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DIGITAL ROAD CONSTRUCTION ENTERPRISE SOLUTIONS

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ABSTRACT

Paper proposes the concept of Digital Road Construction Enterprise, that integrates the processes of interaction control systems road construction machinery. On the system tasked motion control construction machinery and spatial position and its working bodies, dispatching transport operations in real time. Search technologies appropriate to the level of economic justification of the main criterion of promotion of automation in the roads construction. Pairing interactive modeling with intelligent data frees engineers and architects to quickly analyze changes and design options in the physical environment. The potential impact is huge for saving time on rework, accelerating the building phase, and producing higher-quality projects.

Keywords: cloud service, internet of things (IoT), road construction information modeling (RCIM), SMART construction, fleet management systems (FMS), project monitoring system, embedded computing system (ECS).

1. INTRODUCTION

Digital transformation journey has to be adopted in order to stay competitive. The road construction productivity in general is largely left behind, compared to other industries, due to the slow digital transformation movement. Poor planning, lack of automation, insufficient communication, inadequate risk management, and unsophisticated supply chain practices are the major factors hampering productivity and causing significant cost and time overruns.

The need to boost productivity, coupled with the need to minimize project overruns and the reliance on unskilled labor, is the top driver for digital transformation in the road construction. In addition, the combination of new mega trends like urbanization, connectivity & convergence, smart is the new green, artificial intelligence, and other social trends are driving transformational changes in the industry. Ultimately, the move toward digital transformation will be inevitable for the road construction.

Digital Road Construction Enterprise helping you manage and share information in real-time using the Internet [1-7].

2. ROAD CONSTRUCTION INFORMATION MODEL

Road construction projects are ever more complex and larger in scale. The growing demand for environmentally sensitive construction means traditional practices must change. And the shortage of skilled labor and supervisory staff will only get worse. These are deep issues that require new ways of thinking and working.

These challenges highlight the need for a technology-enabled solution that can potentially streamline a Road Construction Information Model (Figure-1). The key lies in facilitating more collaborative decision-making across the organization and beyond. By implementing mission-oriented solutions that connect the work of stakeholders in the field and office, organizations can reap the rewards of collaborative action and higher operational efficiency.

SMART Construction includes a wide range of services. To begin with, it is possible to visualize the topographical differences that will have occurred after construction is complete by using drones or other equipment to perform high-precision surveys of the current state of the construction site, then transforming blueprints of the completed work into three-dimensional data [21-35]. Based on this data, the amount of excavated dirt etc. can be quantified.

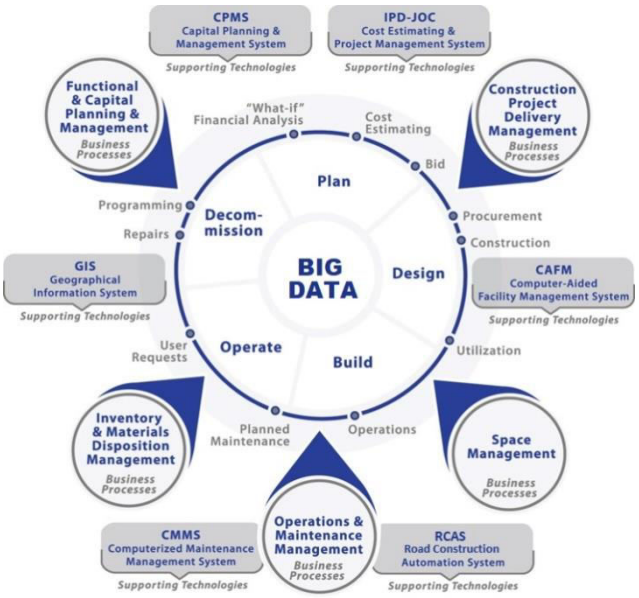

Figure-1. Road construction information model.

Another benefit is the ability to offer construction plans that are optimized on the basis of a predetermined construction scope. Furthermore, by collecting various types of data during work, information regarding the results of all work can be saved, which is not only useful for managing the progress of current construction work, it can also be applied to simulations for subsequent construction plans. This chain of services organically unifies people, construction sites, and construction

equipment, providing a three-pronged unit which transforming to Digital Road Construction Connected Site based Internet of Things Cloud Service.

3. COMMUNITY WORKFLOW

Road construction projects are ever more complex and larger in scale. The growing demand for environmentally sensitive construction means traditional practices must change. And the shortage of skilled labor and supervisory staff will only get worse. These are deep issues that require new ways of thinking and working.

