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Impact of digitalisation on increasing the fragility of the system (on the example of 'Digital Road' project)

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Abstract

Today, digitalisation is seen as a tool that can significantly improve the efficiency of all production processes. In fact, digitalisation has led to some impressive successes, but it has also brought with it some qualitatively new risks.

The article aims to examine the impact of digitalisation on the fragility of social and technical systems, using freight transport as an example. The development of 'Digital Road' is expected to radically improve the freight transport service system. However, with the advent of remote process control technologies, the main customers of transport services – the mining and manufacturing industries – could see radical changes in the transport system.

According to the author, routine and repetitive types of activities are most suitable for digitalisation while innovation and uncertainty hinder it. The maximum level of uncertainty is associated with social and natural factors that set the upper limit for the process of digitalisation of production activities.

Experience with the use of digital tools in various fields suggests that the consequence of this process is uniformity, increased monopolisation of markets, reduced diversity and the dominance of a single technological solution for typical situations. This reduces the technological adaptability of the production system and increases its vulnerability to social and natural risks. The article suggests that fragility in the transport sector could be halted by using a variety of transport services that would be in demand after mining and manufacturing industries move to fully unmanned and remote-controlled technologies.

Keywords: digital road digitalisation, transport, transportation service, routine, innovation, uncertainty, fragility, risk.

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数字化对加剧系统脆弱性的影响 (以数字之路项目为例)

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简介

如今，数字化已被视为一种能够显著提高所有生产流程效率的工具。事实上，数字化在许多领域都取得了重大进展，使数字化成为一个整体过程。然而，在这一过程中出现的新风险仍处于阴影之中。

本文旨在以货运为例，探讨数字化对社会技术系统脆弱性的影响。数字化道路的建立有望从根本上改善货运系统。然而，随着远程过程控制技术的出现，货运服务的主要客户--采掘业和制造业--可能会经历翻天覆地的变化。

作者认为，常规的重复性活动最适合数字化，而创新和不确定性则会阻碍数字化。不确定性的最大程度与社会和自然因素有关，这些因素决定了生产活动数字化进程的上限。

在不同领域使用数字化工具的经验表明，这一过程的后果是单一化、市场垄断加剧、多样性减少以及典型情况下只有一种技术解决方案的主导地位。由于这些原因，生产系统的技术适应性降低，其在社会和自然风险方面的脆弱性增加。文章认为，在运输领域，运输方式的多样性将克服脆弱性，在采掘业和制造业过渡到完全无人驾驶和遥控技术后，运输方式的多样性将成为需求。

关键词：数字道路、数字化、运输、交通、常规、创新、不确定性、脆弱性、风险。

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Introduction

Further research should concern a complete study of the process of creating knowledge-based innovations: their success may require both certain skills and technological support from the organisation. At the end of the study of this theoretical and practical category, it would be appropriate to propose a methodology for implementing knowledge-based innovations, which will be proposed by one of the authors as a dissertation study.

In the context of this article, digitalisation is understood as the process of transferring production functions from humans to artificial software and hardware systems, which is a consequence of the development of the technosphere (more precisely, a consequence of the process of improving tools).

Of fundamental importance is the digitisation of the economic infrastructure, especially transport, which directly or indirectly affects every inhabitant and every organisation in the country, and which has no close substitutes.

The set of digitisation projects in transport, which can be called the 'Digital Road', implicitly assumes that an information intermediary will first appear between technical systems and humans, which will then completely replace humans, leaving only the functional link 'technical system - programme'.

The set of projects 'Digital Road' concerns all the main elements of the transport system, including multimodal transport, transport and logistics hubs, transport process, traction vehicles, etc. [Sukonnikov, 2022]. At the same time, the same tools will be used as in other sectors of the economy: BigData, cloud technologies, new generation robots, virtual and augmented reality [Tsenzharik et al., 2020], machine learning technologies, automatic identification and tracking of objects, voice services, digital twins, electronic platforms, etc.

