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Технологии виртуальной и дополненной реальности в менеджменте и образовании

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Аннотация

Потенциал некоторых технологических инноваций длительный период времени остается или не до конца исследованным или недооцененным. В статье дана краткая характеристика технологиям виртуальной и дополненной реальности (VR/AR), показаны возможности их использования в различных секторах и отраслях современной мировой экономики. Приведен обзор положительных сторон и конкурентных преимуществ, которые AR- и VR-технологии могут принести компаниям, занимающимся разработкой и производством устройств и инструментов, позволяющих использовать эти технологии. Это рост продаж продукции и услуг, снижение операционных издержек, повышение удовлетворенности потребителей, улучшение качества продукции, услуг и сервиса. Рассмотрены также ограничения использования AR- и VR-технологий в образовательных средах. По мнению авторов, существует больше отраслей и сфер, где AR- и VR-технологии могут быть применены.

Проанализированы объемы инвестиций в область VR/AR, даны прогнозы возможных улучшений AR- и VR-устройств, ведущих к созданию более широких возможностей их использования в промышленной, финансовой и образовательной сферах. Приведены наиболее успешные примеры внедрения AR- и VR-технологий в 2012–2021 гг. в зарубежных и российских компаниях. Для статистического подтверждения полученных результатов проведен корреляционный анализ прогнозных оценок развития AR- и VR-технологий в 2021–2023 гг. Сделан прогноз продаж технологий и устройств в некоторых секторах экономики к 2024 г. На основании проведенного анализа сделан вывод, что между рынком электроники в целом и рынком VR/AR есть существенная взаимосвязь.

Ключевые слова: инновация, инновационная политика, дополненная реальность, виртуальная реальность, смешанная реальность, повышение эффективности, конкурентное преимущество, прогноз

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AR/VR technologies in management and education

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Abstract

The potential of some technological innovations for a long period of time remains either not fully explored or underestimated. The article gives a brief description of the AR and VR technologies, shows the possibilities of their use in various sectors and industries of the modern world economy. The paper provides an overview of the positive aspects and competitive advantages that AR and VR technologies can bring to companies engaged in the development and production of devices and instruments that allow using these technologies. This is a growth in sales of products and services, a reduction in operating costs, an increase in customer satisfaction, an improvement in the quality of product, services and service. The study also considers the limitations of using AR and VR technologies in educational environments. According to the authors, there are more industries and areas where AR and VR technologies can be applied.

The paper analyses the volume of investments in the field of VR / AR, gives the forecasts of possible improvements of VR and AR devices, leading to creating of wider opportunities for their utilization in industrial, financial and educational spheres. The article presents the most successful examples of the implementation of AR and VR technologies in 2012-2021 in foreign and Russian companies. For statistical confirmation of the obtained results the authors performed a correlation analysis of the forecast estimates of the development of AR and VR technologies in 2021–2023. The paper makes the forecast of sales of technologies and devices in some sectors of the economy by 2024. Based on the analysis, the study concludes that there is a significant relationship between the electronics market as a whole and the VR/AR market.

Keywords: innovation, innovation policy, augmented reality, virtual reality, mixed reality, increased efficiency, competitive advantage, forecast

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Introduction

Technologies are one of the most significant factors of economic development. It significantly increases the amount of value added per a person. The potential for the use of individual technologies can be very large-scale and give a significant economic effect. The specialization of individual countries on specific technologies provided them with significant profits at different historical periods of civilizational development. From the point of view of the authors and a significant number of experts, technologies (VR/AR) have such a promising potential.

At the International Mobile Congress held in Spain, one of the founders of "Facebook" M. Zuckerberg expressed the opinion that the virtual reality will soon become a new social platform and will change the world.[1] To develop this trend, "Facebook" acquired "Oculus" – a developer of VR devices. Virtual Reality (VR) is an artificially created 3 dimensional digital world that allows to place a human being into any time and space. With the help of different sensors and peripheral devices the virtual world is perceived almost as the real one.

"Google", "Samsung", "Microsoft", "HTC", "Sony", "Acer", "Epson", "Amazon" and other companies started selling VR devices. The "Samsung" company applied to register a patent for smart contact lenses which should be developed.[2] The auditing company "PwC" identified eight key technologies that will greatly affect the business in the nearest future, and on their list of technologies there were the technologies of virtual and augmented reality.[3]

The augmented reality (AR) helps to visualize a 3D image of any object in front of a person, choose its elements, rotate this object in space, change its scale and get comments. This technology supplements the human perception with virtual information which is interpreted as elements of real life information by a human.

An engineer can work with a 3D model of an engine or a transmission, a surgeon can work with Magnetic resonance imaging (MRI) of a patient, a developer of engineering systems can work with a project relating it to the environment and surrounding buildings, a teacher can demonstrate models of an atom or a corpuscule or of a DNA. The positive effects of AR on learning include improved performance, increased motivation and engagement, and fostered collaboration amonglearners [Radu, 2014].

VR is not only applied in many industries, but is also used by scholars for education applications as it enables students to have an immersive learning experience to enhance their learning effectiveness and motivation [Chang et al, 2020].

