question some of Darwin’s original ideas on the mechanisms of evolutionary change, but generally agrees with Darwin’s theory of evolution by natural selection.

Evolution theory can explain the vast diversity that we see in the animal kingdom. As will be shown in this paper, by a figurative analogy it can also help explain the vast diversity that we see in trucking in various parts of the world. Gradual improvements in vehicle design within a fixed ‘habitat’ (i.e. regulatory environment and market forces) include, *inter alia*, the development of lightweight trailers for carrying heavier payloads and better geometric design to increase payload volume. On closer inspection many others can be identified. When the habitat experiences a rapid change, such as a spike in fuel prices or a change in the regulations (the Australian performance-based standards scheme is a particularly good example), the vehicle configurations that had come to heavily populate the roads over previous years may evolve into new, more productive ‘species’. Notable examples include the longer and heavier truck-trailer configurations, quad axle semi-trailers, and B-triples seen in Australia, and the B-trains (doubles) and longer combination vehicles (LCVs) seen in Canada.

The purpose of this paper is to examine the impact of regulation on trucking in Australia and Canada by figuratively applying evolution theory. The examination focuses on how changes to the regulatory ‘habitat’ can lead to the evolution of more productive truck ‘species’. Specifically, the objectives of the paper are to:

- identify aspects of evolution theory that are analogous to trucking and describe how the analogy can be applied;
- provide evidence of the impact of changes in the regulatory habitat on trucking in Australia and Canada through three case studies; and
- present guiding principles, developed from the evidence, to support regulatory initiatives that promote trucking innovation and productivity.

Australia and Canada are two of the developed world’s trucking habitats that are most conducive to evolution in trucking. Both of these habitats pose a high demand on road freight transport, with relatively small populations, sparse networks, and long distances between major cities. Governments have necessarily taken a pragmatic approach to improving productivity through regulations that encourage innovation.

2. Applying Evolution Theory to Trucking

2.1. The Reproduction Analogy

At the core of the trucking evolution concept is the notion that sexual reproduction of the type that normally takes place in the natural world, which is either helped or hindered by the fitness of the individuals and therefore their ability to reproduce, is loosely akin to the sales of trucks, which is either helped or hindered by how well they perform in a given habitat because that determines how popular they are to the buyers in that market. For example, a heavy duty truck that can carry a greater weight than a light duty truck is more likely to be purchased in a habitat where the freight to be hauled is mostly of a high density (e.g., from mine sites to rail heads). This purchase represents a generational change which is most likely to occur when a truck reaches the end of its operating lifespan and is no longer well-suited to its environment. Conversely, a truck that can carry a greater cubic volume than another will flourish when the environment is mostly concerned with low density freight. Other examples include operational flexibility, modularity, robustness, reliability, and fuel efficiency.

There is, however, the possibility that different environmental factors come into play simultaneously. In the earlier example of a heavy duty truck being able to carry a greater weight than a light duty truck, despite the potential market demand for the heavy duty truck, the additional strength of the heavy duty truck is of no use if the regulations permit only a light weight to be carried. In such a case the heavy duty truck is unnecessarily heavy in its construction and would be less favourable to the market than the light duty truck from the perspective of payload capacity. If, for some reason, the regulations changed in the future and from that point onwards trucks were allowed to carry a greater weight, then the heavy duty truck would begin to dominate sales and become more abundant in the fleet.

2.2. The Effect of Regulatory Habitat

It can be understood from the above discourse that a given regulatory habitat would see, over many generations, a convergence of truck design and use towards what is considered to be optimal for that habitat. If two completely segregated regulatory habitats existed, and if those regulatory habitats were sufficiently different, one would expect truck design and use to converge on different solutions in the two habitats. The two unique regulatory environments in Australia and Canada provide two distinct habitats within which we may observe trucking evolution in action.

Drawing an analogy between the regulatory habitat in which trucking occurs and the natural habitat in which biological species live is instructive, though imperfect in at least two respects. First, we acknowledge that regulators purposefully adjust (that is, punctuate the equilibrium of) the regulatory habitat to induce changes to trucks and trucking operations. (This purposeful action may be more analogous to the concept of intelligent design than classical evolutionary theory). These purposeful adjustments, however, do not always achieve predicted outcomes. Further, regulatory adjustments that affect trucking are not always specifically directed at the trucking industry, and certain changes happen in the trucking industry without any purposeful consideration. Second, it is naïve to assume that the regulatory habitat is only impacted by regulators, as many other forces are influential, including the trucking industry itself. This paper seeks to develop relevant insights despite these imperfections.