As rightly noted in the study [Plotnikova, 2020], the division of labour was a basic condition for digitalisation. According to the author of this article, the necessary conditions for digitalisation are:

1) the divisibility of the production process into separate stages (the possibility of constructing a process model): it is difficult to digitise the work of a universal (and therefore unique) specialist, as opposed to a labour process with clear stages of division of labour;
2) maximum transparency of the production process and quantitative expression of all its key parameters (possibility of formalising process data);
3) the standard nature of the product, work, service, which allows comparison, aggregation, planning, etc. (quantitative commensurability and reduction of variability);
4) the possibility of separating information and material flows (absence of tacit knowledge);
5) repeatability of the production process without significant changes that could affect the technology (routine);
6) The presence of a production management subject (process owner) with stable and quantifiable objectives.

The transport industry meets all the above requirements. In terms of routine, different types of transport have different levels of readiness for digitisation:

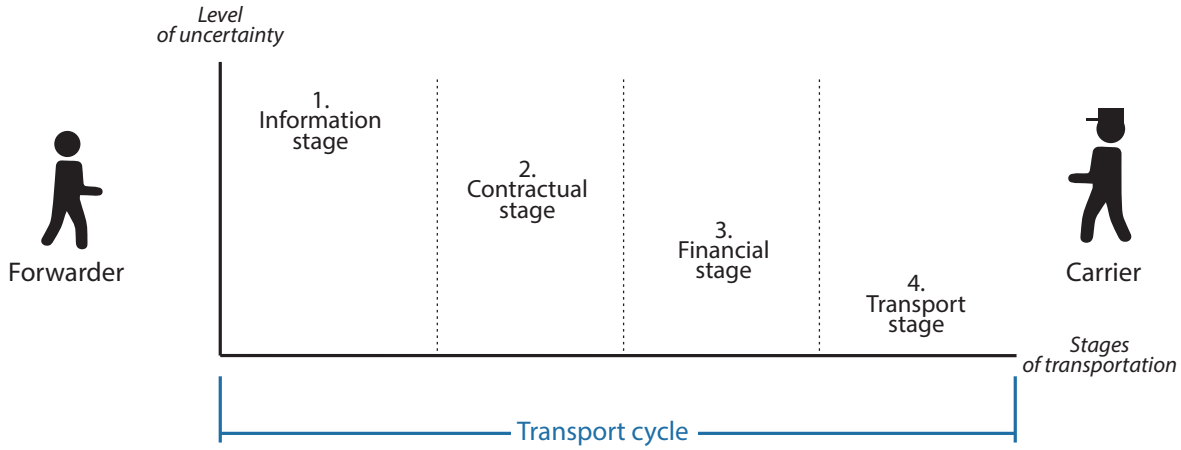
1) pipeline transport:
   – centralised transport system (new entrants to the market are limited),
   – minimal human presence,
   – means of transport remain stationary: the goods themselves move,
   – no need to return means of transport,
   – homogeneous mass goods,
   – impersonal consumer;
2) rail transport:
   – centralised transport system (limited entry of new players),
   – separate communication channels,
   – a significant number of industrial workers involved
   – rigid connection of transport to the railway network
   – limited number of professional operators,
   – concentration on long-distance transport of raw materials;
3) car transport:
   – unlimited number of participants,
   – decentralised transport system,
   – significant number of industrial workers involved,
   – maximum mobility of transport throughout the country,
   – focus on transport of processed raw materials over short and medium distances;
4) air transport:
   – centralised transport system,
   – limited number of professional operators (limited entry of new operators)
   – dedicated routes,
   – concentration on the transport of high value products over long distances;
5) water transport:
   – highly dependent on the state of the external natural environment,
   – wide range of participants,
   – connection of transport to the waterway network.

For example, pipeline and rail transport are the most ready for digitisation, as they are relatively less sensitive to the natural and social environment.

1. Routines and innovations

If we consider the relationship between the shipper and the carrier, each physical movement of the cargo is preceded by at least three specific types of activities, the implementation of which takes place sequentially: the exchange of information (on the parameters of the cargo, the technical possibility of transport, the route, etc.), the signing of a contract and the implementation of financial transactions (reservation of funds for payment, prepayment, cargo insurance, etc.). The sequence of these stages is called the transport cycle (Fig. 1).

