Digital Railway as a precondition for industry, science and education interaction by knowledge management

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Abstract. Digital systems in railways known as "digital railways" have dramatically changed the railway industry and the nature of railway employees' work. The Digital Railway is in a large extent linked with the knowledge-based economy, knowledge management and knowledge management technologies which have had a significant impact on digital transformations in the industry and professional education. An ontology characterized the cause-effect and aggregative relations reflecting transformation chains in the various spheres of human activity and shedding light on the Digital Railway place in the context of digital economy is presented. The article argues that the Digital Railway role in changing mechanisms of interaction between industry and universities, which are also specialized research centres with closer ties to the industry, is best understood applying to the idea of "a smart contract" that can be reduced to artificial intelligent agents serving as intermediaries providing interaction between the non-human and human roles in a business process. With the smart contract technology, the Digital Railway might provide a precedent in development of the Hybrid Corporate Intelligence based on industry-related knowledge redistributed between artificial intelligent agents and employees. From this perspective, the process of corporate informatization is seen through a system of artificial intelligent agents implying the formalization of operational rules and regulations into a shared knowledge base in a form of ontologies. The proposed idea can be transferred to universities where smart contracts may support professional training as a business process.

1. Introduction

The research literature on development a "smart" transport infrastructure highlights that digital systems in railways known at present as "digital railways" (DR) have dramatically changed the capabilities of the industry and the nature of railway employees’ work. At the same time, the DR is a logical consequence of the digital economy. With the implementation of the DR projects, a significant decrease in prices for transportation of people and goods is expected while increasing the capacity of this transport mode. Historically, the DR core as a collection of digital signalling, control and communication systems has been formed in high-speed railways. The United Kingdom is a large-scale example of the integrated implementation of the DR scientific and technological project. Similar projects are being implemented in the EU, USA, Russia, China, Australia and other countries of the world.

A comprehensive study of relevant publications suggests that there are various interpretations of the DR concept. However, a common semantic core can be identified. It is a set of technologies together leading to the fundamental changes in all fields of activity of railway transport enterprises and their counterparts, including the social sphere. Jones [1] associates the DR with the introduction of new technologies that massively change the principles of how the railway operates, operational rules, procedures, professional activities of railway employees and their methods of work. Love et al. [2]
focus their attention on improving the quality of information transfer between interacting contractors. Other researchers turn to the operational level of the DR. For example, Shi et al. [3] define the DR as an information management system based on GIS, GPS, RS, the Internet of Things, virtualization, information integration, etc. Parkinson and Bamford [4] state a similar view. It is apparent that the DR phenomenon is related to the knowledge-based economy, knowledge management and knowledge management technologies [5]; this determines many of the DR features and the course of transformations in the industry.

The implementation of digital approaches is impossible without establishing a connection between the physical state of transport infrastructures and their digital images to manage both physical and intangible assets. Knowledge-based technologies were known and actively utilised in the 80s as expert systems. Their new format to intelligent agents became available in the 90s, but has yet to be widely used in corporate systems of industry enterprises. The main reason is the difficulty of extracting knowledge.

The latest scientific achievements in the field of Big Data provide technologies for extracting corporate knowledge from large stores of data. Current practices show that huge amounts of corporate data are archived and hardly used, whereas they provide the tremendous hidden corporate experience. The mainstream of today is applying to neural network technologies as universal interpolators based on Big Data. However, there are alternative machine learning technologies for extraction of patterns "hidden" in data and turning them into knowledge. The extracted knowledge is represented in a form of rules, frames, semantic networks, etc., i.e. the elements of knowledge bases, which, unlike neural networks, can be interpreted by humans. This fact, against the background of an obsession with the statistical approach (think neural networks), had received scant attention. However, as for the authors, this is a symbolic approach ("traditional" for artificial intelligence) that is the most interesting for knowledge management as it involves using the forms of knowledge representation shared both by a machine and a man.

The above has given ground to suggest that the DR implies the ability of railway transport enterprises in managing knowledge. From this perspective, the nature of professional competency of railway employees (mostly engineers) is revealed [6]. We believe that education in railway universities, which are also specialized research centres with closer ties to the industry, to a large extent lays the foundation of becoming and development of professional competency for the new working environment [7].

