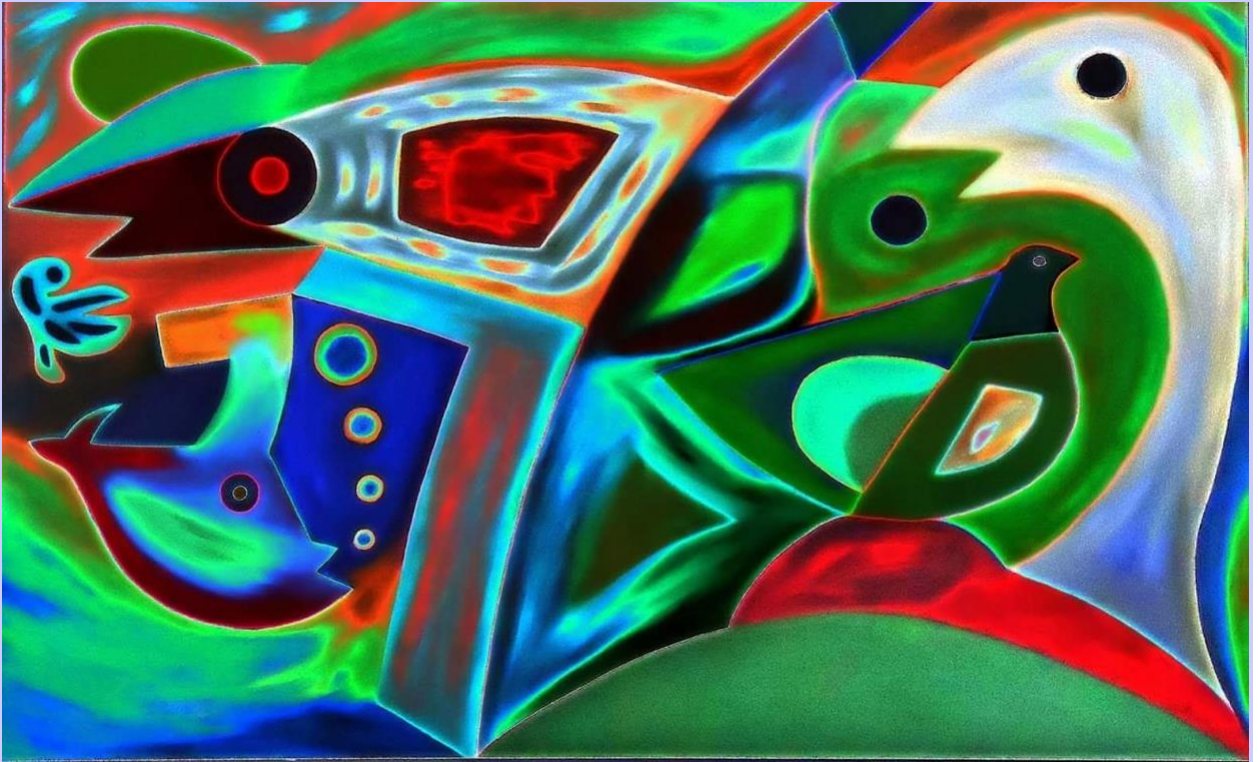


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Photogrammetry method: A key to creating 3D models of Cultural Heritage

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Abstract. An increasing number of memory institutions are now exploring the intricacies of three-dimensional digitization for their collections. While various methods for creating three-dimensional models are available, not all of them are necessarily accessible or suitable for these institutions. Factors such as financial constraints and the technical proficiency of their staff can pose limitations. Recent research has shed light on photogrammetry as a viable digitization method for memory institutions, particularly museums. This study seeks to validate this proposition through the examination of multiple collection items. The results will indicate whether photogrammetry can be consistently applied within memory institutions, offering valuable insights for museums and similar organizations.

Keywords: photogrammetry, digital humanities, digital heritage, digitization, 3D scanning, LiDar, Trnio, Artec Leo, conservation of monuments, museum.

1. Introduction

We live in the era of the fourth industrial revolution characterized not just by the automation of production and the inevitable benefit of changes in the labour market, but also by digitization. Besides the digitization of signals, and television and radio broadcasts, further steps towards the digitization of books, documents, sound, and video recordings have been taken. The same goes for museums, culture, and memory institutions where 3D models are created. Such 3D models can serve not only for the presentation of the data itself to the public, but also as a backup or potential protection against the ravages of time. Last but not least, in specific cases of 3D modelling, 3D models can also be used as an option to display long forgotten and materially non-existent monuments.

The objective of the article is to point out the selected ways and methods of 3D digitization, which would be applicable to the widest possible selection of types of material monuments available to memory institutions, most often museums.

Although the primary focus of this article is on the aforementioned objective, we will also endeavor to address several research questions, such as: *what the advantages and disadvantages of various methods of digital capture for 3D modeling of heritage sites are; what influence different sizes and material characteristics of digitized objects have on the digitization process; how 3D digitization can contribute to the preservation and safeguarding of cultural heritage materials.*

To achieve our objective and address the research questions, we will use a combination of descriptive and analytical approaches to evaluate and compare various methods of 3D digitization of material heritage. We will focus on the description and analysis of selected techniques for 3D digitization, such as 3D scanning, photogrammetry, and to a lesser extent, the RTI method, among others. Through this approach, we will aim to provide readers with an overview of different 3D digitization

methods and their suitability for digitizing material heritage found, for instance, in museums and other memory institutions.

In the article, we will first attempt to outline the *Theoretical Aspects* that can help us better understand the *Digitization possibilities in Relation to Cultural Heritage* and provide context for our research. Subsequently, we will address the *Current possibilities of digitization methods usable in museums*, which are commonly encountered in memory institutions of this nature. We will focus on the issues related to the *Usability of 3D scanners for digitizing material monuments* and delve into the chapter titled *The method of photogrammetry and its use in the digitization of material monuments*, which highlights the photogrammetry method, frequently employed due to its versatility. Furthermore, we will describe *Other possibilities of digitization techniques applicable in memory institutions* and introduce our project, which will be explored in the chapter titled *Selected digitization methods applied to a sample of material monuments*.

The article was created as part of Specific Research from 2022 entitled *Analysis of digitization methods for the creation of virtual exhibitions on the example of museum collection objects*, Faculty of Arts, University of Hradec Králové. The objects for digitalization were borrowed from *the Museum of Eastern Bohemia in Hradec Králové, the Náchod Museum and the Broumov region in the Czech Republic*.

2. Theoretical Aspects

In this section of our article, we intend to explore the theoretical framework that will serve as the intellectual foundation for our research in the field of 3D digitization of tangible historical monuments. This theoretical framework, as we hope, will become an essential component enhancing our ability to comprehend the contextual environment in which our research is situated. Our specific focus, not only for this article but also in the realm of our scientific research, is the digitization of tangible cultural heritage, and the quest for various avenues, methods, and tools to acquire the finest 3D models that can furnish researchers with rich and detailed information about the digitized subject.

Within this domain, we will strive to gain an understanding of various selected methods of 3D digitization that are pertinent to the preservation and digitization of tangible three-dimensional cultural heritage. Through this journey, our aim is to provide readers with the utmost appreciation of the significance of this matter.

Currently, 3D digitization and the creation of 3D models play a significant role in preserving and protecting cultural heritage. [1,2]

3D digitization allows for the capture of tangible objects with relatively high detail, including their texture, structure, and shape. This enables the preservation of information about historical monuments that closely resembles those found in the real world. The 3D models themselves can also serve as potential digital backups. If physical objects were to be destroyed or degraded, well-executed 3D replicas could still be available for future generations. 3D models allow researchers and scholars, as well as students, to study cultural heritage without the need for physical presence. This can facilitate research and analysis and ensure protection against potential degradation of the heritage. Furthermore, digitization of tangible cultural heritage enables the dissemination of information about these monuments among the cultural public, some of which may be unknown or less accessible. Lastly, digital copies can be used for the identification or restoration of stolen or damaged artifacts. In case of damage, 3D models can also assist restorers in restoring the original appearance of the heritage site. [3,4,5,6,7]

3. Current possibilities of digitization methods usable in museums

Material monuments are traditionally documented using well-known (perhaps we could say traditional analog) methods. However, advanced 2D and 3D digitization methods are emerging, utilizing various and expensive technologies and processes that may gradually find their way into some memory institutions. Digital museums supporting public understanding of cultural heritage are also in development.[8] New academic programs and fields of study, such as digital humanities and digital heritage, are being established. These programs gradually educate professionals at the intersection of historians, archivists, and digitization specialists who are sufficiently proficient in modern technologies to create sophisticated 3D models and understand the importance of fully preserving the original form of such objects.

Questions related to digitization primarily concern the objects themselves, the chosen digitization methods, and suitable tools. A 3D digitization technician should have at least basic knowledge of 3D modeling and gain insight into the digitized object itself.[9] As indicated earlier, it is essential to be familiar not only with modern technologies and 3D modeling/digitization but also have a basic understanding of subjects such as history and even auxiliary historical disciplines. Furthermore, issues related to data backup and accessibility need to be addressed, along with, finally, copyright law, especially concerning potential 3D printing.[10] However, this matter may significantly differ depending on the country where the institution is located. It is typically governed by the laws of the given country, or by the regulations and recommendations of the institution itself, especially in cases concerning 3D printing of historical object models, data backup, and potential public accessibility.

3.1. Usability of 3D scanners for digitizing material monuments

There are many types of scanners designed for the digitization of tangible objects. They vary depending on the scanning technology employed (such as optical, radar, sonar, or microwave scanners [11]), the size of the scanned device (handheld, stationary, mobile, among others, typically chosen based on whether it is feasible to bring the object to the 3D scanner or if it's necessary to bring the 3D scanner to the object), resolution, scanning speed, accuracy, and the size of the digitized original (for instance, contact or non-contact scanners [12]). Scanners can also be categorized by whether they employ destructive digitization methods (which can be problematic for historically valuable and fragile objects where potential damage during digitization is a concern), are contact or non-contact, and by price [13], which can sometimes play a significant role in the realm of memory institutions. The scanners considered for digitization in this project will be described in detail further on (Table number 1).

Indirectly related to 3D scanners but connected to other digitization methods is also photogrammetry and, to a certain extent, the Reflectance Transformation Imaging (RTI) method (more will be written on both topics later). These digitization methods primarily use a digital camera, ideally in conjunction with high-quality lighting and specialized software, enabling the creation of a 3D model or a type of 2.5D model, or "pseudo-3D" (in the case of RTI).

In this context, we can also mention LiDAR (*Light Detection And Ranging*) technology [14], which employs laser beams to measure the distances to individual objects in the vicinity. We frequently encounter LiDAR technology in applications like automobiles or drones. In the realm of digital photography, this technology can be utilized to determine which object is in the foreground and which is in the background.

LiDAR can also be employed for the digitization of three-dimensional objects, provided that specific software is installed on the device (often a smartphone), such as Trnio or its enhanced version, Trnio+ [15]. For example, Apple utilizes LiDAR technology in its newer iPhones and iPads PRO and PRO Max [16].

Table 1. Basic description of scanners suitable for digitization in a given project and their characteristics. These are optical, non-contact 3D scanners

Name of the scanner	Scanning technology	Basic characteristics	The size of the digitized object
Artec Spider [17]	Structured blue light	Digitization through structured blue light. Capture texture.	5 mm -? (In general, objects larger than 200-250 mm more difficult to digitize can be digitized in parts).
Artec Leo [17]	Structured light of the VCSEL type (Vertical Cavities Surface Emitting Laser is a type of laser diode. Here the light is emitted perpendicular to the level of the semiconductor chip [18])	Processing 3D data in real time. Mobile, for digitizing even larger objects in the field semiconductor chip [18])	At least 214 x 148 mm

If the data acquisition process for 3D creation is digitized without problems, the resulting 3D model does not usually need too many modifications. However, there are exceptions. Objects that are shiny or transparent, perforated, too dark, are difficult (or even impossible) to scan using traditional methods. Also, materials such as sandstone, clay, stone (covered with moss) can be problematic to scan.

In certain cases, it is possible to use matting spray or crushed chalk to mattify the object, alternatively, to combine multiple digitization methods, for example, 3D scanning and photogrammetry.

3.2. The method of photogrammetry and its use in the digitization of material monuments

The basis of the entire process is photographs (around 50-500 images per object). They are taken with sufficient coverage of adjacent images (approx. 60%-80% overlap). Thanks to this, it is possible to find identical points through a specific program and calculate their spatial coordinates. [18,19,20]

Photogrammetry has many advantages (data collection speed, close-up shots, digitization of objects more demanding to scan, no necessity to have close contact with the object, affordability [21,22]). On the other hand, it also has several disadvantages (different quality of output data, which can significantly affect the resulting 3D model and its entire processing, error rate that depends on different types of surface, as well as inaccuracy in lines and edges [23,24,25]).

