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AUTOMATED DISPATCHING CONTROL SYSTEM OF TRANSPORTATION CONCRETE PRODUCTS

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ABSTRACT

The article is devoted to the process model which is a mean of structured description of the technology of concrete mixtures transportation by road at the level of industrial processes. Range of activities related to the concrete mixtures transportation is represented as hierarchically embedded processes to be coordinated on the basis of general theory of systems. The model is described in a strict sequence: process train → process stage → technological link, and all built process trains consist of indivisible units. Automated Dispatching Control System (ADCS) has a layered structure, and may include multiple geographically distributed plants connected into a single technological system integrated into the enterprise management system. The proposed system is scalable and can include management subsystem concrete plants, air traffic control, laboratory, hydrothermal treatment, weight management, warehouse aggregates and cement, concrete targeted distribution, access control subsystems, jobs management personnel.

Keywords: concrete products, concrete batching plants, transportation, construction materials, data mining (DM), expert systems, data warehouse (DW), OLAP, OLTP, automated dispatching control system (ADCS).

1. INTRODUCTION

Currently, despite the widespread use of the monolithic construction technology, there are very few methodological developments aimed at improving the transport process of Concrete Products (CP) delivery [6, 8 -10, 34, 35].

It is quite difficult to develop a methodology capable to take into account all given indicators and improve performance of the technology "production-transportation-consumption" [1, 2, 7, 11, 13, 22 - 25] but it is possible if we consider models, methods and tools for motor vehicle support of construction industry as an interrelated set of tasks on production, transportation and use of concrete mixtures, materials and building products at construction sites.

A significant effect can be obtained as a result of submission of building materials production processes, including concrete mixtures as a basic component of cast reinforced concrete construction, their transporting at the objects and organization of a set of works - as a single chain of interconnected subsystems [12, 14 - 18, 22, 23] and also in the development process of new methods and models for motor vehicle maintenance reducing production risks

Center dispatch control road transport CP solves the problem of shift-day planning of rolling stock for the delivery of products on construction sites from House-Building Factory (HBF). Delivery shall be performed in accordance with planned hourly chart CP shipment from HBF (assembly graphs) - the first control level.

A separate problem is the operational control - correction of shift-day plan for delivery of a CP in real time and coordinate the work of managers of motor transport enterprise. These activities are performed at the second control level.

In the study on the feasibility of upgrading software formulated a strategic goal - improving the efficiency of the planning and operational management of delivery trucks CP tracking modes of the rolling stock and the issuance of recommendations for targeted reasoned impacts on operations for the entire transport chain [11, 12]. Currently, the argument can not be precise impact of formalization, that is, the controller on the basis of known only to him precedents and operational factors holding rescheduling of individual units of rolling stock, which entails the adoption of arbitrary decisions.

2. BACKGROUNDS

The existing technology of concrete mixtures transportation by road used in the Russian Federation is shown in the Figure-1.

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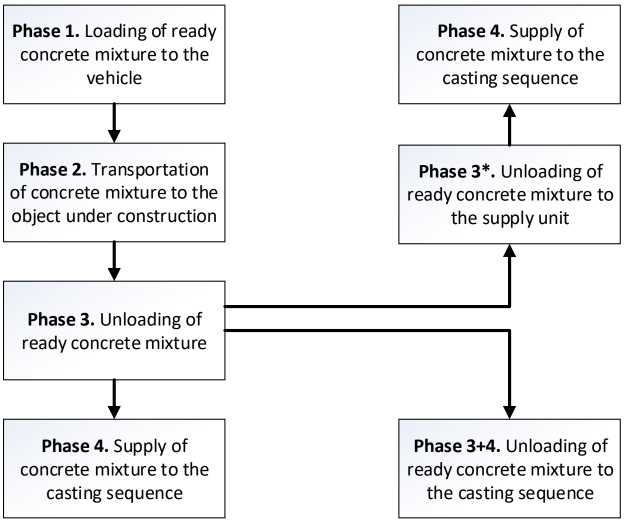

Figure-1. Flow process diagram of finished concrete mixture transportation.

