Can We Control Traffic? Instilling a Proactive Traffic Management Culture

Robert L. Bertini
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INSTILLING A PROACTIVE TRAFFIC MANAGEMENT CULTURE

About the Authors

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Hoogendoorn graduated cum laude in Technical Mathematics at TU Delft in 1995. For his PhD research, he conducted research into the possibilities of dynamic lane allocation on motorways. He was awarded his Ph.D. in 1999 under Prof. Piet Bovy and subsequently joined the Faculty of Civil Engineering and Geosciences. He received a VENI grant (for recent Ph.D. graduates) from the Netherlands Organization for Scientific Research (NOW), for his research into the behavior of pedestrians in public areas. In 2003, Hoogendoorn was awarded a VIDI grant by NWO for his research on driver behavior in traffic jams.

In 2006, he was appointed Antoni van Leeuwenhoek Professor by the Executive Board of TU Delft. Hoogendoorn was appointed to this chair for outstanding young researchers because of his international reputation and his excellent research and teaching. In 2009, Hoogendoorn received a VICI grant for research into traffic and transport management in unusual situations.

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He joined the faculty at Portland State University in 2000, and was founding director of the Intelligent Transportation Systems Laboratory and the Oregon Transportation Research and Education Consortium. He was awarded the National Science Foundation CAREER award in 2002 for his research on the use of archived traffic and transportation data for improving system performance.

From 2009-2011 he served as Deputy Administrator of the Research and Innovative Technology Administration (RITA) at the U.S. Department of Transportation, including one year as acting director of the Intelligent Transportation Systems Joint Program Office. He is currently a visiting professor at the Delft University of Technology in the Netherlands.

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In January, 2011, Prof. Hoogendoorn delivered the annual Dies Natalis address to mark the 169th anniversary of the founding of the Delft University of Technology (TU Delft). An anniversary like this is a formal occasion, and the speaker needs to grab the attention of a room full of TU Delft staff, students and associates for thirty minutes. After some agonizing, he decided to offer a general introduction to traffic management. His specialization, traffic flow theory, has its most practical application in traffic management. Moreover, there is often a limited understanding of what traffic management actually involves, sadly also among citizens, administrators, policymakers and decision-makers. People ask whether traffic management is really necessary since vehicles are becoming smarter all the time. People also have doubts about its effectiveness. So Prof. Hoogendoorn’s aim was to use the anniversary address to convince the audience of the benefits and necessity of traffic management.

In view of the audience response, it appears that the speech was a success: “So those devices alongside and over the roads really do have a purpose after all!” This provided food for thought. People tend to fear and dislike things they do not know. Perhaps the skepticism towards traffic management is based on people’s lack of familiarity with the underlying scientific principles. This is certainly something that can’t be ruled out.

Between 2009 and 2011, Prof. Bertini had the opportunity to serve as the Deputy Administrator of the Research and Innovative Technology Administration (RITA) at the U.S. Department of Transportation in Washington, D.C. Among other things, RITA oversees the Intelligent Transportation Systems (ITS) Joint Program Office, which has been responsible for moving ITS technologies into deployment for the past 20 years. This experience provided the opportunity to work closely with numerous colleagues, collaborators and partners aiming to improve the operation of our multimodal transportation system – including government agencies at all levels (federal, state, metropolitan planning organizations, counties, cities, transit agencies, etc.), as well as the private sector including the auto industry and numerous other stakeholders in the communications and technology sectors. It was clear that the ITS and transportation
operations communities need to do a much better job making the case for investment in a proactive transportation and traffic management system: elected officials, policymakers, decision-makers, and citizens do not have a strong sense of the value of such systems.

At the same time, vehicles on the market now have features available such as: adaptive cruise control, forward collision warning, blind spot warning, traffic sign recognition, lane keeping assistance and driver alert systems. How do these systems work synergistically with traffic and transportation management systems? How can we use traffic management systems to collect the data we need to continue to describe the benefits of these systems in a compelling way? As we aim to improve the safety, efficiency, sustainability, accessibility, equity and reliability of our multimodal transportation system, we need to instill a culture of innovation and accountability in the traffic management industry.