More and more educational centres around the world have started to introduce powerful new technology-based tools that help meet the needs of the diverse student population. Over the last several years, virtual reality (VR) has moved from being the purview of gaming to professional development. It plays an important role in teaching process, providing an interesting and engaging way of acquiring information [Kamińska D. et al, 2019].

Technologies of virtual and augmented reality can provide companies with a lot of competitive advantages. Developers of both the devices themselves and the software for them can get a significant segment of the information technologies market as they have the potential to improve the quality and cut the costs, which will be in demand even in a crisis.

Investment market analysis in VR/AR technologies

In recent years, investments in these technologies have steadily increased, which has allowed improving them and reducing their cost (Fig. 1).

According to the forecasts of IDC[4], the investments in VR/AR systems the market was supposed to reach 162 billion US dollars in 2020. Based on such forecasts, many professionals believe that AR technologies will greatly change and improve many production processes and practices within the next 10 years. According to the estimates of Digi-Capital consulting company[5], the market of AR devices is growing 4 times faster than the market of VR devices. According to the experts of the consulting company, the directions that will become the most popular by 2024 are shown in Figure 2.

The value of investments made by the market leaders of IT shows the importance of the role of these technologies. The best example of such investments is a young company called Magic Leap that managed to attract 1.3 billion US dollars of investments from companies like "Google", "Qualcomm", "Alibaba", "Legendary Entertainment" and "Lucasfilm". The company

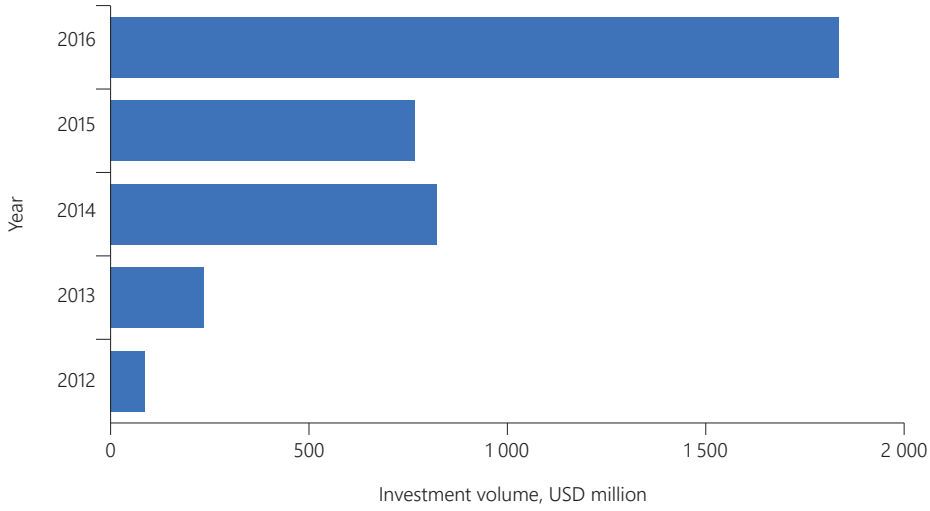
[1] Mark Zuckerberg: Facebook in virtual reality is the future. Available at: https://www.nbcnews.com/tech/tech-news/mark-zuckerberg-facebook-virtual-reality-future-n523721 (accessed 18.04.2021).

[2] Samsung applies for smart contact patent with embedded display and camera. Available at: https://www.theverge.com/2016/4/7/11383200/samsung-smart-contact-camera-patent-application (accessed 15.04.2021).

[3] PwC (2016), The essential eight technologies. Available at: https://www.pwc.ru/ru/publications/8technologies.html (accessed 18.04.2021). (Further – PwC Russia (2016)...).

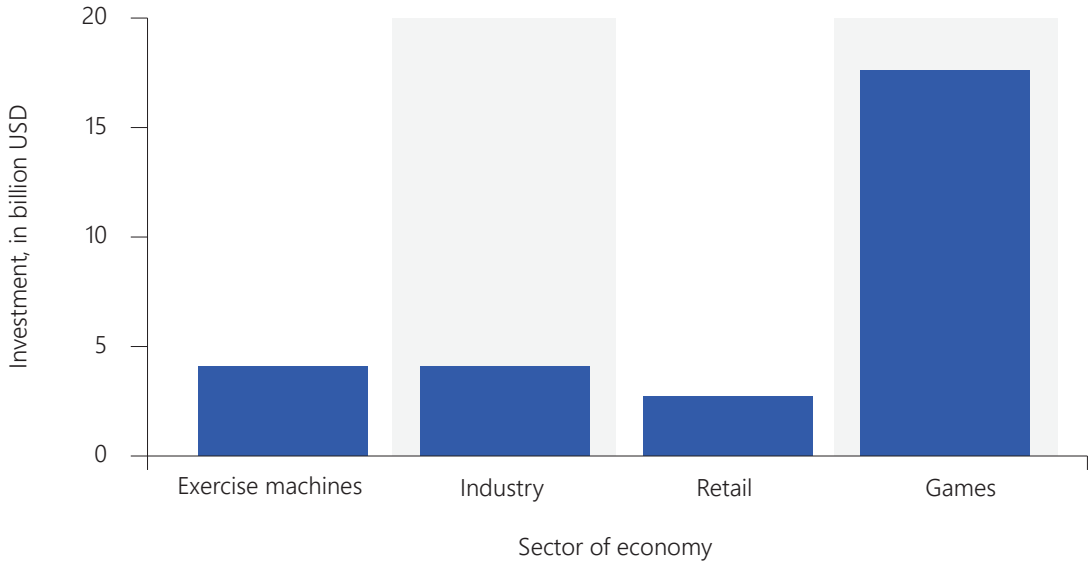
[4] The virtual and augmented reality market will reach $162 billion by 2020. Available at: https://www.businessinsider.com/virtual-and-augmented-reality-markets-will-reach-162-billion-by-2020-2016-8?utm_source=reddit.com (accessed 18.04.2021).