The regulatory habitat in which trucks operate is diverse and complex (Montufar and Clayton, 2001). The diversity of truck regulations, however, can be generally categorized as those pertaining to (a) vehicle size and weight (and their geographic and temporal applicability), (b) safety, (c) driver and vehicle credentials, and (d) operational conditions. The implementation of these regulations may occur in a prescriptive manner, within a performance-based scheme, or using some hybrid of these approaches. In this paper, we focus on regulations pertaining to truck size and weight and their impact on truck innovation and productivity; necessary details about the regulations and how they are implemented are presented in the case studies.

3. Evidence of Evolution in Australian and Canadian Trucking

We examine the impacts of regulatory habitat on truck innovation and productivity through three case studies. First, the evolution of the truck and dog configuration in Australia is described. This case study focuses on changes to vehicle design that have occurred in response to regulatory changes. Second, we demonstrate the evolutionary effects of regulation at a system-wide level by providing evidence of fleet mix changes that have occurred in the Canadian Prairie Region. Third, using the example of LCVs in Canada, we illustrate how regulations impact the size of a truck's habitat and thus also influence its popularity.

Case Study A: The Longer and Heavier Truck and Dogs of Australia

This case study summarizes the recent evolutionary changes to an Australian truck configuration known colloquially as the truck and dog. The truck and dog configuration comprises a rigid (straight) truck and a full trailer and is predominantly used for the transportation of bulk commodities. Bulk payloads such as grain, sand, and woodchip are typically loaded via a hopper into the truck bins and are then tipped or dumped into stockpiles once the vehicle has reached its destination. The granular payload and method of unloading has a strong influence on the design of the truck and dog. The vehicle must be manoeuvrable, allowing for improved access and efficient loading and unloading, as illustrated in Figure 1.



Figure 1 – A 3-axle Truck and 5-axle Dog Trailer Demonstrating Manoeuvrability and Tipping Both Bins Simultaneously

(The term ‘dog’ is thought to be based on the conceptual similarity between the way that the trailer loyally follows the truck while cornering and the way that a dog follows its master. A dog trailer can also be referred to as a pup trailer, particularly in Canada and the United States. There may be other explanations for these terms, but regardless of the origins, the vernacular is apt for a paper linking trucking and Darwinian theory.)

The purpose of the truck and dog is to deliver bulk commodities as efficiently as possible. The most successful vehicle (dominant species) will be the most productive (voluminous and/or heaviest) vehicle that still maintains an acceptable level of manoeuvrability to achieve this purpose. The simplest way to increase the productivity of a truck and trailer is to add another trailer to the combination, but this is not an option for a truck and dog that must remain highly manoeuvrable. Another possible evolutionary change for a truck and dog is for it to be replaced altogether by the highly productive and popular B-double. However, the heavier B-double is unlikely to be a threat to the truck and dog because of the limitations in its manoeuvrability and unloading.

Therefore, the evolutionary path that the truck and dog followed was to simply become heavier and longer and to add axles to the trailer. For a long time the evolution of truck and dogs was stunted by prescriptive regulations that placed overall limits on the size and weight of these vehicles, not allowing them to load to the sum of their individual axle group mass limits. Through the 1990s, more consideration was given to the performance of truck and dogs. How these truck and dogs performed on the road was quantified and this improved understanding began to shape some minor changes to truck size and weight regulations. For example, special allowances were made for truck and dogs carrying logs to operate at an overall length of 22.0 m (72.1 ft) (VicRoads, 1999), an increase beyond the maximum vehicle length previously permitted. Truck and dogs evolved to the maximum lengths and weights permitted by the regulations. The evolution of truck and dogs changed dramatically in 2007 when the performance-based standards (PBS) regulatory scheme was implemented in Australia. In terms of truck size and weight, this was a revolutionary change that allowed access to the road network based on how the vehicle performs rather than its size and weight. Importantly, PBS lifted the requirement to remain under a total mass cap, and allowed loading to individual axle group mass limits provided safety and bridge loading requirements were met. The following paragraphs describe this evolution in more detail.

While compatibility with neighbouring countries is not an issue for Australia, different regulations have existed between states. The basic prescriptive regulations for truck size and weight are the *Australian Vehicle Standards Rules* and the *Mass and Loading Regulations* which apply to all truck and dogs in Australia. These regulations limit vehicle length to 19.0 m (62.3 ft), vehicle width to 2.5 m (8.2 ft), vehicle height to 4.3 m (14.1 ft), and maximum combination mass to 42.5 t (93,500 lb). There are also mass limits imposed on each axle group within a vehicle combination. Axle mass limits exist under three operating schemes: general mass limits, concessional mass limits, and higher mass limits. Despite the 42.5-t basic mass limit on a combination vehicle, truck and dogs have generally been allowed to operate at a higher total mass under a special prescriptive provision in each state. This total mass generally does not allow the vehicle to load to the maximum allowed on each individual axle group, but is an overall mass cap. The dog trailer is usually downloaded to keep the combination within the total mass cap. Table 1 provides a summary of the prescriptive capped maximum combination masses under the general mass limits scheme for four Australian states.