Photogrammetry can be encountered in the creation of 3D models of cities, in historical fields or in projects that try to digitize objects of cultural heritage (for example, The 3D Czech Republic Project or Projection Studio [25,26]).

3.3. Other possibilities of digitization techniques applicable in memory institutions

A certain hybrid between 2D and 3D digitization is the Reflectance Transformation Imaging (RTI). Digital reflectance information is obtained from the 3D aspect of the object and the digitized image can be modified in such a way as to offer the user a 3D effect (even if it is not a classical 3D model [27,28,29,30]). The RTI method is very useful wherever 3D scanning fails or cannot be applied and 2D

scanning is too “flat” [30]. This method is applied less often at our digitization workplace, so we do not include it in this research.

It is not only in the field of geodesy and mapping that we can encounter digitization using drones [31], thanks to which both photogrammetry and, in some cases, LiDAR can be used. These devices are suitable for digitization of specific monuments, such as historical buildings [25,26] or statues, crosses, or divine torment [31,32,33]. In most cases, these are monuments that are more difficult to access from the ground or monuments of a larger area.



Fig. 1. On the left, a drone taking pictures of the Virgin Mary statue in Hejtmánkovice. On the right, the finished 3D model of the sculpture presented on the Sketchfab platform. You can view the 3D model of the statue of the Virgin Mary on Sketchfab at the following shortened link: <https://skfb.ly/oqxDr>

The advantages of using photogrammetry with drones is accessibility in hard-to-reach places. On the contrary, one of the disadvantages is the accuracy of the obtained images, which is directly dependent on the quality of the camera (in this case, the camera in the drone). We also need to take into account the weather (rain or stronger wind can cause problems for the drone pilot), darkness or dust.

Another method is the use of a smartphone or a tablet for 3D scanning. In this regard, it is a device with LiDAR technology, for example, the iPhone PRO 13 and iPad PRO 2020 devices that were available at the time of writing the article. The program we tested is called Trnio (there is also a new version of Trnio+). In our research, we used the basic variant of Trnio to digitize the relief of the Samaritan Woman under Table Mountain Ostaš. We digitized this monument using three methods, Artec Leo, photogrammetry and iPad PRO 2020. In Fig. 2, we show two base photos to compare two methods. The model obtained from Artec Leo 3D scanner was not suitable for presentation, the scanner could not correctly capture the areas covered with moss (the resulting model was leaky).



Fig. 2. On the left, the Samaritan woman digitized through the iPad and the Trnio program. On the right, a 3D model obtained using the photogrammetry method. The differences are hardly noticeable at first glance. However, the Samaritan woman digitized through photogrammetry method has a better resolution. The 3D model of the Samaritan Woman, created through photogrammetry and also with the assistance of the Trnio software, can also be viewed on our institution's Sketchfab page, or alternatively, by following this shortened link of photogrammetry: <https://skfb.ly/oq7OR> and Trnio: <https://skfb.ly/oq7QQ>.

In terms of digitizing objects using Trnio, it is essential that the objects are ideally larger than 10 cm, as depicted in Fig. 3. Our experience with digitizing smaller objects has not yielded favorable results. For instance, when it comes to digitizing coins, employing images from a digital microscope can be a viable alternative. This approach is reminiscent of other photogrammetric techniques and offers a practical solution for capturing intricate details on smaller objects.



Fig. 3. These are antique coins digitized by the iPhone 13 PRO using the basic version of the Trnio program. The coin on the left has a relatively nice legible structure, but it is not sharp around the edges. In the middle of the coin embedded in the shaft- a complete failure, the smartphone did not pick up anything. The two coins were digitized through an iPhone with a LiDAR sensor. Photogrammetry through the Trnio program was used on the last coin. The coin is too dark, it should be illuminated better.

4. Selected digitization methods applied to a sample of material monuments

The chosen methods, which include, among others, 3D scanning and photogrammetry, were tested on a selected sample of material monuments. Only the Artec Leo was used for better handling in the field (there is no need to deal with electrical connections and to use a laptop with a scanning program). Photos for the photogrammetry method were taken with an iPhone 13 PRO with automatic setting. The software used was Agisoft Metashape Professional Edition Educational License, Blender 3D (version 3.3.1) and Artec Studio 15.

Table 2 summarizes the basic knowledge of digitized objects. In the text, we focus on the description of the specifics in the digitization of specific museum objects. We divide objects into categories according to their size. The photographs of objects with the greatest value, or the images of their 3D models, will be presented later in

the text with a specific description of the digitization method. Selected models can be viewed in the online database Sketchfab KPVHA FF UHK [34].

A total of 20 objects were selected to verify digitization methods. These were objects of various types, for example, aids for teaching biology, coins, order, fans, umbrellas, plaster casts, Easter eggs, period clothes, puppets, statues and the like. The selection of these objects was based on a single criterion - to choose diverse types of materials and objects found in museum collections.

Table 2. Summary of digitization categorization according to the method used. We created the size categories artificially - according to the collection items that were available

Digitalization method	Categorization of objects	Approximate digitalization time	Approximate time of creating a 3D model	Further adjustments required	User friendliness	Note
Artec Leo scanner and use of the Artec Studio Program [22]	Small (object up to 15cm in size)	Cannot be used	Cannot be used	Cannot be used	Cannot be used	This kind of scanner is not able to digitize such small objects
	Medium (objects 20-50cm in size)	10-15 minutes	Within 60 minutes if no further adjustments are sides necessary	Yes, most often the connection of two sides	Intuitive. In case of necessary adjustments, additional necessary. At least the basic of 3D modelling	
	Large (over 50cm)	Between 10 and 100 of minutes depending on the size and complexity of the object	Between 10 and 100 minutes - see above	Yes, most often combination of two sides - see above	Intuitive - see above	
Photogrammetry using the iPhone 13 PRO and the Agisoft program Metashape professional edition educational license version from 2020	Small objects up to 10 cm	Tens of minutes depending on the complexity of the object and quality of photos	Between tens of minutes and several hours, depending on the need to join sides, glue holes, model or retouch the object	Yes, most often a connection of two sides	Basic knowledge of the given software	
	Medium objects 20-50cm in size	Tens of minutes - see above	Between tens of minutes and several hours- see above	Yes - see above	See above	
	Large objects over 50cm	Tens of minutes - see above	Between tens of minutes and several hours- see above	Yes - see above	See above	

During the digitization of objects, we had to contend with typical challenges such as ensuring adequate lighting of the object, providing sufficient space around the object (it is necessary to circumnavigate the object), and ensuring the best possible stability for objects that lack a solid base (e.g., textiles). This last issue, especially in the case of textiles, can be particularly problematic. While clothing can be placed on a stand, some parts may still pose difficulties for digitization.

Concerning the digitization of objects falling into the Small category, the primary challenge is the size of these objects, as well as the material properties and relief of the object. The Artec Leo scanner cannot accurately capture coins and any items smaller than 20 cm. For this reason, we excluded it from the comparison. In this case, the issue was not always just the size but also factors like the worn (less visible) relief on coins. Artec offers solutions for digitizing smaller objects, such as coins (Artec Micro), but unfortunately, we did not have it available.

Hence, the photogrammetry method appears to be more suitable, although it cannot be used in all cases (specific objects, such as glass and glossy materials, pose difficulties in capturing high-quality photographs and creating 3D models through photogrammetry, and so on). In a similar manner, we digitized, for instance, typesetters or orders (see Fig. 5 and 6).



Fig. 4. Although the coin (left) looks like a photo, it is a 3D model of one of the sides of the denarius with the background not yet cleaned. The coin was about 1.5 cm in diameter. Thus, it became a challenge for our digitization workplace. Although both sides turned out passable, their most precise joining required nearly an hour of work. The same is the case with the seal in the middle, even if it is a larger object. Unfortunately, the „foot“(on the right) on which the sealer is mounted is a frequent problem in this case. Due to the glossy surface and the thinness of the digitized part, it sometimes happens that the model „breaks „despite high quality photos.

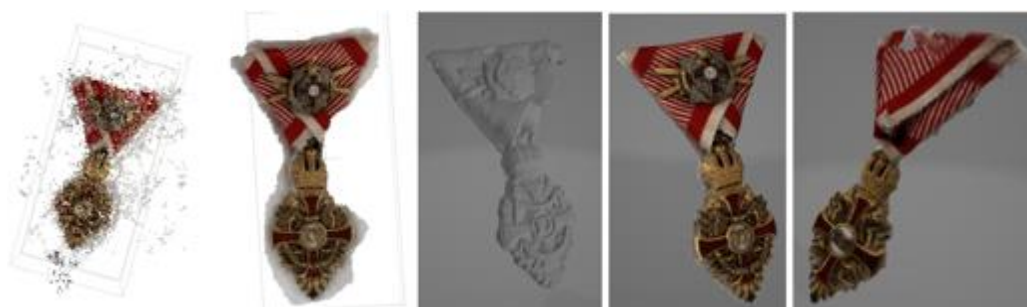


Fig. 5. Order. From the left, an example of creating a cloud of points, which is one of the first steps in the Agisoft program Metashape for the subsequent creation of a 3D model from photographs. In the second photo from the left, one part of the 3D model can be seen retouching is required. In the middle of the grey image, a data completeness check-it can be seen that the model is not accurate and contains many errors that will need to be corrected. The last two photos show two sides of the model. Closer to the left is a fairly decent 3D model. Its other side (the last photo on the right) shows unglued holes in the fabric that will need to be repaired. It will also be necessary to combine both halves of the order together and perform a final data cleaning.

As an example of one of the frequent problems during digitization, we present Fig. 7, where the cross-sectional model of the human head turned out very well when scanned, but the black pedestal on which it was placed could not be captured well. It had to be remodelled and retextured. We encountered similar difficulties with shiny or semi-transparent objects, slightly or more perforated objects and the like. This is an object classified in the Medium category.



Fig. 6. Object category Medium. On the left, a 3D cross-sectional model of a human head taken with an Artec Leo scanner. The base is irregular and too thin, the texture does not correspond to reality. It had to be remodelled. In the middle, a scan taken with the iPhone 13 PRO and the use of photogrammetry software in the Trinio program. On the right, the final model with a redesigned base and other adjustments in the Blender program. You can view the final 3D model at this shortened link: <https://skfb.ly/oAXFt>

In the Large category, i.e., which includes objects larger than 50 cm, we did not encounter significant challenges during 3D scanning or photogrammetry, only difficulties similar to those previously described in the Medium category. It is important to emphasize that the specific nature of each object to be digitized will always play a crucial role.

In terms of photogrammetry, the digitization process proceeded well for the most part. In cases where certain issues arose, it might be feasible to adopt a gradual approach by photographing different parts of the object. Subsequently, these 3D parts could be assembled using relevant software to create the final composite model. However, this approach could be relatively time-consuming. Similarly, if we were to opt for creating a 3D model based on a template (without 3D scanning), it would once again involve a more time-intensive process.



Fig. 7. Large category and first results of photogrammetry of a parasol (left), which is partially lacy. The unfolded parasol has a "spilled" edge. On the other hand, it is almost unreadable due to the wire construction, which is too thin, and the program misread the data. In the folded form, the result is more readable. Also, a dark parasol with a tassel. It looks better when folded, but the edges are bad again when unfolded. It must be added that 3D models look worse due to translucency of the materials.



Fig. 8. Puppet from the left- photogrammetry method, then 3D scanning. In the middle, two images of period clothing (photogrammetry, the last one is a 3D scan). The photogrammetry issues are obvious- a slight fraying is visible at the edges of the model. The texture/shape of the dress was not captured in the soffit (of the dress). The 3D model was able to process this. Colours/material are more believable with photogrammetry than with 3D models. The final 3D models can be viewed on our institution's Sketchfab, or at the following shortened links. The puppet: <https://skfb.ly/oMMzt> The dress: <https://skfb.ly/oMMzs>



Fig. 9. If we were to discuss the specific shortcomings of the created 3D models, or the limitations of 3D scanners, then clothing and its material could potentially serve as a good example in a certain case. Two shortcomings are immediately visible in the image. On the left, the clothing of the doll looks artificial, and the fabric (burlap) wrapped around the figurine is barely recognizable. On the right, the lace hem of the dress doesn't really resemble lace. The dresses themselves appear artificial, as if they were made of plastic. Once we become aware of these potential issues, we can work with them. First and foremost, a new 3D scan (3D model) can be obtained, or even the mentioned photogrammetry method can be tried, and both results can be compared, which may differ considerably. Furthermore, one can attempt to use specialized 3D modeling software (e.g., Blender) to apply tools for highlighting a specific material (which may have certain distinct properties). Lastly, experimenting with different lighting is possible because during the capture of photographs, 3D scanning, and the rendering of the final 3D model, properly chosen lighting can bring the project closer to reality. Lighting for the model can be adjusted within the web application Sketchfab, which we use for presenting our 3D models.

