An Artificial Intelligence Emergency Response Layout For Managing Highways

Emmanouil Papadimitriou, Grigorios Papageorgiou

Abstract: The rapid pace of development in Artificial Intelligence (AI) provides unprecedented opportunities to enhance the performance of many infrastructure projects, including those in the field of transport infrastructure management. The innovations introduced by Artificial Intelligence include highly advanced computational methods that mimic the way the human brain works. As the road infrastructure of modern highways often stands for a scene of emergency facts, a crucial aspect for adequate operation is the management of these incidents rapidly and effectively. The exploitation of AI potentials with the development of an AI emergency response layout is the main objective of this paper. Road operators and users benefit from on-time information and relative suggested actions, derived from the proposed AI layout. Improved management of road operation and minimized incidents' costs are the main goals of such implementations. Furthermore, an increase of safety and comfort levels for road users are the crucial aspects an AI layout shall aim at. The proposed AI application collects important information from the road area and either decides or suggests proper, in each case, actions.

Index Terms: Artificial intelligence, highway management, emergency response, roadway management

1. INTRODUCTION

AI, nowadays, is at the forefront as one of the emerging sectors of Transport Infrastructure. Academics have been talking about AI since the 1950s. Since then, AI has fluctuated, with optimistic expectations followed by bitter disappointment. In recent years, AI has made great progress, as machine learning techniques have been combined with technologies used to search and analyze large amounts of data (also known as big data and data mining) generated by the growth of the digital world. Other reasons for its successful development include the development of communications networks and the Internet of Things (IoT), as well as advances in transport devices. The future development of copyright technology in the transport sector is expected to be even more spectacular, although there is no agreement as to the timing and precise nature of these developmentsRoad infrastructure management is defined as the systematic process of operating, maintaining and upgrading the infrastructure in an efficient (profitable) way. On this basis and to make the task of managing motorways, roads and road work easier, a series of brief descriptions of tools are presented hereafter:

- Digital twins (Glaessgen and Stargel, 2012), which help to better manage the overall project and deal with damage and incidents.
- Automated construction, which is based on the recognition of the environment through laser sensors, mathematical models, data interpretations and digital imaging as well as robotics applications for unmanned machines.
- Intelligent systems for smart work zones, used in road projects, consisting of:

a) Light / digital direction signs;
b) Zipper merge;
c) Rumble strips.

- Real-time safety level rating systems, which mainly alert and update drivers on dangerous driving, off-road, road conditions, and generally critical lane situations.

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2. ARTIFICIAL INTELLIGENCE IN HIGHWAYS - LITERATURE REVIEW

Transport problems have some features that make them acceptable to Artificial Intelligence techniques. Initially, transport problems often include both quantitative and qualitative data (TRB, 2007). Subsequently, in transport, we often encounter systems whose behavior is very difficult to model with the traditional approach, either because interactions between the various elements of the system are not fully understood or because one faces high uncertainty arising from the human component of the system. For such complex systems, the creation of empirical models, based on observed data, may be the only option left (TRB, 2007). Furthermore, the transport problems often lead to demanding optimization problems that are difficult to solve using traditional programming techniques, either because the relationships are difficult to determine in detail or because of the magnitude of the problem and its computational difficulty. For these problems, genetic algorithms can provide an alternative solution (Michalewicz, 1991). The transport industry has always been shaking up its growing community. This is mainly since the industry is faced with challenges that generally exist at an international level (EU, 2019). These are efficiency, reliability, and safety, as well as road pollution, which has been a lasting threat to the integrity and completeness of the system. The efficiency and operational efficiency of the industry should be such that the whole system operates in such a way as to make transport more reliable. It is also the concept of reliability that balances the function and confidence of road users to make their transport as safe as possible. It should be noted that safety is undoubtedly the most important issue for those working in the transport sector (WEC, 2016).
What this technology has achieved is to increase the response time of the traffic managers, as well as to increase the users' response time in network saturation or situations of increased risk. Nowadays a growing proportion of the world is targeting the environment and how this can be made sustainable. They focus on addressing the impacts of industrial transport, such as reducing pollutants. Artificial intelligence could meet this