These factors, plus the fact that Prof. Hoogendoorn is hosting Prof. Bertini at TU Delft for a sabbatical, have inspired the idea for this joint publication for an international audience. The principles of traffic flow theory and its practical applications are very close to our hearts—and those of our students, colleagues and collaborators. If we can take one small step toward convincing a wider public audience of the benefits of and need for a proactive traffic management framework, we will be satisfied with our efforts. We hope that you will find this introduction to traffic management (for vehicles of all kinds and pedestrians alike) interesting and useful, and that it will leave you to draw one conclusion: we can’t live without traffic management!

We look forward to your comments.

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April 2012
The Love Parade
JULY 24, 2010, DUISBURG, GERMANY

2:00 P.M.
The Love Parade, a popular electronic dance music festival, begins, ultimately drawing 1.4 million people to the venue. The site is filling up quickly – too quickly, in the view of the crowd manager. At 2:30 p.m., he calls for police assistance. But the on-site team does not have access to a radio or mobile phone. Later, the crowd manager explains that it took him 45 minutes to reach the police chief.

3:00 P.M.
The security staff is closing as many access gates as possible. The flow of visitors from the western entrance starts to recede slightly.

3:30 P.M.
There are still masses of crowds thronging the main entrance. Some of the visitors waiting there decide to scale the western and eastern embankments into order to reach the festival site more quickly. This only increases the congestion.
3:50 P.M.
The police create the first blockade along the western viaducts. At the same time, a small exit near the main entrance is closed. A little later the eastern access route, near the eastern tunnel entrance, is sealed off by a police cordon. Both of these blockades result in long queues.

4:02 P.M.
The western access gates are reopened shortly after 4:00 p.m., probably to enable an ambulance to enter the site. A large group of visitors then flows into the site from the western entrance towards the first police cordon. At the same time, the police set up a third blockade at the main entrance. This blockade then prevents a large group of people from exiting the festival site.

4:15 P.M.
The situation deteriorates when the crowd breaks through the police cordon on the eastern side. These people then move towards the main entrance, where they hit the third police cordon. A little later, the police decide to remove the first cordon on the western side. This crowd of people also moves towards the main entrance. At the main entrance, there is now an ever-growing group of people who wish to enter the site facing a growing group of people who want to leave it, at that point still separated by the police cordon.

4:24 P.M.
Nine minutes later, the third cordon also gives way, simply due to the pressure exerted by the mass of people. At this point, the situation becomes uncontrollable and untenable. The consequences? Sadly, 21 people were killed and hundreds of people were injured.
Hurricane Katrina
AUGUST 2005, NEW ORLEANS, LOUISIANA, USA

**Tuesday August 23**
Hurricane Katrina forms off the coast of the Bahamas.

**Thursday August 25, 6:00 P.M.**
Katrina makes land fall in Florida.

**Saturday August 27, 5:00 P.M.**
Voluntary evacuation of New Orleans called.

**Sunday August 28, 9:30 A.M.**
Mandatory evacuation of New Orleans. It is estimated that 80-90% of the population (430,000 vehicles) were able to evacuate over a 48 hour period using contra-flow lanes on freeways. An estimated 100,000-300,000 people did not or could not be evacuated. It is understood that 112,000 people did not have access to personal vehicles.

**Sunday August 28, noon**
Superdome is refuge of last resort for up to 25,000 people.

**Monday August 29, 6:10 A.M.**
Katrina makes landfall in Louisiana.

**Monday August 29, 2:00 P.M.**
First levee is breached. Hurricane Katrina and the levee failures resulted in the deaths of at least 1,464 Louisiana residents. The major causes of death include: drowning (40%), injury and trauma (25%), and heart conditions (11%). Nearly half of all victims were over the age of 74.
Reconstructions of tragic events in Duisberg in 2010 and in New Orleans in 2005 are certainly not a cheerful way to begin a publication on the subject of traffic flows and traffic management. We nonetheless decided it was important to include these specific examples. Why? First because they provide an immediate demonstration of the fact that traffic flows and traffic management apply not only to highway vehicles of all kinds but also that large groups of pedestrians create traffic flows, as do groups of cyclists, trucks, buses, ships or any other moving objects. In principle, the phenomena that we observe in all these traffic flows are analogous. Indeed, we can also draw analogies with phenomena from other subject areas, such as biology, physics, electrical engineering and telecommunications.