[5] Digi-Capital (2019), Augmented (AR), virtual reality (VR) investments ($B). Available at: https://www.digi-capital.com (accessed 15.04.2021). (Further – Digi-Capital (2019)...).



Source[6]

Fig. 1. Investments in VR/AR technologies in 2012–2016



Source[7]

Fig. 2. Investment in augmented and virtual reality AR/VR technology worldwide in 2024, by use case

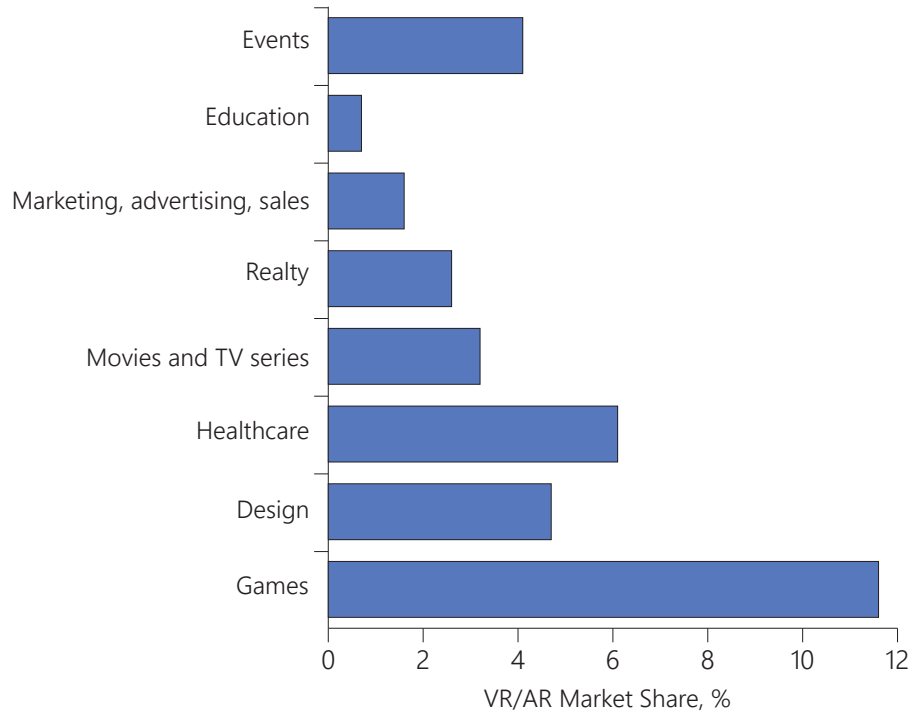
is developing the devices that can help to get a 360 degree view of an object a customer is going to buy.

The market is being supplied with devices that are now demanded by gamers only and have a lot of disadvantages. But these devices are being constantly updated and upgraded and this is likely to result in their improvement and wider use in the market. According to Goldman Sachs estimates[8], by 2016, a market with the following structure was formed (Fig. 3).

[6] CB Insights (2016), The 2016 AI recap: startups see record high in deals and funding. Available at: https://www.cbinsights.com/research/artificial-intelligence-startup-funding/ (accessed 18.04.2021).

[7] Alsop Th. (2020), "Investment in AR/VR technology worldwide in 2024, by use case", *Statista*, Nov. 17. Available at: https://www.statista.com/statistics/1098345/worldwide-ar-vr-investment-use-case (accessed 18.04.2021).

[8] Goldman Sachs (2016), "Virtual & augmented reality: the next big computing platform", *Goldman Sachs*, Jan. 13, 30 p. Available at: https://www.goldmansachs.com/insights/pages/virtual-and-augmented-reality-report.html (accessed 13.04.2021). (Further – Goldman Sachs (2016)...).



Source[9]

Fig. 3. VR/AR technologies market share in different industries estimated by Goldman Sachs

There are not so many instruments of VR/AR applicable in business spheres. However, Russian companies that follow modern technological trends have already started using them. Among the biggest companies that have started doing so are "Sberbank", "Magnit" and "Svyaznoi".

"Sberbank" invested 3 million roubles into the game "Pokemon Go" when it was at its peak and quickly developed an application "Sberbank Go" to attract target audiences and to promote new products. This resulted in receiving 6 500 requests for Sberbank insurance products from people in their mid-twenties.