The conducted analysis showed that to the date there are following conditions under which rationalization of the technology in question may be possible:

a) evidence-based rationalization of the technology of concrete mixtures transportation should have a predetermined basic idea for growth organization of the technology or its processes;

b) rationalization of the technology in question should be based only on a clear, developed action plan, as concrete mixtures transportation is a complex series of interrelated processes and procedures;

c) provision of reasonable integrity, continuity and uniformity of implementation of the technology of concrete mixtures transportation by road;

d) all changes to be made upon rationalization of the technology of concrete mixtures transportation should be agreed; otherwise it leads to a decrease in organization of the entire technology and failures in its work;

e) rationalization of the technology must take into account the optimal concentration of each process of concrete mixtures transportation in a certain area of activity.

f) ensuring optimal allocation of tasks, functions, information flows and communication between processes in the entire technology of concrete mixtures transportation by road.

In course of this analysis there were determined for deficiencies in the field of concrete mixtures transportation by road in Russia:

- lack of any clear and structured description of the technology of concrete mixtures transportation in thematic literature and sources studied by the author;
- incomplete and non-specified description of organizational aspects of preparatory operations for loading concrete mixture to the rolling stock and unloading it at the delivery point in thematic literature and sources studied by the author;
- insufficient degree of rationalization of the technology of concrete mixtures transportation by road for use at modern enterprises in conditions of uncertainty, multicriteriality and production risks.

Based on the above, the author believes it to be necessary to create models and methods, new system of organization and management of a single process "production-transportation-consumption" of motor vehicle support in construction industry in form of an interconnected set of problems related to production, transportation and use of concrete mixtures, materials and construction products at construction sites, taking into account production risks.

Using traditional approaches, select the characteristics of solutions interrelated tasks two-tier control system for transportation concrete products (Figure-2):

- collection, compilation, analysis of data on the implementation of the work of rolling stock on the routes on the basis of monitoring in real time or, alternatively, in the mode after the fact, with the preparation of a daily report to the control room service logistic company (second control level) to enable more rapid take selection alternative control action on the disturbances in the system of delivery of CP;
- processing of information on extraordinary situations in the delivery process in order to take the leadership of logistic company and CP-making plants for the preventive measures, neutralization and elimination of the consequences of such situations;
- prompt submission of data on the state of roads and facilities on routes of delivery CP - to make basic information on the operational modes of traffic units of rolling stock;
- ensuring the registration and archiving of completed routes with accommodation "purified" of information in the Data Warehouse (DW) and automation support queries in the process of retrospective analyses to account for previously identified error conditions and unreasonably high (or understated) standardized indicators, in particular, the run-time routing tasks.

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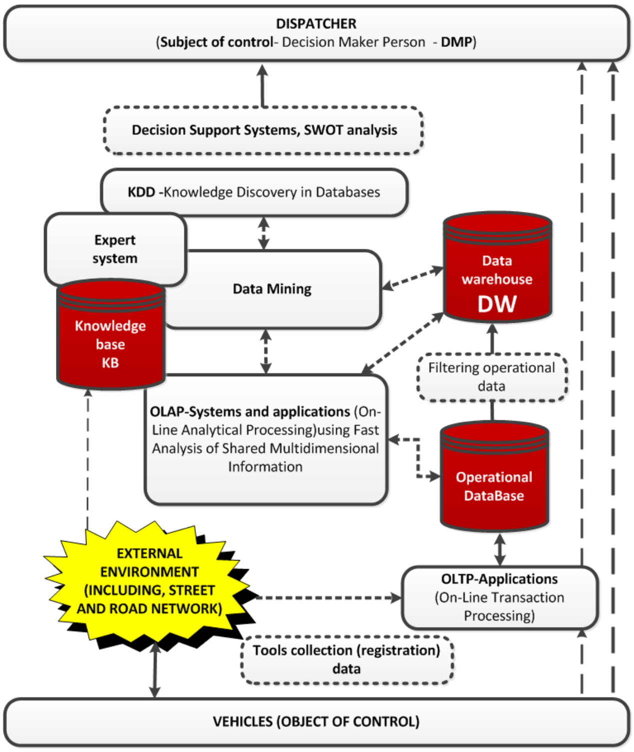