Table 1: Truck and Dog Mass Limits

Australian jurisdiction	3-axle truck and 3-axle dog trailer	3-axle truck and 4-axle dog trailer
New South Wales	48.0 t	50.0 t
Victoria	45.0 t	50.0 t
Queensland	45.0 t	50.0 t
South Australia	45.0 t	49.5 t

NOTE: 1 t = 2200 lb

In addition to these mass limits, all axle spacings (distance between axle groups) must comply with the following bridge formulae:

- $M = 3L + 12.5$ (for M up to 42.5 t)
- $M = L + 32.5$ (for M between 42.5 t and 50.0 t)

where L is the distance between the extreme outer axles of any two axle groups, in metres, and M is the sum of the masses carried by those axle groups and any axle groups in between, in tonnes. The result of these mass caps and bridge formulae was that the full capacity of the truck and dog (sum of individual axle mass limits) was not being realized.

In 2007 when PBS was implemented, the remaining productivity gains were unlocked because the scheme allowed vehicles to load up to the sum of individual axle group mass limits provided they performed satisfactorily. Introducing the PBS scheme to regulate truck size and weight provided the stimulus for truck evolution. The effect of including a performance requirement in truck regulation is illustrated in Figure 2.

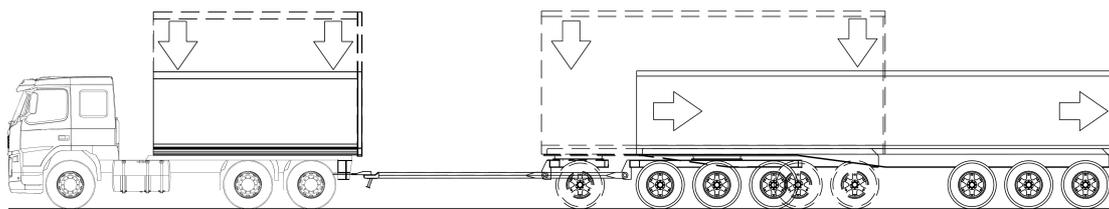


Figure 2 – The Evolving Truck and Dog Combination

Figure 2 shows the evolution of the truck and dog from a 42.5-t (93,500-lb) vehicle with a 3-axle trailer to a 68-t (149,600-lb) vehicle with a 6-axle trailer. To achieve this transformation there are a number of key links in the evolutionary chain. The first step is to reduce the overall height of the vehicle, which lowers the centre of gravity height of each vehicle unit, improves vehicle dynamics, and increases vehicle stability. Therefore, the new breed of PBS truck and dog can outperform its predecessors or perform equally with a greater payload. The first step in the evolution is complete—the truck and 3-axle dog trailer once weighing 42.5 t (93,500 lb) has been replaced by the 48.0-t (105,600-lb) version. At this point the individual axle group mass limits are reached. However, not all truck and dogs are able to reach this point of advancement in the evolutionary chain. The bin heights have been lowered and subsequently the payload volume has reduced considerably. This adaptation only suits truck

and dogs with dense payloads. Truck and dogs with payloads such as wood chip and some grains are unable to benefit with these confined bin heights.

The next evolutionary step is to increase productivity by adding axles to the combination. This is illustrated in Figure 2, in which a 3-axle dog trailer is replaced by a 6-axle dog trailer. In order to comply with bridge loading standards the distance between axles must increase as the individual axle group masses increase. The result is a truck towing a heavier and longer dog trailer via a longer drawbar connection. In the process of evolving to have a longer and heavier trailer, the payload volume has also increased allowing this option to be accessible to those previously excluded operators carrying low density payloads.

The increases in mass and length between the 6-, 7-, 8-, and 9-axle truck and dog variants are summarized in Figure 3. The longer and heavier truck and dog exists today because of the flexibility accommodated by the PBS regulatory scheme. However, there are certain prescriptive regulations that these vehicles must comply with, such as individual axle group limits and the associated bridge loading standards and also the few prescriptive limits that currently exist under PBS. Fundamental to PBS are the levels of access granted to operate on the Australian road network. The Australian road network is segmented into four levels each with a maximum permissible length. Therefore, a vehicle can evolve to reach the maximum permissible length under each level, but beyond this length their access is restricted to specific routes. The first level of access has a limit of 20.0 m (65.6 ft), thus any vehicle below this limit (that meets the PBS requirements) can have unrestricted access to the road network as is the case for all 6- and 7-axle truck and dogs, shown in Figure 3. However, the 8- and 9-axle truck and dog variants exceed this limit and can only operate on a smaller restricted portion of the road network. For many operators these restrictions are considered an acceptable compromise for the productivity gains realized.