Fig. 1. Successive stages in the freight transport cycle



Source: compiled by the author

Figure 1 shows that with each stage in the freight transport cycle, the level of uncertainty among stakeholders decreases. This in turn facilitates the digitalisation of these stages. In addition, each of the stages has its own duration. In the author's opinion, it can be assumed that in a routine situation (i.e. extremely stable and repeated an unlimited number of times), the duration of each preceding stage is significantly shorter than the duration of each subsequent stage. This can be expressed by the inequality:

$$T_I < T_C < T_M < T_T, \quad (1)$$

where T_I – duration of the information phase, T_C – duration of the contract phase, T_M – duration of the financial stage, T_T – duration of the transport stage.

A quantitative test of this disparity is unlikely to be feasible, but some arguments can be made in its favour. In particular, the more stable and predictable the market situation (there is information transparency), the less the need to update the content of contracts and the longer their validity. The risks of receiving payment are reduced, and partners can therefore refuse, for example, advance payments, insurance, guarantees, etc. As a result, more and more flights are carried out as part of a market transaction.

In times of unpredictable changes in the external environment, the opposite process occurs. An example of this is the situation with the Ever Given container ship accident, which led to the closure of the Suez Canal on 23 March 2021 [Gerson, 2023; Rakha, El-Aasar, 2024]. This event immediately increased the level of uncertainty among all transport stakeholders, which required an intensive exchange of information. Once the situation became relatively clear, a calmer revision of contracts for new transport on available routes began. And it was only after this significant preparation that the financial and transport phases were resumed.

If we are talking about new and strategically important deliveries, then agreeing the terms (this activity in Figure 1 corresponds to the information stage) can take years, but once signed they can be in force for decades[1] (contractual stage), which greatly increases the duration of other stages (financial and transport).

Thus, in a fundamentally new situation, the information phase closes in on itself and the next, contractual phase does not begin until some picture of what is happening has been formed. However, if such events become constant (military actions, pirate attacks, etc.), they will be incorporated into standard action algorithms, i.e. they will also become routine.

In very routine situations, contracts represent a public offer: the contract is automatically concluded with any interested party on the terms specified in the offer. Once the offer has been accepted, the movement of financial documents is automatically initiated and the cargo is sent along the planned route.

In the author's opinion, the types of specific activities shown in Fig. 1 have different degrees of readiness for digitalisation. The transport stage is currently being actively digitalised by replacing drivers with software and hardware systems, and the financial stage - with the help of online payment systems. At the same time, activities such as documenting the transport, concluding a contract, planning the transport are characterised by higher uncertainty and therefore require mandatory human participation, and the prospects for their digitalisation are extremely vague. These stages are shown in Fig. 2.

Fig. 2 shows that routine, repetitive operations are primarily digitised, whereas information activities are extremely difficult to digitise due to the unpredictability of the external environment.

In other words, full digitisation requires the complete routinisation of all types of activity and the minimisation of the uncertainty factor. To this end, there is an arsenal of measures in various stages of readiness, including:

1) a numerical expression of each transport process, allowing comparison and management. Numbers can be considered as a universal expression of a symbol [Kleiner, 2020]. In relation to transport, such relative

