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BRIDGE SCOUR AND ROAD POTHOLES HAZARDS ASSOCIATED WITH THE TRANSPORT SYSTEM AND THEIR DETECTION METHODS

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Abstract: The Transport is among the most significant human activities on the planet. Better transportation allows for more trading and a wider distribution of people. Transportation infrastructure like bridges and roads significantly influences the environment and is the primary energy drainer, making transportation sustainability a key concern. This paper also analyses current bridge scour and road potholes detection equipment and methodologies and their effect on the transport system. In scouring regards, a particular emphasis on those uses the structure's complex reaction to suggest the presence and severity of the scouring phenomena affecting the structure. A Sensitivity Analysis of a newly introduced monitoring system is also assumed. This report examines the similarities and differentials between the bridges scour detection methods and potholes methods. Our key aim is to minimize human effort in identifying road potholes and bridge scouring by using a quick, easy-to-use, cost-effective process, resulting in fewer injuries and economic savings. On the other hand, many initiatives have been taken to create a technology that can instantly identify and detect potholes, leading to improved survey reliability and pavement quality through prior inspection and prompt intervention.

1 Introduction

Scour can generally be defined as sediment corrosion around an obstacle in the flow field's direction. Scour can significantly break down structures such as bridges, spillways, and weirs when their foundations have been undermined. Scour around bridge foundations is classified into three types. First, long-term aggradation and degradation cause elevation and supplementary variations in the river's shape over a very long period due to geomorphic modifications. Second, contraction scour happens due to flow restriction for natural reasons or the presence of any obstacle such as river embankments or contraction caused by a bridge opening. Third, local scour around the bridge foundations happens when bridge abutments and piers choke the flow in the rivers' main channel and valley (Figure 1) (Chang, 1988).

Several recent bridge structure failures have resulted from local bridges scouring nearby piers. Furthermore, they concentrated on understanding the causes of pier scour causes and developed new methods for protecting bridges against scour effects. Over three decades, 1,000 bridges collapsed, 60% due to hydraulic failures, including bridge scooping, in the United States (Lagasse and Richardson, 2001). They reported that the local scour along bridge foundations was caused by river flooding, which is thought to be the chief cause of the bridge disaster. Furthermore, bridge failure results in the deaths of many people and economic damage due to the cost of rebuilding and reconstruction. For instance, in 1987, Scholarie Creek Bridge collapsed in New York (USA), killing around ten people. In 1989, a part of the U.S. 51 Bridge was demolished into the Hatchie River close to Covington, the U.S., resulting in eight deaths. The collapse in California in 1995 of the Interstate 5 bridges over Arroyo Pasajero resulted in seven people's murders. The reports of these disasters show that the local scour is the chief reason for their collapses. In addition to the human life lost, the bridge collapses cost approximately millions of dollars as indirect payments to refurbish and replace bridge structures per year and the indirect expenditure for the disruption of transportation services. The Federal Highways Administration 1978 reported a concentrated study of bridge failure in the U.S., proving that bridges and highways collapsed due to severe floods between (1964 and 1972) and cost about $100 million. In New Zealand, the scour consumed $36 million per year. The bridge's collapse resulting from the scour is a common incidence, and millions of dollars are expended each year to repair or rebuild bridges affected by the water scour.