In [8], knowledge management is attributed to the following significant events that have intensified the study of an engineer’s professional competency:

- applying to the key technologies of the digital economy (in particular, artificial intelligence methods);
- formation of the "knowledge management" concept based on the idea that knowledge as an element of a person’s competencies can be used by organizations to gain competitive advantages (to increase business intelligence);
- development of knowledge management technologies based on Semantic Web to allow developing global ontological knowledge resources (at present ontologies are approved as the international standard for knowledge representation in industries and e-learning [9]);
- designing employee-centred competency models;
- emergence of a new e-learning 2.0 paradigm where an important feature is a person’s access to corporate, industry-related and global knowledge resources while lifelong learning.

The competitive advantages of the DR can be achieved through a deeper understanding the nature of interaction between the railway industry and railway universities. In particular, these advantages are hidden in digital logistics, which is considered to be not only as a transfer of people and goods by rail,
but also as a transfer of information including knowledge for professional training of railway workforce. A growing body of research provides the results of digital formats implementation in the operational activities of railways [10; 11]. At the same time, the issue of digital formats implementation in industry-related universities requires further research.

The DR project is considered to be a necessary precondition for the transition to a new model of corporate management systems leading to substantial fluctuations of the traditional mechanisms of interaction between the railway industry and its partner organizations, including universities [12; 13].

2. Research methods
The study relied on the following methods: interdisciplinary analysis of scientific literature related to the knowledge-based economy, the digital transformation in the railway sector and professional education; artificial intelligence methods of knowledge representation.

3. Results
The following ontology describing the digital economy logic and shedding light on the DR place in the context of rapidly emerging changes encompasses the results of scientific literature analysis (the => sign is interpreted as a cause-and-effect relations) (Figure 1):

![Figure 1](image.png)

Figure 1. The DR place in the context of Industry 4.0 Ontology.

The given ontology characterises the cause-effect and aggregative relations reflecting transformation chains in the various spheres of human activity within the new technological paradigm [5; 6]. This article argues that the role of the DR in changing the mechanisms of interaction between the industry and its partners (business, government, scientific and educational organizations) is best understood in the context of the following key phenomena of digitalization - virtualization, artificial intelligent agents, a complementary client-server pair, a smart contract, and digital logistics.

These phenomena are worth to examine in some detail. The economic space *virtualization* made reference to the "virtual realm" concept. Accelerating logistics in the digital economy while
minimizing the transaction costs is impossible without virtualization of real objects in a form of artificial intelligent agents to simulate their behaviour. Particularly, artificial intelligence and blockchain technologies provide the implementation of a smart contract between a client and a server without engagement of "third parties" (intermediaries). Their interest adds significantly to the time of value flows exchange and the transaction costs. However, there is no guarantee to avoid unwanted outside interferences in the relations of a complementary pair.

Thus, digital technologies provide a different type of mechanisms for accelerating ("warming up") the economy based on the efficient implementation of contracts in the broadest sense. Therein lies the weakness of general culture of industrial relations in countries with an imperfection of the legislative and executive authorities. The consequence is poor negotiability, violation of parties' obligations, corruption, etc. Ultimately, these problems cause chaos, low efficiency and other negative impacts. From this angle, the essence of the digital economy is seen as the total implementation of smart contracts based on digital technologies with a distributed crypto-secure method of organizing and storing data (blockchain) to ensure confidentiality. Introduction of such technologies has enhanced confidence in an opportunity to create economic relations on a completely new (digital) basis without shortcomings related to the human factor. In other words, these technologies have made fundamental changes of partnerships between economic actors possible by incorporating artificial intelligent agents into an interaction processes between stakeholders to clearly differentiate and control their responsibilities, respond to situations, monitor the terms of contracts, and perform financial transactions automatically.

In this regard, the understanding of corporate management at all levels is being transformed through the implementation of smart contracts for all roles involved in these processes. The usefulness of automated process management is evident and new opportunities and prospects are opening up. Business processes as the "carriers of contracts", where the parties' responsibility and its delegation are anchored, have become the primary objects of automation supported by virtual intelligent agents. Guaranteed security of contracts based on blockchain technology, as we see, is a major breakthrough in the implementation of the digital economy.