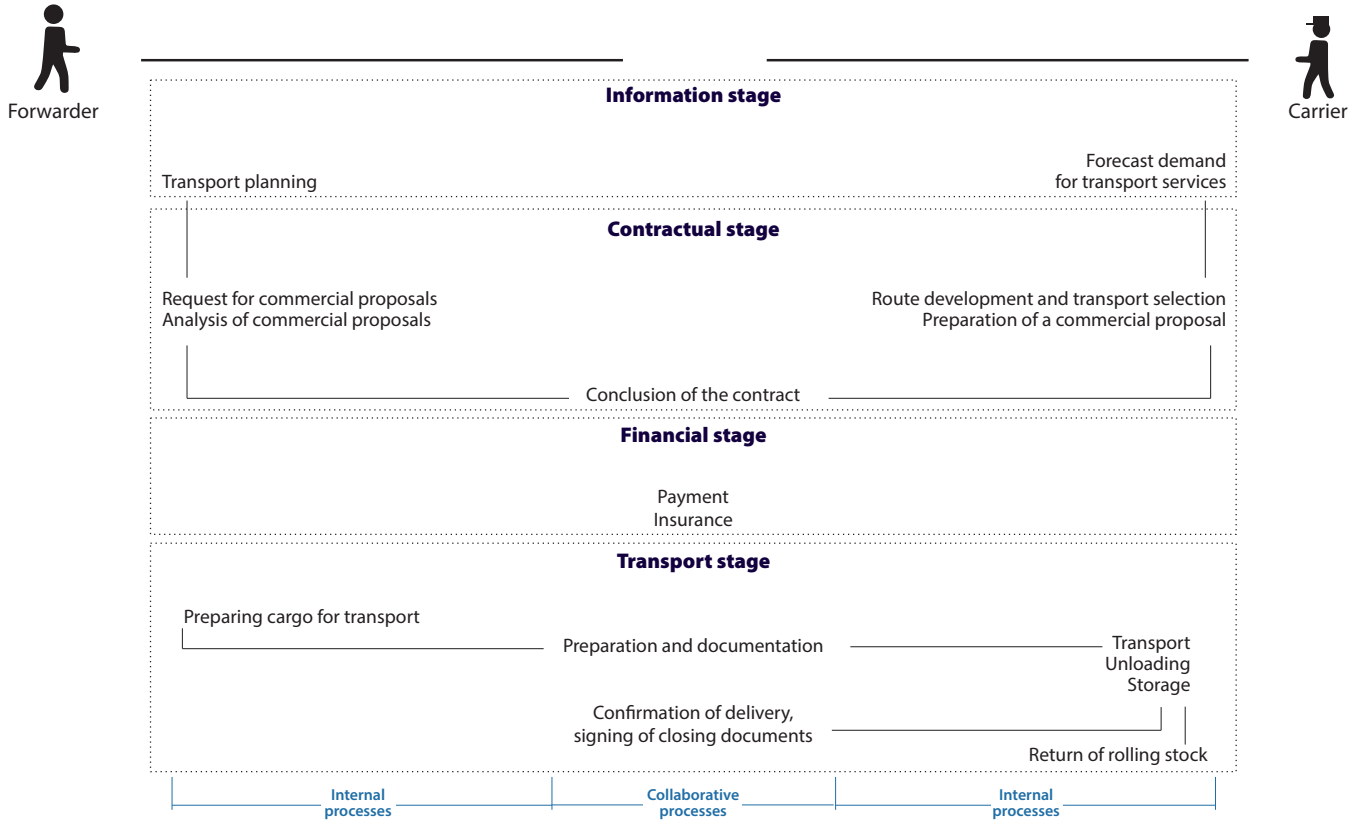
[1] Russia will sell gas to China with minimal profitability. https://www.rbc.ru/economics/21/05/2014/57041d219a794761c0ce9fb9.

and absolute indicators as freight turnover, average freight delivery speed, operating coefficient, average hourly productivity, throughput, transport network density, etc. are used;

2) unification and standardisation of the cargo unit: standard storage units (platforms, containers, tanks, etc.) have been developed for the entire range of cargoes, which greatly facilitates the transfer of cargoes between different modes of transport and also makes the transport process planned and predictable;
3) automation and maximum elimination of human beings from all areas of production. This will reduce the level of uncertainty, which can be clearly seen when studying the causes of accidents in transport: in road transport, 90% of all accidents are caused by human error [Andreev, Pavlov, 2015, p. 172]. In sea transport, the human factor is the cause of 80% of accidents [Ermakov, 2016], in rail transport - 75-80% [Klimov, Lezhenkina, 2006], in road transport - 85.2% [Kuprienko, Grefenstein, 2023];
4) gradual transfer of activities to the virtual world, improvement of artificial intelligence, etc., which also serves to eliminate the human factor;
5) regulation and algorithmisation of the actions of the participants. At present, at the information level, protocols have been developed for each routine and abnormal situation in order to neutralise the instability factor - this is a prescribed sequence of actions by all participants, initiated in response to a given event. Moreover, the more participants involved, the stricter the protocol: failure to comply with it is unacceptable, as it increases the risks of the entire system. At the contractual level, such protocols are codified in various forms of legal contracts (classical, neoclassical, relational, etc.) [Ivaschenko et al., 2019], which focus on a particular level of uncertainty.