When evaluating the suitability of a method for creating 3D models for memory institutions, a crucial question arises. *Which of the available digitization methods is the most suitable in all aspects?* To answer this question, various variables must be taken into account, such as the institution's specific digitization requirements, equipment costs (including any additional workspace setup), and the skillset of the personnel involved. It's not common for museum staff, for instance, to be proficient in 3D modeling software like Blender or be familiar with operating specialized equipment such as a 3D scanner or adept at creating 3D models through photogrammetry.

Nevertheless, photogrammetry appears to be the most appropriate solution. It is a versatile digitization method that is user-friendly and can be relatively cost-effective (especially when compared to the price of a professional 3D scanner like the Artec Leo). However, it's essential to acknowledge that photogrammetry, like any method, has its limitations. Certain constraints discussed in the article may manifest during the creation of the final 3D model and subsequent work with it. All these aspects must be taken into consideration when selecting the appropriate method for the specific digitization of three-dimensional material objects.

5. Conclusion

Currently, the field of three-dimensional modeling offers various techniques and tools, including 3D modeling itself, 3D scanning, specialized microscopy, the intriguing "2.5D" or, in other words, "pseudo 3D," *Reflectance Transformation Imaging* (RTI), and digital photogrammetry. Navigating this wide range of options for creating 3D models that faithfully represent reality can be daunting, especially for the average worker at a museum or other memory institution. Many professionals involved in digitization still approach 3D scanning with caution and gradual familiarity, often uncertain about the significance of creating 3D models of historically valuable objects and their importance for preserving the appearance of a given heritage. The cost of technologies intended for 3D scanning, software, or hiring experts often represents a significant barrier, as effective 3D scanners capable of capturing objects ranging from miniature coins to massive buildings are relatively rare. Typically, institutions need to possess multiple similar devices to cover the various sizes of their historical artifacts. Alternatively, they can establish collaborations with other institutions dealing with similar issues. Lastly, it's also possible to explore other digitization technologies and methods, such as photogrammetry.

The primary goal of this article was to emphasize specific methods of three-dimensional digitization suitable for a wide range of material artifacts housed in memory institutions. Based on practical examples, our research has demonstrated that the 3D scanner, particularly the professional-grade Artec Leo utilized in our study and employed in our digitization facility, offers a highly efficient and suitable solution for digitizing medium to large objects. However, when it comes to creating 3D models of smaller objects, like coins or items with dimensions below 20 centimeters, the capabilities of a 3D scanner (such as Artec Leo) are found to be insufficient. In such cases, if an institution is unwilling or unable to acquire an additional 3D scanner suitable for digitizing small objects, we recommend using photogrammetry as a viable alternative, primarily because it is usually more cost-effective than purchasing a wide range of high-end, specialized 3D scanners.

Thanks to its practicality and ease of implementation, photogrammetry emerges as the least intricate approach for many memory institutions, especially museums seeking a versatile method for 3D digitization of a broad spectrum of material artifacts. It is a method that is applicable and user-friendly, and, with a touch of exaggeration, can even be utilized through modern smartphones.

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References

1. Brejcha, M., Brůna, V., Marek, Z. & Větrovská, B. (2015). Metodika digitalizace, 3D dokumentace a 3D vizualizace jednotlivých typů památek: certifikovaná metodika. Odborné a metodické publikace (Národní památkový ústav). Ústí nad Labem: Národní památkový ústav, územní odborné pracoviště v Ústí nad Labem. ISBN 978-80-7414-954-2.
2. Li, R., Luo, T., & Zha, H. (2010). 3D Digitization and Its Applications in Cultural Heritage." In: IOANNIDES, Marinos; FELLNER, Dieter; GEORGOPOULOS, Andreas, and HADJIMITSIS, Diofantos G. (ed.). Digital Heritage. Lecture Notes in Computer Science. Berlin, Heidelberg: Springer Berlin Heidelberg, 2010, pp. 381-388. ISBN 978-3-642-16872-7. Available at: https://doi.org/10.1007/978-3-642-16873-4_29. [Accessed: 2023-10-06].
3. Nikonova, Antonina & Biryukova, Marina. "The Role of Digital Technologies in the Preservation of Cultural Heritage." *Muzeologia a Kulturne Dedicstvo*, 5, 169-173 (2017).
4. Guidi, G., Frischer, B.D. "3D Digitization of Cultural Heritage." In: Liu, Y., Pears, N., Rosin, P.L., Huber, P. (eds) 3D Imaging, Analysis and Applications. Springer, Cham, 13 (2020). https://doi.org/10.1007/978-3-030-44070-1_13
5. Bernat, M., Janowski, A., Rzepa, S., Sobieraj, A., & Szulwic, J. "Studies on the use of terrestrial laser scanning in the maintenance of buildings belonging to the cultural heritage." 14th Geoconference on Informatics, Geoinformatics and Remote Sensing, SGEM. ORG, Albena, Bulgaria, 3, 307-318 (2014).
6. Di Angelo, L., Di Stefano, P., Fratocchi, L. & Marzola, A. An AHP-based method for choosing the best 3D scanner for cultural heritage applications. *Journal of Cultural Heritage*. 34, 109-115 (2018). <https://doi.org/10.1016/j.culher.2018.03.026>
7. Kantaros, A., Ganetsos, T. & Petrescu, F., I., T. Three-Dimensional Printing and 3D Scanning: Emerging Technologies Exhibiting High Potential in the Field of Cultural Heritage. *Applied Sciences*. 13, č. 8 (2023). <https://doi.org/10.3390/app13084777>
8. Giakalaras, M. (2020). 3D Technologies for Cultural Heritage. Gaming Engines. Department of Cultural Technology and Communication, University of Aegean, Lesvos 81100 Greece.
9. Rybenská, K. (2021). The issue of digitizing of historical heritage on the example of selected historical clocks. In HISTORICAL AND CULTURAL HERITAGE: PRESERVATION, ACCESS, USE. Kyiv, Ukraine: National Aviation University.
10. Science Word. (2014). 3D tisk a autorská práva [Online]. [Cit. 2022-08-22]. Available from: <https://www.scienceworld.cz/aktuality/3d-tisk-a-autorska-prava/>
11. Cervanová, A. (2018). 3D tisk a práva duševního vlastnictví (2. část – právní důsledky). Kropacek Legal: Law office [Online]. The Czech Republic: Kropacek Legal. [Cit. 2022-08-13]. Available from: <https://www.citacepro.com/dok/Rti1uhANj7O521f>
12. Jaké jsou typy 3D skenerů?. (2021). 3DeesD: Manufacture the Future [Online]. The Czech Republic: 3Dees Industries. [Cit. 2022-08-13]. Available from: <https://www.3dees.cz/faq/82-jake-jsou-typy-3d-skeneru>
13. Chen, T. (2009). New 3D Scanning Techniques for Complex Scenes: Skin, Jelly Candy, Alabaster, Fruits and More. VDM Verlag.
14. Jelič, P. (2022). Na obzoru je levnější LiDAR, brzy se nejspíše objeví u konkurence. *Letem Světem Applem* [Online]. The Czech Republic: Text Factory. [Cit. 2022-08-13]. Available from: <https://www.letemsvetemapplem.eu/2022/04/13/na-obzoru-je-levnejsi-lidar-brzy-se-nejspise-objevi-u-konkurence/>
15. Trnio. (2022). Welcome to Trnio. Trnio [Online]. USA: Trnio. [Cit. 2022-08-13]. Available from: <https://www.trnio.com/>
16. Apple. (2022). iPhone 13 Pro. Apple [Online]. USA: Apple. [Cit. 2022-08-13]. Available from: <https://www.apple.com/cz/iphone-13-pro/>
17. Artec 3D. (2022). Artec 3D Scanners. Artec 3D [Online]. USA: Artec Europe. [Cit. 2022-02-14]. Available from: <https://www.artec3d.com>
18. Di Paolo Emilio, M. (2019). Vertical-Cavity Surface-Emitting Lasers for 3D Depth Detection. EDN: Asia [Online]. Aspencore. [Cit. 2022-02-20]. Available from: <https://www.ednasia.com/vertical-cavity-surface-emitting-lasers-for-3d-depth-detection/>
19. Pavelka, K., Řezníček, J., Bílál, Z., Pavlík, M., & Kašička, F. (2017). Exaktní metody průzkumu památek. Prague: Česká technika – publishing CVUT.

20. Maršík, Z. (1982). Fotogrammetrie. In: Technical University Brno. Faculty of Civil Engineering. Fotogrammetrie. 1. díl, Základy letecké fotogrammetrie. 2. unaltered edition. Prague: State Publishing House of Technical Literature.
21. Pavelka, K., & HODAC, J. (2008). Fotogrammetrie 3: Digitální metody a laserové skenování. Praha: CVUT.
22. Cardaci, A., Versaci, A., & Azzola, P. (2019). 3D Low-cost Acquisition for the Knowledge of Cultural Heritage: The case study of the bust of San Nicola da Tolentino. In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences [Online], 42(2), 93-100. [Cit. 2022-10-16]. ISSN 2194-9034. doi:10.5194/isprs-archives-XLII-2-W17-93-2019
23. Kosmelová, N., & Nosek, V. (2019). Porovnanie digitálnych a klasických archeologických dokumentačných metód na príklade stredovekých šachových figur. *Studia Archaeologica Brunensia* [Online], 2(24), 29-74. [Cit. 2022-06-12]. ISSN 1803-0386. Available from: https://www.researchgate.net/publication/342684318_Porovnanie_digitalnych_a_klasickych_a_rcheologickych_dokumentacnych_metod_na_priklade_stredovekych_sachovych_figurok
24. Dvořáková, B. (2022). Spojení fotogrammetrie a metod laserového skenování pro digitalizaci kulturního dědictví. UHK. Hradec Králové.
25. 3Dčesko. (2022). Fotorealistické 3D modely českých památek a zajímavostí [Online]. The Czech Republic: 3Dčesko. [Cit. 2022-08-13]. Available from: <http://3dcesko.cz/>
26. Projekční atelier. (2022). Fotogrammetrie. Pro dokumentaci, průzkum a obnovu historických staveb, s.r.o. [Online]. The Czech Republic: Design studio. [Cit. 2022-08-13]. Available from: <https://www.pamatkovyatelier.cz/fotogrammetrie/>
27. Borůvková, B., & Burianová, K. (2020). RTI metoda jako způsob digitalizace kulturního dědictví. *Muzeum: Muzejní a vlastivědná práce*, 58(2), 32-38. ISSN 1803-0386.
28. Woody, R. C. (2021). RTI Digitization in the Museum. LUCIDEA [Online]. Lucidea. [Cit. 2022-05-29]. Available from: <https://lucidea.com/blog/rti-digitization-in-the-museum/>
28. Cultural Heritage Imaging. (2022). Reflectance Transformation Imaging (RTI) [Online]. Cultural Heritage Imaging. [Cit. 2022-05-29]. Available from: <https://culturalheritageimaging.org/Technologies/RTI/>
30. Cultural Heritage Imaging. (2022). CHI: Cultural Heritage Imaging [Online]. Cultural Heritage Imaging. [Cit. 2022-05-29]. Available from: <https://culturalheritageimaging.org/Technologies/RTI/>
31. Murison, M. (2018). LiDAR vs fotogrammetrie pro letecký průzkum. Bezpilotně [Online]. The Czech Republic: Bezpilotně – drony pro profesionály. [Cit. 2022-08-13]. Available from: <https://bezpilotne.cz/lidar-vs-fotogrammetrie-pro-letecky-pruzkum/>
32. Agentura pro rozvoj Broumovska. (2021). 3D modely [Online]. Broumov: Pixman. [Cit. 2022-08-13]. Available from: <https://pamatky.broumovsko.cz/3d-modely>
33. University of Hradec Králové, Faculty of Arts. (2021). Research and projects: Projects of CDHV members related to Digital Historical Sciences [Online]. Hradec Králové: University of Hradec Králové. [Cit. 2022-08-13]. Available from: <https://www.uhk.cz/cs/filozoficka-fakulta/ff/katedry-a-pracoviste/katedra-pomocnych-ved-historickych-a-archivnictvi/o-katedre/nazvem-centrum-digitalnich-historickych-ved/vyzkum-a-projekty>
34. KPVHA-FF-UHK. (2022). Sketchfab [Online]. Sketchfab. [Cit. 2022-08-13]. Available from: <https://sketchfab.com/KPVHA-FF-UHK>

Demographic characteristics as effectiveness indicators of the national health care systems

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Abstract. The purpose of the study is to investigate the impact Russian Federation and the Republic of Uzbekistan's demographic trends on the development of national healthcare systems. We studied official data from the websites of the World Health Organization, the Statistical Committee of the Union of Independent States, and the State Statistics Service of Russia and Uzbekistan for 10 years. Using analytical, statistical research methods and the SPSS program, the reliability of the differences in the obtained data was assessed at $t > 2$ and $p < 0.05$. Demographic characteristics Russia and Uzbekistan are population indicators of the health status and national health care systems indicators of the effectiveness. Monitoring of morbidity, mortality and disability indicators in Russia and the Republic of Uzbekistan revealed both similarities and differences in the levels of epidemiological indicators, which is due to different types of age structure of the population in these countries (regressive and progressive, respectively). In order to reduce the economic burden of disease within the framework of intersectoral cooperation and at the level of health systems within the framework of primary health care, it is necessary to conduct epidemiological studies, including systematic analysis of morbidity, disability and mortality rates, which predetermines the development of international scientific cooperation in order to improve and implement strategic directions development of healthcare systems.