Another reason for beginning with examples from Duisburg and New Orleans is that the phenomena that occur in traffic flows sometimes call for intervention. What we call traffic management can be effective in combating congestion on a freeway, but the same principles can also be applied to evacuations during extreme weather events, other emergencies, and for guiding groups of people safely at major events (in this case we call it crowd management). Knowledge of these principles is therefore important for reducing congestion that occurs in every city every day, and also for preventing tragedies such as the events in Duisburg and New Orleans.

This brings us to the main topic of this publication: the study of traffic flows is highly relevant for society because the effective control of traffic flows – in other words: traffic management – is essential in many circumstances.
In transportation and traffic management intervention and external control are not always necessary or beneficial. Quite the contrary. Providing that there is not too much congestion, the traffic system can effectively organize itself.

In this case, in the absence of major congestion, travelers can easily choose their own favorite or optimal routes, with or without the support of a map or an in-vehicle navigation system. Provided that the traffic is calm, transportation system users do not cause any significant disruption to one another. The great thing is that the individual choices of system users also result in a balanced situation at the level of the network, in which the available space is used effectively. On a roadway, we see motorists spreading themselves evenly across the traffic lanes, leading to a synchronized situation.

This applies to highway vehicles and also to pedestrians. A good example is when two groups of pedestrians are walking toward one other. Although you might expect otherwise, we do not observe chaos or logjams. Almost automatically and very quickly, we see dynamic walking lanes emerge in which pedestrians encounter little or no hindrance from pedestrians coming from the opposite direction. This is self-organization at its best!
Is Self-organization Intelligent?
One might assume that this efficient self-organization occurs because we humans are such clear-thinking, intelligent and cooperative beings. However, that would be an erroneous assumption, since self-organization also occurs outside human societies. It is a well-known characteristic of what are known as **driven multi-particle systems**, familiar from biology, physics and chemistry. When the particles’ room for maneuvering in such a system decreases, collective patterns form from which the individual particles appear to benefit. Consider, for example, the fascinating dynamics of a school of fish or a flock of starlings, or the way in which dunes are formed in the Sahara desert.

The dynamic patterns that emerge are often extraordinarily complex. Nevertheless, there is no orchestrated coordination and no conscious, intelligent cooperation between the particles, the fish, the starlings or the grains of sand. It is possible to describe the *individual* behavior of the particles using a few simple behavioral rules: the particles do not want to collide with each other, but they also do not want to move too far away from each other either. These basic rules form the underlying secret of complex self-organization.
However efficient the self-organization of traffic flows may be, we have already stated that it only works when traffic is not too busy. This is because self-organization has its limits.

**Stagnation**

Let’s return to thinking about the flow of pedestrians. We have seen that pedestrians walking in different directions group themselves and walking lanes emerge in situations with two-way traffic. But this lane-forming process will stagnate as things become busier. The walking lanes fall apart, resulting in congestion: shuffling, some pushing here and there, standstill, etc.

Occasionally, this may be a temporary or highly localized problem, but depending on where the congestion is and how busy things are, a chain reaction can occur. Within a short time, the density of people can increase substantially, and can be as high as ten pedestrians per square meter (about one person per square foot) in large masses of people. In many cases, there are also uncontrolled movements within the crowd, which we call turbulence. The forces that pedestrians exert on one other in such movements are intense. Obviously, these kinds of scenarios are both literally and figuratively oppressive, but can above all be extremely dangerous. We’ve all heard about terrible situations where people can be crushed to death in situations like this. One terrible example is what happened at the football (soccer) match in Port Said, Egypt, in early 2012.