In the long term, digitisation can instantly initiate the required protocol type (with the corresponding action algorithms), not only within an organisation, but throughout the entire production chain (right up to the end user). This allows the digitised transport system to function as a single whole - predictably and without delay. However, this is hampered by the uncertainty of the external environment (social and natural). Moreover, in an internal digital environment, the risks and uncertainties of a particular, even small, entity become the risks and uncertainties of the entire system. For example, a lorry on a local road may not affect the movement of other vehicles. On a digital road, the same truck can affect not only a specific section, but the entire transport system at once (e.g. by blocking a lane on a high-speed motorway).

Fig. 2. Block diagram of the interaction between the shipper and the carrier



Source: compiled by the author

Many researchers implicitly assume that full digital transparency will reduce some of the risks, or at least manage them effectively [Tagarov, 2023]. This is probably true to a certain extent, but it is also true that at the same time the system becomes qualitatively more fragile and more sensitive to any deviation from the norm. According to the author of this article, the reason for this is that digitalisation leads to the monopolisation of markets.

On the one hand, digitalisation makes production and market processes transparent and therefore predictable and manageable. On the other hand, it enables large companies to squeeze smaller competitors out of markets. This is the case in markets where small and medium-sized companies are currently protected by high transaction costs. Today, for example, production processes in areas such as car service, repair, household services, etc. are usually non-standardised and therefore unattractive for large players (their costs for individual services in the economy sector do not pay off). However, digitalisation can eliminate this factor (e.g. in the car service sector, this can be manifested in the fact that renting a car becomes more profitable than buying and repairing it, or in the transition to 'disposable' cars). This reduces the grey area of the economy and makes small and medium-sized enterprises less competitive.

As a result, digitisation is followed by monopolisation, which can be clearly seen in the example of taxi markets (the number of taxi companies is decreasing), operating systems (for mobile devices, this is Android and, to a much lesser extent, iOS; for PCs, this is the dominance of Windows with a very limited presence of macOS, Linux, Chrome OS), video hosting (despite many years of attempts, a real competitor to YouTube has not yet been created), city navigation systems (in Russia, this is only 2GIS and Yandex.Maps), etc. The same goes for rental markets, office equipment, online shops, ticket offices, tourism and much more. Even something as familiar as a bulletin board has become a monopoly in the Russian digital environment (the Avito Internet service). But this is only the first circle of monopolisation. The next circle is the monopolisation of access to markets. For example, Sberbank has clearly stated that it intends to cover all human needs [Galazova, 2023]. Such a continuous ecosystem will entail both the complete isolation of the consumer and a total monopoly. If competitors remain in any of the markets, they are likely to be little different from each other, being in fact variants of the same digital solution.

But more importantly, the number of technological possibilities in each market is now greatly reduced, and the economy is transforming from differentiated to fractal, where the same digital matrix is reproduced in each segment. This thesis can be explained using the example of the interaction between subjects.

In inter-subject interaction (coordinating the activities of many people), a single protocol is required. Moreover, the greater the number of subjects involved in the interaction, the smaller the variety of protocols and the stricter their observance. Although such a requirement existed before digitalisation, it previously concerned small groups and professional communities. Today, this requirement has become total: an increasingly limited list of digital systems and their protocols is used in every single field of activity. The same processes are taking place here as in linguistics: world languages are irrevocably absorbing local ones.