These challenges highlight the need for a technology-enabled solution that can potentially streamline a Digital Road Construction Enterprise Community Workflow based on Internet of Everything (IoE, Figure-2). The key lies in facilitating more collaborative decision-making across the organization and beyond. By implementing mission-oriented solutions that connect the work of stakeholders in the field and office, organizations can reap the rewards of collaborative action and higher operational efficiency.

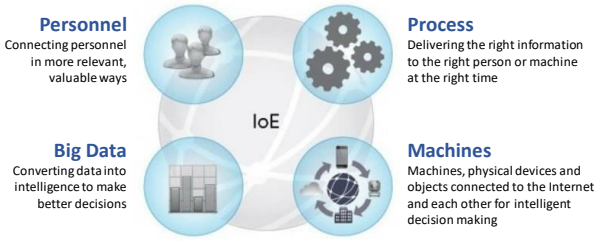

Figure-2. Digital road construction enterprise community workflow.

SMART Construction includes a wide range of services. To begin with, it is possible to visualize the topographical differences that will have occurred after construction is complete by using drones or other equipment to perform high-precision surveys of the current state of the construction site, then transforming blueprints of the completed work into three-dimensional data.

As a mediator positioned at the interface between Operational Technologies (OT) and Information Technology (IT), real-time fog computing is key to seamlessly converging these heterogeneous worlds.

On the one hand, real-time edge computing is based on some of the technologies characterizing cloud computing, but with the pivotal difference that they are applied to compact and embedded computing systems. Such technologies include the virtualization of all resources, the automation of resource management, application lifecycle management and fully software-defied networking approaches.

On the other hand, real-time fog computing is also able to effectively break through the "constraints of the cloud" by integrating the following functions:

- hard real-time and deterministic behavior;
- direct support of a wide set of networking technologies, including wireless and sensor networking, as well as legacy fieldbus networking typical of OT deployments;
- support for interoperability with non-homogeneous data sources, and compact, streaming data analytics with real-time capability, along with networking, system and physical security and safety.

Based on collection data, the amount of excavated dirt etc. can be quantified. Another benefit is the ability to offer construction plans that are optimized on the basis of a predetermined construction scope. Furthermore, by collecting various types of data during work, information regarding the results of all work can be saved, which is not only useful for managing the progress of current construction work, it can also be applied to simulations for subsequent construction plans. This chain of services organically unifies people, construction sites, and construction equipment, providing a three-pronged unit which transforming to Digital Road Construction Enterprise based Connected Servicies and IoE Fog Computing Platform (Figure-3).

4. IoE FOG COMPUTING PLATFORM

Fog Computing brings Cloud features close to the industrial floor together with real-time and safety features. It enables scalable computing at the edge with resource virtualization supporting both real-time and non real-time computing. It incorporates modern application management and data interoperability middleware, edge storage, analytics, security, and advanced networking.

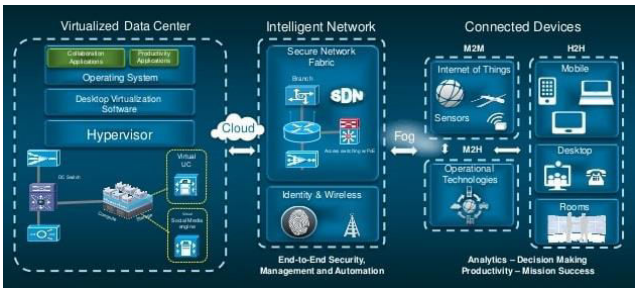

Figure-3. Internet of everything general solution architecture.

The Internet of Things (IoT) is a reality in many other sectors; sensors and wireless technologies enable equipment and assets to become "intelligent" by connecting them with one another [11-15]. On a construction site, the Internet of Things would allow construction machinery, equipment, materials, structures, and even formwork to "talk" to a central data platform to capture critical performance parameters. Sensors, near-field-communication (NFC) devices, and other technologies can help monitor productivity and reliability of both staff and assets [7-10].

A major service provided by collecting and storing the aforementioned data is the IoT Cloud Service (Figure-4), based Microsoft Azure. The various data

originating at construction sites is collected using DataStax Enterprise (Apache Cassandra), Azure BLOB Storage, Azure SQL Database, and Azure HDInsight (Apache Spark), and can then be used from various applications.