The free on-line game "Pokemon Go" has brought "Nintendo", its developer, 950 million US dollars. The game was downloaded by more than 500 million people.

One of the major analytical agencies Digi-Capital forecasts[10] the growth of the VR/AR market by 30 times up to 150 billion US dollars by the year of 2020. According to their estimates, the largest segment of this market will be the production of VR/AR devices, then the segments of sales via VR/AR technologies, AR data, AR voice technologies, AR films.

IDC estimates[11] a five-year compound annual growth rate (CAGR) in AR/VR spending of 76.9 % worldwide in 2019–2024 to reach 136.9 billion US dollars by 2024.

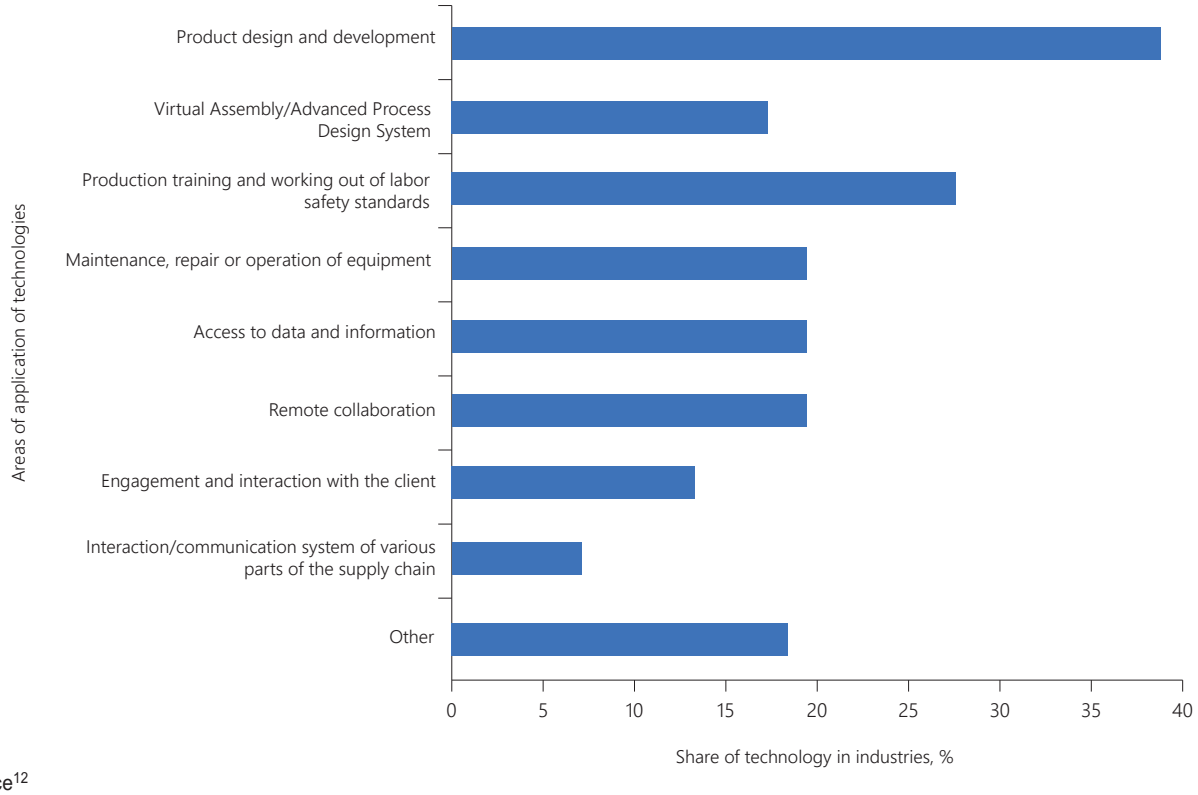
One of the first companies that started using AR technologies successfully is IKEA. It developed an application that allows users to choose the furniture and to see what it will look like when they position it in their rooms from different points of view. The user takes a photo of the room, sets up its measurements and installs a 3D piece of furniture from the IKEA catalogue. A similar application has also been developed by "Leroy Merlin". This application is likely to increase customer satisfaction and reduce the number of furniture items customers return to the shop because those items didn't fit the premises they were bought for.

The biggest retailer in the world Walmart implemented the technology which allows customers to scan bar codes of goods with the application "Scan and GO" and pay for them with their mobile phones. The "Tesco" company, the biggest retailer in the UK, stopped using cash registers and trolleys in their shops. Holders of Tesco club cards activate special bar code scanners when entering Tesco shops and use the "scan as you shop" application. After the customer scans the bar codes and

[9] Goldman Sachs (2016)...

[10] Digi-Capital (2019)...

[11] IDC (2020), Pandemic tempers growth in AR/VR spending, but the long-term outlook is positive, says IDC. Available at: https://www.idc.com/getdoc.jsp?containerId=prEUR146720420 (accessed 18.04.2021).