The history of languages also provides us with examples of the fragility of systems: many languages and writing systems have disappeared due to social and natural causes, resulting in the loss of a significant part of the accumulated knowledge. In the author's opinion, the digital system poses similar risks, caused by:

- dependence on one type of energy - electricity - which is slowly but surely becoming the only acceptable one (without convincing economic arguments);
- impairment of many important human abilities: spatial orientation, information retrieval, reading long texts, etc;
- the disappearance of human subjectivity: from a subject of control he becomes an object of control by depersonalised computer programs; instead of a full person, as a result, only his digital profile may remain [Kondakov, Kostyleva, 2019];
- intentional or accidental errors in digital systems, exacerbated by blurred lines of responsibility;
- distortion of human consciousness: misunderstanding of nature (man will be increasingly isolated from nature by the technosphere), deterioration of the understanding of cause-and-effect relationships (man can no longer repeat AI operations and double-check his decisions), deformation of the world view as a whole;
- isolation of individuals: gradually, all interaction becomes possible only through the mediation of digital systems (including social skills and connections);
- forgetting the knowledge accumulated by civilisation in favour of easier access to knowledge through artificial intelligence, which, as it turns out, is capable of falsifying data;
- the loss of the goals and values that man has set for the technosphere; in this case, man is transformed from a creator of meanings and values into a subordinate subsystem of the technosphere.

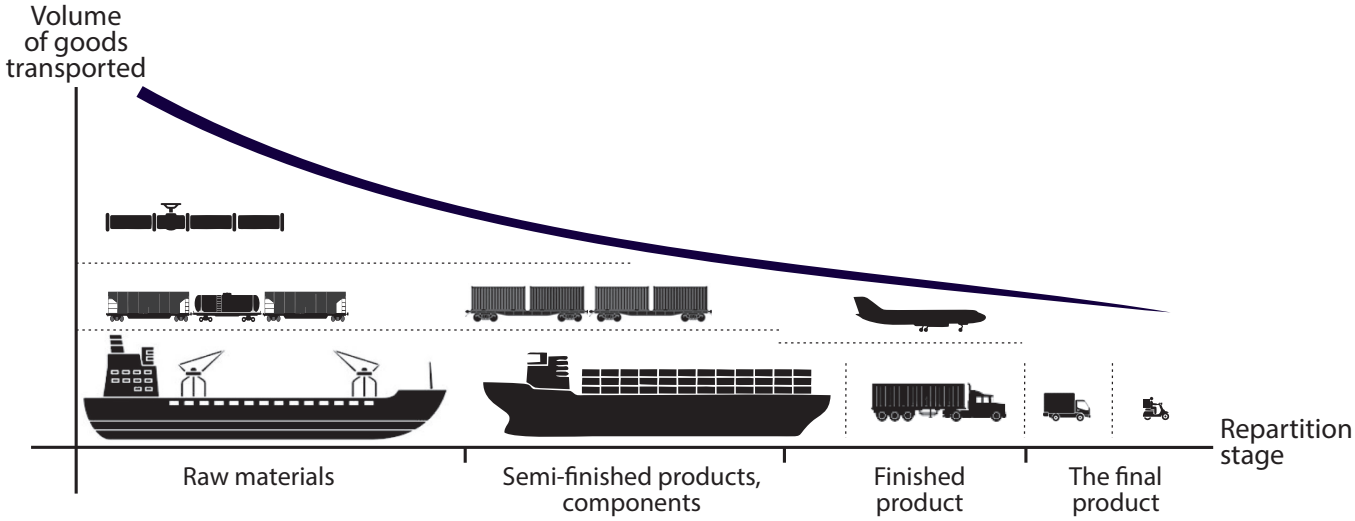
Each of these risks individually, and all of them together, means an increase in the fragility of both the macro-economy and the transport system. In the long run, even one of these factors will be enough to seriously destabilise the system.

So any monopoly is destructive, and a digital monopoly is many times more destructive because it penetrates all segments of the economy and irrevocably destroys competing technologies: a type of energy, a database, a way of interacting.

2. An alternative path to digitisation

Let's look at the consequences of digitalisation that are likely to be manifested in the interaction between industry and transport.

Fig. 3. Change in volume aof goods handled and type of transport by stage of processing



Source: compiled by the author

At present, transport is structured according to the type of cargo transported, the volume of which depends on the processing stage (Fig. 3).

Fig. 3 shows that the most voluminous cargo is raw materials, and the higher the stage of processing, the less transport is needed. Digitalisation can significantly change this situation.

