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Monitoring and control of atmospheric conditions using mobile method of measurement in urban area

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ABSTRACT
One of the elements interfering road safety are weather conditions. Supporting instrument for identification of threats are weather information systems. They are responsible for control and minimizing disadvantageous impact of atmospheric phenomenon's on traffic. This research presents technologies used in road meteorology. Wide range of discussed systems include intrusive sensors that require mounting in road surface, as well as non-intrusive ones. One of the modern solutions are mobile sensors that allows to monitor current weather situation in variable locations. This idea seems to be an useful instrument supporting traffic management in urban areas. Mobile technology enables fast intervention of traffic authorities and eradicating dangerous effects on road network.
The research elaborates on weather exemplary data collected by mobile sensor. Authors also established possible solution for monitoring and control atmospheric conditions using public transportation system in urban area.

Keywords: traffic safety, atmospheric conditions, Road Weather Information System, RWIS, weather sensors, road weather station, active road sensor, mobile road sensor, winter maintenance

1. Introduction

Although man has no control over the weather, it is possible to observe it and draw conclusions from these observations. Intelligent transportation systems are a big help in gathering the necessary information. One of the areas of ITS is road meteorology. Knowledge of weather conditions allows to reduce its negative impact on road safety. Maintaining the proper condition of road surface is one of the key aspects, especially during heavy rain, snow, or the occurrence of black ice on the road, or wet leaves. Accumulation of these substances on the road creates a great risk of slipping by reducing traction and extending braking distance. These dangerous situations increase the chance of losing control of a vehicle which in turn affects the likelihood of a traffic incident.

Road meteorological systems:

- provide information about weather conditions in the vicinity of the road and on its surface
- allow sending an alert concerning the possible occurrence of black ice or similar events adversely affecting the road safety
- support the planning and effectiveness of road maintenance operations, especially during the winter
- support in the coordination of preventive measures based on forecasting models and monitoring their effectiveness

2. Measurements in urban areas

Urban areas, due to the diversity and specificity of different traffic conditions are treated as independent transport systems. This is largely due to variety of internal and external conditions, such as the number of movements performed in a given urban area, the number of traffic generators and terrain and microclimate characteristics. Modern road user in urban areas, takes for granted that the communication route, which uses will be maintained at a sufficiently high standard, enabling passable

and safe to travel. Therefore, one of the most important elements of traffic management and road infrastructure is to maintain roads. Problems in ensuring an adequate operability level of linear infrastructure in variable weather conditions in urban areas, can lead to paralysis of the road network and to extend the travel time. In this area, it is necessary not only to quickly identify changes in the conditions on the road but also take actions aimed at early warning and prevention of adverse surface conditions. Although the organization of urban road maintenance activities is usually adjusted according to microclimatic specifics, it is necessary to introduce a decision support systems. These systems, in addition to the delivery of timely and reliable data, allow you to specify exactly what actions must be taken to ensure a high standard of maintenance [2,4,5].

Both abroad and in Poland, one can observe roadside structures equipped with sensors, solar panels and various measuring instruments. They are compact, road weather stations. Their primary purpose is to help the maintenance services in their activities under the current weather conditions. Assessment of current conditions is possible thanks to the metrological surveying of environmental parameters in the vicinity of the road, and sending them to data distribution centers. Where, after appropriate processing it is possible to use them to control information and warning devices (eg. Various message signs, information boards) or with the drivers of traffic lights. Depending on the type of station and degree of supervision, the station can measure the following parameters: air temperature, humidity, dew point, wind speed and direction, the presence and intensity of precipitation, temperature of the road surface and the foundation, the freezing point of the liquid on the surface and the surface conditions of the road (pavement condition: dry, wet, muddy, snow-covered, icy), the concentration of the brine. Read parameters to allow determine the conditions of the road and to the develop of short-term forecasts (up to 4 hours).

From the point of view of road meteorology and road safety, one of the most important parameters that require continuous monitoring are road surface conditions. Information such as, temperature and humidity, the thickness of the water film and the presence of ice on the road, are provided by the road sensors. Usually these sensors require strict interference in surface structure, which causes the faster depletion of its fatigue capital. Currently, the market of invasive road sensors is dominated by two technologies. The first is a passive sensor, the second uses the active measurement methods. Passive technology measures the meteorological parameters without changing the existing situation. This method utilizes the phenomenon of electrical conductivity and is a valuable source of information on the actual state of the conditions on the road. However, in the case of winter road maintenance, danger warnings are generated only when snow or ice already covers the route. In case of active sensors it's different. They are able to accurately measure the temperature of the freezing point of the liquid through the cooling liquid in the vicinity of the roadway. The liquid turning into ice crystals releases portion of energy, this process is recorded by the sensor which determines the freezing temperature. Then, the sensor uses a heating element and repeats the measurement cycle. In the market of roadside meteorological sensors there are also non-invasive sensors, which do not interfere in the structure of the surface. These solutions are based on optical measurements. Generally, the laser technology (spectrophotometric) and the sensor itself resembles a thermal imaging camera. Measurement parameters are based on the analysis of infrared radiation reflected of the surface of the roadway. Non-invasive sensors are suitable for year-round monitoring of surface friction, and the detection of the road forming ice crystals that may pose a threat to road safety. Their advantage is that they can be easily installed, they may be placed on a jib on the side of the road or they may use existing road infrastructure for mounting, eg. Road signs, signs VMS [2,6].

