OPPORTUNITIES OF IMPLEMENTATION OF "INDUSTRY 4.0" FOR DEVELOPMENT OF TRANSPORT INDUSTRY IN UKRAINE

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Abstract: *Due to intentions of Ukrainian economy to join European Union there are many threats and opportunities on the way. Ukraine has a number of industries producing goods, products and services needed in Europe. The growth of economic ties with EU makes Ukrainian manufactures stronger and has become a question of key importance during last decade. Meantime, Ukraine remains within rather tense conditions of technological lag but with some promising abilities in agriculture and food industries supplemented with a great potential in area of information technologies. This distinctive combination of abilities make it feasible for Ukraine both to become a strong partner for EU and to do a great leap of industrial progress within "Industry 4.0" concept. Nevertheless, one of crucial problems for Ukraine is to build an innovative infrastructure to meet requirements of intellectual transport system conforming to EU "Industry 4.0". This research paper is focused on discussion of these new features of transport industry and opportunities for Ukraine to make its transport industry a leading advantage for the whole economy. Those drastic changes in Ukrainian transport would procure an excellence for other industries implementing "Industry 4.0", the same as to become a test ground and an exclusive source of experience for EU on "Industry 4.0" implementation.*

Keywords: INDUSTRY 4.0, TRANSPORT INDUSTRY, UKRAINE, SMART FACTORY, AUTONOMOUS RAILWAY

1. Introduction

There are many aspects of "Industry 4.0" remaining a mainstream for development of modern economics during recent years [1]. A great interest to develop the concept of "Industry 4.0" in Europe was led by German governmental efforts since 2010 [2]. Many other countries within European Union payed much attention to develop and adopt those concepts for needs of their own. Actually, the interest to "Industry 4.0" became one of the key features in contemporary globalization [3]. One of the key problems felt to become crucial is the problem of building new infrastructure to support "Industry 4.0" and to update transport logistics. Some countries, like Austria, are doing efforts to find their own place in circumstances of a new world economy [4]. Some researchers are investigating the scope of problems of "Industry 4.0" [5–7] or solving some particular problems like "learning" or "smart" factories [8]. One should understand the complexity of the problems being raised by "Industry 4.0". It requires consolidating efforts of both governments, businesses and society, with the support of some NGO, like EFFRA (European Factories of the Future Research Association) and others. Despite of progress in technologies development to build smart factories and to automate goods production, there are some important aspects of supporting the factories supply chains and ensuring both continuous resources supply and products distribution. This yields different thoughts about changing transport and logistics [9].

Present research discusses the problem of implementation of "Industry 4.0" and its opportunities for Ukraine to find own place within newly built European economy. The particular attention is focused on transport industry of Ukraine as a fundamental basis to connect Ukrainian factories with European Union and to meet challenges of global logistics. According to agricultural potential of Ukraine [10], we are making some accent to agriculture and food industry.

2. Prerequisites and means for solving the problem

Ukraine is a very good situated from the point of view of geographic position (Fig. 1). There is a center of an imaginary "crossroad" connecting Europe with Asia and Africa: the cross lines from Ireland to Japan and from Sweden to Egypt. The crossroad falls directly in the Western Ukraine near the city of Lviv. Moreover, it is not the only convenience: Lviv, as a western gate of Ukraine, is a center of 800 km circle with almost equal distance both to a port of Riga in Latvia and to a port of Varna in Bulgaria (Fig. 2). There are ports of Odesa in Ukraine, Gdansk in Poland Kaliningrad in Russia and Klaipeda in Lithuania within the distance. Straight line of 800 km in length reaches also Berlin and Dresden in Germany, Sofia in Bulgaria, Salzburg in Austria, Constanţa in Romania, Ljubljana in Slovenia, Zagreb in Croatia, Sarajevo in Bosnia and Herzegovina, Prishtinë. There are inside this circle the whole Belarus, Lithuania, Poland, Moldova, Romania, Hungary, Slovakia and almost whole Czech Republic, most territory of Austria, Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Bulgaria and Latvia.