Keywords: performance indicators, national health systems, demographic characteristics.

1. Introduction

There are three categories of causes of death: infectious diseases, non-infectious diseases and injuries, among which the leading places are occupied by diseases of the circulatory system (CVD), respiratory system and perinatal pathology [1]. In the structure of total population mortality, non-communicable diseases account for 77%, of which CVD accounts for 32% [2]. In 2020, the global mortality rate was 7 per 1000 people population, the highest rates were recorded in developed countries (10 per 1000) and in countries with high per capita income (9 per 1000). In Russia and Uzbekistan, mortality rates in 2020 were 13 and 5 per 1000 respectively [3].

The highest mortality rates from CSD are observed in Central, Eastern Europe and the CIS countries. In 2019, in the CIS countries, the mortality rate from CSD was 6 per 1000 people population, in Central and Eastern Europe - 4 per 1000 people population [4]. CVDs are one of the main reasons for the high costs of states on health care: the economic costs associated with disability, mortality, and treatment costs in the European Union (EU) amount to about 210 billion euros per year [5,6].

To reduce mortality and disability rates in order to reduce the economic burden of disease, countries around the world are developing strategic programs aimed at improving the health of the population. WHO recommends, within the framework of intersectoral interaction and at the level of health systems, within the framework of primary health care, the introduction of developed strategic directions for their prevention [7]. Thus, Russia has adopted national projects Healthcare and Demography, including the Federal projects "Combating Cardiovascular Diseases", "Fighting Cancer", "Strengthening Public Health" [8,9]. In Uzbekistan, a Development Strategy for the years 2017–2021 has been developed, taking into account the national characteristics of the country [10].

Demographic characteristics are indicators of the health status of the population - the types of population structure of different countries determine public health indicators [11].

The population's health status in different countries is determined by demographic characteristics, i.e. different types of population structure affect trends in public health characteristics [9].

Thus, one of the important mechanisms for monitoring the health status of the population is epidemiological research, including a systematic analysis of morbidity, disability and mortality rates, which predetermines the development of international scientific cooperation in order to improve and implement strategic directions for the development of healthcare systems.

The purpose of the study is to investigate the impact of the Russian Federation and the Republic of Uzbekistan's demographic trends on the development of national healthcare systems.

2. Materials and methods

We studied official data from the websites of the World Health Organization, the Statistical Committee of the Union of Independent States, and the State Statistics Service of Russia and Uzbekistan for 10 years (2010 - 2020) [12,13,14]. Using analytical, statistical research methods and the SPSS program, the reliability of the differences in the obtained data was assessed at $t > 2$ and $p < 0.05$ [15].

3. Results

Despite the population growth from 2010 to 2020 in the Russian Federation (by 3%) and in the Republic of Uzbekistan (by 15%), the age structure in the countries has not changed (Fig. 1).

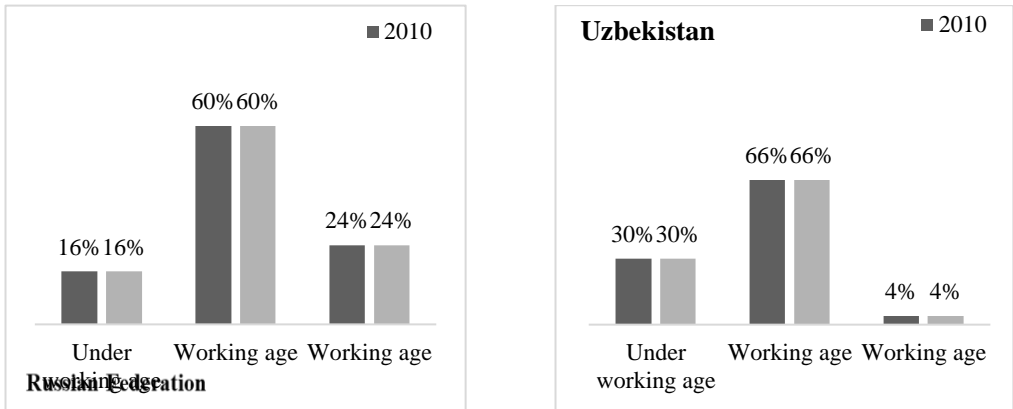


Fig. 1. Comparative characteristic of the population's age groups in the Russian Federation and Uzbekistan in 2010 and 2020 (in %).

The Republic of Uzbekistan maintains a progressive type of age structure, while Russia maintains a regressive type. In the structure of the entire population, the number of people under working age in the Republic of Uzbekistan is 30%, over working age – 4%; in Russia – 16% and 24%, respectively.

A comparative analysis of the demographic indicators of the population of the countries studied was carried out (Fig. 2).

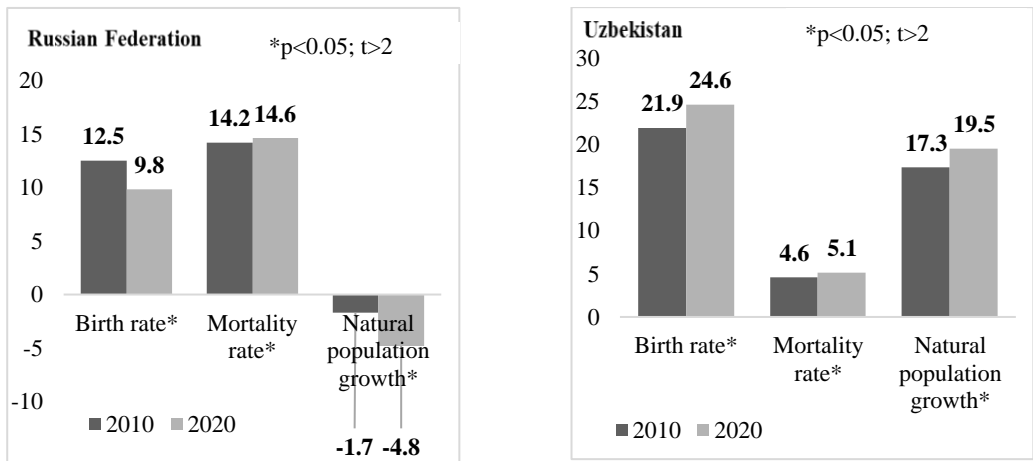


Fig. 2. Comparative characteristic of demographic indicators in the populations of the Russian Federation and Uzbekistan over the period of time from 2010 until 2020 (per 1000 people).

Over the period of time from 2010 to 2020 in the Russian Federation there was a statistically significant decrease in the number of births by 13% ($p < 0,05$) with mortality rate increasing by 34% ($p < 0,01$) and the corresponding tripling growth of negative values of the natural population growth rate ($p < 0,05$). Results from Uzbekistan show a statistically significant increase in birth rate and mortality rate (11% each) and an increase in positive values of natural population growth by 14% ($p < 0,03$).

In the year 2020, circulatory system diseases took the first place within the structure of mortality rate coefficient in the Russian Federation and Uzbekistan, they

accounted for 48% and 69% respectively among all causes of death. The second place belonged to death caused malignant tumors, which accounted for 16% of deaths in the Russian Federation and 8% of deaths in Uzbekistan. The third place in the Russian Federation was taken by deaths caused by external causes (11%), while in Uzbekistan it was taken by death caused by respiratory system diseases (4%). In Russia until the year 2018 there had been a statistically significant decrease in the overall mortality rate from 14 to 12 cases per 1000 people ($p < 0,01$). In 2020 this rate statistically significantly ($p < 0,01$) increased by 19% (in the year 2011 there were 14 cases, in the year 2020 there were 15 cases per 1000 people). In Uzbekistan, the overall mortality rate increased by 11% ($p < 0,01$) between 2018 and 2020.

When analyzing primary disease incidence in the population according to major disease types over the period of time from 2010 until 2020, the following tendencies were observed (Table 1).

Table 1. Dynamics of primary disease incidence in the population of the Russian Federation and the Republic of Uzbekistan according to major disease classes over the period from 2011 until 2020 (per 1000 people)

Disease classes	Number of disease incidence cases according to disease classes					
	Russian Federation*			Uzbekistan *		
	2011	2015	2020	2011	2015	2020
Infectious and parasitic diseases	32,8	28,1	20,4	11,5	12,1	20,5
Respiratory system diseases	323,8	337,9	370,5	120,1	164,1	133,9
Circulatory system	26,1	31,2	29,3	16,3	23,3	28,5
Digestive system diseases	33,5	35,3	90,4	56,0	70,5	102,6
Traumas and food poisoning	91,6	90,4	81,3	32,6	31,0	28,5

* $p < 0,05$; $t > 2$

As shown in Table 1, there was a statistically significant increase ($p < 0,05$) in the Russian Federation in the primary disease incidence in respiratory system diseases (in 2010 there were 323,8 cases, while in 2020 there were 370,5 cases per 1000 people) and circulatory system diseases (in 2010 there were 26,1 cases, while in 2020 there were 29,3 cases per 1000 people). There was a statistically significant decrease ($p < 0,05$) in deaths caused by infectious and parasitic diseases, digestive diseases, traumas and food poisoning. Starting from the year 2010 in the Republic of Uzbekistan there has been a statistically significant growth ($p < 0,03$) of primary disease incidence for infectious and parasitic diseases (in 2010 there were 11,5 cases, in 2020 there were 20,5 cases per 1000 people), for circulatory system diseases (2010 – 16,3 cases, 2020 – 28,5 cases per 1000 people), respiratory system diseases (2010 – 120,1 cases, 2020 – 133,9 cases per 1000 people), diseases of the digestive system (2010 – 56,0 cases, 2020 – 102,6 cases per 1000 people). For traumas and food poisoning there was a statistically significant decrease ($p < 0,03$) in the morbidity rate.

Disability rates in both countries had also undergone changes over the period of time under study. In the Russian Federation there had been a statistically significant ($p < 0,006$) decrease in the value of primary qualification for disability rate from 7,7 cases per 1000 people in 2010 to 5,6 cases per 1000 people in 2020, while in Uzbekistan there had been a statistically significant growth ($p < 0,009$) in the value of primary qualification for disability rate from 0,1 cases to 2,2 cases per 1000 people respectively.

There was a statistically significant increase in the primary qualification for disability rate in individuals with malignant tumors (by 33%) and musculoskeletal

system diseases (by 19%) ($p < 0,03$) in the Uzbekistan. There was a significant decrease in the rate of primary qualification for disability in all disease classes ($p < 0,03$) over the period of time from 2017 until 2020 in the Russian Federation.

4. Conclusion

In order to study the impact of demographic trends in the Russian Federation and the Republic of Uzbekistan on the development of national healthcare systems, monitoring of indicators in Russia and the Republic of Uzbekistan was carried out according to data presented on the official websites of international and state statistical bodies for the period from 2010 to 2020, which revealed similarities, and differences in the levels of epidemiological indicators, which is due to different types of age structure of the population in these countries (regressive and progressive, respectively).

There was a decrease in the overall level of premature mortality from non-communicable diseases despite the increase in the share of deaths in the overall structure of mortality from these causes, during the study period [16].

To improve the health of the population, the governments of Russia and Uzbekistan have adopted strategic documents aimed at strengthening measures to prevent, treat and control non-communicable diseases and their risk factors, reducing premature death and morbidity of the population. Russian Federation has approved the National Healthcare Project (acting until 2024), which contains federal projects aimed at combating cardiovascular diseases, as well as developing systematic motivation for healthy lifestyle, i.e. healthy eating habits and giving up unhealthy habits. The Republic of Uzbekistan approved the Concept for non-infectious diseases' prevention, healthy lifestyle promotion and increase in the level of physical activity of the population for 2019-2022. These regulations include target values for population health indicators that countries must achieve within specified time frames [17,18].