Roads offer a vital contribution to global prosperity and deliver significant social benefits. They are of critical importance to making a nation grow and develop. Roads are connecting more areas and promoting economic and social growth. Road connection is among the essential public properties for these purposes. However, due to constant loading and weathering on the roads, a pothole can be caused, severely affecting human life. A pothole is defined as a scouring in the road's surface, frequently asphalt pavement, and traffic removes these broken portions of the pavement surface. This action causes the water in the soil structure under the pavement surface and the highest traffic moving over the pavement's affected part (Figure 2). The flowing water at the beginning deteriorates the underlying soil structure, and as a consequence of traffic, fatigue led to the break of the soft supported road surface in the exaggerated area. Transport vehicles started excavating, resulting in a road break, the pavement, and the underlying layer of land (Rioja, 2003). Most potholes appear during the wet or rainy season. However, potholes are not unusual to grow and deteriorate during the dry season due to road activity and temporary wet conditions from localized irrigation, ponding, and water seepage. The bad reinstatement of trenches excavated by bituminous roads usually leads to potholes. Potholes could be accompanied by extreme cracking and breakage or distortion of the pothole's surface, indicating a deeper cause of the potholes' formation. Water intrusion into surficial cracks in the road pavement and erosion of only the pavement's surface and upper structural layers are more likely to be the source of minor deformation in the pothole area. The distress should be present as a bowl-shaped hole with minimum plan dimensions of 6 inches to be called a pothole. The low gravity potholes are less than 1-inch, moderate gravity is between 1 and 2 inches, and the high-gravity potholes are more than 2 inches wide. Furthermore, A pothole has three characteristics that differentiate it from any entity on the street from an outer appeal. At first, the potholes are more profound than the surrounding field. Second, the pothole outline is roughly like an ellipse to a circle seen from the driver's viewpoint. Third, the surrounding area's composition around the potholes is more delicate than the texture within the pothole itself, thicker and grainier. Potholes may have arisen when snow and icefall, and the water flows under cracks formed due to road corrosion. As a result, freezing temperatures at night freeze the water, and the pavement below it grows. Consequently, cold night temperatures and water become ice, forcing the pavement to grow beneath. The traffic continues to pound on the expanding segment; thus, a low divot happens below, breaking down the pavement and forming a pothole (Koch et al., (2011).Kornél Almássy, C.E.O. of B.K.K. Public Roads reported that the number of potholes on Budapest's roads had risen dramatically due to the rapid temperature fluctuations. Due to current weather conditions, more than four hundred potholes have developed, and repair staff is working three shifts to developing the consistency of the Budapest road network. The weather in Budapest is affecting the city's road system. The main challenge is not the cold weather only, but the unexpected rise and fall of the temperature. One day, it was less than 10-15 degrees and another 15 degrees, damaging the capital's road network, with hundreds of potholes reported daily. Inspectors continually check the roads, and if they come across a large pothole, they would cover it with bagged asphalt. Potholes can grow up to several feet across but usually just a few inches in diameter. Harm tires, wheels, and car suspensions will likely occur if they become high enough. In addition, serious road crashes can occur directly, particularly at higher vehicle speeds. Potholes can be the product of four major causes: Insufficient pavement thickness to sustain traffic through freezing/dew cycles without localized failures, failures in service trenches and castings (maintenance hole and drain casings), insufficient drainage, and Pavement flaws and gaps left not sustained and opened to allow moisture and to damage the structural reliability of the road surface.

The Hungarian Statistics office, where the last study was conducted in 2017, found that about half of the road conditions in Hungary (about 54%) are wrong. Forty percent of the prominent and 60 percent of the secondary network are in a terrible state. The condition is currently the worst in Komárom-Esztergom County, where 73% of local roads are poorly paved. In the Nógrád and Győr-Moson-Sopron, 69 %-70 % of roads are only in the fair and bearable condition in Pest County. Potholes are caused mainly by excessive rain when the water reaches the road by its tears, freezes, and bursts the asphalt. In 2018, -about 1,600 claims of poor road conditions arrived at the Hungarian Road Authorisation. Out of 1,600 reports, roughly 640 were confirmed and spent a total of 43 million HUF on repairing (Kátyúhelyzet: pocsék állapotban vannak az útjaink | Világgazdaság, 2021).The Automobile Association of the United States reported an annual loss of $4 billion in 16 million vehicles, including tire puncture, twisting, and suspension injury. There is a greater risk to the economy due to potholes, which includes risks associated with road users and businesses in the form of a higher rate of incidents and potential payments for insurance rates. Driving on potholed roads increases consumer prices as it accelerates vehicle degradation and depreciation. In addition, it raises the level of much-needed repairs and extra fuel consumption. The industry has suffered annual losses in Nigeria due to vehicles' poor roads. They calculated a loss of over a million dollars per year, in addition to the other economic damages associated with poor highways, such as air pollution, traffic delays, armed robbery, and frequent deaths (Ericksson et al. 2008).