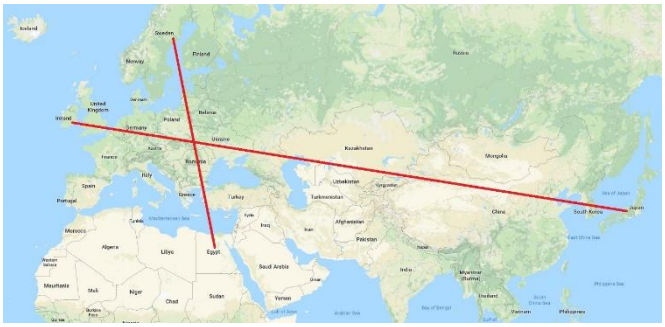

Fig. 1 *Geographic location of Ukraine as a "crossroad" (map retrieved form Google Maps)*

This can be the motivation to consider Ukraine as a good location for the purposes of logistics: placing transport and storage facilities, organizing transport hubs etc.

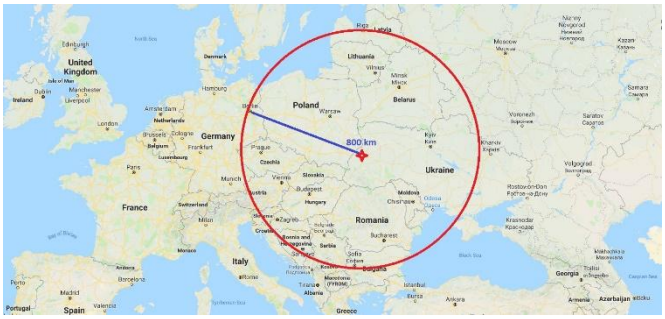

Fig. 2 *Geographic location of Lviv in Western Ukraine: 800 km circle (map retrieved form Google Maps)*

One may wonder about the distance of 800 km that we choose for the circle radius at Fig. 2. We offer a very easy explanation for that. The simplest way to define a distance is to multiply an average speed to a maximum time limit for transportation:

$$Distance = Speed \cdot Time. \quad (1)$$

According to equation (1), it is very easy to guess a possible distance of transportation with respect to maximum possible speed for each type of transport (see Table 1). We considered for Ukraine three types of transport: air, railway and auto. Due to speed limits for auto transport, we assume its possible speed up to 60–120 km/h. Both air and railway transport we can divide into two groups each – fast and regular. Due to current experience of railway transport in Ukraine, there are two evident speed groups: a regular one with old rails (trains move slow enough here, 50–100 km/h) and a fast one with a newer rails (trains move fast enough, 120–180 km/h, but it is not a high-speed rail yet). The speed groups for air transport represents typical speeds of the planes. For example, many planes (similar to Boeing-737 or Airbus A 320) can fly faster than 800 km/h and up to approximately 1000 km/h (for Boeing-747 or Airbus A 380), and some Ukrainian transport planes (like An-124 "Ruslan") has a regular speed 800–850 km/h. Meanwhile, there are many planes in Ukraine like An-24 or An-12 having regular speed about 460 km/h or 550 km/h, but definitely less than 800 km/h. That is why consideration of fast and regular speed groups for railway and air transports in Table 1 seems reasonable.

***Table 1**: Options for definition of convenient transport.*

Time	*Transport*	*Speed*	*Distance*
< 1 hour	Air (fast)	800–1000 km/h	800–1000 km
	Air (regular)	400–800 km/h	400–800 km
	Railway (fast)	120–180 km/h	120–180 km
	Railway (regular)	50–100 km/h	50–100 km
	Auto	60–120 km/h	60–120 km
< 2 hours	Air (fast)	800–1000 km/h	1600–2000 km
	Air (regular)	400–800 km/h	800–1600 km
	Railway (fast)	120–180 km/h	240–360 km
	Railway (regular)	50–100 km/h	100–200 km
	Auto	60–120 km/h	120–240 km
< 5 hours	Air (fast)	800–1000 km/h	4000–5000 km
	Air (regular)	400–800 km/h	2000–4000 km
	Railway (fast)	120–180 km/h	600–900 km
	Railway (regular)	50–100 km/h	250–500 km
	Auto	60–120 km/h	300–600 km
< 12 hours	Air (fast)	800–1000 km/h	9600–12000 km
	Air (regular)	400–800 km/h	4800–9600 km
	Railway (fast)	120–180 km/h	1440–2160 km
	Railway (regular)	50–100 km/h	600–1200 km
	Auto	60–120 km/h	720–1440 km