There is a low level of preventive work in the provision of primary health care to patients with socially significant diseases and the need to optimize its organization, despite the trend towards improving the efficiency of clinical examination of the population in Russia [19].

Therefore, different types of population structure in Russia (regressive) and Uzbekistan (progressive) determine differences in their demographic characteristics, which are indicators of the health status of the population and indicators of the effectiveness of national health care systems. The high level of mortality rates and the increase in morbidity in classes of diseases of the circulatory system and neoplasms in both countries justify the need for improving primary and secondary prevention measures at the state level.

References

1. WHO. Top 10 causes of death. <https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death>.(25.01.2022)
2. Townsend N, Wilson L, Bhatnagar P et al. Cardiovascular disease in Europe: epidemiological update 2016. *Eur Heart J*. 2016; 37(42): 3232-3245.
3. WHO. Global health estimates: life expectancy and leading causes of death and disability. <https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates> (25.01.2022)
4. Movsisyan N, Vinciguerra M, Medina-Inojosa J et al. Cardiovascular Diseases in Central and Eastern Europe: A Call for More Surveillance and Evidence-Based Health Promotion. *Ann Glob Health*. 2020; 86(1): 21.
5. Wilkins E, Wickramasinghe K, Bhatnagar P et al. European Cardiovascular Disease Statistics 2017. European Heart Network Brussels; 2017

6. Passport of the national project "Healthcare" (approved by the Presidium of the Council under the President of the Russian Federation for Strategic Development and National Projects, protocol dated December 24, 2018 N 16 https://www.consultant.ru/document/cons_doc_LAW_319209/ - access date 01/25/2022 G.
7. Core health indicators in the WHO European Region <https://www.euro.who.int/ru/data-and-evidence/evidence-resources/core-health-indicators-in-the-who-european-region/> (15.12.2021)
8. Passport of the national project "Demography" (approved by the Presidium of the Council under the President of the Russian Federation for Strategic Development and National Projects, protocol dated December 24, 2018 N 16) https://www.consultant.ru/document/cons_doc_LAW_317388/ - date of access 25.01 .2022
9. Ibragimova, N. M. Major results of the implementation of national goals and objectives of sustainable development of Uzbekistan / N. M. Ibragimova // Economics: analyzes and forecasts. – 2021. – No. 3(14). – P. 22-33.
10. Lee R., A. Mason (2010). Fertility, human capital, and economic growth over the demographic transition // European Journal of Population. 26(2): 159–182.
11. Priority areas for the prevention of non-communicable diseases on the agenda of the 75th World Health Assembly: plans for the future / O.M. Drapkina, G.Ya. Maslennikova, R.N. Shepel [et.al.] // Preventive medicine. – 2022. – Vol. 25, No. 6. – P.7-11. – DOI 10.17116/profmed202250617
12. Monitoring of population's quality of life indicators in the Commonwealth of Independent States' countries <http://www.cisstat.com/> (15.12.2021).
13. Federal State Statistics Service of the Russian Federation <https://rosstat.gov.ru/incomparisons/> (15.12.2021).
14. State Statistics Committee of the Republic of Uzbekistan <https://stat.uz/ru/> (15.12.2021).
15. Paniotto V.I. Quantitative methods in sociological studies. /V.I. Paniotto, V.S. Maksimenko. – Kiev, 2003. –170 pages.
16. World health statistics 2020: monitoring health for the SDGs, sustainable development goals. Geneva: World Health Organization; 2020. <https://apps.who.int/iris/bitstream/handle/10665/332070/9789240011977-rus.pdf?sequence=32&isAllowed=y/> (15.12.2021).
17. Resolution of the Government of the Russian Federation dated December 26, 2017, № 1640 "On the approval of the State Programme of the Russian Federation "Healthcare Development" (as amended on July 24, 2021). <https://base.garant.ru/71848440/> (15.12.2021).
18. Resolution of the Government of the Republic of Uzbekistan dated 18.12.2018 "On prevention measures for non-infectious diseases, promotion of healthy lifestyle and increase of the population's physical activity level. <https://lex.uz/docs/4111360/> (15.12.2021). (15.12.2021).
19. Sazanova G.Yu. Peculiarities of morbidity, disability and mortality of the population of Saratov region / G. Yu. Sazanova // Kuban Scientific Medical Bulletin. – 2012. – № 1(130). – P. 144-146.

A model of clinical symptoms in patients with chronic fatigue syndrome with postCOVID

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Abstract. Post-covid syndrome was defined as the presence of symptoms and/or signs of damage to various organ systems that develop during or after a previous COVID-19 infection persist for more than 12 weeks and cannot be explained by an alternative diagnosis. (A Quick Guide to COVID-19: Managing the Long-term Effects of COVID-19 (NG188)). Chronic fatigue syndrome/myalgic encephalomyelitis (CFS/ME) can be described as a disease of unknown etiology characterized by the presence of permanent fatigue that does not recover after the proper rest, accompanied by various somatic symptoms. Establishment of the diagnosis is based on the analysis of clinical manifestations, however, due to their diversity; it takes a lot of time and medical experience. The application of the statistical analysis may allow simplifying and unifying this task. At the same time, considering diverse manifestations of the CFS/ME, one may allude that there are several different clinical variations of this disease and, therefore, symptoms can be grouped into "clusters".

In this paper a possible correlation was revealed between various clinical symptoms of CFS/ME, using the principal component analysis (PCA) associated with the correlation coefficients of the Pearson's matrix. A hypothetical physical model of the correlation of immunological symptoms was created. In addition to the positive correlation expected for the symptoms of one disease, negative relationships were also revealed, which may represent some unknown pathophysiological processes of CFS/ME and requires further study. The identification of key symptoms in patients of this group can contribute to the introduction of new diagnostic criteria, which will lead to an improvement in the quality of life and medical care for these patients.

Key words. Chronic fatigue syndrome/myalgic encephalomyelitis (CFS/ME), principal component analysis (PCA), fever, chills, skin rash, flu-like symptoms, swollen lymph nodes, postCOVID, COVID-19

1. Introduction

Chronic fatigue syndrome/myalgic encephalomyelitis (CFS/ME) is a chronic disease of unknown etiology, mostly characterized by the increased physical and mental fatigue, which persists after the proper rest for the more than six month and is accompanied by a variety of multiple somatic symptoms [1, 2]. Precise data on the prevalence of this disease is unknown, but is assumed to be approximately 0.2 - 0.3% in general population [2, 3].

Considering that up to 70% of patients note the presence of a previous viral infection [4], in some groups of patients this syndrome may be of an autoimmune nature [5, 6]. The pathogenesis of CFS/ME also include autonomic, endocrine, and metabolic components; however, the degree of their influence still needs to be studied [2, 7].

Infectious triggers of the disease are widely discussed in the literature. At the moment, the role of the Epstein-Barr virus, herpes viruses type 6 and 7, human parvovirus B19, enteroviruses, lentiviruses, Ross River virus, Coxiella burnetii, mycoplasmas have been described [8, 9]. At the same time, many other viruses and bacteria have never been associated with the development of CFS/ME, despite their widespread prevalence in the population. Thus, the pathogenesis of the disease may have the features of molecular mimicry of the certain infectious agents [10].

Immunological dysfunction in CFS/ME include changes in the cytokine profile and concentration of immunoglobulins, the phenotype of T and B cells, and a decrease in the cytotoxicity of natural killer cells [11, 12]. The role of T-follicular helpers, type 17 T-helpers and T-regulatory cells is assumed; however, full-fledged studies have not yet been performed [11]. The presence of various autoantibodies has been described, in particular, antinuclear antibodies, antiganglioside antibodies, antibodies to neurotransmitters and their receptors, especially to β -1 and β -2 adrenergic receptors, and m3/4 acetylcholine receptors [11, 12, 13].

The risk of CFS/ME development increases when a patient has certain alleles of the HLA-DQA1, HLA-DQB1 and HLA-DRB1 genes [1-3]. The disease is most likely to have a polygenic predisposition [5, 14].

The variety of clinical symptoms, the lack of reliable laboratory and instrumental verification, and pathogenetic heterogeneity led to the fact that today there are more than 20 diagnostic criteria for CFS/ME [15]. Medical professionals often underestimate the severity of the patient's condition, which is associated with the subjectivity of the complaints, at the same time, other subjective symptoms, such as pain, usually cause increased attention. On average, the clarification of this diagnosis takes from several months to several years and is accompanied by the prescription of incorrect and sometimes dangerous methods of treatment.

To establish a CFS/ME diagnosis, chronic fatigue must be present for 6 months or more, without relieving after adequate rest. As a result, habitual activities such as work, exercise, or self-care become challenging [13, 16]. In addition, patients note a wide range of cognitive symptoms, such as "fog in the head", difficulties with concentration and memory. Dysregulation of the autonomic nervous system, primarily of the cardiovascular and gastrointestinal tract, is also noted. The development of postural disturbances in pulse and blood pressure may play an important role in the pathogenesis of intellectual and physical limitations. Patients also may note chronic pain (arthralgia, myalgia) and flu-like symptoms with a fever. All these symptoms significantly reduce the patients' quality of life [2, 3, 17].

Most of the standard medical examinations, such as routine CT/MRI of the brain and internal organs, electroneuromyography, and basic blood tests, do not give objective results, which makes it difficult to establish a diagnosis. In this case, the clinical examination methods become more important. It is the correct analysis of the patient's complaints with the highlighting of the key symptoms of CFS/ME that can help in a quick and accurate establishment of the diagnosis. Taking into account the relationship of CFS/ME with the infectious diseases, special attention should be paid to the immunological reactivity of patients.

The use of statistical analysis methods allows to simplify and unify the diagnosis [2]. In this paper, the presence of immunological CFS/ME symptoms were analyzed, as well as their positive and negative correlations. The identification of key symptoms of the disease can contribute to the introduction of new diagnostic criteria, which will lead to an improvement in the quality of life and medical care for these patients.

2. Materials and methods of the study

In 2020-2021, an examination of CFS/ME patients was performed at the SPbSU clinic of high medical technologies. 24 patients were examined, including 15 (62.5%) women and 9 (37.5%) men, average age 33 (28.5; 40.5) years. Patient survey and CFS/ME diagnosis was based on the results of the DePaul Symptom Questionnaire (DSQ) that was developed and validated at DePaul University (USA) [14]. The following complaints of patients with CFS/ME were analyzed: chills, night sweats, rash, sore throat, swollen/sore lymph nodes, nausea/vomiting, loose and frequent stools, pain/swelling/redness in the joints, fever. All these symptoms can be described as immunological, according to the recommendations of the National Institute of Neurological Disorders and Stroke (NINDS) (<https://cde.nlm.nih.gov/home>). The data was characterized by the simple statistical methods and a test was performed for their compliance with the normal distribution law, then the histograms presented in Fig. 1 were constructed. The correlation coefficients (r_{xy}) were interpreted based on the absolute values of the Pearson correlation coefficient (Table 2). The estimation of the statistical significance of the correlation coefficient r_{xy} was performed using the t-test, calculated by the following formula:

$$t_r = \frac{r_{xy} \sqrt{n - 2}}{\sqrt{1 - r_{xy}^2}}.$$

All the obtained dependencies are asymmetric, which implies the difference of the histograms from the normal distribution law. Descriptive statistics data is summarized in table 1. The table shows that the standard deviation for a number of parameters represent values comparable to the mean ones.

A smaller standard deviation indicates that more data is clustered around the mean. Larger, in turn, indicates that the data is more prevalent.

Then the pairwise correlation coefficients were calculated using the Pearson correlation coefficient. Table 2 shows a positive correlation between all clinical manifestations of CFS. Further, using the numerical recipes given in [18], the principal components are identified using the coefficients of the correlation matrix. Scree plot and figures of accounts and loads are calculated and presented, performed in the coordinates of the selected principal components. The analysis of the relative position of the selected vectors to each other and to the axes of the main components is performed. The comparison allows us to conclude that there is a hidden factor affecting the clinical manifestations of the CFS.

3. Results

Various clinical symptoms were preliminarily analyzed by methods of simple descriptive statistics, the data is given in Table. 1. The deviation from the normal distribution is also evidenced by the form of distributions (histograms) constructed for various symptoms.

Table 1. Descriptive statistics

Item name	N analysis	N missing	Mean	Standard Deviation
incr temp	26	0	1.5	1.27279
Chills	26	0	1.19231	1.26552
night sweats	26	0	1.19231	1.09615
throat pain	26	0	1.26923	1.25085
lymp nod	26	0	1	1,32665
Rash	26	0	0,42308	0,64331
Gastro pain	26	0	0,69231	0,83758
joint pain	26	0	0,61538	0,85215

The components of the Pearson correlation matrix are presented in Table 2. The method of identifying the principal components associated with the paired coefficients of the Pearson correlation matrix were applied.

