TECHNOLOGICAL PROPERTIES OF 3D STATION ENGINEERING MODEL

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ABSTRACT

Relying on alleged conceptual basis for development of model samples of railway stations in the three-dimensional format (see World of Transport and Transportation, Vol. 14, 2016, Iss. 1), the author highlights important, in his view, technological guidelines and locations. The research is essentially focused on peculiarities of construction of an engineering model, correctly reproducing technology of 3D station operations and basing on reconstruction of consequences of physical laws acting in the real world.

Keywords: railway, station, design, engineering 3D model, localization, information technologies, physical laws, consequences reconstruction.

Background. *The behavior of objects in the engineering model of a railway station as a functional form of transport system should be adequate in terms of technologies of operations carried out with their participation. Correct prototyping consequences of physical world phenomena is important for development of a base environment of a virtual station. In terms of model gravity and of the action of reproduced elasticity and friction forces, highly realistic movement of trains, movement of cars near freight fronts, loading and unloading of the transported goods are achieved.*

However, besides «situational», cartographic basis, which is a model physical environment, the technological field of operations is of particular interest for engineering 3D station, into which the objects are put. The technology within the model can also be reduced to some regulations of conduits of objective laws, strict rules for variations of state and location of cars, locomotives, goods, means of mechanization and others. For example, a change in the state of the model station's objects is determined by simulated physical laws that provide movement of cars from the hump yard with some acceleration in accordance with accumulated potential energy.

By analogy with physical laws technological laws could be established, which again will have an effect of objective existing rules, but of local ones, existing only within the territory of the station, that is to say within a so-called transport location. In addition to properties of mass, elasticity, inertia, speed, station objects are endowed with specific attributes that determine safe execution of operations, safety of goods, labor protection of station workers and others.

Objective. *The objective of the author is to consider technological properties of 3D station engineering model.*

Methods. *The author uses general scientific and engineering methods, simulation, comparative analysis, computation.*

Results.

The rules for functioning of objects

Model reproduction of technologies in such a complex technical system, as a railway station, to a large extent is ambiguous on criteria, objectives, results. Existing studies [1–5] reflect many problem aspects and offer sufficiently effective solutions to various problems of technology modeling. The principal difference of the engineering model of the station is that all its objects are immersed in a certain environment of constant changes and transformations in full compliance with a number of objective requirements on which all model structures are dependent. This environment makes tracks, cars, warehouses to transform under the influence of certain external forces of physical and technological origin. These changes naturally relate to the established temporal scale, time counter of which is activated immediately after loading of the model.

The local nature of technological law indicates first and foremost the less pronounced force vector of its action on station facilities. This vector is a narrow, selective one, providing an effective and safe solution to this challenge. A more acceptable name for technological requirements of the transport location can be formulated as technological rules that can be divided into regulatory, recommending, stabilizing, conventional and alternative rules.

Regulatory rules have a status of strict requirements, strictly carried out, without any limitations and exceptions. This category should include all the requirements for safety of trains, shunting work, labor protection.

Recommending rules are considered as softer positions, connected with existence of certain properties of the objects that are activated by the user instructions. For example, unloading of cargo of carload shipment in 3D storage is performed using several automatic loaders. In this case, it may require calculation of parallel routes of unloading mechanisms and activation of control of warehouse space filling by each automatic loader.

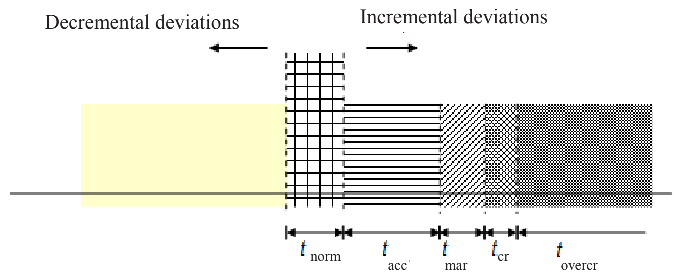
Stabilizing rules are required upon occurrence of specific conditions that can cause adverse continuation of operations. An example of this is automatic setting of alignment of individual packages during model unloading of packaged goods from a covered car on bolsters installed on the forklift truck.

Conditional rules extend capabilities of objects, not built into the model as a default, but in certain situations leading to less costly implementation of individual technological operations. For example, more rapid completion of operations for loading of a covered car with small shipments can be achieved thanks to inclusion into the engineering model of the automatic search the final group of goods on the site, ensuring full utilization of capacity or of load capacity of the car.