multifaceted range of challenges, which hampers the development of new innovative methods, both academically and mechanically. So, artificial intelligence is the optimal solution to massively end up with much more environmentally friendly techniques. An enormous benefit of artificial intelligence is the predictive capabilities of traffic management systems. This is reflected in the recognition of the physical and environmental conditions that are capable of leading to higher traffic flow phenomena. For example, in India, Siemens Mobility is testing an original surveillance system, which uses artificial intelligence techniques on all traffic lights to establish a solution to high traffic jams (Lanner, 2019). This reform of technology could help Indian authorities tackle traffic jams. Modern traffic management systems often use a combination of cameras and sensors on the road itself to estimate vehicle density, future user reaction, as well as the total traffic sizes present along the entire length of the road network (TIM, 2018). Smart node cameras offer the ability for the traffic management system to be adapted to the needs of an event to be addressed. The transport industry has already used this technology logic, in aircraft autopilot or smartphone applications that can predict traffic jams (TST, 2017).

3. CONCEPT OF PROPOSED APPROACH / METHODOLOGY

Bearing in mind that the existing AI systems are quite sophisticated, it could be said that future data will be obtained from state-of-the-art and highly real-time sensors and surveillance devices. The resulting data will then be collected and compared directly with the limit values set after extensive and highly specialized studies. Afterward, the smart operation system, in turn, decides whether the situation is simple or complex. A simple situation is one in which countermeasures are automatically taken by smart systems simply by informing road users through the variable message plates that are displayed throughout the road network. Such cases related to emergencies due to heavy rainfall or high vehicle crowding at one point on the road network. So, in simple cases, the optimal decision is taken and the system itself reacts instantly to the benefit of road users. In complex cases - for example, when monitoring a period of road overcrowding to artificially decide the best way to deal with the resulting problem - each system thoroughly informs the road control center and the proposed self-action resulting from. In smart systems, qualified personnel need to reach a mass decision, based on potentially applicable energy scenarios, to achieve better measures to deal with the aftermath.