Source[12]

Fig. 4. Areas of implementation of virtual reality and augmented reality technologies

puts the goods into plastic bags, they pay for their purchases at a self-service pay point. The "Lenta" company in Saint Petersburg has started testing a similar technology. Obviously, the technology allows retailers to decrease the number of staff thus reducing the operating costs, and bring down the amount of time people have to spend in shops while choosing the purchases and paying for them. This can lead to the increase in traffic in shops and, consequently, to the growth in sales.

Amazon and Alibaba opened several staffless stores. Automation technologies and face recognition technologies improving the stores' efficiency are highly likely to lead to a significant increase in the number of such stores.

It is obvious, that retailers can raise their profits not only by selling bigger volumes, but also by cutting their costs. Many retail shops in Russia are using self-service pay points. Next, they are very likely to start using the solutions developed and tested by retailers abroad.

Technological innovations are widely used in production. To increase its efficiency, the Ford company has launched a pilot project on the use of AR glasses in their plant in Naberezhnye Chelny. The management of the plant believe that these glasses will help to improve the logistics, automate the procurement processes and decrease the number of employee mistakes. According to PwC estimates[13], virtual and augmented reality technologies were most often used in the following sectors of the economy (Fig. 4).

The Russian company "VR CORP" engaged in developing augmented reality solutions made "The virtual engineer" application that can make the repairs of complicated devices easier. To tackle the problem, an engineer or a device user has to focus the camera of a smart phone on a defective element and the application provides information about the function of this element in the devices and its relation to other elements. The application will be of great use to unskilled people due to its interactive information service that shows the structure of a given device and its elements.

The Fiat company also implemented the augmented reality devices into the assembly process. Every employee gets information about their consecutive steps, projected on their augmented reality glasses.

In 2014 the Boeing company implemented AR devices – its employees started using Google Glasses to install the plane components connected to each other with

[12] PwC Russia (2016)...

[13] PwC Russia (2016)...

a system of wires[14]. The AR glasses help to reduce the number of mistakes and to fasten the production of wiring harnesses. Now the process of laying the harness starts with a voice command given to the application. After identifying the order number, the employee sees the virtual road map showing how to produce and lay the wiring harness for this order in the AR glasses. According to the report, the implementation of Google Glasses reduced the production time by 25 % and the number of mistakes became twice as low.

AR devices are installed into jet fighter's pilots' helmets or glasses to help the pilots not to get distracted by different indicators on the control panel, to see threats and make decisions faster.

AR technologies are likely to become popular and widely-spread in education. Research shows that since in contemporary students' lives technology is everywhere, students expect technology to be used in teaching as well, and traditional teaching methods can sometimes fail as they are not considered motivating enough to make students learn [Peixoto et al, 2019].

We believe that with the help of AR/VR technologies great visual aids can be created for such subjects as Geometry, Astronomy, Physics, Chemistry, Biology which is going to help learners to better understand them. There are studies [Martin-Gutierrez et al, 2017] that show that incorporating AR/VR technologies in teaching increases students' motivation and engagement in the learning process as using 3D models as visual aids instead of relying on conventional learning materials enhances the students' learning experience, allows to create a constructivist approach to learning and creates a feeling of immersion which permits to experiment environments with realistic objects that could not be accessible otherwise.

It is necessary to mention that AR/VR technologies can be employed in further and professional education to conduct training of employees in professions that require great precision like surgery, in the sphere of workplace safety or maintenance in high risk facilities like nuclear power plants or firefighting. AR/VR technologies are widely used to train apprentices, to help them develop various professional skills. In aviation, for example, simulation devices have been used for a long time to conduct pilot training.

A lot has been said about the possibilities of incorporating AR/VR technologies in foreign language teaching. One of the most important factors that contributes to the successful learning of a foreign language is the opportunity of being exposed to the language by talking or listening to it. The English Institute of Vila Real, a language school in Portugal, carried out an experiment in using VR technologies for developing listening and speaking skills in their students. They used VR devices and developed scenarios for the listening sessions held during classes. Instead of listening to traditional audio files or watching videos and then simulating conversations with classmates, students observed the situations in the Virtual Worlds and then communicated with virtual characters. The study shows that both the students and the teachers at that school evaluated their virtual experience as positive and acknowledged that using VR technologies facilitates and helps with the language teaching methods [Peixoto et al, 2019]. The researchers also point out that simulation games traditionally used in foreign language teaching become more realistic with the help of VR technologies. Simulated environments resemble the culture, the society and the country of the language being learnt and thus create the correct language context.

Despite considering AR/VR technologies beneficial for the education sphere, researchers see a lot of limitations to their large scope utilization [Martin-Gutierrez et al, 2017]. One of the most important challenges, in our opinion, is likely to be the design and development of content – pedagogical scenarios for simulation activities and learning environments allowing to obtain full learning benefits.

AR applications in education have a significant contribution to the area of knowledge, as they contribute to facilitating the teaching of didactic content that would otherwise be more difficult to transmit. Therefore, the inclusion of this technology in educational practices favours obtaining better quality standards [Abad-Segura, 2020].