Alternative rules go beyond technical capabilities of existing transport; they assume a more rational solution of operational task by using basically achievable structural or technological innovations. As an example we can cite simulation of operations on breaking-up of trains on hump-less yard using a high-speed turn-table, able to deduce from the train an uncoupled sections of cars, to fix it on the receipt section and to transfer it to the sorting track position via a certain traction force. The second example of alternative technological rules is associated with transportation of packaged goods in small shipments with e-marking on self-propelled bogies, providing in automatic mode unloading, sorting and loading of covered cars without any mechanization means.

A significant area of technological field

Technological operations at railway stations are carried out in strict compliance with requirements of guidance documents and standards of established practices. Saving of substantial base of real stations in the engineering model leads to the need to transfer,



Pic. 1. Incremental deviations of technological operations duration.

restore regulations in replicated transport location objects.

Setting the scope of the technology law it is necessary to differentiate its sphere of influence with sphere of model physical laws that form fundamental, «pseudo-material» basis for the existence of engineering models. In certain cases, this limit can be quite blurred with possible object interpenetration of action of physical and technological fields. This subset of model structures of transport location is classified as diffusion of fields. In turn, the exact division of consequences of action of physical laws and technological regulations by certain criterial parameter can be defined as differentiation of fields.

Technological operations in the engineering model of a structurally adequate real station are executed in the prescribed manner with exact fixing of targets controlled by information system. It should be noted that due to correct physical and technological simulation of processes, taking place at a real station and ensured by a powerful information support, this engineering model may be in demand. Its functioning with some advance of real time scale helps to «calculate» possible situations of the near future and to transfer or «broadcast» model actions into operational commands.

Confidence of personnel in reliability of such simulations will allow to verify model physics and technology. In this respect, particular importance belongs to the development of subsets of simulation designs of diffusion and differentiation of physical and technological simulations.

Analysis of maintenance operations of train flows in the station parks shows that it is impossible to unambiguously fix a separate action of technological fields on objects involved in simulation.

Receipt of a train in the engineering model park is accompanied by introduction of 3D train according to data on input traffic lights on a free station track with calculation of impact on it of mass of each car and of possible longitudinal track displacement due to locomotive braking. Carrying out such a technological operation includes mechanisms of friction forces action. Dissolution of train at a hump yard also means that an engineering model needs to calculate speed of rolling of uncoupled sections depending on thrust speed, height and geometry of the longitudinal profile of the hump. Therefore, in this case the technological field of dissolution operations is organically linked with the physical field of model gravitation, providing conversion of potential energy of a body raised above the earth (uncoupling) in kinetic energy of its motion with sliding into hump yard.

On cargo fronts of areas of loading and unloading of a model station a diffuse effect of physical and technological fields is also observed. Along with set of operations for relocating of mechanization means in warehouses, and stacking of cargo on sites of a virtual station, the calculation of load on a site is carried out under the terms of preventing caking, loss of useful qualities of cargo, ignition during storage and so on. Even restriction of temporal area of implementation of a technological operation does not break unity of relations between two fields.

For current conditions of the material world the action of physical laws is absolute, their consequences must be stated and taken into account by operational employees making management decisions. In the engineering model it is necessary to simulate all the laws – global (physical) laws, and local (technological) laws.

Formation of location

Technological requirements provide preserved, safe and efficient operations with possible tolerances in deviations from existing rules. This deviation from the norm is not considered as a violation, but allows in the model to take into account features of operations, in accordance with specific local conditions. Deviations from the norm are largely incremental in nature, contributing to an overestimation of the duration of technological operations. Decremental deviations indicate decrease in operation duration compared with established standard and are rare in practice. As a rule, incremental deviations reflect the fact of occurrence of any adverse or unusual situations, preventing fulfillment of technological operation according to the regulations. It is necessary to consider acceptable, marginal, critical and overcritical incremental deviations (Pic. 1).

Incremental deflection range is different for diverse technological operations. Perhaps it would be proportional to time of operations execution in normal mode (except for overcritical):

$$t_{acc} \vee t_{mar} \vee t_{cr} \vee t_{overcr} = f(t_{norm}) = at_{norm} + b ,$$

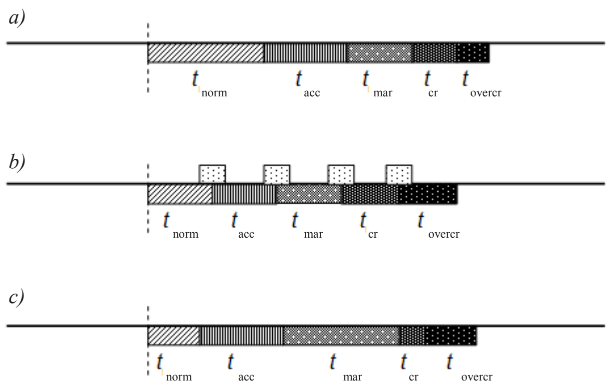
where a, b are parameters, characterizing technological operations.

