Process Model of the Technology of Concrete Mixtures Transportation by Road

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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.

Key words: Road transport • Process train • Transport process • Concrete mixtures transportation

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 mixtures delivery [1-6]. In turn, this is due to the need to record a number of indicators upon concrete mixtures transportation:

- It must be done in a given period;
- With initially specified and unchangeable quality upon concrete mixtures transportation;
- Proper use of concrete mixture, due to the fact that it irrevocably losses it’s former properties after laying and acquires other.

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" [7, 11, 13, 22-25, 33-35] 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.

Analysis of the Existing Technology of Concrete Mixtures Transportation by Road: The existing technology of concrete mixtures transportation by road used in the Russian Federation is shown in the Figure 1.

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

- 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;
- 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;
- Provision of reasonable integrity, continuity and uniformity of implementation of the technology of concrete mixtures transportation by road;

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Phase 1. Loading of ready concrete mixture to the vehicle

Phase 2. Transportation of concrete mixture to the object under construction

Phase 3. Unloading of ready concrete mixture

Phase 4. Supply of concrete mixture to the casting sequence

Phase 3\*. Unloading of ready concrete mixture to the supply unit

Phase 3\+4. Unloading of ready concrete mixture to the casting sequence

Fig. 1: Flow process diagram of finished concrete mixture transportation

- 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;
- Rationalization of the technology must take into account the optimal concentration of each process of concrete mixtures transportation in a certain area of activity.
- 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 transport ation 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.

The Model of the Technology Of concrete Mixture Transportation by Road: 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 2). 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 determinist interfacial bonds in form of not violated mutual obligations.

Here, \( f_{1,2,3} \) – serial number of tuple phase; \( c_{1,2,3} \) – serial number of tuple phases connection; \( o_{1,2,3} \) – inverse connection between tuple phases; \( x, y, z \) – phases of concrete mixture transportation process, for example: \( x \) – departure of loaded vehicle (LV) from the concrete mixing station; \( y \) – supply of LV to the object under construction; \( z \) – 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 3), 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.

Decomposition of the investigated object into functional subsystems is performed by using elementary functional process model (Figure 4). It is the lowest combination of basic tuple process model elements describing the above technology in detail.

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”: \( N_1 = (X_i, f_i) \) – element of “input”; \( N_2 = (f_i, Y_i) \) – element of “output”; \( N_3 = (K, f_i) \) – element of “control”; \( N_4 = (M, f_i) \) – element of “mechanism”; 2) under connection “many to many”:

Here, \( X_i \) - set of accumulated labor objects (related with the technology of concrete mixtures transportation) used as part of element of “input” (accumulation); \( Y_i \) - set of converted labor objects (also related to the technology of concrete mixtures transportation) used as element of “output” (conversion); \( f_i \) - 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”.

Methods of Choosing Rational Parameters for the Process of Motor Vehicle Support for Concrete Mixtures Consumers: 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: LLC “StroyHolding”, LLC “Base-Beton”, LLC “ShmelBeton”, at which there was conducted for dissertation research.

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 5.
Step 1. Identification of potential and realized threats, their impact on the technology

Fig. 4: Elementary functional process model

Step 2. Determination of disturbances following potential and realized threats in the process of technology

Fig. 5: 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.

Then, experts draw up a diagram (Figure 6) 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.

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,
Fig. 7: Identified risks

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.

Optimal Binding of Consumers to Concrete Mixing Plant in Presence of Deterministic and Stochastic Application Flows and Record of Production Risks: Risks to be identified in the process of structuring the technology of concrete mixtures transportation are showed as a set “P” and are saved in the database: P = {P_i}, i = 1 (Figure 7).

According to the developed classification and typing of risks involved in concrete mixtures transportation by road, it should contain:

- Organizational risks - typified by: a) defects (of organizational process), b) violation (of organizational process);
- Technical risks - typified by: a) failures, b) defects (of necessary qualities);
- Operational risks - typified by: a) failure to comply with (operating rules), b) defects (of existing principles and rules of operation);
- Production risks - typified by: a) inconsistency (with given parameters of object or labor object) and b) impossibility (to save any desired object or labor object).

On the Figure 7: P_1 - costs on using any hired transport due to technical fault of their own vehicle management; P_2 - additional costs to remedy the situation, as well as decrease in strength of any finished product (up to failure in commissioning) due to enough thin/thick concrete mixture loaded into the truck; P_3 - costs to reduce quality of any finished product (up to failure in commissioning) or additional costs on cleaning the mixing drum, purchase of new mixture portion and its transportation due to excess of time lost on the road by reasons of: accidents, traffic block and other technical failures; P_n - n-risk.