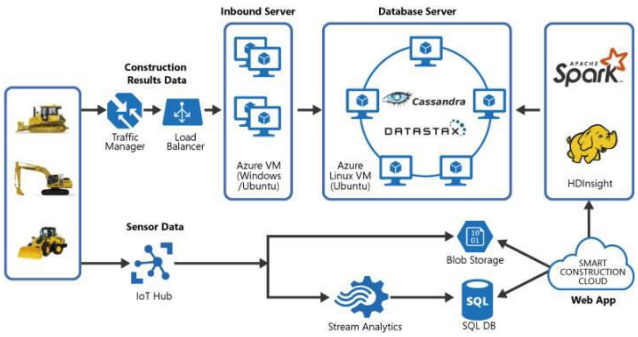

Figure-4. Internet of Things cloud service.

IoT Cloud Service ascertains work conditions; collecting information regarding the bucket edge position of an excavator can generate approximately five sets of data every second per machine [11, 12]. If 10 excavators were operating at a construction site, an amount of data exceeding 1 million records would be collected in a six-hour period. To handle such a large amount of data, an in-memory distributed processing framework such as Apache Spark and a distributed NoSQL database such as Apache Cassandra are essential. For this deployment, we decided to use Azure HDInsight - an Apache Spark managed service - and DataStax Enterprise - an Apache Cassandra application package. Because UL Systems already supported Azure, we were able to deploy Apache Cassandra without any problems. DataStax Enterprise (DSE) was selected because it was often mentioned as a product with enhanced support functions for operational management, including backup and restoring, visual monitoring, and support for periodic maintenance work.

5. DIGITAL SYSTEMS

5.1 Machine Monitoring Process

RCM, as the control object, is located within the interaction structure of the operator, the environment, software/hardware tools, forming automated monitoring system (Figure-5).

Figure-5. Machine monitoring process.

Dealers are on the front line of monitoring customer machines for potential issues. Most of our construction machines come with five years of machine telematics service. This gives our dealers the capability to monitor fleet around the clock through their individual Machine Monitoring Centers.

Response time is quick; so many problems can be addressed before they cause a major unplanned downtime event. Remote diagnostics and programming enable your dealer to read codes and record performance data without even having to make a trip to the jobsite. And if a jobsite visit is warranted, remote diagnostics can help the technician show up with the right parts the first time [16 - 21].

By aggregating and analyzing data from thousands of machines, the Machine Health Monitoring Center (MHMC) can identify trends that warrant a closer look. This helps us identify problems that may not surface on a local level and develop new, improved maintenance and repair protocols that the dealer can leverage [5].

The codes generated from your iron are sent to your dealer's Machine Monitoring Center, where your dealer identifies issues and fixes problems via limited site visits. Simultaneously, codes from thousands of other connected machines are sent to our central MHMC. Specialized engineers identify trends in machine data across products to develop improved preventative-maintenance and repair protocols.

5.2 Fleet Management Systems

Fleet Management Systems (FMS, Figure-6) offers a unified view of health, location and productivity for the entire fleet, regardless of manufacturer. FMS applications are mobile-ready, with faster and better performance. Easily navigate through the intuitive interface and leverage telematics device information to improve your return on investment.

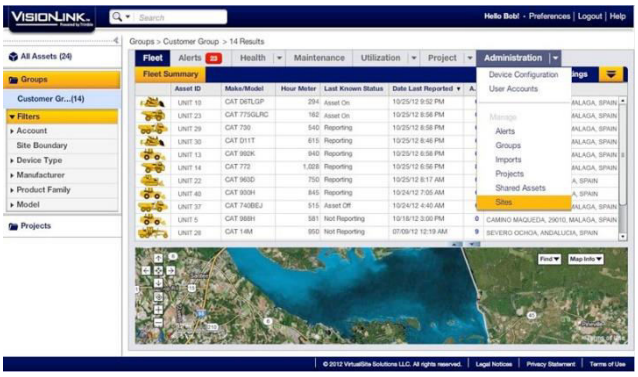

Figure-6. Fleet management systems.

FMS provides actionable information for key decision-making to help you improve your bottom line.

No matter what brand of machines you own, FMS is designed to help better manage a mixed fleet from a desktop computer, laptop, tablet or mobile device.

Developed with the fleet or equipment manager and owner/operator in mind, FMS user-friendly screens

display information such as: hours, miles, fuel, odometer, locations, idle time, asset status, asset utilization and operation, and customer-defined asset states. FMS ready for quick load times, simplified screens, easy-to-read content and simple navigation.