Digitalisation is displacing humans from all areas of activity. As a result, the nature of both production and freight transport may change: many activities can already be performed remotely or unmanned (e.g. operating dump trucks in a quarry, piloting locomotives and aircraft). This involves major technological changes. For example, the development of a large mine today requires the relocation of hundreds or even thousands of workers and their families to the production site, which requires the creation of a capital-intensive social infrastructure around it. As a result, such production is tied to a specific territory. However, this link can be broken with the help of unmanned technologies, making the place where workers live and the place where they produce completely independent of each other. In such a scenario, a significant part of the production chain can be concentrated in one place: from the extraction of natural resources to the manufacture of the finished product. In this case, the need to transport the most bulky types of raw materials (oil, coal, ore, grain, etc.) disappears, and the transport system will only transport less bulky cargo with a high degree of processing.

For example, the digitalisation of manufacturing and extractive industries may lead to the concentration of their production in one place and to the transformation of some types of transport from interregional to intraregional (e.g. organised according to the conveyor principle).

This, in turn, will have the following macroeconomic consequences:

– radical reduction in the volume of freight transport and the consequent strain on roads and motorways, which will raise the question of the economic viability of their maintenance (passenger transport will not be able to cover the costs of maintaining the transport infrastructure);
– growing demand for differentiated delivery methods that do not require expensive and long roads: water and air transport. In turn, the elimination of roads will lower the entry threshold for many participants and increase the level of competition. In such a scenario, we should expect a renaissance of paraglider, seaplane, cargo airship technologies, etc.

The risk zone mainly affects rail transport, which focuses on non-containerised bulk goods (liquids, bulk goods, loose goods, etc.). The decline in demand also affects road transport, but to a lesser extent as it focuses on the transport of processed raw materials over shorter distances.

This means that, for technological reasons, the market for transport services will enter a phase of compression, requiring a transition from narrow specialisation to universality. As a result, instead of a large number of differentiated means of transport (tanks, wagons, refrigerators, etc.), there will be a need for a single means of transport suitable for transporting all or most types of cargo. In the future, this role could be played by containers, which are equally suitable for rail and road transport.

The container can also be presented in a more advanced form of contrailer[2], , which gives each specific transport unit the property of mobility and manoeuvrability. From here, it is only a step to give it complete autonomy, i.e. the ability

[2] A contrailer is a container fitted with car wheels and intended for the combined transport of goods: car-water, car-rail or mixed car-rail-water.

to move using its own engine, as well as the ability to plan its own route and carry out loading and unloading without human intervention.

If we continue with speculation and probabilistic scenarios, in the future contrailer vehicles travelling along the same route may acquire the technological ability to join together to form trains and travel as a single unit along the same route by combining their engines into a single power plant and then disassembling into individual delivery vehicles. In this way, piggyback transport will combine the advantages of both rail and road.

This scenario does not eliminate the risk of a person losing subjectivity and other risks generated by digitalisation, but it does eliminate one key risk - the risk of losing the plurality of technological solutions.

Conclusion

Digitisation must be cross-cutting, at least on a macro-economic scale, and is therefore impossible without digitisation of the basic sectors of the economy: energy, transport, communications, trade. This article examines this process using the transport sector as an example.

Tools and other components of the technosphere were originally conceived as complements to the human body, but eventually became its substitutes. In other words, by creating and improving tools, humans created another self.

The highest form of development of the technosphere is digitalisation, which has so far functioned on the principle of 'in the interest of man, but without human participation'. However, the completion of the digitalisation process will ultimately mean that man will turn from the goal of the system into its subordinate subsystem on the principle of 'without human participation and only in the interest of the digital system'. At the same time, the system itself will lose the purpose and value of its activities, and will also become many times more sensitive to social and natural risks. It is already clear that digitalisation has led to a dramatic reduction in the number of market players, a decrease in diversity and the dominance of a limited number of technological solutions.

Digitalisation may also have consequences that are not yet apparent, in particular the reformatting of the industry and the elimination of demand for the transport of whole categories of goods, which will lead to a radical change in delivery technologies.

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