**Fire Alarm**

How can this self-organization suddenly descend into chaos? What happens is that self-organizing patterns continue to occur as traffic flow increases, but these patterns actually impede one other. The efficiency decreases and the system becomes unstable.

This decreasing inefficiency can be seen in the case of evacuations, especially if they are uncoordinated. Imagine that the fire alarm suddenly sounds in a crowded movie theater. You might think that the best course of action is for everyone to make their way outside as quickly as possible via the nearest marked exit: with a little pushing and
shoving you can be out of the building in an instant. But nothing could be further from the truth! The more people hurry, the longer the evacuation will take.

Within the discipline of traffic flows, we call this the *faster is slower* effect. As demonstrated by the Washington State Department of Transportation’s Doug MacDonald Challenge\(^1\) you can easily mimic the effects using a funnel and a package of rice. If you pour the rice slowly into the funnel, the grains will emerge smoothly out the bottom. But if you dump all of the rice into the funnel at once, the rice gets blocked in the funnel and the grains do not flow through as smoothly.

This also happens if everyone tries to leave the movie theater at once. The pressure caused by people pushing leads to people becoming jammed in by the exit doors who have to worm their way out with great effort and *therefore more slowly*. The more people hurry, the greater the pressure and the longer the evacuation will take.

\(^1\) See [http://wsdot.wa.gov/traffic/congestion/rice](http://wsdot.wa.gov/traffic/congestion/rice).

**Phantom Traffic Jams**

Another example of inefficient self-organization can be seen on the freeway. It is a familiar situation: the traffic is busy, but speeds remain relatively high. There is no bottleneck in the immediate area, and yet you suddenly find yourself braking and in a traffic jam. You come to a complete standstill. There may have been an accident, you think, but after a few minutes, the jam disappears and you simply accelerate again. No problem at all!

In traffic flow theory, we call this phenomenon a *traffic wave*. This kind of wave only occurs in heavy traffic, or more precisely: when the traffic flow has become unstable. A minor disruption – for example, a single driver being startled by something or distracted and braking too abruptly – can create a short traffic jam which is very dense and slow-moving. The jam moves backward at a speed of approximately 18 km per hour (about 11 miles per hour). However trivial the initial disruption may have been, the traffic wave can sometimes last for more than an hour.
For scientists and engineers studying traffic flows, this is a fascinating phenomenon, but it is clearly far from desirable. It can be shown that traffic waves can reduce highway capacity by around 30%, which is very inefficient. They are also relatively unsafe: before you know it, you can have a rear-end collision. This can even lead to a secondary crash further upstream. Traffic waves also increase emissions and fuel consumption. In other words, this is a highly undesirable example of inefficient self-organization.

**Spillback**

So far we have only presented relatively simple problems. However, within transportation networks a phenomenon occurs that makes things even more complicated: spillback or gridlock effects. This happens when a bottleneck in one location impedes other traffic flows. As an example in Figure 1: there is so much traffic entering the freeway via entry point A, that a traffic jam is caused on the freeway. This grows and grows until the earlier exit B also becomes blocked. The result is that drivers who need to use exit B (and who have nothing at all to do with entry point A) also come to a halt. This just causes the traffic jam to continue growing as it spreads like an oil slick across the network.

**Number of Vehicles Versus Productivity**

All of these phenomena – self-organization, inefficient self-organization, spillback effects – are characteristics of traffic networks of any kind. To reiterate, this does not concern traffic networks for vehicles alone, but also
for pedestrians, cyclists, ships or anything that moves across a network. But however complex these phenomena and their interactions may be, at the network level it is possible to describe the results by means of a very simple relationship. In the graph in Figure 2, the horizontal axis represents the number of vehicles in the network and the vertical axis shows the productivity of the network. By productivity we mean the number of vehicles that reach their destination or leave the network within a specific time period. It is clear that everything runs efficiently provided that there are only limited participants in the network (on the left of the graph, the green section). In this situation, an increase in the number of vehicles within the network leads roughly to a proportional increase in productivity.