Figure 1 the pier scours at the eastern Yuriage Bridge Kayen

Figure 2 The potholes on the road surface (tirereview.com, 2021)

2 Scour monitoring using instrumentations

Monitoring concepts for structural structures have been through a steady growth phase over the last decade. As a result, they play a role in designing new and emerging architectures. Traditional instrumentation used for tracking and measuring scour and their characteristics is discussed in this chapter based on literature analysis of sensors and instrumentation technologies used to monitor scour at particular site conditions. This chapter briefly reviews selecting the more often used scour detection and measuring techniques. Then, the instruments used are divided into portable and integrated or fixed instrumentation methods. Portable instrumentation methods include Physical probing, fathometers (Sonar), and Geophysical information, while fixed or integrated instrumentation methods include buried sensors, sonar, and similar devices.

2.1 Portable instrumentations

Portable scour samples have been taken using several instruments. In particular, there are three approaches for creating a portable scour measurement and diving probing. Fathometers are the second kind of meter (Sonar) and Geophysical data.

2.1.1 Diving probing and sound rods

Diving is a basic scour screening system in which a trained bridge inspector conducts a manual inspection of the bridge underwater. This system will capture scour data from various sites, and the water clarity does not affect the data collection process. However, the downside of this approach is that it can be costly, making it more ideal for worst-case cases. It also has a strong potential for risk. Furthermore, owing to the subjectivity of the regulators, the data produced from such visual inspections may have a high degree of uncertainty (Zheng, 2013). A sound rod is used for the bridge inspector to manually test a bridge by placing a rod or weight on the Streambed to determine the sediment depth. The bottom of the shaft must be low to prevent it from contacting the Streambed due to its weight and friction created by rushing water. When the riverbed is sand, sounding rods travel through it, decreasing accuracy. Diving probing offers several benefits, including that it is not affected by air entrainment or high sediment levels and may be employed in rapid, shallow water. The main flaw in this methodology is the inaccuracy of the data samples acquired and the potential hazards involved. Furthermore, this strategy is pricey and lacks the potential for automated alerts.

2.1.2 Fathometers

For portable scour measures, fathometers or acoustically depth sounders are typically utilized. Hydrographical assessment fathometers and fish locators of precision survey grade are also utilized. While measurements are performed from the bridge, transducers are attached to a pole, thumb, tethered buoy, or boom. Tethered float platforms include kneeboards and pontoon-style floats. The floating volume seems crucial for stability in fast-moving, whirling water. A bridge inspection vehicle may also deploy both floating and non-floating structures. This is exceptionally effective whenever the bridge is considerably above the river. For example, bridges taller than 15 m are ordinarily unreachable from the bridge surface unless this procedure is applied. Mueller and Landers developed an articulated arm for positioning a sonar transducer in 2000. The trailer-mounted equipment could work on highway bridge lengths up to 15 meters high. Based on the angle and distance between the teaser and the transducer, an onboard computer calculated the transducer's orientation around a given point on the bridge deck. The researchers also illustrate a manned boat as a scour measuring platform, requiring a safe distance between the bridge and the launch facilities. During floods, however, the river level may reach or submerge the low chord of the bridge, and watercraft ramps may be flooded. A fathometer is often used for depth measurements, while position detectors are usually GPS devices. The benefit of GPS above traditional land-based vulnerability screening is that it eliminates the necessity for control stations to have line-of-sight. The GPS can be used in the dark and bad weather, making it particularly valuable for flood monitoring. The disadvantage of GPS is that it can be utilized in areas with overhead barriers, such as trees or bridge decks. GPS readings of the structure's surface have proved correct without walking beneath the bridge.

2.1.3 Geophysical data

Geophysical instruments use wave spread and recurrence data to detect the interfaces between different resources with different physical qualities. The distinction between acoustic and geophysical procedures is that geophysical techniques can detect semi-detail, but acoustic can only identify the water-soil contact, not the sediment layer. The primary differences between geophysical approaches are the delivered signals and the tangible asset alterations that create reflections. Lower-frequency acoustic waves are used in seismic instruments, similar to sonar (2-16 kHz). Seismic waves can be propagated by air bubbles and huge silt concentrations, just as sonar can (Yankielun and Zabilansky, 1999) (Figure 3). The best use of the geophysical technique is to determine scouring depth in increasing the water zones during a flood at lower flow conditions. These challenges have become minimized as more advanced, low-cost GPR devices with digital data dispensing capability have been identified. However, GPR can be limited by cost and difficulties, as well as the necessity for borehole data and trustworthy bridge influences the development to recalibrate and understand the results.