Table 2. Pearson Matrix

	incr temp	chills	night sweats	throat pain	lymp nod	rash	gastro	joint pain
incr temp	1	0.48425	0.07168	0.51505	0.28427	0.02443	0.26265	0.07376
chills	0.48425	1	0.28946	0.57244	0.14295	-0.00567	0.13353	-0.15122
night sweats	0.07168	0.28946	1	0.33998	0.11003	-0.23344	-0.02011	0.08235
throat pain	0.51505	0.57244	0.33998	1	0.36157	0.10133	0.15859	-0.0866
lymp nod	0.28427	0.14295	0.11003	0.36157	1	0.60929	0.072	0.14153
rash	0.02443	-0.00567	-0.23344	0.10133	0.60929	1	0.02855	0.01684
gastro	0.26265	0.13353	-0.02011	0.15859	0.072	0.02855	1	0.50007
joint pain	0.07376	-0.15122	0.08235	-0.0866	0.14153	0.01684	0.50007	1

Table 3 shows the eigenvalues of the Pearson matrix and the corresponding percentage of the partial share and the cumulative contribution to the description of the variance.

Table 3. Pearson Matrix

	Coefficients	Coefficients	Coefficients
incr temp	0.47259	-0.05084	0.08861
chills	0.46148	-0.31813	-0.0442
night sweats	0.24082	-0.35229	0.1485
throat pain	0.52892	-0.17577	-0.09195
lymp nod	0.37456	0.42781	-0.30031
rash	0.16612	0.56383	-0.43389
gastro	0.22897	0.28251	0.57425
joint pain	0.07501	0.40058	0.59286

These eigenvalues as a function of their ordinal number are shown in Fig. 1, this figure is called the Scree plot [18, 19], and a good approximation in the description of the variance is the retention in the subsequent analysis of those eigenvalues of the Pearson matrix (Table 1-3) that lie to the left of the break point

(including the breakpoint itself). Therefore, in this case, three eigenvalues claim to be complete, which correspond to three main components. Further, to interpret the data, the construction of figures, called biplots, is used.

The vectors on the biplot correspond to the projections of single vectors directed along the axes of the coordinate systems of the pairs of initial data onto the plane of the selected pairs of principal components. The vectors themselves are often called loads [18]. The dots show the components of the so-called score matrix, i.e. projections of the initial data on the plane of the pairs of the corresponding principal components.

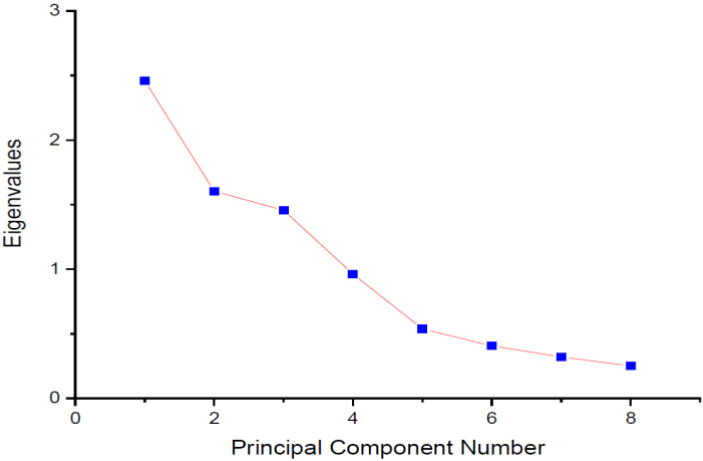


Fig.1. Scree plot.

Figures 2-4 show the accounts and loads for the pair of principal components PC1 and PC2, PC3 and PC1, PC3 and PC2, respectively.

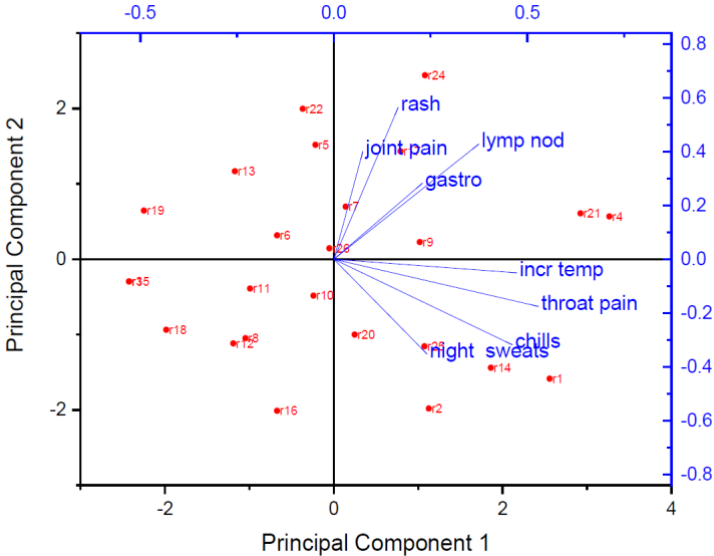


Fig. 2. Scree plot principal component analysis PC1 и PC2.

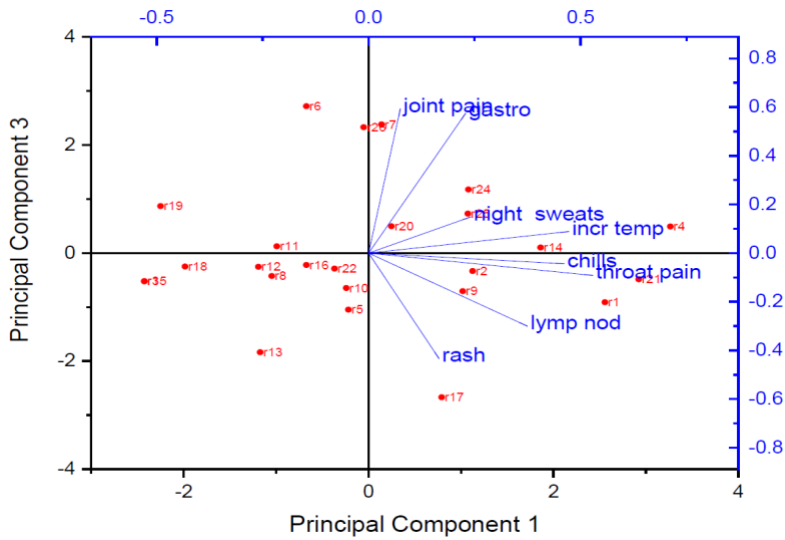


Fig.3. Principal Component analysis PC3 and PC1.

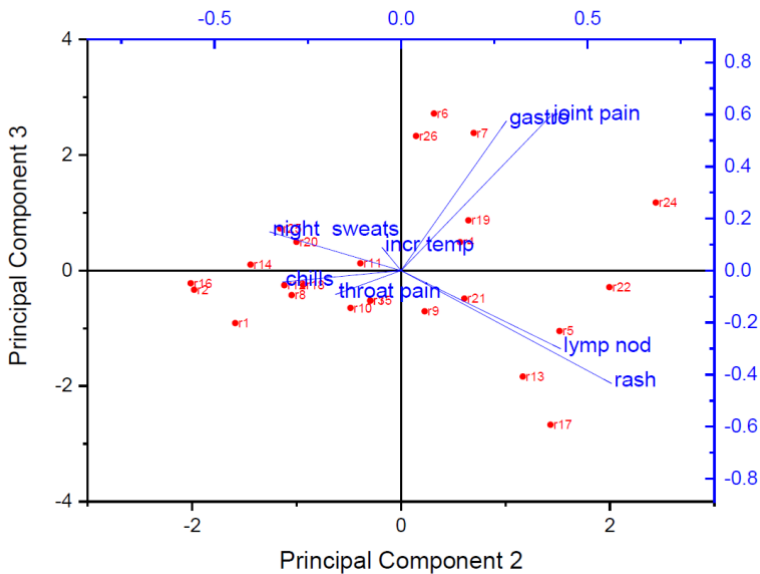


Fig. 4. Principal component analysis PC3 and PC2.

Correlation matrix analysis revealed a **strong positive** correlation between the following symptoms:

- Between Chills and Fever, the correlation coefficient was 0.48425
- Between Pain/swelling/redness in the joints and Nausea/vomiting/loose and frequent stools: 0.50007
- Between Sore throat and Fever: 0.51505
- Between Chills and Sore Throat: 0.57244

- Between Swollen/sore Lymph Nodes and Body rash: 0.60929

A **medium positive** correlation was also found between the following symptoms:

- Between Fever and Nausea/vomiting/loose and frequent stools: 0.26265
- Between Fever and Swollen/tender lymph nodes 0.28427
- Between Chills and Night Sweats: 0.28946
- Between Sore Throat and Night Sweats: 0.33998
- Between Sore throat and Swollen/sore lymph nodes: 0.36157

A **weak negative** correlation was found between the following symptoms:

- Between Chills and Arthralgia: -0.15122
- Between Night Sweats and Body Rashes: -0.23344

4. Discussion

The aim of this study was to analyze the main immunological complaints in patients with CFS/ME and to identify clinical patterns that require special attention while establishing a diagnosis and drawing up a treatment plan for these patients.

A strong positive correlation was revealed between chills and fever, arthralgia and nausea/vomiting/loose stools, sore throat and fever, chills and sore throat, swollen/tender lymph nodes and rashes [20]. It was also expected to find a medium positive correlation between fever and nausea/vomiting/loose stools, fever and swollen lymph nodes, chills and night sweats, sore throat and night sweats, sore throat and swollen lymph nodes. Considering that these symptoms characterize manifestations of immunological diseases, it was expected to evaluate their positive correlation in patients with CFS/ ME.

However, the two pairs of symptoms were negatively correlated. These included chills and arthralgia, as well as night sweats and rashes. Despite the fact that there is a need to repeat the calculations on a larger sample of patients, it cannot be ruled out that the obtained data reflects the possible pathophysiological patterns that play a role in the development of different CFS/ME subtypes. In each pair of negatively correlated symptoms, there is one that reflects the process of systemic inflammation (chills, night sweats) and one that may be a result of a local immune response (rash, arthralgia). The possible pathophysiological basis of these correlates is an issue for further research.

5. Summary

It is known that immunological symptoms (such as chills, night sweats, rash, sore throat, swollen/sore lymph nodes, nausea/vomiting, loose and frequent stools, arthralgia, and fever) are common among patients with CFS/ME. In patients with CFS/ME, the most common immunological symptoms were chills, night sweats, rash, sore throat, swollen/sore lymph nodes, nausea/vomiting, loose and frequent stools, arthralgia, and fever. It is crucial for the medical specialists to pay attention to such symptoms in patients with unexplained fatigue, that may lead to the faster and more precise evaluation of the CFS/ME diagnosis. During the statistical analysis, it was noted that while most of these symptoms are positively correlated with each other, two pairs of complaints demonstrated a negative correlation. Those pairs included chills and arthralgia, as well as night sweats and rashes. Further study is required to clarify the pathophysiological background of the obtained results, which will improve the quality of treatment and the quality of life of patients.