5.3 Road Construction Project Monitoring System

Road Construction Project Monitoring System (RCPMS, Figure-7) helping you manage and share information in real-time using the Internet. Whether you're in the office working on a design or in the field working on a machine, you'll be in the know.

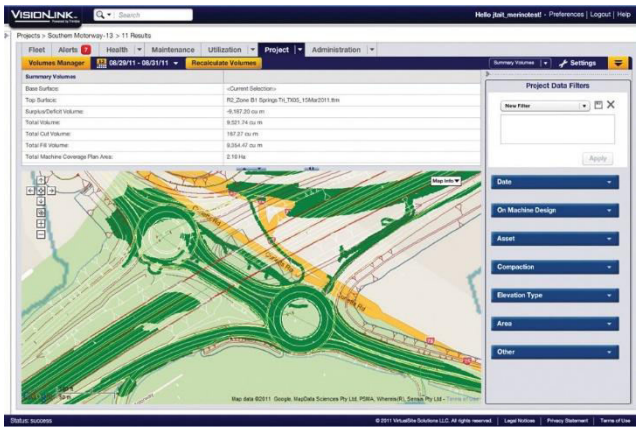

Figure-7. Road construction project monitoring system.

Feature and benefits:

- integrates with Connected Site applications and Connected Office (see Figure-1);
- capture cycle counts, load counts and material volumes;
- monitor completed work, map pass counts and create progress reports to keep projects on time and budget;
- make proactive decisions regarding production efficiency and minimizing costs.

With secure hosting, unlimited data retention, upgradeable storage plans and data back-up, RCPMS make your workflow easier and more productive. RCPMS sending email notifications and alerts to the site and office, file sharing and automatic file synchronization.

5.4 Field Service Management System

Durable goods manufacturers and their service partners rely on skilled field service technicians to provide installation, inspection, repair, and maintenance services at customer locations. Companies are currently managing the field service through multiple systems, using phone calls, emails, sticky notes, and paper forms. The inefficient field service processes and systems result in increased customer churn, unproductive service technicians, and missed revenue opportunities with the customers.

Companies need to streamline and mobilize Field Service Management (FSM) to:

- Enhance customer experience by delivering the expected service during the first visit,
- Improve the cost-efficiencies and productivity of the service delivery teams, and
- Increase predictable revenue streams from service plans and maintenance agreements.

Field Service Management (Figure-8) solution enables field service organizations and their service network partners to improve customer retention, increase technician utilization, and grow service profits.

Figure-8. End-to-end field service management.

Mize FSM solution powered by Connected Customer Experience platform and Smart Blox includes:

- Customer-Centric Field Service to drive customer experience and retention;
- Complete Mobilization of Service Technicians to improve utilization and productivity;
- Orchestration of field service performance to grow service sales from loyal customers;
- Mize Field Service Management.

6. EMBEDDED COMPUTING SYSTEM OF CONNECTED ROAD CONSTRUCTION MACHINES

Embedded Computing System (ECS) of connected road construction machines (Figure-5) and, more precisely, the construction processes, performed with the use of these machines, provide integration in information management space of the integrated automated control system of road construction works [7-15]. Trend development of process automation is a project, which directly affects the quality and efficiency of construction.

Figure-9. Connected road construction machines.

It is possible to say about the network connected interacting of the integrated automated control system of road construction works subsystems.

The fully connected digital worksite is more than likely the biggest opportunity construction project managers and fleet owners are missing out on when looking at enhancing their operations.

Intelligent construction is the way of the future. It's not how hard you work in today's construction industry, but rather how smart you work that is going to improve your bottom line. Having a fully connected digital worksite removes the guesswork and empowers contractors to expedite their projects with confidence.

On a local level connected road construction machines can collect the data on executive survey for transmission to the construction office, and also they can get the online amendments.3D-project data, created in the design office, can be transmitted to the operator of the machine for more quickly and accurately excavation.

Technical support for the implementation of excavation can be carried out remotely, without leaving the office building. Furthermore, is used to measure the volume of production, to produce a less expensive measurement with a help of surveyors.

Time for transfer and alteration is also reduced to a minimum, since the construction of the office and remain machines in this area can always provide the data with the relevant information in a single information environment of design and management.

7. CONCLUSIONS

Process digitization means moving away from paper and toward online, real-time sharing of information to ensure transparency and collaboration, timely progress and risk assessment, quality control, and, eventually, better and more reliable outcomes.