We choose time limits in Table 1 to discuss the ability to meet prompt response with a fast transportation for the needs of smart factories (or automated factories, or robotic factories) and to keep satisfied its high demand supply chains. It is evident, that building European factories of the future requires using some kind of "European transport of the future" for the purpose of continuous and sustainable production. It looks here almost like a dilemma of "chicken or egg" to decide what should be built first within "Industry 4.0" concept – a smart factories network or a smart transport system.

Nevertheless, analysis of possible distances with respect to shortest elapsed time for the transportation reveals that less than 800 km distance allows satisfying supply demand with almost any type of transport. For the purpose of accuracy, one should consider also a cost of each type of transport. However, in case of our study we may disregard this cost as a yet unknown value for future robotic transport (like a drone air transport, or a railway robotic locomotive, or an autonomous truck).

We are accenting now, that we leave the sea (water) transport without attention due to less or absent ability to use it within Ukraine. This can be interesting, for sure, to study the perspectives of a river transportation with a "remote-controlled cargo ships" within "Industry 4.0" concept. However, there is a single big enough river, Dnipro, and a very poor experience in building river ships in Ukraine. Meanwhile, there are some opportunities for Ukraine to develop small autonomous robotic ships to use on shallow water rivers: Dnister, Southern Buh, Western Buh, Prut or Tysa [11].

Finally, to understand the system of railways and airports in Ukraine, one should consider Fig. 3 with the six divisions of Ukrainian national railways (named "UkrZaliznytsia") and Fig. 4 with the seventeen international airports of Ukraine.

Now, we can define the key questions for Ukraine to understand the problem of implementation of "Industry 4.0" concept in Europe:

- Does have Ukraine the ability to meet needs of neighboring European countries in supply and support of automated factories?
- What would be the most valuable resources for Europe to come from Ukraine?
- How would Ukraine supply European partners with its resources, goods and services?
- How can Ukraine make profit of convenient geographic position?
- What does Ukraine need to receive from Europe to hold within trends of "Industry 4.0"?
- How can Ukraine raise its value while implementing "Industry 4.0" in Europe?
- Can the "Industry 4.0" become a mainstream for Ukrainian economy?

Answering all these questions requires a deep and detail analysis. We are conducting current research to clarify the vision of what should become the first step for Ukraine within the way to join "Industry 4.0" and to meet demands that could be the most valuable for European neighbors.

***Fig. 3** Railways map of Ukraine (map retrieved form http://railway.lviv.ua/info/maps/)*

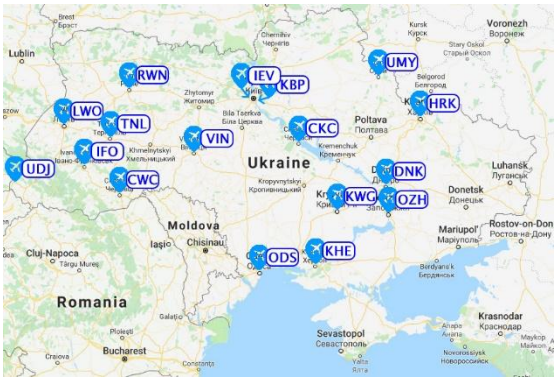

***Fig. 4** Airports map of Ukraine (map retrieved form Google Maps; airports list retrieved from Wikipedia [12])*

3. Solution of the examined problem

First, Ukraine needs to make a tight economic connection with European Union. The best binds to any European country starts with a well-developed transport system. This point comes directly from discussion in previous section. As we have mentioned above, Ukraine may use a convenient geographic situation. One of the most promising routes goes between Baltic and the Black seas.