It should be noted that AR technologies can improve the performance and efficiency in many other industries and spheres. Real estate agents and car sales managers will be able to show 3D models of all available houses, apartments or cars. AR/VR technologies can be enjoyed in the sphere of tourism – both by travel agents advertising holiday destinations and tourists choosing travel attractions or getting directions in an unknown location.

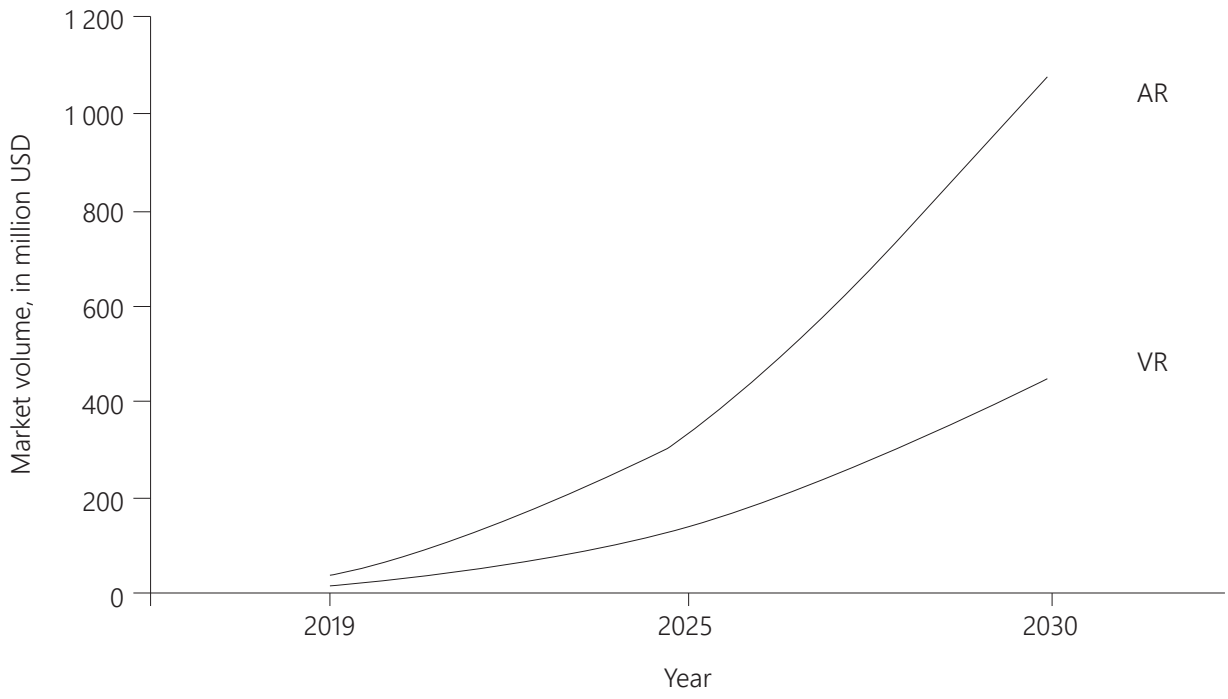
Results

It is estimated by Goldman Sachs[15] that the market of VR/AR technologies can reach the level of 80 billion US dollars (or even a more optimistic figure of 182 billion US dollars) by the year of 2025.

It is also estimated that the prices for VR/AR devices may fall by 20–30 %, which will help to increase the number of its users even further [Murali, 2021].

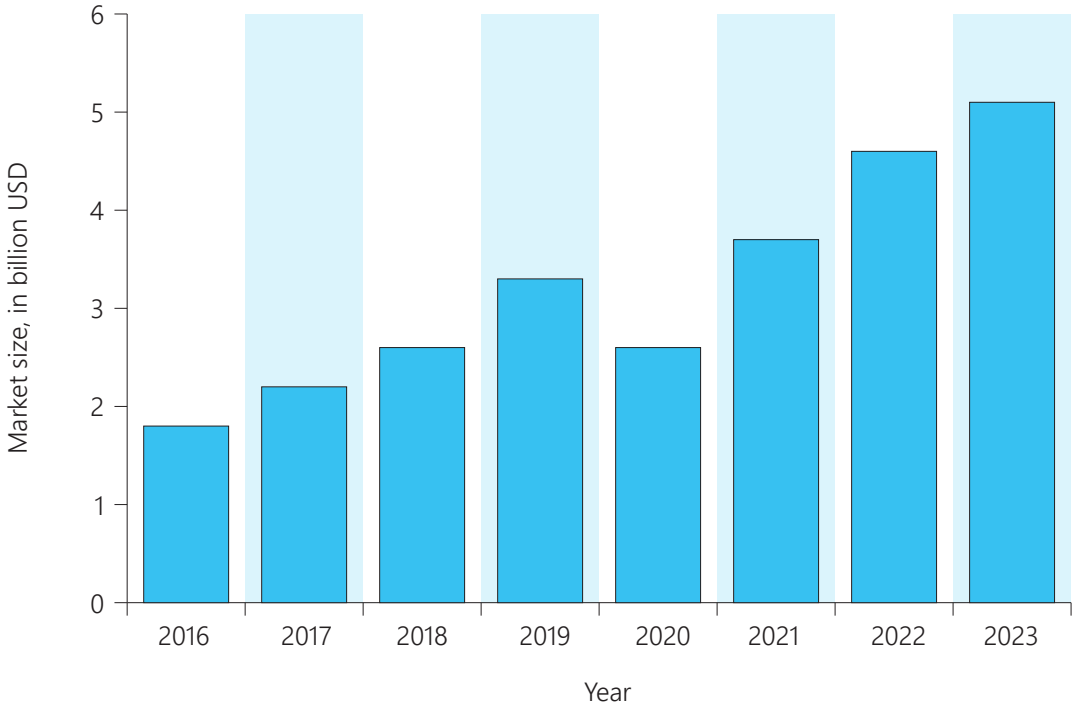
[14] Google Glass takes flight at Boeing. Available at: https://www.cio.com/article/3095132/wearable-technology/google-glass-takes-flight-at-boeing.html?page=2 (accessed 18.04.2021).