One reason for the industry's poor productivity record is that it still relies mainly on paper to manage its processes and deliverables such as blueprints, design drawings, procurement and supply-chain orders, equipment logs, daily progress reports, and punch lists. Due to the lack of digitization, information sharing is delayed and may not be universal. Owners and contractors therefore often work from different versions of reality. The use of paper makes it difficult to capture and analyze data; that matters because in procurement and contracting, historical performance analytics can lead to better outcomes and risk management.

Owners and contractors are beginning to deploy digital-collaboration and field-mobility solutions. Several large project developers have already successfully digitized their project-management work flows:

REFERENCES

[1] Ostroukh A. V. 2015. Intelligent Systems. doi:10.12731/asu.madi.ru/intsys.2015.110

[2] Ostroukh A. and Surkova N. 2018. System Approach to Digital Mining. DES tech Transactions on Computer Science and Engineering, (cnai). doi:10.12783/dtcse/cnai2018/24186

[3] Ostroukh A. 2018. Human-Machine Interface for Mobile Cone Crusher Control System. 18th International Multidisciplinary Scientific Geo Conference SGEM2018, Informatics, Geo informatics and Remote Sensing. doi:10.5593/sgem2018/2.1/s07.056

[4] Ostroukh A. 2018. Automated Process Control System Of Mobile Cone Crusher. 18th International Multidisciplinary Scientific Geo Conference SGEM2018, Informatics, Geo informatics and Remote Sensing. doi:10.5593/sgem2018/2.1/s07.022

[5] Ostroukh A. 2018. Concept of the Machine Health Monitoring Center. 18th International Multidisciplinary Scientific Geo Conference SGEM2018, Informatics, Geo informatics and Remote Sensing. doi:10.5593/sgem2018/2.1/s07.031

[6] Ostroukh A. 2018. Connected Vehicle Remote Diagnostic System. 18th International Multidisciplinary Scientific Geo Conference SGEM2018, Informatics, Geo informatics and Remote Sensing. doi:10.5593/sgem2018/2.1/s07.032

[7] Ostroukh A. and Surkova N. 2018. Digital Road Construction Connected Site. DEStech Transactions on Computer Science and Engineering, (ceic). doi:10.12783/dtcse/ceic2018/24560

[8] Ostroukh A.V. 2013. Systems of Artificial Intelligence in the Industry, the Robotics and the Transport Complex. Krasnoyarsk, RU: Publishing House Science and Innovation Center, Ltd.

[9] Ostroukh A.V. and Surkova N.E. 2015. Intelligence Information Systems and Technologies. Krasnoyarsk, RU: Publishing House Science and Innovation Center, Ltd.

[10] Maksimychev O.I., Ostroukh A.V., Zbavitel P.Yu., Ivakhnenko A.M., Ephimenko D.B., Karelina M.Y. 2016. Technology of Monitoring and Control Algorithm Design for Earth-Moving Machine. International Journal of Applied Engineering Research. 11(9): 6430-6434.

[11] Filippova N.A., Belyaev V.M. 2010. Analysis of the process of management of northern deliveries in current market conditions. Freight and Passenger Cars. (9): 17-20.

[12] Filippova N.A., Belyaev V.M. 2013. Adaptive mathematical model for optimization of cargo delivery in the North conditions. Freight and Passenger Cars. (11): 17-20.

[13] Filippova N. A. 2015. Information support transportation process multimodal system. Science of Krasnoyarsk / Nauka Krasnoyar'ya. 18(1): 8-25.

[14] Filippova N. A., Belyaev V. M., Shilimov M. V., Koshkarev P. P., Odinokova I.V. 2017. The analytical test of methodological approaches to the increasing the level of automation of the basic functions of the car dispatching of the cargo delivery to northern regions of the Russian Federation. International Journal of Applied Engineering Research. 12(21): 11532-11535.

[15] Filippova N. 2019. Software for automated supervisory control of navigation system and accounting of road transport for the Northern regions of the Russian Federation. IOP Conference Series: Materials Science and Engineering, 632, 012077. doi:10.1088/1757-899x/632/1/012077

[16] Belyaev V. M., Filippova N. A. 2017. Fundamentals of transport system organization in Northern Regions. World of Transport and Transportation Journal. 15(1): 162-167.

[17] Filippova N.A., Efimenko D.B., Ledovsky A. A. 2018. Efficiency of transport processes in the Far North. World of Transport and Transportation Journal. 16(4): 150-159.