However, when the network becomes too busy, productivity increases less rapidly and at a specific point it even starts to decrease. The exact position of the tipping point or ‘sweet spot’ varies for each network. But in principle it is possible to create a similar graph with similar results for any network. This relationship – the number of traffic participants versus productivity – is actually what makes traffic management necessary: if the number of vehicles or pedestrians in any traffic network approaches the critical point and you fail to intervene, the problems quickly begin to multiply. From this critical point, the capacity of traffic flows to self-organize becomes insufficient and is actually counter-productive. Serious help is needed through some kind of proactive intervention!
What Kind of Helpful Intervention Do We Need?

So we have now established that some kind of proactive intervention is necessary when traffic flows reach a certain tipping point. But what approach should you adopt? The good news is that the causes and phenomena described above provide useful guidance for the development of intelligent ways of managing traffic in a network.

Although this may be slightly oversimplifying things, it is possible to identify four types of solutions within the field of traffic management:

1. Prevent spillbacks
2. Increase throughput
3. Effectively distribute traffic across the network
4. Regulate the inflow of traffic

These solutions apply both for vehicle and pedestrian traffic. Below, we will examine each of these four points and provide examples. If applied sensibly, the use of these proactive approaches in traffic management can make major contributions toward solving or preventing traffic problems in a network.
1. Prevent spillbacks

Spillback or gridlock effects can cause a traffic network to come to a complete standstill. Preventing this is therefore one of the most important methods used in traffic management. In other words, let’s not block people who want to exit the system. This can be done in various ways. As an example: on page 14, we discussed the impact of spillback on a freeway. If too much traffic enters the freeway at entry point A, a traffic jam can develop that spills back to the next upstream exit. The solution is to regulate the flow of traffic entering the freeway via entry point A in order to prevent the spillback reaching exit B. This is the idea behind ramp metering systems (“one vehicle per green”) used at many freeway interchanges.

At TU Delft, an interesting experiment¹ was conducted to test this principle: a group of students simulated the traffic on a simple freeway, with an entry point and an exit, simply by walking. Two different scenarios were compared: the flow of traffic via the entry point was uncontrolled (leading to a spillback reaching the previous exit) and access to the freeway was regulated, metering out the entering traffic at the entry point at a regular rate rather than in surges. In this case, a simple traffic management strategy resulted in a collective travel time savings of 245 minutes, even though the experiment itself lasted only seven minutes. In other words, by asking some people to hold back, you can actually gain time rather than losing it.

In the U.S., a definitive study of the effectiveness of ramp metering was conducted in Minneapolis in 2001. A total of 430 ramp meters were turned off for 6 weeks and the effects were carefully measured. Without the meters in place, the evaluation found: a 9% reduction in freeway volumes, 22% increase in freeway travel times (corresponding to a 7% reduction in freeway speed), 91% decrease in freeway travel time reliability, and a 26% increase in crashes. In Portland, Oregon, we found that the introduction of a ‘smart’ ramp metering system that linked ramps together in a total corridor had the potential to improve travel time by 3.7% and reduce delay by 18.1%.

¹ See www.youtube.com/watch?v=6ODvNZsXEvs and www.youtube.com/watch?v=EJo7O8f0JiY.
2. Increase throughput

The second solution is to increase throughput, specifically at critical locations in the network. This can again be achieved in various ways. For example, you can adjust capacity temporarily by using an additional lane during rush hour. Combating the creation of traffic waves is another way of increasing throughput. We have already seen that a traffic wave can reduce road capacity by 30%. If you can effectively combat traffic waves, the throughput can increase substantially.

How should you go about achieving that? TU Delft was commissioned by the Netherlands’ Directorate-General for Public Works and Water Management (Rijkswaterstaat) to develop a solution using dynamic speeds. It works as follows: by progressively reducing the speed of traffic upstream of the traffic wave, for example by using overhead electronic speed signs, you can marginally reduce the flow of vehicles into the traffic wave. The result is that the traffic wave dissipates – preventing it from simply moving backwards – and the 30% capacity reduction is solved.