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References

1. Sotzny F, Blanco J, Capelli E, Castro-Marrero J, Steiner S, Murovska M, Scheibenbogen C; European Network on ME/CFS (EUROMENE). Myalgic Encephalomyelitis/Chronic Fatigue Syndrome - Evidence for an autoimmune disease. *Autoimmun Rev.* 2018 Jun;17(6):601-609. doi: 10.1016/j.autrev.2018.01.009. Epub 2018 Apr 7. PMID: 29635081.
2. Ryabkova VA, Churilov LP, Shoenfeld Y. Neuroimmunology: What Role for Autoimmunity, Neuroinflammation, and Small Fiber Neuropathy in Fibromyalgia, Chronic Fatigue Syndrome, and Adverse Events after Human Papillomavirus Vaccination? *Int J Mol Sci.* 2019 Oct 18;20(20):5164. doi: 10.3390/ijms20205164. PMID: 31635218; PMCID: PMC6834318.
3. Shoenfeld Y, Ryabkova VA, Scheibenbogen C, Brinith L, Martinez-Lavin M, Ikeda S, Heidecke H, Watad A, Bragazzi NL, Chapman J, Churilov LP, Amital H. Complex syndromes of chronic pain, fatigue and cognitive impairment linked to autoimmune dysautonomia and small fiber neuropathy. *Clin Immunol.* 2020 May;214:108384. doi: 10.1016/j.clim.2020.108384. Epub 2020 Mar 17. PMID: 32171889.
4. Sharif K, Watad A, Bragazzi NL, Lichtbroun M, Martini M, Perricone C, Amital H, Shoenfeld Y. On chronic fatigue syndrome and nosological categories. *Clin Rheumatol.* 2018 May;37(5):1161-1170. doi: 10.1007/s10067-018-4009-2. Epub 2018 Feb 7. PMID: 29417255.
5. Smith J, Fritz EL, Kerr JR, Cleare AJ, Wessely S, Matthey DL. Association of chronic fatigue syndrome with human leucocyte antigen class II alleles. *J Clin Pathol.* 2005;58:860-3.
6. Ortega-Hernandez OD, Shoenfeld Y. Infection, vaccination, and autoantibodies in chronic fatigue syndrome, cause or coincidence? *Annals of the New York Academy of Sciences.* 2009;1173:600-9.
7. Loebel M, Eckey M, Sotzny F, Hahn E, Bauer S, Grabowski P, et al. Serological profiling of the EBV immune response in Chronic Fatigue Syndrome using a peptide microarray. *PloS one.* 2017;12:e0179124
8. Chapenko S, Krumina A, Logina I, Rasa S, Chistjakovs M, Sultanova A, et al. Association of active human herpesvirus-6, -7 and parvovirus b19 infection with clinical outcomes in patients with myalgic encephalomyelitis/chronic fatigue syndrome. *Advances in virology.* 2012;2012:205085.
9. Bradley AS, Ford B, Bansal AS. Altered functional B cell subset populations in patients with chronic fatigue syndrome compared to healthy controls. *Clinical and experimental immunology.* 2013;172:73-80
10. Brenu EW, Huth TK, Hardcastle SL, Fuller K, Kaur M, Johnston S, et al. Role of adaptive and innate immune cells in chronic fatigue syndrome/myalgic encephalomyelitis. *International immunology.* 2014;26:233-42.
11. Curriu M, Carrillo J, Massanella M, Rigau J, Alegre J, Puig J, et al. Screening NK-, B- and T-cell phenotype and function in patients suffering from Chronic Fatigue Syndrome. *Journal of translational medicine.* 2013;11:68.
12. Katz BZ, Collin SM, Murphy G, et al. The International Collaborative on Fatigue Following Infection (COFFI). *Fatigue* 2018; 6: 106-121.
13. Rasa S, Nora-Krukke Z, Henning N, et al. Chronic viral infections in myalgic encephalomyelitis/chronic fatigue syndrome (ME/CFS). *J Transl Med.* 2018;16(1):268. Published 2018 Oct 1. doi:10.1186/s12967-018-1644-y
14. Jason LA, Sunnquist M. The Development of the DePaul Symptom Questionnaire: Original, Expanded, Brief, and Pediatric Versions. *Front Pediatr.* 2018;6:330. Published 2018 Nov 6. doi:10.3389/fped.2018.00330

15. Berridge M.J. // *Biochem. J.* 2017. Vol. 474. N 8. P. 1321–1332. DOI: 10.1042/BCJ20170042
16. Terenetskaya I.P. // *Integr. Mol. Med.* 2018. Vol. 5. N 2. P. 1–5. DOI: 10.15761/IMM.1000327
17. Szalecki M., Wysocka-Mincewicz M., Ramotowska A., Mazur A., Lisowicz L., Beń-Skowronek I., Sieniawska J., Klonowska B., Charemska D., Nawrotek J., Jałowicz I., Bossowski A., Jamiołkowska M., Pyrżak B., Miszkurka G., Szypowska A. // *Res. Rev.* 2018. Vol. 34. N 2. DOI: 10.1002/dmrr.2962
18. *Principal Component Analysis* / I.T. Jolliffe. Second Edition, Springer NY.: 2002. 487 p. DOI: 10.1007/b98835
19. Verstraete L., Leger A. // *Astron. Astrophys.* 1996. Vol. 240. N 1. P. 55–73. DOI: 10.1007/BF00640196
20. *Guide in Autoimmune Diseases for General medical Practice.* Y. Shoenfeld, P.L. Meroni, L.P. Churilov. Saint Petersburg: ELBI-Medkniga, 2017. 416 c.

Analysis of morbidity in hospitals

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Abstract. The article presents an analysis of morbidity in hospitals and the average length of stay by disease classes and individual nosology in Russia for the period from 2016 to 2021. The aim of the work was to analyze the indicators of morbidity in hospitals among the adult population of Russia for the period 2016-2021. Statistical and analytical research methods were used in the work. The data on the number of discharged adult patients (18 years and older) from medical organizations providing inpatient care as well as on the number of bed-days discharged were used from the federal statistical observation form № 14 'Information about the activities of units of medical organizations providing care in inpatient settings' for 2016-2021. The morbidity in hospitals rate decreased from 205.5 to 196.0 per 1000 people of the corresponding age, the average duration of stay in a hospital bed decreased from 11.7 to 10.6 days. The downward trend in morbidity in hospital is traceable for almost all classes of diseases. Since 2020, due to the pandemic of the new coronavirus infection COVID-19 and the reprofiling of most hospitals to infectious diseases hospitals, there has been a change in the structure of morbidity in hospital in adult patients by disease class.

Keywords: patients, adult, morbidity in hospitals, average length of stay, hospital, disease classes

1. Introduction

The most important task of medicine as a science is to study the state and dynamics of population health. Morbidity is the most important criterion characterizing the health of the population. The adults are the main consumer group of medical care provided in inpatient settings [1].

As of January 1, 2022, there were 145,557,576 people living in the Russian Federation, of which 115,229,293 were adults (aged 18 years and older) or 79.2% of the total population. The number of adults in 2016-2022 decreased by 2.0% (from 117530242 to 115229293), the share of the adult population decreased from 80.2 to 79.2% [2, 3].

The World Health Organization indicates that whatever incidence rate is calculated, it must meet a number of requirements: be reliable, objective, sensitive, accurate. Information about morbidity in hospitals allows one to judge the timeliness of hospitalization, the duration and outcome of treatment, the coincidence or divergence of diagnoses, the volume of medical care provided, etc. Data on morbidity in hospitals are taken into account when planning bed capacity and determining the need for various types of inpatient care [1, 4-7].

2. Data and Methods

According to the federal statistical observation form No. 14 'Information about the activities of units of medical organizations providing care in inpatient settings' for 2016-2021, an analysis was carried out of the number of adult patients leaving hospitals and the number of bed-days spent by those discharged [8-11].

The morbidity in hospitals is the frequency of all cases of diseases registered in patients discharged from medical organizations providing care under inpatient conditions for a given year [12-16].

The unit of observation when studying morbidity in hospitals is of every hospitalization of patients aged 18 and older.

3. Results

In Russia in 2020 there were 22636609 patients aged 18 and older discharged from hospitals, which amounted to 83.8% of the total number of those discharged in hospital organizations (in 2016 - 80.2%). The morbidity in hospitals incidence rate in the country in 2021 was 196.0 per 1000 adult population.

The highest rates of morbidity in hospitals per 1000 adult population by disease class were noted in connection with the new coronavirus infection, diseases of the circulatory system, neoplasms, diseases of the digestive system, genitourinary system, injuries, poisoning and certain other consequences of external causes, diseases of the respiratory diseases, etc. (Table 1).

Table 1. The rate of morbidity in hospitals in adult patients by disease classes in Russia for 2016-2020 (per 1000 population aged 18 and older)

Name of disease classes	Code ICD-10 version	Per 1000 adult population					
		2016	2017	2018	2019	2020	2021
Total	A00-T98	205,5	203,5	205,1	203,7	175,8	196,0
Including: Some infectious and parasitic diseases	A00-B99	6,1	6,1	6,1	5,9	3,7	3,35
Neoplasms	C00-D48	17,6	18,1	18,8	19,9	17,5	19,2
Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	D50-D89	1,1	1,2	1,3	1,4	1,1	1,3
Endocrine, nutritional and metabolic diseases	E00-E89	4,5	4,7	4,8	4,8	3,2	3,3
Mental and behavioural disorders	F01-F99	9,4	9,2	9,2	9,3	7,6	8,1
Diseases of the nervous system	G00-G98	5,3	5,4	5,5	5,4	3,9	4,1
Diseases of the eye and adnexa	H00-H59	6,5	6,7	6,8	6,9	4,8	5,45
Diseases of the ear and mastoid process	H60-H95	0,9	0,9	0,8	0,8	0,6	0,6

Name of disease classes	Code ICD-10 version	Per 1000 adult population					
		2016	2017	2018	2019	2020	2021
Diseases of the circulatory system	I00-I99	43,9	44,6	45,2	45,2	32,9	33,3
Diseases of the respiratory system	J00-J98	14,1	13,3	13,7	13,4	12,2	9,3
Diseases of the digestive system	K00-K92	18,6	18,6	18,9	18,6	14,0	14,6
Diseases of the skin and subcutaneous tissue	L00-L98	3,8	3,7	3,7	3,7	2,8	3,0
Diseases of the musculoskeletal system and connective tissue	M00-M99	10,3	10,3	10,5	10,6	7,1	7,9
Diseases of the genitourinary system	N00-N99	17,7	17,8	18,1	18,2	13,5	14,4
Pregnancy, childbirth and the puerperium	O00-O99	104,7	97,6	93,2	87,4	77,6	75,2
Congenital malformations, deformations and chromosomal abnormalities	Q00-Q99	0,4	0,3	0,3	0,3	0,2	0,2
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	R00-R99	0,1	0,1	0,2	0,2	0,1	0,05
Injury, poisoning and certain other consequences of external causes	S00-T98	13,7	13,3	13,4	13,1	10,3	10,7
COVID-19	U07.1-U07.2					17,4	35,0

High rates of morbidity in hospitals among the adult population in the class 'Diseases of the circulatory system' are determined in connection with ischemic heart disease (10.65 per 1000 adults), cerebrovascular diseases (9.3), diseases characterized by high blood pressure (4.9), other heart diseases (4.3), etc.; in the 'Neoplastic' class – malignant neoplasms (15.2); in the class 'Diseases of the digestive system' - the gallbladder diseases, biliary tract diseases (2.6), pancreatic diseases (2.5); in the class 'Diseases of the genitourinary system' - urolithiasis (2.9), in the class 'Diseases of the respiratory system' - pneumonia (3.7), etc.

The rate of morbidity in hospitals in adult patients during the study period decreased from 205.5 to 196.0 per 1,000 population aged 18 years and older. The downward trend in morbidity in hospitals is traceable for almost all classes of diseases (Table 1).

The largest decrease in the rate of morbidity in hospitals was noted in connection with some of infectious and parasitic diseases by 45.1%, diseases of the ear and mastoid process by 33.3%, diseases of the endocrine system, nutrition and metabolic disorders - by 26.7%, diseases of the musculoskeletal system and connective tissue by 23.3% diseases of the nervous system - by 22.6%, injury, poisoning and certain other consequences of external causes - by 21.9%, diseases of skin and subcutaneous tissue - by 21.1%, etc. (Table 1).

Since 2020, a change in the structure of morbidity in hospitals in adult patients by disease class has been established, what can be explained by the pandemic of a new coronavirus infection COVID-19.

Between 2016 and 2021, the national average length of stay for adult patients decreased by 1.1 days.

High rates of average length of stay on a bed were established due to mental and behavioral disorders (40.0 days), to some of infectious and parasitic diseases (31.7 days) (Table 2).

Table 2. Average length of stay in for adult patients by disease class in Russia in 2016-2021 (in days)

Name of disease classes	Code ICD-10 version	Average length of stay					
		016	017	018	019	020	021
Total	A00-T98	1,7	1,4	1,1	0,9	1,0	0,6
Including: Some of infectious and parasitic diseases	A00-B99	0,9	9,9	8,8	8,0	4,3	1,7
Neoplasms	C00-D48	0,5	0,2	0,9	0,4	0,6	0,95
Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism	D50-D89	2,2	1,7	1,5	1,3	0,5	0,8
Endocrine, nutritional and metabolic diseases	E00-E89	1,5	1,2	0,9	0,7	0,3	0,0
Mental and behavioural disorders	F01-F99	2,8	1,6	0,0	8,7	2,0	0,0
Diseases of the nervous system	G00-G98	1,0	0,8	0,7	0,7	0,45	0,2
Diseases of the eye and adnexa	H00-H59	0,25	0,9	0,7	0,4	0,75	0,5
Diseases of the ear and mastoid process	H60-H95	0,0	0,8	0,7	0,5	0,3	0,0
Diseases of the circulatory system	I00-I99	1,4	1,1	0,9	0,8	0,4	0,1
Diseases of the respiratory system	J00-J98	0,2	0,1	0,0	0,9	0,0	0,3
Diseases of the digestive system	K00-K92	0,0	0,7	0,5	0,5	0,1	0,8
Diseases of the skin and subcutaneous tissue	L00-L98	0,6	0,3	0,1	0,0	0,7	0,5
Diseases of the musculoskeletal system and connective tissue	M00-M99	1,65	1,3	1,0	0,7	0,05	0,7
Diseases of the genitourinary system	N00-N99	0,4	0,3	0,1	0,0	0,7	0,4
Pregnancy, childbirth and the puerperium	O00-O99	0,5	0,6	0,5	0,4	0,0	0,9
Congenital malformations, deformations and chromosomal abnormalities	Q00-Q99	0,8	0,3	0,3	0,0	0,6	0,1
Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	R00-R99	0,8	0,4	0,5	0,6	0,0	0,1
Injury, poisoning and certain other consequences of external causes	S00-T98	0,0	0,6	0,3	0,3	0,2	0,8
COVID-19	U07.1-U07.2					2,5	2,2

During the study period, there was an increase in the average length of stay of adult patients due some of infectious and parasitic diseases (from 30.9 to 31.7 days), symptoms, signs and abnormal clinical and laboratory findings, not elsewhere

classified (from 5.8 to 6.1 days).