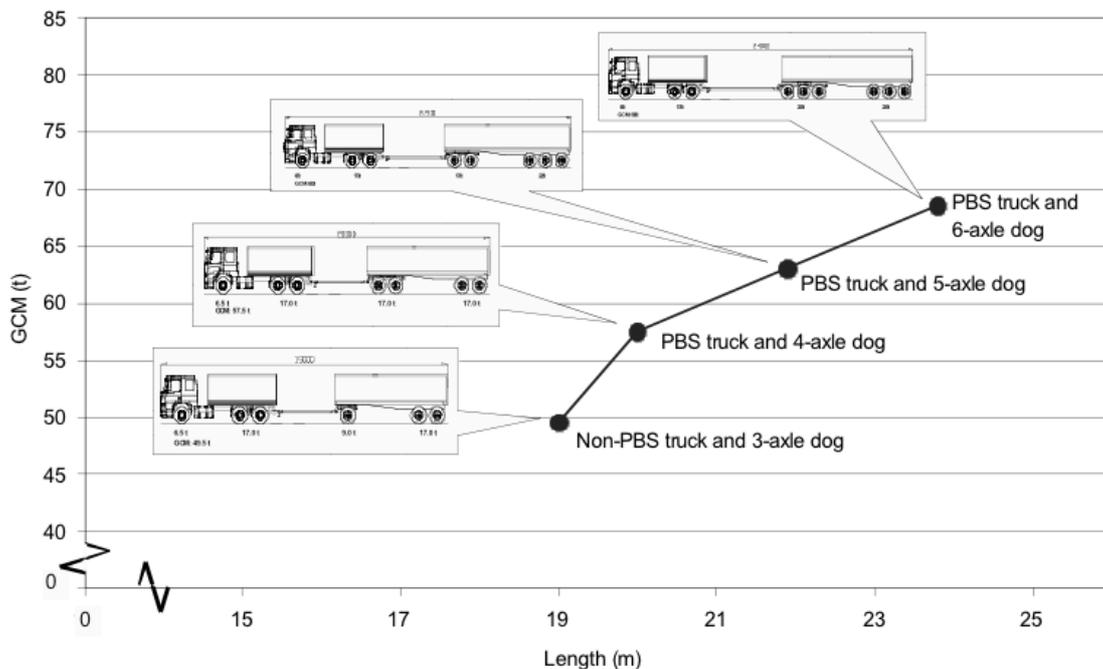


Figure 3 – Increases in Mass and Length from a 3-axle to 6-axle Dog Trailer

Case Study B: Evolution in the Canadian Prairie Region Fleet Mix Resulting from Changes in Truck Size and Weight Regulations

This case study presents historical evidence of fleet mix evolution in the Canadian Prairie Region, resulting at least in part from purposeful changes in truck size and weight regulations. This evidence, which has been updated from research originally reported by Regehr, Montufar, and Clayton (2009), provides a 40-year perspective on how changes in the truck size and weight regulatory habitat have induced extinctions and generated new species within the region’s articulated truck fleet. The historical evidence integrates data collected from weigh-in-motion (WIM) devices, automatic vehicle classifiers (AVCs), and manual vehicle classification surveys on the Trans Canada Highway (Highway 1) west of Winnipeg, Manitoba. This highway is the major east-west trucking corridor in the Canadian Prairie Region, serving principally long-distance, interprovincial trips. Thus, the observations approximately represent the situation occurring on most major highways in the Canadian Prairie Region (Alberta, Saskatchewan, and Manitoba). The dataset distinguishes six articulated truck configuration groups (species) of historical importance in the region: (a) 3-, 4-, and 5-axle tractor semitrailers; (b) 6-axle tractor semitrailers; (c) 5-, 6-, 7-, and 8-axle A-trains; (d) 7-axle B-trains; (e) 8-axle B-trains; and (f) specially-permitted LCVs. Single-unit trucks are not isolated in the dataset.

Evolution of the fleet mix is referenced to three uniquely Canadian initiatives that have shaped the truck size and weight regulatory habitat. The first—the Western Canadian Highway Strengthening Program (WCHSP)—occurred in 1974, with the commitment of federal financial assistance to the western provinces under the condition that larger and heavier trucks be allowed to operate on major routes. This program was directed at strengthening roads and bridges, improving truck productivity, and making trucking more competitive with the rail industry. As shown in Figure 4, the major fleet mix outcome of the program as measured on the Trans Canada Highway west of Winnipeg was the emergence of double-trailer configurations. Over the next 15 years, A-trains and 7-axle B-trains penetrated the articulated truck fleet to a maximum level of about 15 and 10 percent, respectively.