To summarize the foregoing, it may be emphasized that the digital economy is transforming all industries at a rapid speed in accordance with the principle of intelligent (digital) mobility. Mobility, as a concept relating, first of all, to transport and logistics, has significantly changed in the context of digitalization. Logistics is a necessary tool for economic activity and requires more thorough consideration. One may speak about the emergence of digital logistics that is the extension of conventional meaning of a word "logistics". Logistics in its digital interpretation is management of information flows in the virtual economic space. Since logistics is the management of flows of a different nature, it is possible to conclude that the speedup of economic growth is closely tied to the increase in the speed of flows, their intensity and density. And if material flows can be replaced with information flows, it will surely take effect.

It should be mentioned that education as a type of economic activity has also its own digital logistical aspects (content delivery, accumulation and storage of educational resources). One may speak of the contemporary interpretation of academic mobility, e-learning, etc. This is directly related to corporate, industry, government knowledge resources represented in a form to be adequate to the tasks sought. The future is seen as these knowledge resources will be shared by business, scientific and educational organizations.

The digital economy is a paradigm shift in corporate informatization at the railway transport enterprises and the formation of a new mechanism for the interaction between the industry and its partner organizations through an integrated knowledge life cycle. A model explaining this idea was argued in an earlier article by the authors [14]. The revealing of the integrated knowledge life cycle entertains the idea of manageability of synchronization of the local knowledge life cycles formed within the industry and universities. This becomes possible with the standardization of knowledge and consists of establishing answer to the question about a form of content representation to provide
interoperability of knowledge, its processing and integration of local knowledge resources with the
global knowledge resource. It is proposed that ontologies are considered as such a form of knowledge
representation. Ontologies being a key element in Semantic Web technologies are approved by
ISO/IEC as a standard for knowledge representation in a number of industries and e-learning.
Ontologies make it possible to develop an open knowledge base integrated into the corporate
environment shared with railway universities and other partner organizations.

It is clear that the implementation of the proposed model requires the organization of knowledge
co-management, the identification of roles participating in this process, the availability of specialized
tools for users to work with ontological content (see [15]).

4. Discussion
As a basis for discussion, the paper refers to a very universal idea of a smart contract which essence
can be reduced to artificial intelligent agents serving as intermediaries providing interaction between
the roles in business processes. This is the answer to the question of changing the mechanism of
interaction between the industry, science and education in the context of the Digital Railway project
implementation. Artificial intelligent agents (intermediaries) carry knowledge about the corporate
regulations, monitor their execution and control them.

As an example, consider a job description as a focus of a smart contract work. A so-called role
agent [16] adopts a mission to comply its provisions while entering into relationships with a job role
and regulating its rule-based behaviour. In doing so, it also coordinates its own actions with the actions
of other role agents in business processes. In this case, a new corporate system architecture with a
virtual corporate environment based on virtual agents’ interaction emerges as a superstructure to the
real production environment. Interaction with the real-world (physical) corporate environment is taken
place at the level of interaction of virtual non-human agents with the human agents (employees). This
is a fundamentally different approach to the corporate system development. It is important to note that
this approach helps to identify the roles that can be fully automated, i.e. they can be given to artificial
intelligence systems. Regulations are rules to be complied with by contracting parties. Agents adopts a
mission to guarantee the fulfillment of obligations. In view of the foregoing, it is a matter of principle
to translate the regulations into a form of knowledge bases to be utilized for the development of
artificial intelligence systems. In particular, this refers to the development of intelligent agents as a key
element in the process management of railway enterprises and universities.

Rules, regulations, instructions and other regulatory documents are valuable raw materials to
establish corporate knowledge bases. However, these raw materials most commonly exist in forms
solely for human perception (text, hypertext). Extraction of meaning from texts and its translation into
machine-oriented forms of knowledge representation is a key and challenging task. Its solution is
made possible through technologies for knowledge extraction and knowledge representation.