General category of technological operations includes a number of classified positions, indicating the nature of their performance:

– Technical (train, shunting, receipt and departure, repair);
– Cargo;
– Commercial;
– Passenger.

We consider three main hypotheses of change in duration of different types of incremental deviations on the scale of their position (Pic. 2).

Confirmation of validity of one of the hypotheses or areas of their actions can be followed by an analysis of features of technological operations. It should be borne in mind that individual operations are essentially connected to each other, and the appearance of certain events is able to pick off an established connection with access to the operations of another category. For example, as a result of technical inspection of a train (operations on arrival) at the station a fault in the loaded transit train was detected that did not require delivery to



Pic. 2. Possible dependences of changes in duration of incremental deviations: a –reverse (hypothesis A); b–constant duration with stable or unstable oscillation area (hypothesis B); c – random duration (hypothesis C).

depot and overloading. Elimination of fault (repair) is made with a delay of receipt operations, which will continue after recovering the car.

The non-linear nature of relationship of technological operations may affect in a certain way a chain of incremental deviations. For construction of a technologically connected 3D model of a station estimates of values of permissible parameters are important, because as a result of their solution it becomes possible to implement dual selection of duration of individual operations in the field of real stations functioning.

Perhaps in the course of research it will be possible to establish some kind of technical sphere of stable operation of separate points. Remaining in the field of attraction of such a technical sphere, purposeful (behaviorist) incentives embodied in a self-contained transport system, probably include quasigravitational forces that will provide steady-state operation of the whole station. Compensatory mechanisms can be transferred into the model, securing computer simulations of heterogeneous technological operations with sufficiently rigid algorithm to quench oscillations of their duration, to fix functional equilibrium of model environment.

Research in this area indicates the existence of such a compensator in practices not only of biological but also of a variety of complex systems [6]. Be that as it may, the mechanism of self-quenching fluctuations of duration of technological operations, if account of results of a giant number of interactions of objects is organized, looks like a relatively reliable way to build a dynamic model of the railway station.

The nature of technological essence of the station operation is known, while that cannot be said about physical laws of reality. Model image of technology can be reproduced «from scratch», consistently recreating a chain of cause and effect relationships inherent in instructional requirements, calculation methods. But strictly defined, deterministic logic of building of an algorithm for execution of model technological operations is not expected.

Reproduction of work of a «black box» of physical laws is likely possible in the form of a sequence of empirical rules that are based on the logic of modus ponens. It is believed that just those largely conditional dependences, obtained by limited observations and experiments, will be the main challenge at the stage of verification of the current engineering model of the railway station.

Probably, therefore it is necessary to focus on building highly realistic information technological model, copying in detail numerous nuances of processes of receipt and dissolution of trains, passenger and cargo operations, maintenance of rolling stock. There is reason to believe that all transport processes carried out at stations are built on relatively efficient and expedient principles according to existing state of technology and knowledge. Accordingly, the objectivity of technological principles must follow from physical laws, as it is always based on them. Forming a technological model adequate to reality, we thereby bring nearer to our needs understanding of certain aspects of physical nature of material world laws. Engineering technology in its functioning reflects physics of processes, constantly dictating the technical system's specified target settings, and correctness of this preconception is recognized via achievable effect of their implementation.

Physical and technological projections

Let's consider possible embodiments of the engineering model of the car movement on turnout based on technological aspects. Model turnout appears as a receiver for wheel sets of rolling stock, which under the effect of traction generated by other devices (locomotive, crab reel), or gravity force, moves along switch blade through turnout curve on one of two tracks. In fact, the turnout is a switch of model rolling movement to adjacent model track.

For a virtual image of turnout it is essential that the position of switch blades physically determines the movement of rolling stock on the set route. However, the movement can be forbidden, because right behind the turnout other cars can be located or track section is defective (ultraboundary gap in the joints, track repairs, etc.). In other words, it is necessary to distinguish between potential conditions of the operation implementation, which are provided by permissible states of the object (turnout), and real conditions of the operation implementation, which bind with the state of other elements that are technically and technologically interacting with data.