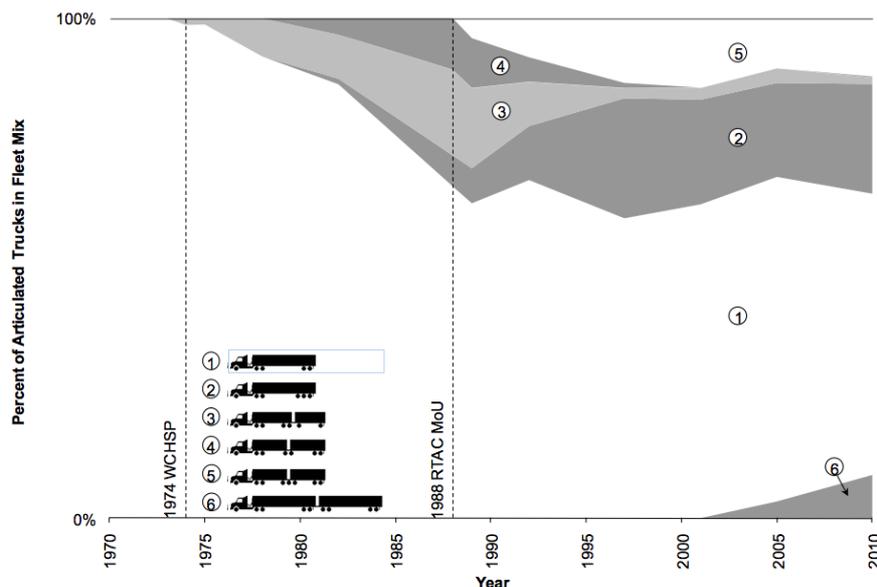


Figure 4 – Articulated Truck Fleet on the Trans Canada Highway West of Winnipeg, Manitoba, 1970-2010 (NOTE: Truck configuration group 6 represents all longer combination vehicles, not just the Turnpike double shown.)

The second regulatory initiative occurred in 1988 with the signing of the Roads and Transportation Association of Canada Memorandum of Understanding on Heavy Vehicle Weights and Dimensions (RTAC MoU). The RTAC MoU focused on uniformity, economic, and safety objectives related to truck size and weight regulations across Canada. Among other items, the MoU introduced a tridem axle group which could be used on both semitrailers and 8-axle B-train configurations. Figure 4 reveals the impacts of this new tridem axle group on the fleet operating on the Trans Canada Highway west of Winnipeg, with both 6-axle tractor semitrailers and 8-axle B-trains emerging from nominal levels to a fleet penetration of about 25 and 15 percent, respectively.

The emergence of these two species occurred in exchange for the near extinction of A-trains and 7-axle B-trains. This evolution, which transpired over the course of about 10 years and currently appears to have stabilized, was intentionally promoted by the regulatory habitat that permitted a substantial allowable weight advantage on 8-axle B-trains compared to A-trains and 7-axle B-trains, primarily in recognition of the 8-axle B-train's superior dynamic performance characteristics. Simultaneously, the cubic advantage of the A-train and the 7-axle B-train eroded with the industry-driven shift towards 16.2-m (53-ft) semitrailers, replacing the previously standard length of 14.6-m (48-ft).

The third regulatory initiative—the special permitting of LCVs—has occurred more gradually across the Canadian Prairie Region beginning in the late 1960s. In Canada, there are three predominant LCV configurations, all of which exceed basic length limits but operate within basic weight limits:

- Rocky Mountain doubles (Rockies) typically consist of a tractor with one 16.2-m (53-ft) van semitrailer and one 8.5-m (28-ft) van pup trailer and are subject to vehicle length limits of between 31.0 and 34.0 m (101.7 and 111.5 ft).
- Turnpike doubles (Turnpikes) typically consist of a tractor with one 16.2-m (53-ft) van semitrailer and one 16.2-m (53-ft) van trailer and are subject to vehicle length limits between 40.0 and 41.0 m (131.2 and 134.5 ft).
- Triple trailer combinations (triples) typically consist of a tractor with one 8.5-m (28-ft) van pup semitrailer followed by two 8.5-m (28-ft) van pup trailers and are subject to vehicle length limits between 35.0 and 38.0 m (114.8 and 124.7 ft).

Until recently, each of the three provinces in the region independently permitted these vehicles on intra-provincial highway networks. The permits generally restrict the operation of Turnpikes and triples to divided highways and Rockies to divided highways plus certain undivided routes. Now, with the effective completion of the interprovincial divided highway network, LCVs have become more prominent regionally. This gradual emergence is evident in Figure 4, with LCVs comprising nearly 10 percent of the articulated truck fleet on the Trans Canada Highway west of Winnipeg in 2010. The next section provides further details about the Canadian LCV experience.