2.2 Fixed instrumentations

Instruments installed in the bridge's vicinity or in the bridge construction itself, usually at piers and abutments, to record data to alert concerned staff when the scour depth becomes extreme are known as fixed instrumentation approaches known as embedded instrumentation scour monitoring. The device is mounted at pre-determined bridge locations to track and measure scour. Sonar-based sensors, sounding rods, magnetic sliding lapels, tilt-meters, and float-out instruments are among the most popular embedded instrumentation tracking methods (Lagasse and Richardson, 2001). The type of fixed scour monitoring device that is used is determined by the information that is required. Fixed scour measurement and tracking tools can be categorized into many groups.

2.2.1 Sonar-based sensors

Which are permanent devices typically mounted on the bridge pier. Sonar emits pulse waves and processes the portable trip time from the riverbed to assess scouring depth. Both scour and accumulation of sediments can be measured using sonar sensors. The only drawback of sonar as a scour measurement instrument is that its measurements are influenced by heavy sediment and turbulent flow in the sea. In addition, high-end sonars with a large depth capacity and high resolution can be costly (Fisher et al., 2013).

2.2.2 Electrical conductivity devices

This type of device uses fluctuations in the electrical conductivity of various media to identify the orientation of the water-sediment contact. They use the principle of determining the electrical connection between two probes to do their work. The potential to draw current changes as the substance between the probes changes. This occurrence could demonstrate the prevalence and severity of the scour.

2.2.3 Magnetic sliding collars methods

Magnetic sliding collars are another helpful method used for scouring identification. This instrument consists of a thick necklace placed on a magnetic pole. The rod is pushed into the stream's bed, and the collar lies on the stream's bed. When the sand is swept away from the stream bed during the scour, the collar slips down the magnetic rod, and the depth falls. The base station senses this difference in the collar height used to deduce the scour. It is a straightforward measure, and the water's consistency does not influence its reading. While this method is very useful in calculating scour depth, the main downside is that its sensors can only be used once and cannot measure sediment deposition (Fisher et al., 2013).