Figure-2. Schematic diagram of the in-system component interaction information-analytical system for Dispatching Control of Transportation Concrete Products.

Solution of these subtasks will require an integrated approach [1, 15-25]. For example, the selection of works on automation planning of rolling stock from the list of tasks in the information-analytical system will lead to insignificant effect. In this case, not be affected by organizational and industrial relations in the two-tier control system.

3. MODELS

The technology of concrete mixtures transportation by road is proposed to shown in form hierarchically embedded processes to be performed by the method of Link [1 - 3, 5]. Ordered set of phases in the model of initial action organization process on modification of the object labor conditions in the technology is a Link, which phases have direct, i.e. indissoluble relation to each other (Figure-3). This process is not subject to further decomposition and is a primary link in any work in the technology of concrete mixtures transportation by road. Each phase in this tuple occupies its special place with rigidly deterministic interfacial bonds in form of not violated mutual obligations.

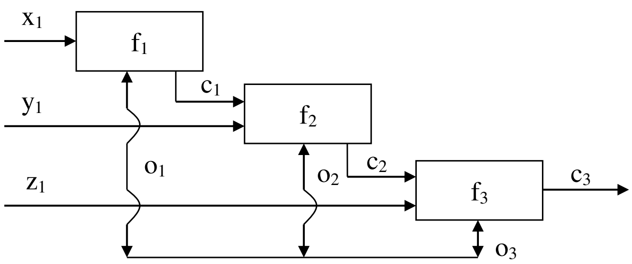

Figure-3. Tuple process model.

Here, f1, 2, 3 - serial number of tuple phase; c1, 2, 3 - serial number of tuple phases connection; o1, 2, 3 - inverse connection between tuple phases; x1, y1, z1 - phases of concrete mixture transportation process, for example: x1 - departure of loaded vehicle (LV) from the concrete mixing station, y1 - supply of LV to the object under construction; z1 - departure of LV to the object under construction.

Further, it is proposed for the technique of the technological chain organization "production - transportation - consumption" providing coordinated functioning of all links upon use of which units the process of forming tuples and set of correspondences between set system elements is set up to the transformation of the labor object in the labor product or commodity [1 - 3, 12 - 20, 22, 23]. Tuples model is formed as long as all the operations necessary for concrete mixtures transportation from the concrete mixing unit to the casting sequence are structured.

Feature of central set in this model as a set of processes is determined by its connection with a set of connected tuples (Figure-4), which reflect the entire technology in question.

Here links reflect some specific content of phases of the technology of concrete mixtures transportation by road:

Link 3 - phase of loading concrete mixture into a vehicle;

Link 4 - transporting of concrete mixture to the object under construction;

Link 5 - unloading of concrete mixture at the object under construction.

This acyclic network, and it is actually a semantic network using an interpretation of connection between graph nodes as "part - whole" reflects content of the process train of tuples chain describing the technology of concrete mixtures transportation by road.

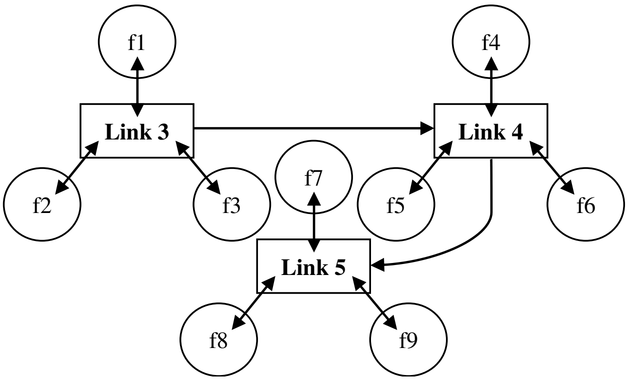

Figure-4. Interconnection of tuples.