[15] Goldman Sachs (2016)...



Source[16]

Fig. 5. Comparative VR and AR economic contributions



Source[17]

Fig. 6. Consumer virtual reality software and hardware market size worldwide from 2016 to 2023

The enterprises, economy and society on the whole are willing to implement virtual and augmented reality.

VR and AR could lead to increase by 1.5 trillion billion US dollars in the global economy by 2030[18], whereas in 2019 its GDP was estimated 46.4 billion US dollars. According to PwC's forecast[19], AR will provide much higher GDP growth than VR by 2030 (Fig. 5).

According to a PwC study[20], the development and implementation of such technologies will lead to creating to 23.3 million new jobs worldwide by 2030 (in 2020 this figure is estimated only 824.6 thousand) and economic growth. Economic growth by areas:

- up to 359.4 billion in goods and services development;
- up to 350.9 billion in healthcare;
- up to 294.2 billion in education;
- up to 275 billion in process improvement;
- up to 204 billion in retail.

The volume of the consumer virtual reality software and hardware market worldwide from 2016 to 2023 is shown in Figure 6.

To establish and evaluate the relationship between the global market volume forecasts for augmented (AR), virtual reality (VR), and mixed reality (MR) in 2021–2023 and consumer virtual reality software and hard-ware market size worldwide, a Spearman correlation analysis (Spearman rank correlation coefficient) was performed [Spearman, 1904; Daniel, 1990]. The forecast values of the development of both markets were ranked by the *Y* and the *X*. These ranks are then used instead of the actual values of *Y* and *X* in the formula for the sample Pearson correlation coefficient and two matrices were compiled (Tables 1, 2).

Table 1

Actual values of Y and X

X	*Y*	Rank *X*, d_x	Rank *Y*, d_y
3.7	30.7	1	1
4.6	58.7	2	2
5.1	124.4	3	3

Compiled by the author on the materials of the study

Table 2

Matrix of ranks

Rank *X*, d_x	Rank *Y*, d_y	$(d_x - d_y)^2$
1	1	0
2	2	0
3	3	0
6	6	0

Compiled by the author on the materials of the study

After that, it was checked, whether the matrix had been made correctly based on the calculation of the checksum using the following formula.

$$\sum_{i,j} x = \left(1+n\right)n/2 = \left(1+3\right)3/2 = 6. \quad (1)$$

As a result of the check, the sum of the columns of the matrix is equal to each other and the checksum, which indicates the correctness of the matrix.

The Spearman rank correlation coefficient was calculated using the above formula.

$$P = 1 - 6\sum d^2 / \left(n^2 - n\right) = 1 - 6\left(0/3^3 - 3\right) = 1. \quad (2)$$

The results of the correlation analysis revealed the strong and direct relationship between the forecast estimates of the two markets, denoted as the *X* and the *Y* respectively. In order to test the null hypothesis that the general Spearman rank correlation coefficient is equal to zero at the competing hypothesis Hi, we need to calculate the critical point.

$$T_{kp} = t(\alpha, k)\sqrt{\left(1 - p^2\right)/\left(n - 2\right)}, \quad (3)$$

where n – the sample size, p – the sample Spearman rank correlation coefficient, $t(\alpha, k)$ is the critical point of the two-sided critical area, which is found from the table of critical points of the t – Student's distribution, by the level of significance α and the number of degrees of freedom $k = n-2$.

If $|p| < T_{kp}$ – there is no reason to reject the null hypothesis. The rank correlation between the qualitative characteristics is insignificant.