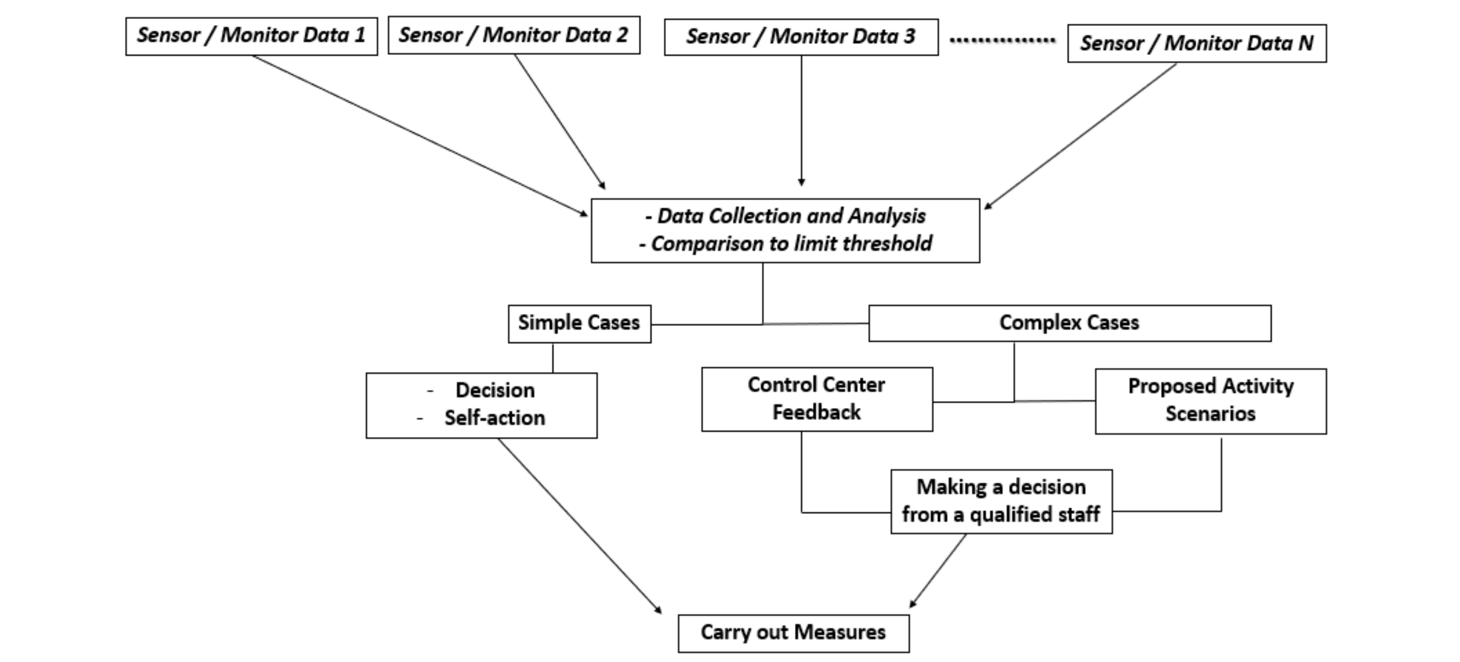

Figure 1: *Emergency resolution methodology on the Road Network*

4. COMPONENTS OF THE PROPOSED MODEL

The road network of each country around the world is exposed daily to a variety of hazards. Users of the road network, as well as its operators, that is to say, the specialized personnel of the road network, which will be able to cope with any situation, must avoid such dangerous situations. Flexibility and adaptability are two of the most important features of the proposed model, which in turn enhance and continue to extend the computing power and real-time information possessed by the hitherto optimized road network management systems. Thus, these systems have the potential to address a large number of transport engineering problems.

4.1 Emergency response due to heavy rain

Driving on a wet road, but also in the rain, is one of the most common situations a driver will encounter and at the same time one of the most dangerous. Almost half (46%) of all weather-related traffic accidents are due to rain (FHWA, 2018). Wet asphalt can cause a serious accident, both for us and for others. All drivers must be educated on how to safely handle their vehicles and avoid weather-related car accidents. Tunnel and bridge traffic management systems require special infrastructure, as well as the road network, with special needs and requirements for safety and security traffic control. Electronic signaling systems for this type of infrastructure include variable message boards (VMSs) such as signals and lane control signs, configured by specific requirements and

European standards (EN, Standards) but also space and layout. Urban tunnels are a good example of where these special features, concerning the environment such as restrictions, high traffic density, congestion, manage to create staggeringly dangerous situations at times. The electronic signs used for these applications must achieve a high degree of reliability with low maintenance requirements. By allowing text and graphics message variables to be combined, to control traffic the system achieves the efficiency of the medium to be achieved. Other benefits include increases in safety levels, an effective means of transmitting useful information to drivers, lower stress levels, and better driving behavior decisions.

Some examples are:

- Lane open / closed / change information to drivers
- Variable speed limit/risk and traffic restrictions (ERSO, 2018)

Modern design is based on a modular approach that allows it to evolve into a variety of different configurations, with dimensions, resolution, size, color display, and text, graphics, and combinations. Quality is not an option, it must be under European standards, including EN 12966, CE.