For example, when performing shunting or train operations inclusion of the turnout in a certain route is significant. For an analogue model it means that there is additional technological feature that is a position of switch blades in accordance with the route (perhaps equal to 1 when included in the route and 0 – otherwise). Wits property of abutment of switch blades to a point rail will be also technologically driven (for ordinary turnouts it is equal to 1 in such a state, so that it is possible to move on a straight track, and 0 – to a side track and from it).

Switch blade of a turnout in the engineering model of the station must have three states: pressed against a point rail, pulled from a point rail and with incomplete abutment, which is qualified as a failure and a dangerous state with the prohibition of movement. Incomplete abutment of switch blades in practice is associated with a number of reasons, the effect of which is difficult to be simulated in a model. However, for a complete internal, «substantial» reality of a model such a state of switch blades should be provided as a potential defect. In this case, the property of a model turnout, characterizing abutment of switch blades to a point rail should be equal to –1. The fault is critical in terms of safety and, therefore, should be reflected in the engineering model.

Incomplete or non-route abutment of switch blades to a point rail in the model, as in reality, should lead to trailing of a point. Trailing of a point is observed when rolling stock is moving on a turnout with unauthorized route in trailing direction, resulting in the forced switch operation by wheels of rolling stock. In the real world consequences of trailing of a point may result in widening of a gauge, violation in density of abutment of switch blades to a point rail, deformation or breakage of throw rod, failure of electric drive. At the moment of trailing of a point prohibiting indication of corresponding traffic light is set automatically followed by inability of subsequent control over switch from the post. These effects must also be transferred to the model.

In addition to movement operations turnout is involved in other technological operations related to maintenance and repair of separate parts of a turnout, clamps, track structure and superstructure. They again are intended to be reflected in the engineering model, providing pseudorealism of constructed images.

Thus, correct model movement on 3D turnout in the engineering model can be provided with necessary compliance with three conditions:

1. Sufficient traction force to overcome friction forces of 3D wheel on a 3D rail.
2. The presence of authorized route of movement.
3. Complete abutment of one of switch blades to a point rail and a sufficient gap between the second switch blade and the second point rail.

The first condition is called physical, the second is deemed to be technological, the third is technical. The physical and technical conditions are objectively linked to each other. If for any reason there is no complete abutment of a switch blade to a point rail, climbing of a wheel set on a switch blade is possible. Traction effort to overcome friction forces, when changing wheel thread, requires complex calculations and reproduction of sophisticated model situations, adequate to real conditions, with possible loss of supporting thread area by a wheel. That is, a failure to comply with the technical conditions of negotiation into a turnout needs forecasting of a more complex behavior of a rolling stock unit, ensured by physical condition.

A relationship of technical and technological conditions is similar. Failure to comply with the latter when trailing of a point entails failure of 3D turnout. In addition, when trailing of a point it is necessary to take into account physical condition as sufficient or insufficient traction is able to influence the degree of damage to the turnout. For example, during trailing of a point by a car, sliding on a flat profile at a low speed, stop of the car can occur due to clamping of wheel flange between a switch blade and a point rail without the forced switching of points.

Modeling of action of physical conditions must be independent on two other conditions. Only then the engineering model of the station will be close to reality. Strictly speaking, the traction force can be activated only in the case of mandatory compliance with technical and technological conditions. However, firstly, if a car begins to move under the force of gravity, the physical condition still objectively starts to operate, not conforming with correct execution of other requirements. Secondly, the inevitable influence of human factor leads to the fact that such a threefold link is often violated. Therefore, the model is designed to simulate not only situations, which are known safe, but also critical, dangerous situations, leading to inability to comply with technical conditions.

The above mentioned ideas mean that as a result of various kinds of negative consequences (derailment of rolling stock, falling of cargo, damage to a track, violation of rolling stock structural integrity) different situations should be modeled when technologically correct functioning of the station in the area of conflict is impossible.

Thus it is necessary to distinguish limited critical situations of non-compliance with technical conditions that do not lead to a disruption of devices by technological condition. For example, we can indicate timely detected hot boxes; lopsided, but fixed mount stands of timber on the platform; elimination of started spillage of bulk cargo through aperture of gondola car; abutment of a switch blade to a point rail with a slight clearance, when the blade is fully pressed against the first wheel set of a train, etc. These situations are more correctly referred to potential positions of non-compliance with all three conditions of a chain: technical, physical, technological.

The presence of a significant number of elements that might be in a transient, boundary state, leads to the fact that the turnout is less reliable in terms of traffic safety. For engineering model this fact is crucial, around it a lot of potentially realized virtual processes «hover», one of which can become predominant under certain circumstances. In the area of straight section of the track the number of processes is less because of the smaller number of components. The situation is different in the area of a curved section, wherein again there are more virtual processes.