This principle was developed and tested on the A12 freeway in the Netherlands. The pilot showed that the method works in practice. Of course, its effect depends on the behavior of road users, who need to follow the speed limit imposed. This kind of system is also deployed in urban areas in Germany and recently in Seattle, Washington, in the USA, and is shown to work well using overhead gantries displaying the dynamic speed limit. The state of Washington has had a winter weather-driven variable speed limit system in place over the mountains along Interstate 90 for many years as well. In the future however, with even more intelligent in-vehicle systems, the benefits will be even greater.
3. Optimally distribute traffic across the network

The third key approach involves distributing traffic across the network. The aim is to try to make more efficient use of the remaining space in the network. This is because it is rare for the whole network to be busy at the same time and it therefore makes sense to distribute the traffic more evenly across the available space, if possible. One way of achieving this is by providing helpful information to users of the transportation system so that they can make better decisions before they travel and while en route. Showing where the network is congested and where it is not, allows the users to make smarter decisions about routes to take and spots to avoid.

For this to be successful, the traffic information must be accurate and reliable. It is necessary to have a good impression of the current situation on the network, which calls for accurate measurements. But a picture of what is currently happening is not sufficient in itself. What is actually most relevant for travelers is the future situation. If you need to drive from Rotterdam to Maastricht, it may be nice to know that there are currently no traffic jams at Eindhoven. And if you are traveling from San Francisco to Sacramento, you may be informed that the MacArthur Maze is clear right now. But these facts tell you nothing about what the situation will be like when you actually reach those points.

Estimating a future traffic situation is far from easy. To paraphrase the Danish physicist Niels Bohr: “Prediction is very difficult, especially when it is about the future.” Predicting traffic is doubly difficult, because of the unpredictable human factors and other random features at play.

Fortunately, though, we are becoming increasingly proficient at looking into the future and anticipating it. A good example of this is the Traffic Jam Radar (FileRadar) designed by two Ph.D. students at TU Delft. It provides a clear picture of the current road situation, but the FileRadar also predicts the traffic situation by means of a smart combination of traffic measurements and a traffic model. This enables travellers to make an informed decision about the best time to depart and the best route to choose.

It is difficult to predict the future if you can’t measure the current performance, so in Portland we’ve developed PORTAL (portal.its.pdx.edu), an online data archive and performance tool that contains nearly 10 years of high resolution data from freeways, arterials, buses, weather, and traffic management actions. By using sensors in many different forms, traffic managers have implemented low cost and high value bus and truck priority at hundreds of traffic signals. Beyond Portland, officials in Chicago now use algorithms developed at Portland State University for their arterial traffic tracker (chicagotraffictracker.com). This effort serves as a national model in the U.S. for archiving the ‘ocean’ of transportation data that is now available and making it accessible and usable for practitioners, researchers, decision-makers and the public.
4. Regulate the inflow of traffic

The fourth and final key approach involves regulating the inflow of traffic. The aim of this is to ensure that the number of users of the traffic network is maintained below a critical number – below the tipping point shown in the graph on page 15. This ensures that the productivity of the network remains at a sufficiently high level.

To illustrate this, we will examine the area of Walcheren, a former island in the southwestern portion of the Netherlands. Imagine that a dyke is about to collapse, threatening to flood the western part of Walcheren within the next six hours. Using the EVAQ traffic model, specially developed at TU Delft to simulate evacuations, we can predict how many of the 120,000 residents under this hypothetical threat can evacuate safely by driving out of the area. Without any direction or guidance, this number would be between 25,000 and 40,000.

However, if we apply appropriate control principles, we can more than double that figure to around 80,000. The previous key approach, of more effectively distributing traffic across the network, would appear to provide a solution here. But by ensuring that not all residents try to use the exit routes at the same time, or restricting the inflow of traffic, it is possible to keep the number of vehicles on the network below the critical level. Productivity remains at or near the maximum level and a loss of productivity is prevented. Of course, the effectiveness of this strategy is determined in part by the willingness of the residents of Walcheren to follow the advice provided by emergency authorities.