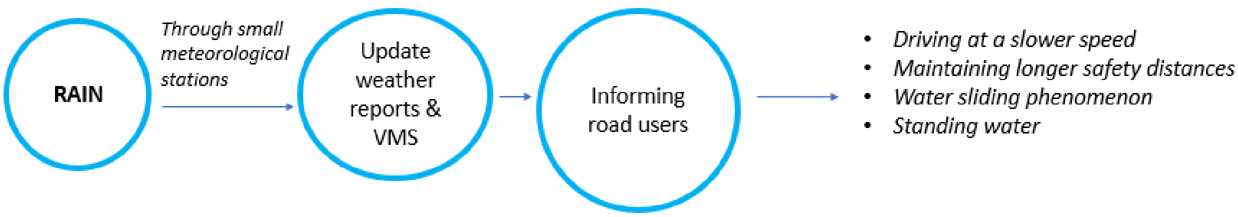

Figure 2: *Emergency response due to heavy rain*

Driving in the rain can turn a pleasant ride into a nightmare. Before embarking on a long walk, consult the weather reports to avoid extreme weather events. Check the vehicle lights, tires and wipers regularly and before a long trip. The malfunctioning of these systems will inconvenience you on your journey with any unexpected repairs and unnecessary expenses that you could save by keeping your vehicle regularly inspected. On rainy winter days where you are called upon to remember that prolonged rainfall can exacerbate fatigue. The water on the roadway reflects the light of passing cars or the environment, which burdens the driver's eyesight. Besides, the continuous operation of the wipers in combination with the cabin heat can lead to drowsiness abruptly and without warning signs. Remember to stop every 2 hours of continuous driving for at least 15 minutes. One in four on European roads is associated with drowsiness on the steering wheel.

4.2 Energy saving on street lighting

In a road network, the operation of the lighting is of utmost importance. Countless and at times uninterrupted hours of operation lead to large energy consumption. Therefore, the goal is energy savings. The operators of the road network should ensure that the lightings are functioning properly, with economical and sustainable use of energy and create the right conditions for visibility and safety for road users.