3. Mobile Weather Stations

Mobile Weather Stations using innovative dynamic measurement method is taking non-intrusive sensors a step further. This cutting-edge technology combines spectroscopic measurements with GPS system and wireless data transmission. The solution allows to monitor pavement state in real time (using thermal mapping). Standard mobile sensor enables to obtain following data: air temperature, relative humidity above of the road surface, dew point temperature and various road conditions as dry, humidity, moistness, ice or snow, critical moisture and ice percentage as well as friction.

Fig. 1. An exemplary mounting of the mobile sensor [10]

Mobile sensor creates thermal maps, which provides a very detailed information about road temperature differences and allows to recognize potentially dangerous situations like ice or black ice on the road surface. This concept seems to be particularly useful at Road Weather Information Systems in urban areas. It enables to control pavement state in variable locations. The dynamic measurement itself take place in normal traffic conditions so it does not create any disturbances in urban traffic system and it provides precise real-time road network information. Weather conditions on road network may differ depending on the lay of the land and differentiation of hypsometry, especially in wintertime. This geographical location favors thermal fluctuations and local visibility deteriorations. The phenomenon has been determined as spatial temperature fluctuations and it depends, not only on lay of the land, but also on type and technical condition of the pavement, vicinity of rivers or water reservoirs and heat-emitting service facilities. All this factors may cause variation in the transport routes on local

road network. The fluctuations of thermal values may reach a dozen degrees Celsius on the several-kilometers route [7].

In urban areas, where the road network usage increases, rapid meteorological conditions changes may lead to dangerous situations by deterioration of road conditions. Mobile Weather Stations delivers complex meteorological information in city center, as well as in the suburbs. Consequently winter maintenance services are provided with precise and accurate data, it allows them to react quickly and effectively in cases of emergency and to generate warning messages to road users, by analyzing the thermal maps of the area.

Fig. 2. An example of a mobile sensor interface [10]

4. An example of the use of MWS in urban area

Cieszyn is a town located in Pogórze Śląskie. Administratively belongs to the county of śląsk cieszyński (town is the county seat), the western border of the city (about 10 km) coincides with the Polish-Czech border, which divides with Czeski Cieszyn. The relief of the city is very diverse. Pogórze Śląskie is a hilly highland area with gentle hills. Hills in the area of the city most often take the shape of long, narrow bands, stretching roughly from east to west, which are separated by heavily branched and deep valleys of rivers and streams. Cieszyn is an area with quite a large variety of hypsometry, closing in the range of 225 to 375 m above sea level. Approximately 3/4 of the city area is elevated at a height of 275 to 350 m above sea level, the maximum heights in Cieszyn, reach the hills on north of the city (378.5 m).

The characteristic landform of Cieszyn, large differences in height, the high rate of urbanization and the typical for medieval towns narrow streets in the city center causing problems in the urban system of winter road maintenance. Another problem arising from the terrain can be surface temperature variations. Because of the location and landform of the city, the preferred embodiment which provide an accurate measurements may be mobile weather sensors. Their use enables the thermal mapping, which helps to visualize the surface temperature changes on the road network. Analysis of existing thermal map of the road network in the area, allows to quickly and efficiently identify dangerous sections, where may appear glaze or ice.

Using public transport in mobile measurement seems to be a good idea. This solution is the most cost-effective due to the usage of the existing superstructure and control of the most important routes in the city. The regularity of public transport ensures a constant time interval between measurements, which improve the winter road maintenance system, as a decision support tool and taking immediate action in cases of emergency. Knowledge of the meteorological conditions in urbanized area allows to optimize hardware, material and human resources. This method of measurement enables to run statistics of meteorological conditions in the area. A similar solution, using public transport tin mobile meteorological measurements, has been implemented in pilot program in Florence in 2013 [8]. According to [7], in western countries, which use a mobile system for measuring the atmospheric conditions were able to achieve a reduction of de-icing material consumption by 20% in the season also to improve decision-making process and increase the efficiency of the reaction forces responsible for winter road maintenance system.

Cieszyn public transport is maintained by the budget of the Department of Public Utilities, which includes transport department to maintain and implementing public transport. Currently, the Cieszyn conducted 9 bus lines (5 urban and suburban 4) connecting residential areas, suburbs and the neighboring town of the city.

Table 1. Lines of public transport in Cieszyn [9]

Number	Length [km]	Color on the map
5	11,6	
10	16,8	
21	14,6	
22	19,7	
30	15,9	
30s	5,4	
32	35,3	
40	17,3	
50	20,5	

Public transport runs, in most cases, every day (except holidays) at different time intervals, increased number of courses occur in peaks: morning and afternoon. The lines of public transport have a total length of 52.6 kilometers. Cieszyn is a medium-sized city, so most of the lines goes beyond its borders.