Case Study C: Emergence of LCVs in the Canadian Prairie Region

This case study focuses on the effect of changes in highway network specification on trucking evolution, presenting evidence about the gradual expansion of the LCV network in the Canadian Prairie Region, and the concomitant growth in LCV volumes. As indicated earlier, LCV operations have existed in the Canadian Prairie Region for over 40 years, although the magnitude and extent of these operations has never been broader than it is today (Burns, 1983; Girling, 1988; Nix, 1995). Unlike the earlier case study, the growth in LCV volumes appears to have occurred in response to changes in the network on which they are permitted to operate, rather than because of a sudden change in the allowable truck size and weight limits. Essentially, the habitat in which the LCV species is able to flourish has increased due to network-related regulations. Although this case study focuses on the Canadian Prairie Region, the LCV network has also expanded in other Canadian provinces, including British Columbia, Ontario, Québec, New Brunswick, and Nova Scotia, following successful pilot testing.

Figure 5 depicts the evolution of the LCV highway network in the Canadian Prairie Region from the early 1970s to 2008. In the 1970s and early 1980s, independent intra-provincial initiatives permitted LCVs to operate on divided highways between major origin-destination pairs within each jurisdiction (e.g., Calgary-Edmonton in Alberta, Regina-Saskatoon in Saskatchewan, and Winnipeg-Brandon in Manitoba). By the late 1980s, substantial expansion (in terms of centreline-distance) of the two-lane undivided highway network allowed regional, long distance trips between provinces by Rockies (e.g., the Trans Canada Highway from Calgary to Winnipeg, and the Yellowhead Highway from Edmonton to Saskatoon). This network also enabled Rockies to access smaller population centres (e.g., Grande Prairie, Alberta and Prince Albert, Saskatchewan) and northern areas. As each of the provinces expanded their divided highway network, Turnpikes and triples were, by 2008, also permitted on a regional basis, although this was typically not the primary intention of twinning highways. This expansion permitted Turnpike and triple operations on a larger portion of the network, but did not increase the total extent of the LCV network.

Di Cristoforo, Regehr, Germanchev & Rempel
Survival of the Fittest: Using Evolution Theory to Examine the Impact of Regulation on Innovation in Australian and Canadian Trucking