Contracting parties are interpreted broadly as any active entities (agents): from dispatchers to
directors of railway transport enterprises. Likewise, "a contract" can be defined as a set of rules parties
to be conduct. Examples of contracts are numerous: these are rules, job descriptions, financial
obligations, etc. Contracts designated "smart" because they are associated with intelligent agents as
interacting parties’ representatives to be responsible for the enforcement of contracts. Hence, a
contract can be understood as a regulator of the relationship between the roles in a business process.
Both employees and artificial intelligent agents may be characterized as "roles".

In particular, when using the smart contract technology, the DR might provide an appropriate
precedent in creating the Hybrid Corporate Intelligence based on the use of explicit and implicit
industry-related knowledge redistributed between artificial (non-human) and human role agents and
concentrated in a form of contracts, i.e. the rules of engagement. Stability of such a system is ensured
by blockchain technology to prevent against malicious external interferences in relations between
counterparties. Big Data technologies enable to use enormous quantities of data from the activity of
interacting organizations cooperating with the railway industry for hidden patterns (knowledge)
extraction and the Hybrid Corporate Intelligence training. Data Mining technologies enable to extract rules from data bulks and use them as regulations, instructions, etc., i.e. as the basis for smart contracts. Machine learning in different types (supervised, unsupervised, reinforcement learning) as well as deep learning makes it possible to train neural networks. In some cases, they can play a role of intelligent agents, for example, in automated control systems of technological process. The Internet of Things (that is the Intranet of Things in the corporate context) enables deep penetration of sensors into the fabric of a corporation for providing feedback and motor skills through actuators.

By way of illustration, let us take an example of the infrastructure facilities repair system (as track and track facilities). The contract is concluded between the operating and repair services and is essentially defined by the Regulation. An artificial intelligent agent can monitor the implementation of the Regulation by receiving information from sensors (which are also agents) and providing data on the technical status of infrastructure facilities. The contract includes an agreement, for example, on the frequency of data transmission from sensors and engineering staff. Employees in their turn "have concluded contracts" with the artificial intelligent agent in a form of job instructions, etc. Thus, the entire corporate system is based on contracts regulating the interaction of subsystems at the operational level. This view seems to fit the S. Beer's concept of organizational cybernetics for a viable system (S. Beer's recursive theorem suggests that any viable system also has viable systems as subsystems) [17]. In this regard, the process of corporate informatization as a whole is seen in a completely different way. It is exercised through a system of artificial intelligent agents implying the formalization of industry regulations into a knowledge base in a form of ontologies.

The new economic conditions are changing the railway employee’s professional competency requirements. This fact has direct and immediate effects on railway universities with close links to the railway industry through an integrated knowledge life cycle. Smart contracts may provide the bases of educational process in railway universities and corporate universities. The fundamental idea was unchanged, namely, that the educational process is considered as a business process with educational programmes as regulations. In such a case, industry-related knowledge bases are supposed to be educational resources for students in their professional training. Thus, a shared knowledge resource is considered to be the core of industry-related research and educational complex.

5. Conclusion
The DR phenomenon is linked to the knowledge-based economy, knowledge management and knowledge management technologies determining the key features of digital transformations in the railway transport industry and railway universities, which are also specialized scientific and research centres. A practical exercise of the railway industry – universities interaction through the integrated knowledge life cycle could grant the DR competitive advantages hidden, in particular, in the digital logistics as a transfer of industry-related knowledge to the process of railway employees training. The change in the mechanism of interaction between the industry, science and education in the light of the DR project implementation is related to the idea of a smart contract that means artificial intelligent agents can serve as intermediaries providing interaction between the roles in a business process. The DR might provide an appropriate precedent in developing the Hybrid Corporate Intelligence based on the industry-related knowledge redistributed between artificial intelligence agents and employees and concentrated in a form of contracts. This idea can be transferred to education: smart contracts may support the professional training in railway universities and corporate universities as a business process. Industry-related knowledge bases shared by the industry and its partner organizations are supposed to be utilized in the process of professional training and build up the core of industry-related research and educational complex. The interaction between the industry, science and education by knowledge management is thus assured.
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