Decomposition of the investigated object into functional subsystems is performed by using elementary functional process model (Figure-5). It is the lowest combination of basic tuple process model elements describing the above technology in detail.

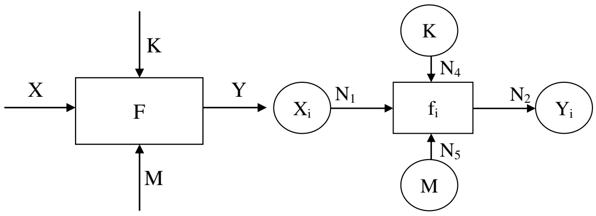

Figure-5. Elementary functional process model.

Principles of parametric optimization of subsystems and methods of choosing their parameters in conditions of multicriteriality, uncertainties and production risks are as follows: 1) under connection "one to many": N1 = (Xi, fi) - element of "input"; N2 = (fi, Yi) - element of "output"; N4 = (K, fi) - element of "control"; N5 = (M, fi) - element of "mechanism"; 2) under connection "many to many »: N3 = (Xi, Yi) - element of "action".

Here, Xi - set of accumulated labor objects (related with the technology of concrete mixtures transportation) used as part of element of "input" (accumulation); Yi - set of converted labor objects (also related to the technology of concrete mixtures transportation) used as element of "output" (conversion); fi - operation used as element "action" (moving); K - set of information objects used as element of "control"; M - set of elements of transport structures used as element of "mechanism" for moving the labor objects".

4. METHODS

Methods of choosing rational parameters for the process of motor vehicle support for concrete mixtures consumers are listed below and illustrated by an example with specific concrete mixing plants.

Record of production risks is performed by using situational exposure model, which is a system that responds to any identified risk with recommendations to minimize it.

Risk identification is carried out by determining potential and realized threats, as well as determination of disturbances following these threats upon actual change in the technology. The very process of risk identification becomes available (possible) due to structuring of the technology in question, because upon structuring of this technology it is possible to clearly trace all glitches and problems. Direct procedure of risk identification is showed in the Figure-6.

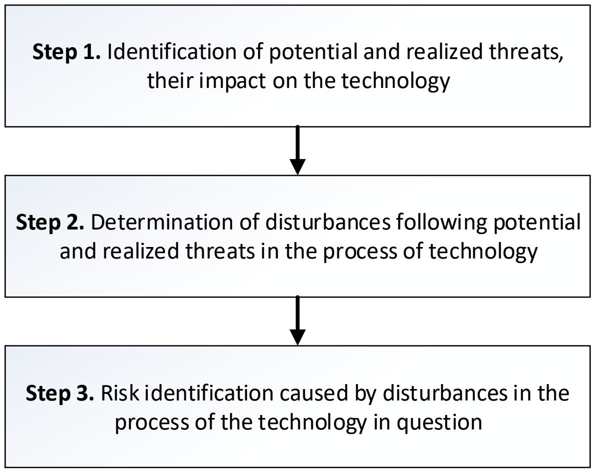

Figure-6. Procedure of risk identification in the technology of concrete mixture transportation by road.

Procedure of risk identification in this technology in question on the example of link "loading of concrete mixture to vehicle" will be as follows:

Step 1: Identification of threats - loaded concrete mixture is usually enough thin/thick (substandard work of concrete mixing plant).
Step 2: Determination of disturbances - inability to use mixture in its current form.
Step 3: Risk identification - additional time and resources to correct this situation.