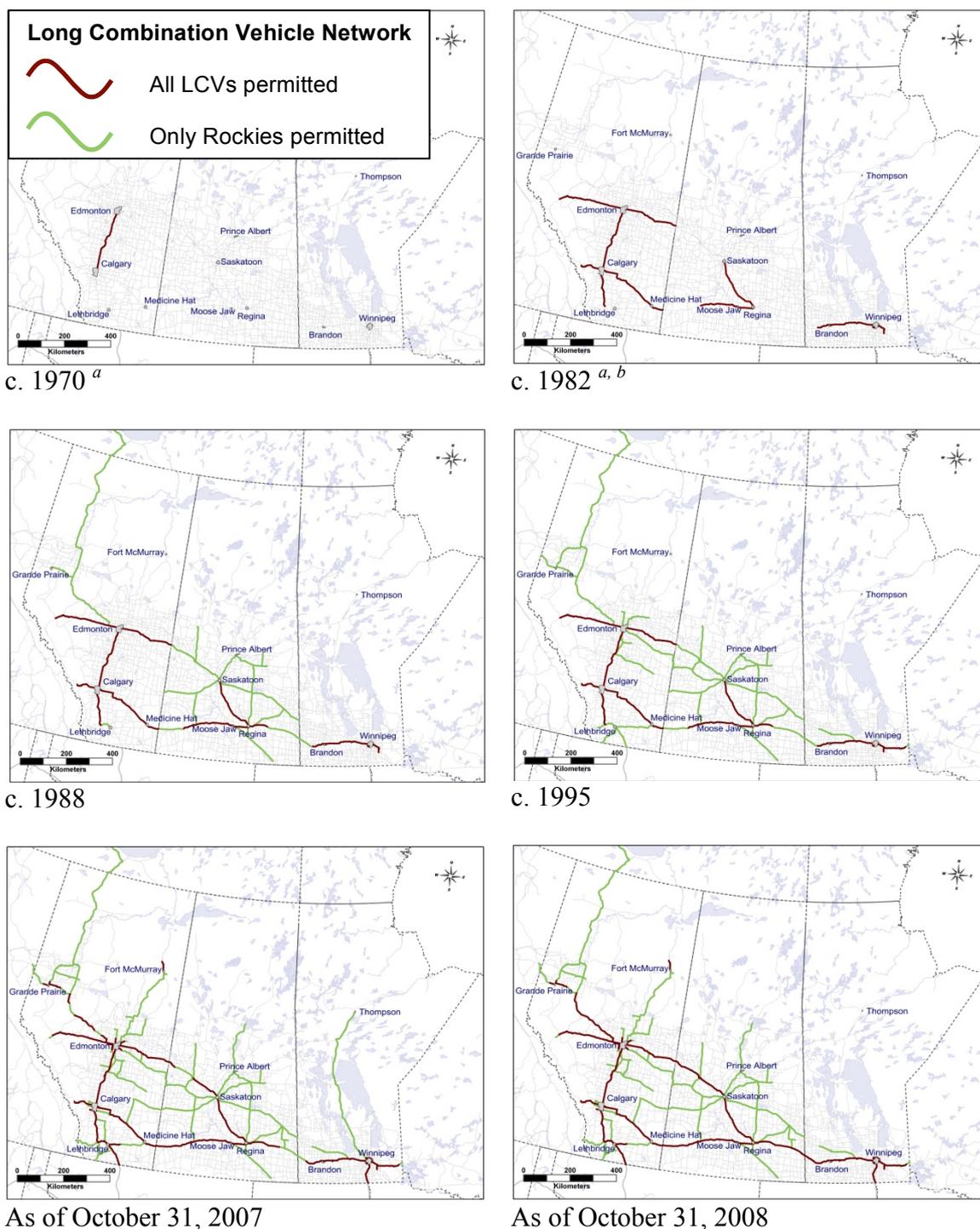


Figure 5 – The LCV Highway Network in the Canadian Prairie Region, 1970-2008
 (NOTES: ^a Only triples permitted in Alberta. ^b Only triples and Rockies permitted in Manitoba.)

As expected from evolutionary principles, a corollary of this network regionalization (habitat expansion) is the increase in LCV volume (population) observed on highways included in the LCV network. While evidence can be drawn from a variety of sources, for the purpose at hand, it is sufficient to examine LCV volume characteristics on the Trans Canada Highway west of Winnipeg, Manitoba. This particular segment of the regional LCV network has

experienced year-over-year growth from 2005 to 2009, particularly since 2007 following the completion of the divided highway network between Winnipeg and Regina, Saskatchewan. Figure 6 shows the average daily LCV volumes observed at a WIM site on this highway. As shown in the figure, the network completion contributed to the increase in overall LCV volume, and also to a shift away from the operation of Rockies (which were permitted on the previously undivided link) to Turnpikes.

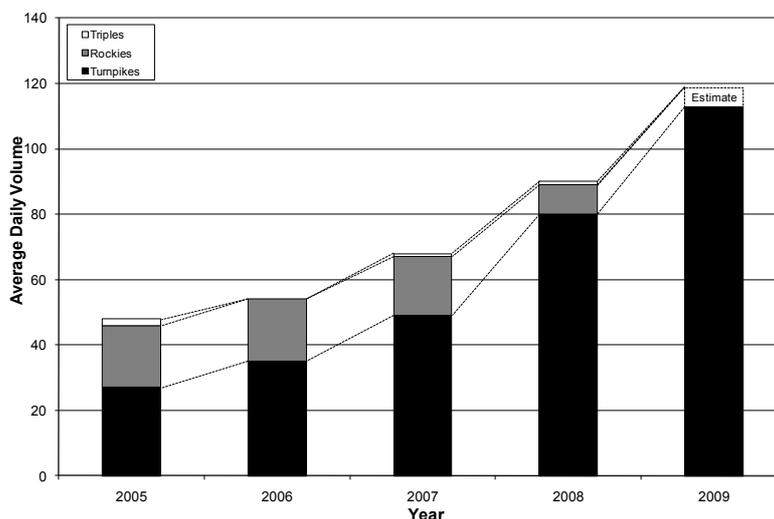


Figure 6 – Average daily LCV volume by type on the Trans Canada Highway west of Winnipeg, Manitoba, 2005-2009 (NOTE: The 2009 average daily volume of Rockies and triples is estimated)

4. Regulatory Principles to Support Evolution in Trucking Innovation and Productivity

The case studies present evidence that demonstrates: (a) the evolution of a single truck species (the truck and dog) in response to the introduction of PBS in Australia; (b) evolution within a regional Canadian trucking fleet as different truck species flourish or become extinct in response to changing truck size and weight limits; and (c) the proliferation of LCVs in Canada as a result of an expanded highway network (or habitat). Examination of this evidence within the context of evolution theory—though subject to several limitations—leads to the development of a number of guiding principles in the regulation of trucking:

- The basic principle that can be drawn from the evidence presented is that changes in the regulatory habitat induce evolution in the characteristics of an individual truck species, the proportions of species within the fleet, and the population of certain truck species. Conversely, given that changes in the regulatory habitat are purposefully controlled, this principle could be interpreted in the sense that a lack of change in the habitat inhibits evolution in trucking. This principle, however, should not be interpreted to mean that trucking evolution can only occur through regulatory change, as other forces are also influential. Nor should it be concluded that all evolution resulting from regulatory change is desirable. For example, in 1970, the Canadian province of Ontario introduced the Ontario Bridge Formula which influenced the regulatory habitat by generally allowing nearly unconstrained axle configurations and spacing, including the use of rigid, liftable axles (Billing, 2006). While this created a habitat which facilitated innovation in truck manufacturing to maximize productivity, the by-product was the evolution of truck

species—namely those with rigid liftable axles—that contributed to infrastructure damage (Woodrooffe et al., 2010). In 2001, Ontario introduced the Safe, Productive, and Infrastructure-Friendly (SPIF) truck size and weight regulations that encourage the adoption of infrastructure-friendly self-steering, liftable axles (rather rigid liftable axles) by granting SPIF vehicles a productivity advantage on allowable payload weight. By 2025, Ontario expects all trucks to conform to SPIF standards (Menzies, 2011).

- Increased truck productivity—for hauling both heavy and light commodities—can be achieved through regulatory change. The three case studies provide examples of unique productivity increases in Australia and Canada. These increases are sometimes realized within a single truck species (e.g., the truck and dog) and other times through system-wide changes to the fleet or the highway network. Truck regulation, however, should be more holistic than this, taking into account the implications of higher productivity on safety, infrastructure deterioration and financing, the environment, traffic operations, and modal competition (U.S. Department of Transportation, 2000). The implementation of performance-based regulations is an approach used successfully in both Australia and Canada to encourage the evolution of innovative and productive trucks while also meeting other policy objectives.
- As with biological species, evolution in trucking occurs through successive generations and eventually converges to equilibrium under constant habitat conditions. Available evidence suggests that a time lag (perhaps up to 10 years) may occur between the introduction of a regulatory change and the time at which equilibrium is reached. During this time, carriers introduce new, more productive equipment into their fleet to replace obsolete equipment as it reaches the end of its useful life. Estimating the potential use of newly permitted truck configurations and the time over which this potential may be realized are recognized challenges of conducting truck size and weight studies (Cambridge Systematics, 2009).
- The size of a truck species' habitat, which is loosely analogous to the highway network on which it is permitted to operate, impacts the population of that truck species. While this principle is simplistic, understanding the cause-and-effect relationship between network size and truck population is not. As discussed in the case studies, accessibility and connectivity of the network influence this relationship, as do a host of demand-related variables. At a local scale, truck populations tend to increase if the truck is allowed to access the origins and destinations of the freight that it is intended to haul. More broadly, population also increases if the network provides connections that facilitate long-distance hauls (for example, between major cities). An extension of this principle is that an effective network for more productive truck operations need not be overly dense or provide continuous temporal access.

The guiding principles presented in this paper provide some insight about the impact of regulation on innovation and productivity in trucking. However, uncertainty remains and with this uncertainty comes an unavoidable element of risk associated with regulatory change. The experiences in Australia, Canada, and other countries reveal at least two strategies that can help inform these decisions. First, conducting performance-based pilot studies in which new configurations are permitted under controlled conditions is recommended (Transportation Research Board, 2002; Cambridge Systematics, 2009). A recent Canadian example is the pilot testing of Turnpike doubles in Ontario, which has recently been expanded

into a permit-controlled program (Ontario Ministry of Transportation, 2011). In the United States, pilot testing of 100,000-lb (45,450-kg) 6-axle tractor semitrailers on interstate highways in Maine and Vermont was initiated in 2009 (Maine Department of Transportation, 2011). These studies involve stringent monitoring and reporting of activity and undertaking data collection programs to analyze the impacts of the new configurations on issues such as productivity, safety, and infrastructure.

Second, the ongoing monitoring of trucking activity over time at key locations is a critical requirement for understanding trucking impacts and making future adjustments to trucking regulations (in effect, controlling the habitat), thus inducing new shifts in trucking activity. Continuously monitoring trucking activity provides an opportunity to further understand how trucks respond to habitat changes and the speed at which these changes occur. Advanced technologies are more capable than ever at delivering this requirement. Principal examples are WIM and other in-pavement sensing technologies, global position systems (GPS), and radio frequency identification (RFID) tracking. With more robust datasets available, the challenge remains to confront this data in a way that informs more innovative regulatory reform.

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Di Cristoforo, Regehr, Germanchev & Rempel

Survival of the Fittest: Using Evolution Theory to Examine the Impact of Regulation on Innovation in Australian and Canadian Trucking

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