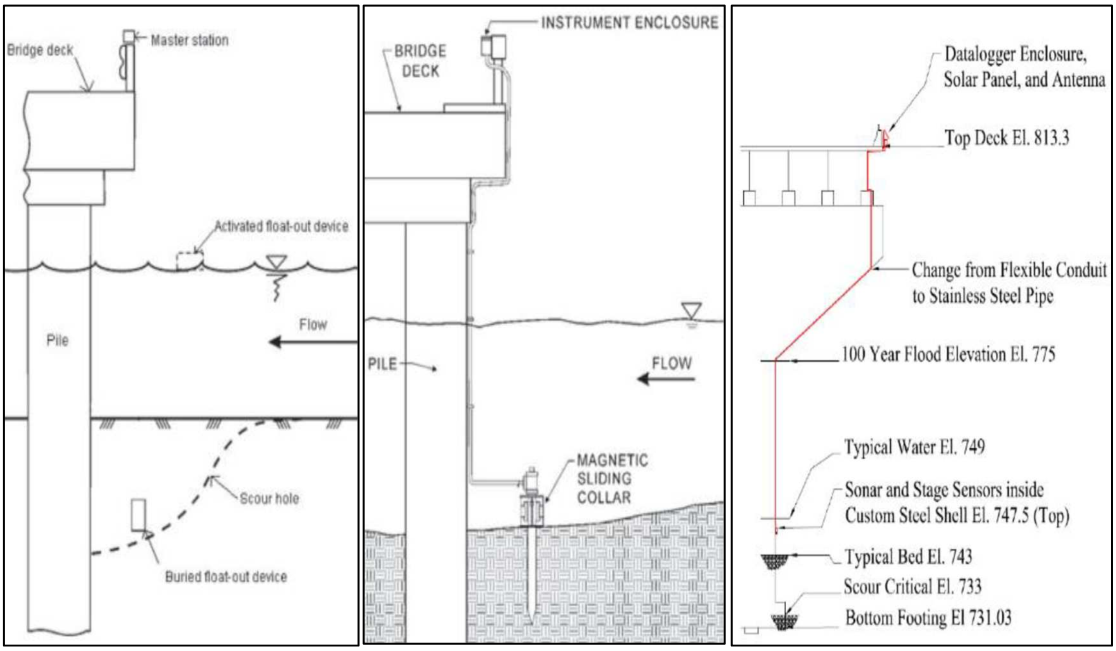

Figure 3. Fixed devices (a) sonar, (b) magnetic collars, (c) float-out devices, modified from (Zabilansky, 1997)

2.2.7 Vibration-based method

This approach uses the principle of calculating the actual occurrence of the rod fixed in the Streambed. To monitor scouring depth, the opposite relationship between essential frequency and the sensor of the rod length is applied. It uses structural vibration sensors, such as accelerometers or fiber-optic (FBG) devices, as the scour sensor's dynamic sensing feature (Figure 4). However, this approach is yet to be thoroughly tested. It is continuing research, and studies are being carried out (Lagasse and Frederick, 2007).

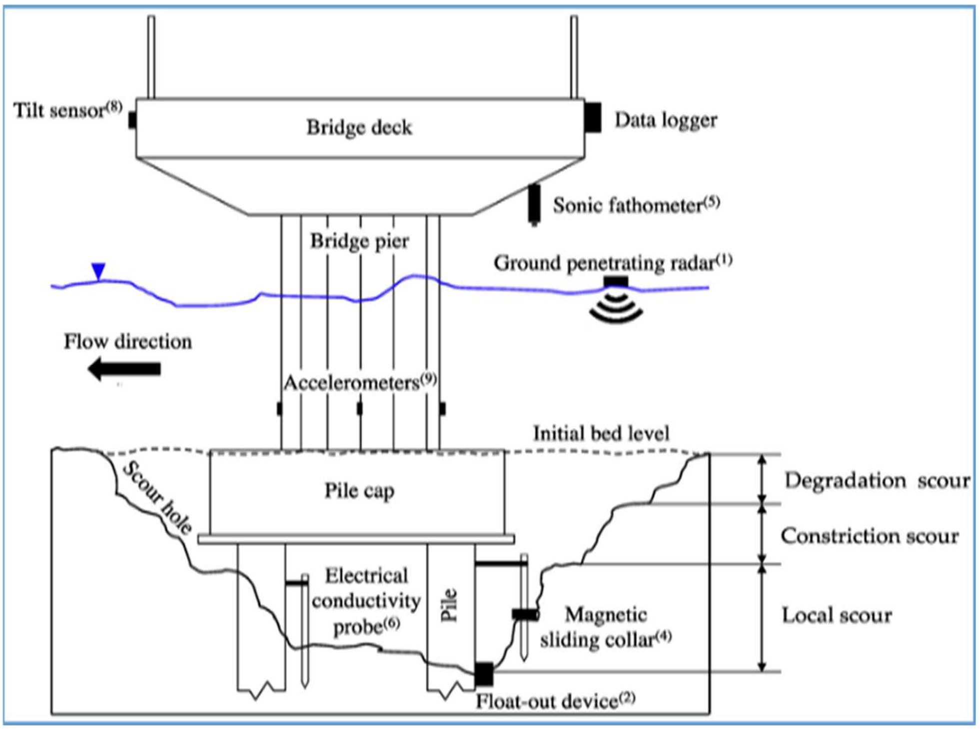

Figure 4 Bridge scours detection methods (Maroni et al., 2020)

3 The approaches for the road potholes monitoring

3.1 Two-dimensional Image-Based Approaches

It is a technique for automatically detecting holes in the asphalt. Using the suggested method, the image is initially segmented into faulty and non-defective parts. The geometric properties of the defective field are then used to estimate the theoretical form of the pothole. Following that, the surface of the prospective region is separated and correlated with the texture of the neighboring non-defective region. For example, if the composition of the defect zone is denser and blurrier than the neighboring regions, the area of interest is classified as a pothole (Koch and Brilakis, 2011).