Along similar lines for non-emergency situations, colleagues at U.C. Berkeley and the Swiss Federal Institute of Technology Lausanne have found that a neighborhood (for example the San Francisco financial district) itself has an ‘ideal’ maximum level of traffic accumulation (similar to the concept shown in Figure 2). This means that perimeter control strategies can be used to ensure that gridlock never happens and that its performance remains as close as possible to its ‘sweet spot’. By maximizing the number of cars, trucks, buses, and taxis that complete their trips, a strategy such as this can improve accessibility for everyone.2

What is interesting about this fourth approach is that the same rule applies as before: you have to hold some traffic back, but by doing so you actually gain time and accessibility for everyone rather than losing it. The same is true for evacuations of buildings and similar sites.

2 See http://tiny.cc/h76yt.
For the four key approaches briefly discussed above – preventing spillbacks, increasing traffic flow, distributing traffic across the network and regulating the inflow of traffic – we have demonstrated in practice or in theory that they are all separately effective in tackling traffic problems for vehicles and pedestrians. In itself, this is reason enough to apply these methods when possible. But these separate key approaches are actually only part of the story. The true benefits can be achieved by means of the coordinated use of these measures. Expectations are that by applying the different types of solutions and associated instruments together, in a synergistic way, the available, limited infrastructure can be even more effectively deployed.

**Actual Implementation**

Unfortunately, our practical experience with this kind of coordinated approach remains limited to a few small-scale trials. In order to make genuine progress, we also need large-scale practical trials. But the question remains as to whether these trials of coordinated network-wide traffic management will ever be conducted. In the Netherlands, we have spent many years developing the most attractive plans. But so far, these plans are as far as things have progressed. In the U.S. many states, regions, cities and transit agencies have implemented individual pieces of intelligent transportation systems (ITS), and a few are making strides toward more proactive, integrated and collaborative traffic management, but it has yet to reach its full potential.

Why is this? It is certainly not because traffic management is a completely new phenomenon to which we have yet to become accustomed. The very first traffic signals to control traffic were already in use as early as the 19th century. Ramp metering was first installed in Chicago in 1963. In the Netherlands, traffic management has been used on motorways since the 1980s. In the U.S., the federal ITS program began in 1991 with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA). States, cities, counties, transit agencies and others in both the U.S. and the Netherlands now...
have a toolbox containing (for example): ramp metering, variable message signs, traffic management centers, traffic information, electronic toll collection, adaptive traffic signal systems, transit and truck priority, electronic preclearance and weigh-in-motion systems for commercial vehicles, automated fare payment systems, high occupancy toll lanes (in the U.S.), variable speed limit systems, and more. When it comes to traffic data and information, one need only consider the meteoric rise of such companies as TomTom, Google and Inrix.

Although not all measures have proved to be equally effective, in general traffic management can lead to a significant improvement in safety, efficiency, reliability, sustainability, accessibility and quality of life. For example, according to figures from The Netherlands Institute for Transport Policy Analysis (KiM), during the period 1996 to 2005 traffic management succeeded in reducing delays by 25%, for a fraction of the cost of the construction of new roads. In the U.S., the Government Accountability Office (GAO) has estimated that a national real time traffic information system alone would provide benefits of more than 25:1. The Texas Transportation Institute estimates that traffic management systems and ITS applications save 336 million hours in 85 urban areas each year in the U.S., with a benefit cost ratio of more than 5:1. And with the prospect of coordinated network-wide traffic management just around the corner, the future is looking promising. The first small-scale trials have clearly demonstrated that!