Using the above mentioned procedure for risk identification in the technology of concrete mixtures transportation, we can identify the maximum number of risks, both potential and already realized [1 - 3].

Then, identified risks are analyzed by expert method using practical experience of experts, as well as taking into account all possible sources of related information. In process of this analysis, experts estimate the probability of any particular risk, based on the following estimates: very low, low, medium, high.

Severity of consequences arising from realization of any identified risk is also determined by expert method based on the following estimates: light, medium, heavy, very heavy.

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Then, experts drawn up a diagram (Figure-7) where boundaries of acceptable risk, probability of its realization and severity of consequences are marked.

If the point specifying the ratio of risk realization probability with severity of its consequences lies on the boundary, or above it - risks shall be taken into account, otherwise - no. Risks taken into account are subject to minimizing, it is to be discussed in the next paragraph.

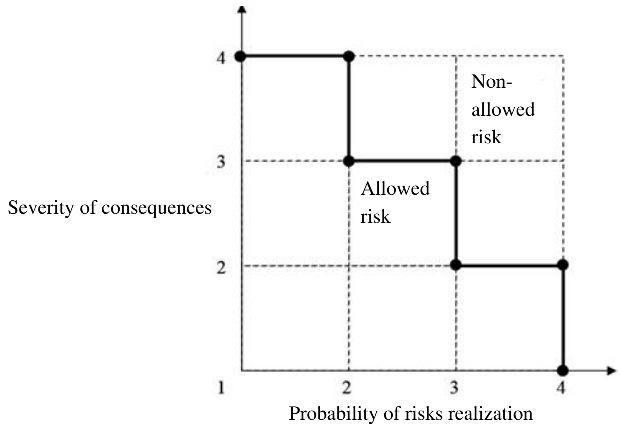

Figure-7. Diagram of risks analysis.

Allowable costs on organization to minimize the risk are specified at the level of recoupment of these costs. If the effect of risk minimizing does not cover costs on its minimizing, such costs are not useful.

Minimization (warning) of some part of potential risks in the technology of concrete mixtures transportation by road may be realized by means of structuring administrative and production processes of this technology. As the structured technology takes into account all peculiarities of their links (stages), its reliability is subject to increase.

To minimize already identified and emerging risks that were not minimized by structuring of the technology in question, it is proposed to apply the situational exposure model, which is a system that responds to identified risk with recommendations to minimize it (both as response and warning). It is based on relies formation in organization of database [21] and knowledge base [8 - 10, 21] associated with the technology of concrete mixtures transportation.

The principle of operation of the above mentioned model is the following - all risks identified through the process of technology structuring are entered into the database. In respect of each risk the experts who analyzed risks establish and enter in the knowledge base all contingency (responsive or preventive) aimed at its minimizing. Finding of these influences in the knowledge base allows you to change them whenever you need, making the, relevant and constantly making new ones. Upon risk identification from the knowledge base or upon identification of any new risk, it is performed for research of influence on such risk in the knowledge base, to minimize it.

5. AUTOMATED DISPATCHING CONTROL SYSTEM

Automated Dispatching Control System (ADCS) to meet the needs of the mining sector and delivers increased productivity and higher production (Figure-8). ADCS is a state-of-the-art, feature rich, system that can be customized to customer requirements.

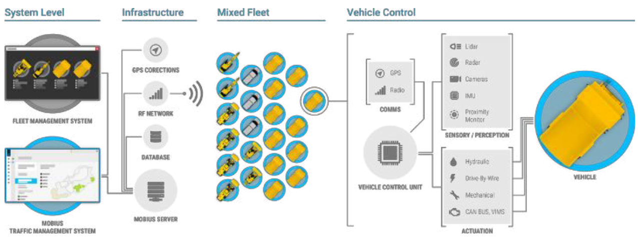

Figure-8. Automated Dispatching Control System (ADCS).

This system has a critical advantage of being able to act as the site ADCS or conversely, integrate with most common ADCS to receive dispatch information and communicate information with an autonomous fleet.