Unlike to other opportunities to cross the Europe from the North to the South (or vice versa from the South to the North) there is great advantage of the Ukrainian route – plain terrain with no mountains and seaports on both sides (see Fig. 5). The idea of using this route is not a new one. There was a "Sarmatia pipeline" (also known as Odessa–Brody) had been built with possible extension to Płock and Gdansk [13]. However, pipeline is a good example revealing the geographic convenience of the route. Another advantage to use the route Gdansk–Lviv–Odessa is that there is an opportunity to use sea transport on both ends of the route and only two countries (Poland and Ukraine) can be involved directly to control the whole route length (this may minimize political risks). Moreover, there is an existing railway connection. Due to examples of successful efforts in developing transport connections with Europe over the railways [14], Ukraine may keep going further and within "Industry 4.0" offer to develop a remote-controlled railway transport with robotic locomotives (we may call this an "autonomous railway transport"). Developing two new robotic railway hubs in Odessa and Lviv may provide European partners with a reliable, secure, fast and cheap transport corridor through Ukraine. Connecting Lviv railway hub to a Central European logistic hub in Austria [4] may boost creation of automated factories across the Central and Eastern Europe, while Ukraine may become a reliable supplier of resources over autonomous railway transport. Eventually, an autonomous railway is considerably more convenient and secure compared to autonomous vehicles. The idea of autonomous transport in Ukraine can be also developed in areas of air and river transports. Nevertheless, the railways now looks like a cheaper and easier way.

Fig. 5 *Possible schema for Gdansk–Lviv–Odessa route (purple line) and its extensions (blue lines)*

Second, Ukraine must offer some valuable own services and products to EU and, obviously, Ukraine have to consume some European services and products. Evidently, the use of autonomous railway transport allows Ukraine to join a brand new world of European "Industry 4.0" economy with its automated factories and European factories of the future. Meanwhile, Ukraine has a potential not only to build a railway locomotives, but also to make these locomotives smart with a support of its fast growing IT industry. Obviously, there is a need to rely on some best European technologies in locomotive building and railway transport, including IT infrastructure (datacenters services, cloud technologies etc.) and necessity of IT-support for autonomous railway transports. This cooperation of EU and Ukraine within "Industry 4.0" concept is supposed to become a great opportunity for both sides to develop new design of intellectually automated supply chains and to provide resources transition directly from areas of its origin to the factories to satisfy its demands "just-in-time".

Third, Ukraine may offer an automated access to its agricultural regions and boost development of its food industry. Further development of autonomous railway may extend the ability both to use big agricultural areas in Ukraine and to support the exchange of food and agricultural products between EU and Ukraine. Another option for Ukraine is to support its metallurgy factories and mining facilities with a reliable transport to supply its products to their European partners and to the European future smart factories. Although, the current state of Ukrainian agricultural and food industry could be possibly more preferable to join new autonomous railway corridor at the first stage. At the same time, EU can be interested in autonomous railway transport to use Odessa port to export products to Middle East, Caucasian Region and Central Asia.

4. Results and discussion

Implementation of the offered ideas allows expecting a deeper integration of Ukrainian economy to new coming EU economy of "Industry 4.0" era and strengthen the Ukrainian economy simultaneously. The solution looks evident and easy enough to develop successfully within existing circumstances.

5. Conclusion

The key result of present research is an idea to use autonomous railway transport. This may become both a simple and a cheap way for Ukraine to meet demands of supply for European smart factories (or "factories of the future") within concepts of "Industry 4.0". Implementation of the idea of autonomous railway in Ukraine we offer to start from construction of Trans-European autonomous railway "Gdansk–Lviv–Odessa" to connect Baltic and Black seas. Meanwhile, building the new robotic locomotives in cooperation with EU. Making locomotives smart can base on capabilities of a fast growing Ukrainian IT industry. Involving agriculture and food industry of Ukraine to exploit new autonomous railway transport may boost its development and become a great experience of implementation of "Industry 4.0" in Ukraine.

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