Lines, which could serve as a meaningful measurement points are lines 32, which runs from the south to the northern border (where the terrain reaches a maximum height) and 40, which range combines eastern and western part of the city. Both lines go outside the city borders, so there is a possibility of measurements at the extreme points. This choice of routes enables to receive an optimal picture of the pavement conditions of the whole road network in the city [9].

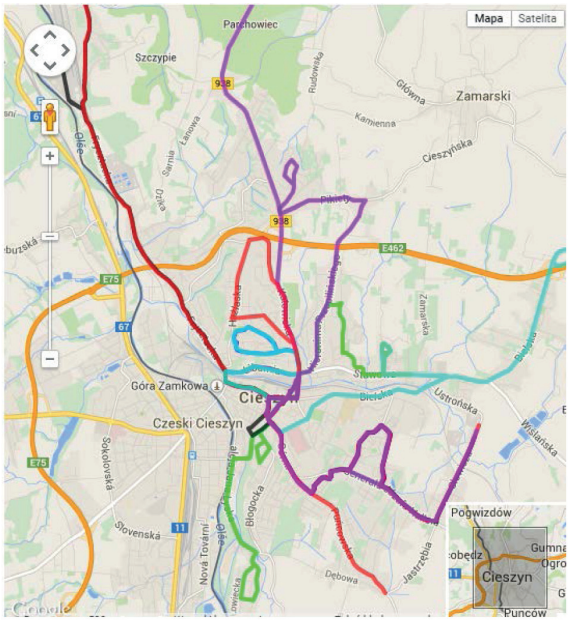

Fig. 3. Course of lines of public transport in Cieszyn [9]

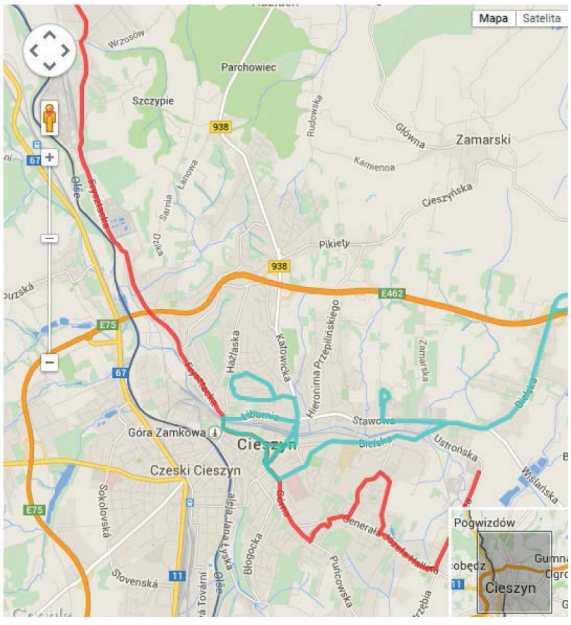

Fig. 4. Course of line 32 and line 40 [9]

5. Conclusion

To sum up, the monitoring of weather conditions is a very important element of road safety. Currently on the market there are many devices to measure meteorological parameters. The most common solution are compact weather stations that combine many functions. From the road meteorology point of view, the most important elements are sensors that measure the state of the road surface, they are dividing into two groups: invasive and non-invasive. Invasive sensors are characterized by the highest measurement accuracy, some of them allows to measure the parameters using active method, which increases the effectiveness of an early warning of danger. The disadvantage of these devices is the interference in the compact structure of pavement, which can lead to deterioration. The second group - non-intrusive sensors - are based on optical measurements, using spectrophotometric techniques. An innovative solution in the group of non-invasive sensor measurements are mobile sensors. They allow to create thermal maps of routes in real time. Their usage, along with the implementation of public transport vehicles can be cost-effective solution that could improve the performance of the winter road maintenance and optimize the resources that are involved in this process. Using of mobile sensors and their integration with public transport seems to be a good and attractive solution for urban areas. In order to illustrate this concept the study presents a exemplary implementation of a system for monitoring and control of atmospheric conditions, using mobile measurement method in the town of Cieszyn. To illustrate the example, sample lines of communication were selected, that are considered the most reliable routes in measuring the city area.

According to a study conducted in the UK [10] the number of serious injuries and deaths in accidents is 25% higher during the day when snow has been recorded, than during the other days. Adverse weather conditions also have an impact on traffic conditions, research conducted at Iowa State University showed that during heavy rain the free movement speed is reduced by approx. 5 to 10 km / h, while during heavy snowfall the rate has decreased by 38- 50 km / h [11]. It is worth to say, that many of the authors examining road accidents and collisions in adverse weather conditions indicated insufficient weather information as the main impediment to conduct a research. It follows that, despite the growing popularity of road weather information systems, their number is still inadequate [12,13].

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