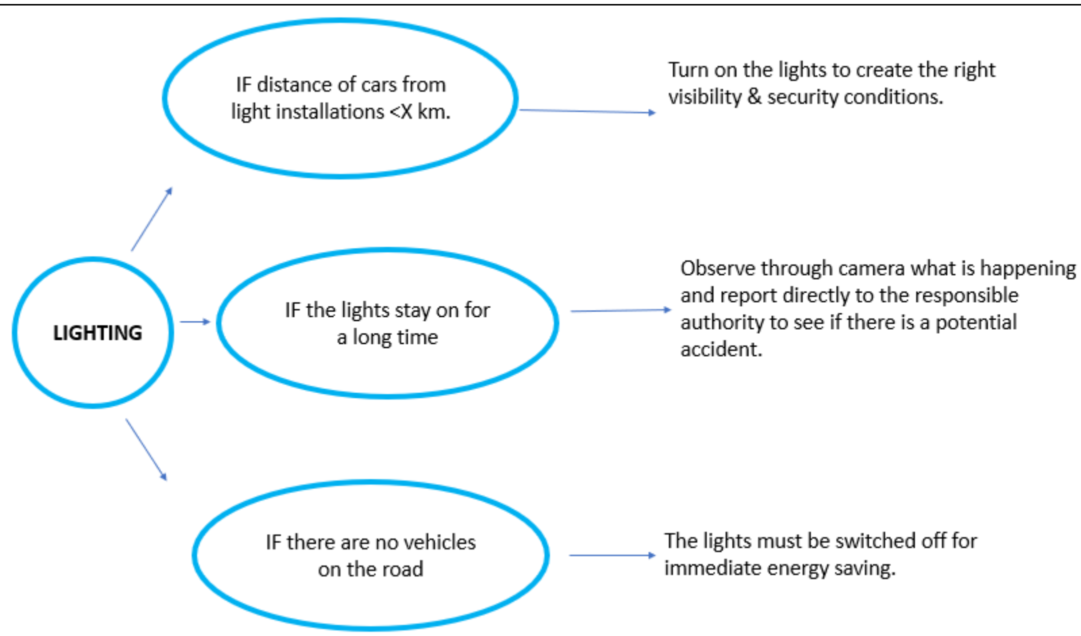

Figure 3: *Energy saving on street lighting*

4.3 Emergency response due to strong crosswinds
The power of the wind is impressive and can easily take a car for several meters off the road. This can have extremely unpleasant consequences if we move alongside other vehicles on roads with many lanes or if we are driven off-road by air. Numerous articles have been written with tips for guides on a wet, snowy and generally slippery road. Few, however, deal with the dangers of driving with high winds and the way we must respond when we are at the wheel and in such conditions. Heavy vehicles have a large front surface and drive very carefully. Especially these can even overturn. Also, mini models weighing less than 900 kg, e.g. Smart, Renault Twingo, Fiat 500, not only because of their relatively lightweight but also because of their center of gravity due to shape. The long-distance from the front vehicle is considered to be longer in such cases that the reaction time is longer, especially for trailers and mopeds. So, with Vs = side velocity = crosswind speed (km/ h) & (a * Vs) = maximum crosswind velocity limit for each country or region in Greece (km / h).

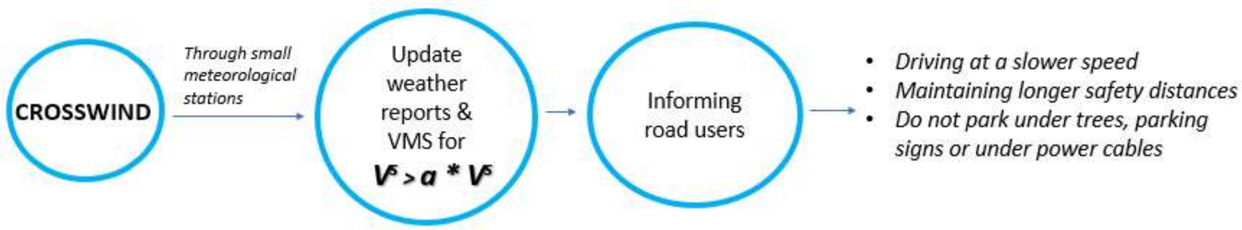

Figure 4: *Emergency response due to strong crosswinds*

4.4 Emergency response due to softening point, Fraass breakpoint
In recent years, in Greece, only one type of common asphalt pavement type, 50/70, has been used in all road construction projects. The use of such asphalt is for many an important reason for the premature destruction of pavements. In trying to address this problem and given the inability to find harder asphalts, sometimes the solution is to use modified asphalts. Laboratory results from a large number of samples of 50/70 common asphalt pavement type modified with SBS asphalt to record their main characteristic properties, is shown in Figure 5 (Nikolaidis, 2005). The asphalt softening point tested ranged from 46.0 ^{o}C to 49.2 ^{o}C and the mean value was found to be 47.4 ^{o}C. It is noted that the melting point indicates how easy or difficult the asphalt softens with increasing temperature. Thus, at high ambient temperatures, one asphalt with a low melting point is easier to soften than another with a high melting point. According to EN 12591, the 50/70 type bitumen should have a melting point of 46 ^{o}C to 54 ^{o}C. Corresponding is the range of the threshold values for other types of asphalt, such as for asphalt 70/100 which is from 43 ^{o}C to 51 ^{o}C.