Nevertheless, we are sure that some citizens and policymakers are still skeptical about the merits of this concept. “Are the costs really outweighed by the benefits to society? Is traffic management really necessary, when everyone has a personal navigation system anyway? Aren’t vehicles becoming smarter all the time? Why aren’t we using the variable message signs we have? Why do we need all these devices along the roadside and gantries over the roadway?” Perhaps these are not really the right questions to be asking. A better question might be: can we afford not to use traffic management? Ultimately, traffic management ensures that the valuable infrastructure is used to its full potential. It is therefore the most logical way forward. Imagine if Shell or Intel were to build an enormously expensive manufacturing plant and then simply tell its employees that they can do as they wish. In other words: traffic management should be seen as a precondition for safe, efficient and sustainable traffic flow. This applies to highway traffic (including cars, trucks, buses, and more) but also equally to large pedestrian flows. The question we need to ask is whether major events will even be possible without a well-considered approach to pedestrian traffic management.

A new perspective
The recent developments in our knowledge of the way in which traffic systems behave, described briefly here, form a solid basis for a new perspective on proactive and coordinated traffic management. This new perspective focuses in particular on the coordinated and integrated deployment of a range of different measures. This new approach, bolstered by new technology, more and better data, new ways of collaborating across agencies and the private sector, and smart vehicles, offers enormous opportunities for a safer, more efficient and cleaner transportation system. This is why there is such an urgent need for progress to be made with large-scale real world implementations.
This brings us almost to the end of this brief introduction to a new way of thinking about traffic management. To conclude, it makes sense to return to our introduction and the events at the Love Parade in 2010 and Hurricane Katrina in 2005. If we apply all of the insights outlined above to these events, what conclusions can be drawn?

One key point is that it is important to take account of unexpected events: always expect the unexpected. This is generally true since roughly half of all congestion is due to unplanned events. We have seen that when the traffic system is placed under pressure, a relatively minor disruption can have enormous repercussions. The organizer of a major event, emergency managers, and our daily traffic managers alike must therefore have the tools, insights and communications mechanisms to be able to intervene quickly and effectively under all circumstances. This means that effective organization, communication, collaboration and the technology to observe the crowd, the network, and take traffic management measures are absolutely essential. If intervention then proves necessary, the four key approaches discussed above must be used to control the situation, based on scenarios devised and tested in advance. This will prevent the productivity of the network at the site from collapsing, with all the consequences that brings with it.

In recent years, researchers at TU Delft as well as Portland State University (and many others) have developed valuable expertise in traffic management. We have knowledge and expertise that can help prevent these kinds of disasters in the future, and we work closely with international colleagues in many venues to advance traffic management research, education and practice. TU Delft and Portland State University are already doing this, making impacts locally in the Netherlands and Oregon, but also in Chicago, Mecca and beyond. In fact, at TU Delft, the Faculty of Civil Engineering and Geosciences is contributing ideas for the new design of the Great Mosque in Mecca, because problems have been occurring during the Hajj religious celebration in recent years, and these incidents have been increasing in scale.
No one within our discipline claims that traffic jams can be solved once and for all, but we can help to ensure that the road network is used as safely, smartly, and sustainably as possible.

**Applicable in Practice**

All of this is what makes the discipline of transportation engineering and the subsidiary area of traffic management so challenging, fascinating and rewarding. At times, it is highly theoretical, touching on mathematics, biology and physics, but at the same time this knowledge is extremely applicable in practice, and affects people’s lives and our economy on a day to day basis. We aim to help solve social and economic problems (traffic jams and how to prevent such tragedies as occurred at the Love Parade and Katrina) but on the other hand we are also contributing to the efficient movement of people and goods around the world and even the most important spiritual and religious experience of millions of Muslims. There are very few disciplines that can make that claim!
Can We Control Traffic?

INSTILLING A PROACTIVE TRAFFIC MANAGEMENT CULTURE

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In 2006, he was appointed Antoni van Leeuwenhoek Professor by the Executive Board of TU Delft. Hoogendoorn was appointed to this chair for outstanding young researchers because of his international reputation and his excellent research and teaching. In 2009, Hoogendoorn received a VICI grant for research into traffic and transport management in unusual situations.

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