[18] Dolenko D. V., Moroz D. G., Filippova N. A. 2018. Application of the network planning and management method for planning the multimodal transportation. International Journal of Advanced Studies. 8(3-2): 49-68.

[19] Dolenko D. V., Moroz D. G., Filippova N. A. 2018. Application of the network planning and management method for planning the multimodal transportation. International Journal of Advanced Studies. 8(3-2): 49-68.

[20] Filippova N. A., Bogumil V. N., Belyaev V. M. 2019. On forecasting navigation seasons with markov chains. World of Transport and Transportation Journal. 17(2): 22-25.

[21] Filippova N. A., Vlasov V. M., Belyaev V. M. 2019. Navigation control of cargo transportation in the North of Russia// World of Transport and Transportation Journal. 17(4): 225-231.

[22] Mamaev A. N., Balabina T. A., Odinokova I. V. and Gaevskiy V. V. 2019. Interaction mechanics of the wheel with the drum. IOP Conference Series: Materials Science and Engineering, 632, 012083. doi:10.1088/1757-899x/632/1/012083

[23] Gaevskiy V. V., Odinokova I. V. and Borisevich V. B. 2019. Electric automobile VS hybrid. Journal of Physics: Conference Series, 1177, 012022. doi:10.1088/1742-6596/1177/1/012022

[24] Gaevskiy V. V. and Ivanov A. M. 2018. Problems of the application of intelligent driver assistance systems on a single-track vehicle. IOP Conference Series: Materials Science and Engineering, 386, 012021. doi:10.1088/1757-899x/386/1/012021

[25] Maksimychev O. I., Ostroukh A. V., Pastukhov D. A., Karelina M. Y., Zhankaziev S. V., Nuruev Y. E. 2016. Automated Control System of Road Construction Works // International Journal of Applied Engineering Research. 11(9): 6441-6446.

[26] Nikolaev A. B., Vasuhova S. A., Ostroukh A. V. 2014. Automated Systems and Industrial Robots Remote Control. SGEM2014 Conference Proceedings, ISBN 978-619-7105-10-0 / ISSN 1314-2704, June 19-25, 1: 51-56. DOI: 10.5593/SGEM2014/B21/S7.007.

[27] Ostroukh A. V., Nedoseko I. V., Surkova N. E. and Bulatov B. G. 2016. Automated Control System for the Milling Unit of Mineral Powders Plant. International Journal of Applied Engineering Research. 11(4): 2625-2628.

[28] Ostroukh A., Maksimychev O., Nikolaev A., Kolbasin A. & Nedoseko I. 2016. Development of automation

of the drying and milling unit for the mineral powders plant. ARPN Journal of Engineering and Applied Sciences. 11(9): 5717-5721.

[29] Salniy A. G., Kukharenko V. N., Nikolaev A. B. and Ostroukh A.V. 2013. General Principles of SCADA Design. Automation and Control in Technical Systems. 2(2): 8-12.

[30] Ostroukh A., Yurchik P., Surkova N., Kolbasin A., Moroz D. 2016. Development of Automated Dispatching Control System for Concrete Batching Plants. ARPN Journal of Engineering and Applied Sciences. 11(9): 5637-5643.

[31] Ostroukh A., Maksimychev O., Nikolaev A., Kolbasin A. and Nedoseko I. 2016. Development of automation of the drying and milling unit for the mineral powders plant. ARPN Journal of Engineering and Applied Sciences. 11(9): 5717-5721.

[32] Ostroukh A. V., Surkova N. E., Polgun M. B., Vorobieva A. V. 2015. Automated Supervisory Control System Of Urban Passenger Transport. ARPN Journal of Engineering and Applied Sciences. 10(10): 4334-4340.

[33] Ostroukh A., Kolbasin A., Surkova N., Fatukhin D. 2017. Automated Process Control System Of Concrete Twin-Layer Paver And Block Production. ARPN Journal of Engineering and Applied Sciences. 12(17): 5208-5211.

[34] Ostroukh A., Soloviev A., Yurchik P., Gusenitsa D. 2016. Development of Automated Fire Fighting System for Using in the Road Tunnels. ARPN Journal of Engineering and Applied Sciences. 11(1): 589-594.

[35] Ostroukh A., Pomazanov A. 2014. Realtime Development and Testing of Distributed Data Processing System for Industrial Company. Middle East Journal of Scientific Research. 20(12): 2184-2193. DOI: 10.5829/idosi.mejsr.2014.20.12.21106.