If $|p| > T_{kp}$ – the null hypothesis is rejected. There is a significant rank correlation between the values. According to the t – Student's table, $t(\alpha/2, k)$ was found $(0.05/2; 1) = 25.452$.

$$T_{kp} = 25,452\sqrt{\left(1 - 1^2\right)/\left(3 - 2\right)} = 0. \quad (5)$$

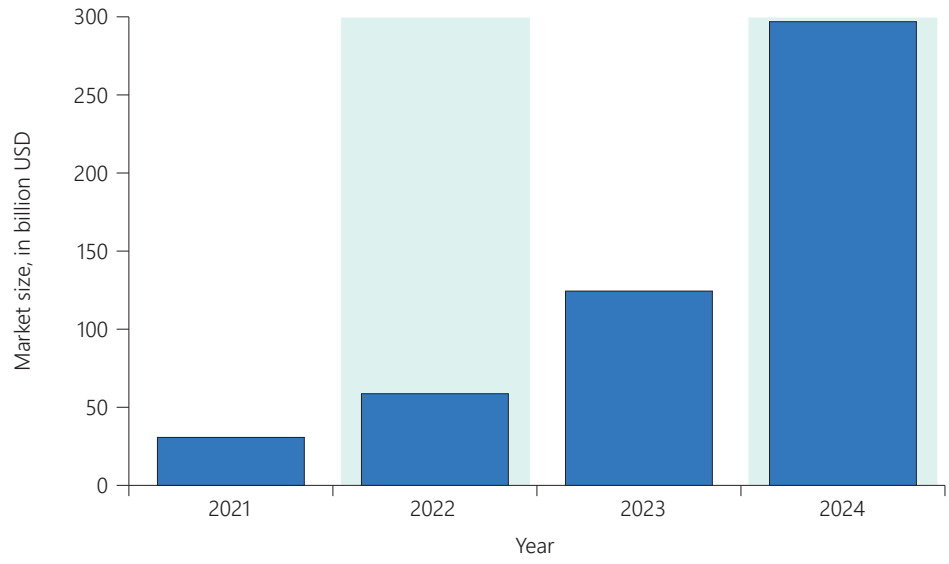
[16] PwC (2019), Seeing is believing. Available at: https://www.pwc.com/gx/en/technology/publications/assets/how-virtual-reality-and-augmented-reality.pdf (accessed 15.04.2021).

[17] Alsop Th. (2021), "Global consumer virtual reality (VR) market size 2016-2023", Statista, Mar 16. Available at: https://www.statista.com/statistics/528779/virtual-reality-market-size-worldwide/ (accessed 15.04.2021).

[18] Why we believe VR/AR will boost global GDP by $1.5 trillion. Available at: https://www.pwc.com/seeingisbelieving (accessed 15.04.2021).

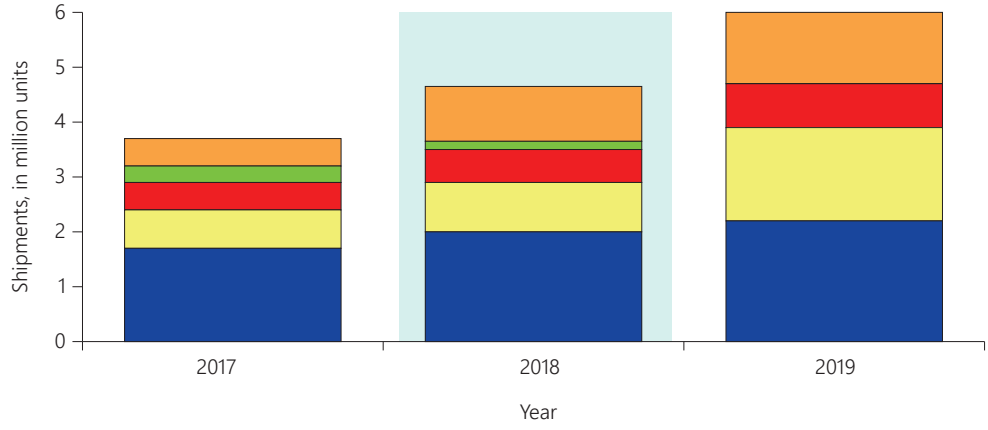
[19] PwC (2019)...

[20] Why we believe VR/AR will boost global GDP by $1.5 trillion Available at: https://www.pwc.com/seeingisbelieving (accessed 15.04.2021).



Sources[21,22]

Fig. 7. Augmented (AR), virtual reality (VR), and mixed reality (MR) market size worldwide from 2021 to 2024



Source[23]

Fig. 8. Unit shipments of virtual reality (VR) devices worldwide from 2017 to 2019, by vendor

Since $T_{kp} < p$, we reject the hypothesis that Spearman's rank correlation coefficient is equal to 0. In other words, the rank correlation coefficient is statistically significant and the rank correlation between the forecast estimates of the further development of the two analyzed markets is significant, which can be considered as a basis to confirm that the forecast estimates are made correctly (Fig. 7, 8).

Conclusion

As early as 2020, consumers were expected to spend around 6.36 billion US dollars on augmented and virtual reality (AR/VR) technology, compared to nearly 2 billion US dollars spent on the services sector. Total AR/VR spending worldwide was estimated to increase to 12 billion US dollars, reaching considerable growth up to 72.8 billion US dollars by 2024.

The global augmented reality (AR), virtual reality (VR), and mixed reality (MR) market is estimated to rise

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to 30.7 billion US dollars in 2021, reaching a peak of 300 billion US dollars by 2024.

The virtual reality (VR) market was valued at 17.25 billion US dollars in 2020 and it is expected to reach 184.66 billion US dollars by 2026, at a CAGR of 48.7 % over the forecast period 2021–2026.

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