Buza et al. (2013) proposed an innovative vision-based unsupervised technique that would not require expensive infrastructure, additional processing, or training. Their technique uses image analysis and spectral clustering to find and estimate potholes. Image classification, contour separation using spectroscopic grouping, and detection and removal are the 3 phases in the suggested model. The technique was evaluated using 50 pothole photos from website image collection and MATLAB. The surface area was estimated to be around 81% correct. As a result, this technique will offer a preliminary estimate for surface repair and rehabilitation. Matlab was used with the Image Processing Toolbox to test the suggested technique. Images were altered from video formats acquired using a wireless router robotic truck prototype outfitted with only an H.P. Premier Image stabilization Camera mounted at roughly 2 ft. hundred twenty images were gathered, with 50 used for training and research. With 82 percent specificity and 86 percent recall, the overall accuracy was 86 percent.

3.2 Methods of three-dimensional Laser Scanner

It works by producing exact digital photographs of existing structures using reflected laser pulses. Actual 3D point cloud points with their heights were gathered during scanning and recovered using a grid-based processing approach concentrating on essential distress characteristics (Chang et al., 2005). Experiments show that pothole covering and distress coverage can be monitored efficiently and precisely to determine the amount of significant material required.

They used elevated 3d cross-scanning techniques with an invisible (I.R.) laser line projector and a virtual camera to build a low-cost real-time inspection approach that distinguishes bothersome features such as rutting, gunshot, and potholes. In the calibration process, a multifunctional coplanar device is applied to increase the system precision to enable the use and distribution of further feature points throughout the camera field of view Potholes can be detected in real-time using laser scanning equipment. However, the cost of laser scanning technology remains high at the vehicle level (Li et al., 2009).

3.3 Methods of Stereo Visualization

An extensive survey of the pavement state using the stereo visual software for a feasibility report. In that way, the asphalt surface is protected by two optical cameras. The first move is an analysis of 2D pictures from both cameras for any cracks to be seen and classified. The findings of two image providers of the same asphalt are then integrated to measure missed damages during one analysis, allowing for better precision. Geometric modeling with lateral and longitudinal profiles is frequently used to set three-dimensional surface models using a pair of photographs taken within the same paving surface. To gather 3D characteristics from specific 2D pairs of photographs on the same pavement surface, procedures should be completed, including camera calibration, correction distortion, aligning stereo dots, template matching, and characteristic reports (Wang, 2004).

The stereo vision technique replicates the base of the 3D pavement with a pair of pictures. In two couples, four cameras were used to capture surface pavement photographs around a 4-meter extensive floor (an individual couple of images covers 200 cm of the road). The approach included four stages: measurement, distortion correction, correspondence, and 3D reconstruction. DHDV (Digital Highway Data Vehicle), an experimental tool advanced by the University of Arkansas, a multi-system road condition investigation, provided preliminary findings on the viability of stereovision for pavement photography. However, in 3D reconstruction, the resolution can only be achieved in a static environment of 2mm and a dynamic motion environment of more than 5mm. Therefore, stereo vision strategies are proposed to calculate pavement status with a stereo-visual device connected to a car to record road network conditions. This method delivers a brief overview of the suggested solution. The road segment was measured as field trials along a local road of 650 m in length. The author found that the proposed stereo viewing system could assess Poland's road network conditions (Hou et al., 2007).

The method of stereo vision requires a high level of computational effort to rebuild asphalt surfaces by comparing feature points between two points of view. Besides, all cameras are correctly positioned, and where there is a vehicle movement vibration, the cameras can be misaligned and impair the accuracy of the result. Therefore, it is impossible to implement them in a real-time setting.

3.4 The radar of Kinect

Using a Kinect sensor (or radar) and USB high-speed camera, a low-cost radar device detects and analyzes potholes. The project was in its early phases at the time of this report. There have recently used low-cost Kinect radar to take pavement depth images and the quantity of an estimated pothole volume. The Kinect sensor extracted a pavement depth picture from the concrete and asphalt roads. Meshes have been created to enhance the depiction of potholes. Detailed analysis of the pothole region, the estimated pothole volume was measured using the trapezoidal area-depth curve test employing a pavement image analysis (Moazzam et al., 201).