Methodological aspects

The main purpose of a full engineering model of a station is development of technological environment of transport facilities.

In practice, all technological incentives as activation motives of individual elements of gridiron, technical equipment, transportation, loading and unloading and other tools are created by a man (station duty master, dispatcher, operator, commodity receptionist, etc.). Objects of the station are waiting for control or are within the control process.

A virtual copy of a separate point is endowed with wider «powers» delegated to it by a person. Few benefits can be achieved from the computer model which reproduces in good technical detailing all station facilities that are capable of performing their operations only with constant human intervention. That's how many alive people are required to service model images of the virtual train station? Therefore, we have consciously tried to give an engineering model its own analog functions, in actual practice, performed by a human.

On the other hand, there is a certain understanding of the fact that it is highly problematic to create a self-sustaining model of a station, ready to automatically perform a full cycle of operations with rolling stock, cargo, relevant transport structures. The «brain» of the system must have comprehensive experience and englobe expertise of numerous specialists in various fields and address constantly evolving complex, non-standard questions.

As a result, we have two diametrically opposed by «intelligence» criterion model positions, one of which includes only a technical side of the process followed *by full control by experts, the second is virtual machine station. Moreover, model image of station objects, controlled by humans, does not mean relative simplicity of its creation. After all, in this embodiment, it is necessary to be able to create a physical and technical pseudo-material construction of real objects, necessarily visualized for usual work of professionals with them. At the same time the virtual machine station (not yet attainable for an understanding of the ways of its construction) offers many advantages, as it can handle internal program functional structures, but not visualized images, significantly reducing a required number of calculation operations.*

It is a reasonable compromise of these two strategies, in all probability, that will form an effective model system, the basis of which, in any case, will be a certain technological consistent element reproducing operations using the most adapted virtual resources with some human intervention.

In this case, it is important that physical and technological symbiosis of model implementation will provide a software product, on the basis of which we can solve a wide range of applications. Priority of technological component possibly narrows the scope of subjective perception of such a global image as computer copies of real train stations, which are in operation. It is difficult, of course, to be aware of many functional links of facilities, separate units and elements of the system in the absence of reliable methods for verification of model simulations. However, given the fact that the operation of the station is conditioned by a need to perform technological operations of a certain amount and contents, it is logical to target a desired model image at a constructive reproduction of a technology.

Exaggerating to some extent, we can say that only a model of the station will be practically useful, in which all technological operations would be properly and adequately reproduced under the influence of abstract forces that simulate the action of natural and other factors. This effect can be somehow ranked by specifications laid down in the model algorithm. Estimated abstract force is recognized under relevant attributes, and as a result, the mechanism of adjustment according to nature and duration of technological operations turns on.

Considering under this view a general problem of the engineering model, we can hope to identify characteristics that are unique to various external factors affecting the very process of technological operation. This will help to reduce many-sided manifestation of the infinite string of natural and human-generated impacts on railway station objects to an abstract, but efficient scheme of correct modeling of operations. Technological reincarnation of the station facilities is built on a completely unrealistic physics, on unnatural control by a human, who in this model, most likely does not exist, but the status of objects at any temporal cross section is adequate to all events occurring at the station at starting position coinciding with model objects.

Conclusions. *All these considerations show a high complexity of implementation of technologically adequate model of a station, taking into account physics of car motion with a complex wheel thread when passing a turnout. Many potentially dangerous conditions are largely predetermined by the existing design of the mechanism of transfer of cars from one track to another. Maybe that would be better to implement first a model scheme with physics of motion through non-frog turnout, in which sections of rails of intersecting routes instantly «neck down», when it is necessary, taking a form providing passage of wheel tire, and after departure of the train from a switch immediately restore original structure of the metal of a model rail. And in the future it may be possible to obtain a rail on the basis of the use of «smart» materials with a memory of structure (a kind of reverse passage of reconstruction of reality from the virtual world).*

Thus, within the framework of the engineering model there is a need for a comprehensive account of impact of physical and technological laws acting at 3D station that perform themselves as specific synthetic conglomerate, which determines integral properties of model station facilities. Virtual technological operations cannot be performed unless they are provided with the calculations of changes in physical properties of the objects themselves and their environment. Therefore, the changes of model station's objects will always have a dual nature. The more accurately the engineering model will be able to reproduce this dualism, which leads to a corresponding change of the coordinate position and status of all interacting objects, the more adequate to its prototype generated image will be expected.

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