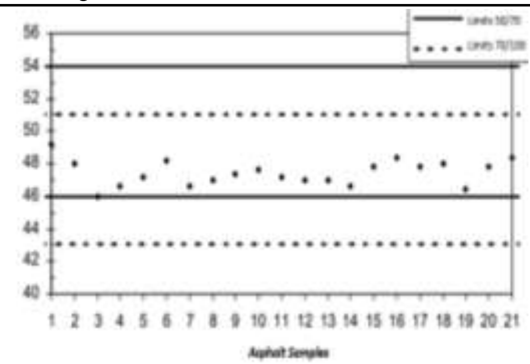

Figure 5: *50/70 Asphalt softening point variability (Nikolaidis, 2005).*

Figure 5 shows that the values of the softening point found to fit better with the 70/100 asphalt boundary zone than with the 50/70 asphalt equivalent. The Fraass breaking point determines the behavior of asphalt at temperatures below zero. Essentially, it determines the temperature at which the bitumen cracks under Fraass control conditions. The lower this temperature, the better its behavior at temperatures below zero that occur during the winter months. From the results obtained it appears that the asphalts examined have Fraass fracture limit values for type 50/70 asphalt, by EN 12591 (Nikolaidis, 2005). Therefore, the temperatures that will develop will be recorded even if they are greater / lower or equal to the permissible limits leading to the fracturing effect or the Fraass breaking point. The recording will be done by special mechanisms mounted at the edges of the road. This will measure the period of occurrence of the phenomenon and if the relevant authorities are subsequently informed to take measures for possible maintenance or even replacement of the existing road, e.g. mounting harder asphalt than they have been installed. Studying the many decisions that are being made and continue to be made under different circumstances, as well as at different levels, has shown that some basic logical steps, a process, are followed when making decisions. This process is a system of input, creation, use, and output of information shown in Figure 6.

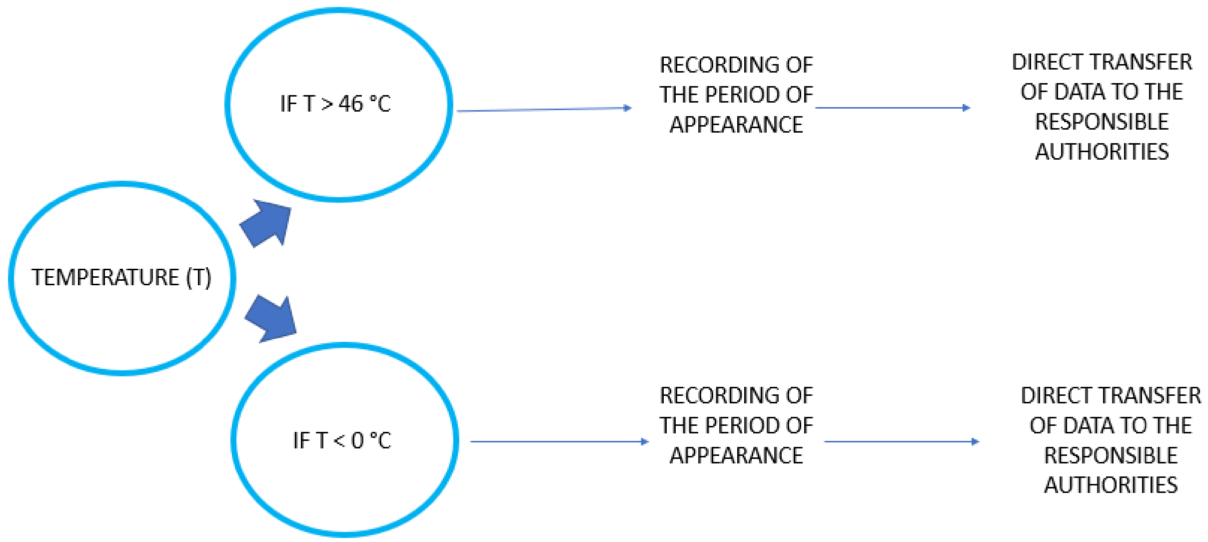

Figure 6: *Emergency response due to softening point and Fraass breakpoint*

5. BENEFITS FOR ROAD OPERATORS/USERS

The benefits of road network users are the storage advantages that drivers or owners receive through the use of one road traffic installation compared to another. The benefits are calculated in terms of reducing the costs of road users and increasing the services of road users. The services of road users are the benefits gained by the driver or the owner of the vehicle through the features of safety, comfort, convenience, etc. Reducing the rate of accidents due to improvements in highway installations brings significant benefits to road users and others. The cost of an accident may include the cost of damages for vehicles and other assets, costs for investigations, litigation, etc. Benefits for users other than road users include increased land value, increased employment opportunities and relative economic growth. Operators of each section of the road network benefit from the proposed smart systems as they will initially be allowed to react directly to any emergencies that may arise, that is to say, in terms of the immediate purpose of their work, the greater safety and security and better road infrastructure management. More specifically, they were to become more precise professionals and directly dependent on the essential legal requirements related to safety classification, internal controls and the assessment of the consequences of road safety. Finally, it is important to manage the road network in question, as well as the inspections that should take place during the life cycle of the road network, at what times and by what means. These questions will be able to be answered more easily at this time with the proposed development.