4 Discussion

Poor road and bridge conditions and an inadequate transportation infrastructure impede the flow of products and people in metropolitan areas. Inadequate infrastructure may also be a deterrent to both domestic and international investors in our metropolitan regions. Productivity constraints at the city level, such as infrastructural limitations, impacted the productivity of enterprises and families, affecting the economy's aggregate productivity. Transportation development's economic relevance is linked to improved society's welfare through proper social, political, and economic conditions. Quantitative and qualitative gains in human capital, such as income and education levels, and physical capital, such as utilities, transportation, and telecommunications, are predicted.

One of the severe challenges in evaluating adequate roadway repair and refurbishment techniques is accurately identifying potholes. Physically recognizing and testing procedures are expensive and timewasting. As a result, several investigations have been made to implement technologies that can quickly identify and recognize potholes, increasing survey reliability and pavement quality by allowing for early detection and intervention. First, existing pothole detection approaches are examined and evaluated, with the most common vibration-based, 3D renovation, and perception systems. Although perception methods are much less costly than 3D laser scanning methods, because of the fuzzy signal created by pollution, it can be hard to diagnose a pothole because they observe by evaluating the acquired picture and video data. As a result, to improve the current pothole identification approach and consistently discover a pothole, a pothole identification system based on diverse 2D pictures is necessary.

Traditional Scour detection equipment is typically expensive to install and operate and is frequently destroyed by debris during floods. Data processing from this equipment can be time-consuming and difficult. The structural dynamic behavior is frequently used in research to identify and identify the level of scour around buildings. The research offers the door for non-intrusive condition monitoring and intermediate maintenance to diagnose and track scour progression. Easy installation above the waterline and inexpensive maintenance are two advantages of dynamic measurements versus traditional scour computation instrumentation. Frequency shifts will assess the stiffness distortion and, ultimately, the influence on the structure of interest of the stiffness effect. The instruments of the Streambed often neglect this factor since the global influence of scour cannot be detected until a high number of instruments are used nearby scour critical points. There is already much space for improvement in complex measuring methods. Some of the challenges associated with these approaches include the large amount of acceleration data needed to collect helpful knowledge, the high power necessities for data achievement systems, and other effects.

5 Conclusion and recommendations

Transportation of goods and services to people is made more accessible by adequate road infrastructure, which is the development wheel. Good roads make it easier to carry products and services and deliver them on schedule. They can also help with agricultural production and high-quality health care. Aside from that, excellent roads reduce the loss of human life, commodities, and property, provide a convenient and comfortable transit route, and function as a recreational avenue. In addition, good roads minimize the cost of transportation upkeep, fuel, and operation. The methods are presented in scouring, and potholes detection is costly in monetary costs and requires more human resources. Therefore, instead of investing so much money on new gadgets, sensors already integrated into our smartphones can be used. A primary mobile phone, which anybody can use, can identify potholes on the lane; regarding the bridge monitoring, it can connect the smartphone to sensors fixed in the bridge structure, which can function for a long time and give an alarm during the flood period. Our key aim is to minimize human effort in identifying potholes and bridge scouring by using a quick, easy-to-use, cost-effective process resulting in minor injuries. On the contrary, primarily underwater instruments are used by standard methods to detect bridge distance profiles that can also be detected using instrument deployments and services. Additionally, the advancement of these fixed and portable scouring measurement devices, GPS, remotely operated ships, instrumented vehicles, and knowledge of the need to calculate and monitor bridge spacing have greatly enhanced the scour database, methods for forecasting spacing depths, bridge scouring, and bridge protection. Recently, the theory of vibration-based harm sensing has been investigated to address particular challenges by examining the natural bridge or bridge frequency spectrum.

Finally, there are some similarities in monitoring bridge scour and road potholes, such as sonar, sensors, and vibration-based methods, which can significantly depend on them. However, there is still a problem with some of these methods to monitor the scour and potholes' depths, and places need to examine again.

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