Software platform is the leader in OEM agnostic command and control of autonomous mining vehicles. Mobius operates at the system level on a dedicated server housed in a site control room. Mobius is connected to each vehicle via an RF Network such as wireless mesh, LTE, or others [4 - 7].

ADCS are designed for modular, yet scalable deployment and recognizes the daunting task of automating all aspects of a surface or underground mines in one step. Yet, a piecemeal approach often introduces risk of deploying independent systems which are unable to integrate later into an overall mine system.

ADCS easily scales from small mines to very large mines with multiple pits and dumping areas. FMS is rugeed, built specifically to operate in the harsh mining environments. Designed to be user friendly is highly configurable on the fly.

System has some leverages software to allow highly flexible, modular implementations of individual autonomy solutions, all using a common control platform.

With software installed as a foundation, mines can implement individual projects that can then scale into larger integrated solutions with the aim of ultimately realizing a fully autonomous, yet integrated mining operation:

- move more coal without having to buy more trucks or excavators;
- lower fuel costs: Trucks don’t wait as long for an excavator;
- park trucks when they are not needed, saving fuel and maintenance;
- more accurate loading: Excavator operators can see the tonnage as they load;

- real-Time KPI's and Management Reporting Current Information: don't make decision with yesterday's data;
- view real-time production data onsite or from the company HQ office anywhere in the world;
- better equipment preventive maintenance using OEM Engine Health real-time data and prestart check functionality;
- lowest price for a high quality system;
- in country support and maintenance;
- locally developed, managed, installed and maintained by experts in the business for over 10 years.

6. RESULTS AND DISCUSSIONS

Indicators of the net present value (NPV), internal rate of return (IRR), reduced pay-back period (Pay-back Period), payback period (T) and return of investment (ROI) are used for the evaluation. If the value of ROI < 20 %, the investments made into the project are ineffective. "Aggressive" companies should focus on the ROI of about 150-300 %. However, any positive NPV is considered as a good indicator of the effectiveness of the project.

The calculation was made on the basis of statistical data of the Czech branch of the company BDP International, where the implementation of control system had being performed. In Figure-9 below the company's economic indicators obtained using both the existing software and the implemented integral control module are presented.

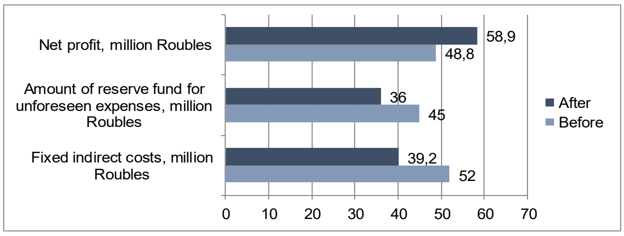

Figure-9. Efficiency of using control system.

Based on the calculations, the payback period of the project was about 4 years. Indicator of the project investment efficiency ROI was 207 %, the increase in net profit - 305.4 thousand dollars, the net present value NPV - 5, 26, and the profitability - 24%. Calculation result showed that this investment project is cost-effective. The quality of information, its reliability and accuracy are also improved. Processing time gets reduced; the required level of safety is provided. As a result, the level of information management gets increased.

7. CONCLUSIONS

Thus, the existing technology of concrete mixtures transportation by road was analyzed, including organization of the preparatory operations for loading of concrete mixture on the rolling stock and it's unloading at the delivery point for purpose of its further rationalizing.

There was implemented for a system-wide study that allows presenting a set of works in form of hierarchically embedded processes, to be coordinated on the basis of general theory of systems.

The proposed methodology is based on using the model of tuples, developed in the second chapter; as a result it becomes possible to identify existing risks in it (the last one is connected with threats and disturbances). Choosing risk to be minimized is performed by using the expert method based on the situational model. To confirm effectiveness of the proposed methodology, study shows the formula for determining reliability of the technology.

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