In accordance with these risks, there should be specified for sets of situational influences “B” that help to minimize the impact of risk and are contained in the knowledge base B = {B_i}, i = 1.

Organizational and technological solutions are used as situational (responsive and preventive) effects (Figure 8).

On the Figure 8: B_1 – to organize placement of dead line of vehicle by another one; B_2 – to organize linerepair and to correct the fault; B_3 – observing by the drive of mixture in the process of loading in to the LV and informing operator of the concrete mixing plant on change in concrete consistency; B_4 – delivery of concrete mixture back to the plant: discharge of previous lyprepared mixture and replacement by new one (at cost of the manufacturer); B_5 – in some cases, it is required for adding special ingredients to bring mixture in certain consistency; B_6 – sending qualified drivers to the route providing them with technically sound motor vehicles; B_7 – pre-faced familiarization of drivers with alternative routes from the concrete mixing plant to the object under construction; B_8 – for avoiding any traffic blocks and proving drivers with updated navigation aids marking such traffic blocks; B_n – networking between drivers of transport mixers in order to inform on current conditions on the route; B_n – n-situational effect.

It should be noted that information contained in databases and knowledge bases must meet the following reliability criteria: to be justified (valid) – to be able to measure anything (information acts as a measuring tool); be sustainable – to be able to be similar in different situations, to be exact – to be a sensitive tool with its validity.
Table 1: Process of situational effects issues simulation (responsive or preventive)

Name of process link

\[ \begin{array}{c}
P_1 \\
B_1 \cdot B_2 \cdot B_3 \cdot \ldots \cdot B_n
\end{array} \]

- B1.1 – the first offered measure to minimize any identified risk;
- B1.2 – the second offered measure to minimize any identified risk;
- B1.3 – the third offered measure to minimize any identified risk;
- Bn – n-offered measure to minimize any identified risk.

P1 – the first identified risk.

Subject to identification of a set of identified risks and situational effects, it should be performed for simulation which is expressed in form of issuing recommendations (response or warning) to minimize any identified risk (P1, P2, ..., Pn) (Table 1).

Rationalization (through structuring) of the technology of concrete mixtures transportation by road, used together with a situational exposure model, allows to minimize all identified risks by issuing organizational and technical solutions within the enterprise, for appropriate responses to those risks. Due to minimizing risks, reliability of the technology increases.

Identification of the Concrete Mixtures Transportation Technology Reliability: System reliability is probability that upon operation under given conditions the system satisfactorily performs all the desired functions within a specified time interval. At this, indicators of processes reliability are data of probabilistic values in the range 0 ≤ P ≤ 1. At this, “0” is an indicator of total inactivation and “1” is an indicator of total interaction. To determine quality of their work, the process of concrete mixtures transportation uses such indicators as: stability, reliability, recoverability. In this case, reliability affects recoverability of the system. As the concrete mixture transportation technology may be considered as the process, its reliability may be expressed using the formula.

Reliability of the technology of concrete mixture transportation within certain time interval \( t \) is completely specified by the function \( R(t) \) if we know the function of reliability of certain stages of this technology, i.e.:

\[
R(t) = \prod_{i=1}^{n} R_{pi}(t),
\]

where \( R_{pi}^{(+)} \) is reliability of certain links of the technology of concrete mixture transportation. Reliability of these stages is calculated based on number of identified and included risks. To calculate \( R_{pi}^{(+)} \) it is used for statistical data. Calculation formula \( R_{pi}^{(+)}. \):

\[
R_{pi}(t) = e^{-\lambda t}
\]

where \( \lambda (\text{Lambda}) \) is the risk ratio for a certain stage of the technology of concrete mixture transportation; \( t \) is duration of a certain stage of the technology of concrete mixture transportation (h); \( m \) – stage number.

Identification of the Concrete Mixtures Transportation Technology Reliability: System reliability is probability that upon operation under given conditions the system satisfactorily performs all the desired functions within a summarized root mean square deviation on included risks. The reliability of the system, \( h_i \), is optimized probability of i-risk realization; \( h_{pi} \) – average probability of i-risk realization.

\[
f = \frac{\sum_{i=1}^{n} (h_{pi} \cdot h_{TIi} - h_{opt})}{n}
\]

where \( h_{opt} \) is optimized probability of i-risk realization; \( h_{opt} \) – average probability of i-risk realization; \( n \) – number of risks included in the link.

CONCLUSION

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 its 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.

The developed methodology was proposed for the first time and has never been used before. For consistency of actual evidence of this methodology, it has been implemented in the organization of LLC “TechnoMash” and results of this implementation are presented in the fourth chapter of this study.

REFERENCES