6. IMPLEMENTATION EXAMPLE

To further understand the proposed model, an implementation example is discussed below. Assuming the process unfolds overnight on a large motorway, in the early morning hours of the day, the sunshine can be felt without a trace of heavy rainfall. In the afternoon, it starts raining suddenly, making the pavement very slippery, especially when the pavement needs to be repaired and the likelihood of an accident becoming ever more likely. Thus, because the proposed smart system is intended to prevent any dangerous resulting situation, it operates immediately in such a way, having previously collected information through meteorological stations located

laterally on the road network and then informs road users of their trip and indicates to road managers to be careful about any emergencies. This model is based on the rainfall intensity factor. If the rainfall intensity is strong or torrential, then the model starts to operate significantly. If a potential rainfall over 6 mm/h or 50 mm/h (less frequently) occurs, the automated system informs through the electronic signs of the upcoming situation and also sends warning remarks - solutions on how to respond to that situation (HNMS, 2020). On the same road network, one important issue is energy saving as well. An immediate solution to this is to make optimum use of street lighting. That is, if the traffic on the road is not continuous, the lighting must be adjusted to operate less than a few kilometers until the vehicles reach the illumination point, with the unique details being adjusted so that the conditions of visibility can be favored and, by extension, road safety conditions. Of course, through this system and fixed-distance lighting installations on the road network, it will be possible for operators to be informed in real-time of any accidents and congestion situations to act appropriately. Of course, the distances from one lighthouse to another and how this distance will be determined depends on the policy of each country. In some parts of the country, the lateral thrusts of the wind are quite noticeable. They create a variety of problems, making the flow of traffic difficult. That is, when the speed of lateral winds exceeds the permissible limits set by each country by applicable law, existing or potentially applicable systems can inform users promptly to monitor how they move and how they will react in such cases, as well as the credible road network management authorities with the ultimate goal of acting where necessary. In Greece according to EN 1991-1-4, the fundamental base wind speed is for islands and coasts up to 10 km from the coast are $V_{b,0}$ = 33 m/s and for the rest of the country at 27 m/s. So, if the lateral thrusts of the wind exceed those limits, then the logic of the system starts to apply.

Finally, it would be useful to note that prevention in the field of road network maintenance is both important and of particular importance, as it forms the basis for vehicle traffic and in general the immediate source of safety for network users. Our proposed model shows that we must maintain the pavement and asphalt to be more weather-resistant, whether it is maximum positive temperatures or high temperatures below zero. This requires frequent and systematic monitoring and evaluation of the health of the pavement so that qualified scientists can act in a manner that avoids its complete failure causing multiple accidents and impeding the operation of the road network. That is, if there is a temperature over 46 ^{o}C or under 0 ^{o}C, then the system starts functioning (Nikolaidis, 2005).

7. CONCLUSIONS

New technologies bring significant breakthroughs to road project management methods and tools aimed at improving quality, safety, and economy, complementing their appropriate scope in combination with sustainable practices. The present work presents a comprehensive approach of AI applications in a variety of transport-related problems. The range of applications is expected to increase as cities and transport systems become increasingly demanding for data delivery, with the ultimate goal of developing innovative technology applications. The proposed layout performs a more effective way of design and deployment of an optimum community network, thereby improving timetables for public transport, traffic signals and optimizing routes for individual drivers. Besides, through the proposed techniques, it is easily understood that these systems serve to predict traffic demand and weather conditions, as well as upcoming traffic conditions for management and control purposes, as well as for congestion and fast but better decision-making during dangerous situations, such as in road accidents. In conclusion, they improve efficiency and immediate technical understanding, as well as the optimized action-reaction process, both by road users and by its managers, who should be able to judge, using their critical thinking based on specialized knowledge, and decide on the best solution.

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