4. Conclusion

The aim of the work was to analyze the indicators of morbidity in hospitals among the adult population of Russia for the period 2016-2021. Comparison of data on appealability and hospitalization makes it possible to navigate the selection for hospitalization for individual diseases, allows us to judge the level of selection of patients for an inpatient bed, as well as the satisfaction with hospitalization of patients who need it.

The study showed that in Russia the rate of morbidity in hospitals decreased by 4.6%, the average duration of stay for adult patients - from 11.7 to 10.6 days. The downward trend in morbidity in hospitals is traceable for almost all classes of diseases. This can be explained by the fact that since 2020, in connection with the pandemic of a new coronavirus infection COVID-19, a change in the structure of morbidity in hospitals of adult patients by disease classes due to the repurposing of most medical organizations into infectious diseases hospitals is identified.

Next, it is planned to analysis of morbidity in hospitals of adult patients for individual nosologies of the leading classes of diseases in the Russian Federation for 2022.

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References

1. Shchepin V.O. The hospital morbidity and mortality of adult population of the Russian Federation. Report 1. Problems of social hygiene, public health and history of medicine, 22(2), pp. 3-8 (2014)
2. Population by sex and age as of January 1, 2016. Statistical Bulletin. Moscow: Federal State Statistics Service (Rosstat), 2016. 344 p.
3. Population by sex and age as of January 1, 2022. Statistical Bulletin. Moscow: Federal State Statistics Service (Rosstat), 2022. 443 p.
4. Pavlova E.A., Skrebtsova N.V., Svetlichnaya T.G., Sovershaeva S.L. Analysis of hospitalized morbidity of working-age population living in ecologically unfavorable districts of Arkhangelsk region. Human Ecology, 7, pp.48-53 (2005)
5. Mikhailova U.N., Solovyova N.A., Varlamova M.A., Kurtanov H.A., Pavlova N.I. Hospital morbidity rates as a factor in the selection of pathology to develop personalized prevention and treatment methods. Yakutsk medical journal, 4(64), pp. 106-108 (2018)
6. Shlyafar S., Shikina I. The Use of High-Tech Medical Care in Patients Older Than Working Age in the Russian Federation. 2022 T. Antipova (Ed.): DSIC 2021, LNNS 381, pp. 379-391, 2022. https://doi.org/10.1007/978-3-030-93677-8_33
7. Voskanyan Y., Shikina I., Kidalov F., Davidov D., Abrosimova T. Risk management in the healthcare safety management system. Journal of Digital Science 2021; 3(1), https://doi.org/10.33847/2686-8296.3.1_4
8. Rosstat Order No. 591 of November 27, 2015 'On Approval of Statistical Instruments for the Organization of Federal Statistical Observation in Health Care by the Ministry of Health of the Russian Federation'.
9. Rosstat Order No. 812 of December 18, 2020 'On Approval of the Forms of Federal Statistical Observation with Guidelines for Completion to Organize Federal Statistical Observation in the Field of Health Protection by the Ministry of Health of the Russian Federation'.
10. Rosstat Order No. 932 of December 20, 2021 'On Approval of the Forms of Federal Statistical Observation with Guidelines for Completion to Organize Federal Statistical Observation in the Field of Health Protection by the Ministry of Health of the Russian Federation'.
11. Rosstat Order No. 679 of November 19, 2018 'On Approval of the Statistical Tools for the

Organization of Federal Statistical Observation in the Field of Health Protection by the Ministry of Health of the Russian Federation’.

12. Application of Statistical Analysis Methods for the Study of Public Health and Health Care: Textbook for Practical Training / Edited by V.Z. Kucherenko. M.: GEOTAR-Media, 2007. 256 p.

13. Shlyafar S.I., Ivanova M.A. The hospitalized morbidity of the population older than working age of the Russian Federation. *Advances in Gerontology*, 26(5), pp.690-694 (2016)

14. Shlyafar S.I., Shikina I.B. Evaluation of indicators characterizing inpatient surgical care delivery to older patients in the Russian Federation. *Social aspects of population health* [serial online] 2021; 67(5):5. DOI: 10.21045/2071-5021-2021-67-5-5

15. Shlyafar S.I. The hospital medical care support of individuals older than able-bodied age in the Russian Federation. *Problems of social hygiene, public health and history of medicine*, 29(2), pp. 238—244 (2021). DOI: <http://dx.doi.org/10.32687/0869-866X-2021-29-2-238-244>

16. Shlyafar Sofia, Shikina Irina High-Tech Heart Surgery in Elderly Patients in Russia. *ICS. Journal of Digital Art & Humanities*, ISSN 2712-8148, 4(1), June 2023 https://doi.org/10.33847/2712-8148.4.1_6.

Public debt from the viewpoint of national security and sovereignty

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Abstract. The paper examines public debt from the viewpoint of national security and sovereignty. The current situation with public debts in different types of countries is revealed. The risks, challenges and threats in the public debt sphere are presented. Different forms of public borrowings, such as loans from international organizations and banks, issuance of the securities on the domestic and international markets were analyzed. It was shown, that the international credits are characterized by the conditionality. In the case of borrowing on the open market using securities, the debtor depends on the current market conditions and can face significant deterioration of the situation. It was proved, that no form of borrowing is free from potential problems. The suggested classification of risks, challenges and threats can be useful for the efficiency of the public debt management.

Keywords: public debt, risks, challenges, threats, debt crisis, management, national security, sovereignty

1. Introduction

Public debt is a serious problem, that can affect national security and provoke restrictions on state sovereignty. It should be noted, that public debt is a controversial phenomenon. On the one hand, government borrowing can contribute to economic growth, industrial production, building and improvement of the necessary infrastructure, and development of new technologies. On the other hand, excessive public debt is a strain on the state budget, slows investment and hinders economic growth for years, all this reduces the well-being of the population and becomes a burden for future generations.

In modern conditions, the pressing issue is the sovereignty of the state and non-interference in its political and economic issues. At the same time, problems associated with external public debt create the opportunity for debtor countries to become dependent on creditor states and their representatives. However, internal public debt does not make the state free from the risk of losing independence in making decisions. For example, accumulated significant public debts complicate the fight against inflation, since an increase in the key rate to combat inflation conflicts with the objectives of managing public debt, leading to significant additional costs for servicing it.

In extreme cases, a debt trap situation may occur, that means in case of international operations that a creditor country or institution extends debt to a borrowing country partially, or solely, to increase the lender's political leverage. The creditor country extends excessive credit to a debtor country with the intention of extracting economic or political concessions when the debtor country becomes unable to meet its repayment obligations.

Currently we observe the elevated public debt, for instance, at the end of 2022 the average public debt in advanced countries was about 112 percent of their GDP, that is significantly higher than recommended [1, p.56].

Sovereign debt sustainability metrics continue to worsen around the world, especially in frontier and low-income countries, with many of the most vulnerable already facing severe strains [2, p. xiv]. Additionally to the absolute and relative numbers for the public debts (volumes and ratios of public debts to GDP), we should pay attention to the considerable surge in debt service payments on public and publicly guaranteed debt in recent years because of the increase in interest rates globally. For frontier economies and emerging markets with lower credit ratings, the situation is more worrisome. Some countries have lost market access, and debt distress pressures have become more pronounced.

Problems with public debts and even debt crises reveal the inadequacies, imperfections and inefficiencies in conducting public debt management in different countries. Particularly urgent question is the effective public debt management. Countries need the development of the credible risk-based frameworks that promote consistent macroeconomic policies, reduce debt vulnerabilities over time, and build up the necessary room to perform independent economic policy.

Different international organizations (IMF, World Bank) pay attention to the situation in the area of public debt and the need for vigorous action to avoid the debt crisis [1], [2], [3].

Many authors emphasize the need for effective management of public finances and offer their solutions. Among them we can note such scientists, as Antipova T. [4], [5]; Fattorelli M. L. [6], Batubara F. R., Ubacht, J., Janssen M. [7], Faber, A.S. C., Budding, G.T. [8], who wrote about strengthening of the instruments, methods and institutions to increase transparency, accountability and, finally, credibility of the public sector.

But, still there is the need for the methodological support of public debt management, including approaches to public debt problem prevention and resolution. Thus, this study is an attempt to contribute to the significant amount of efforts to develop the approaches to public debt management.

The research questions are as follows:

- 1) is it possible to apply an approach from another domain (security sphere) to the sphere of public debt management;
- 2) and if this is possible, what will be the calibration of risks, challenges and threats in relation to public debt;
- 3) what are the general risks, challenges and threats, that relate to all types of public borrowings, and what are the specifics of the certain types of debt.

We are not aware of any work devoted to public debt management using an approach that involves the distribution of negative factors into risks, challenges, and threats.

Thus, this paper aims to analyze the application of the «risks-challenges-threats» framework from the national security management to the sphere of public debt. To achieve the results of the research, it is necessary, firstly, to clarify the essence of above mentioned framework and clearly define the terms such as risk, challenge, threat, then to reveal the current situation in the sphere of public debt within the «risks-challenges-threats» framework, and present the final conclusion about the opportunities and difficulties, connected with this approach. All this has determined the structure of this paper.

2. Literature Review

An analysis of scientific papers on the topic of public debt shows that there is a huge number of works devoted to certain negative events and effects in the field of public debt. But the authors often use the words such as «dangers», «risks»,

«instabilities», «vulnerabilities», «challenges», «threats» in intuitive manner, on the empirical level and without special analysis and clear distinctions between these categories. It is necessary to agree with I.A. Veruhs, that clarity, intelligibility and elaboration of the conceptual-categorical apparatus are necessary [9]. Without understanding of the semantic content of the main categories, it is difficult to build an effective and adequate system of management. To ensure effective management of public debt it is necessary to have clear understanding of the basic categories, that underlie decisions taken to minimize the factors that are considered to undermine security.

In our study, we used two groups of publications.

The first group of sources is related to research on debt and the challenges facing debt management. Among such publications, we can name the research of the following authors: J. Bulow [10], K. Rogoff [10], [11], [12], C. Reinhart [10], [11], V. Reinhart [11], C. Trebish [10]; A. Abbas and A. Pienkowski [12]; M.A. Kose, P. Nagle, F. Ohnsorge and N. Sugawara [13].

The second group of publications is devoted to the concepts of the security and their application in economy, finance and management [9], [15], [16], [17].

3. Data and Methodology

Statistical data of international economic and financial organizations (IMF, World Bank), as well as publications of foreign and domestic authors were used as sources of information. The time period covered in the analysis is mainly the period from the global economic and financial crisis until 2023 year. Variables are collected from both the developed and developing countries.

The methodological basis of the research is system approach, fundamental provisions of the theory of international economic relations, methods of comparative analysis, expert assessments.

This article pays special attention to the conceptual-categorical apparatus. We take as a basis a methodological approach, according to which risk, challenges and threats are considered as factors unfavorable for security in any area, as different degrees of danger, where risks are the lowest level of danger, and threats are the highest level [9]. They are distinguished by varying degrees of destructiveness, leading to different consequences.

Risks, challenges, and threats in the area of public debt reflect varying degrees of insecurity and require a response in accordance with the degree of danger, which will be discussed below.

In the research we will use the following meanings of risk: «1. a possibility that an action or activity causes damage or loss of material or persons; and 2. risk is used when the consequences are uncertain» [16, p.79].

As for the challenge, it is defined in different ways as follows: «1. something difficult ... that tests strength, skill, or ability...; 2. questioning rightness: a refusal to accept that something is right and legal; 3. invitation to compete... 4. a demand to stop ... or a demanding task or situation; as well as: call to try one's skill or strength; demand to respond or identify oneself; formal objection; or a call to engage in a fight, argument or contest; a questioning of a statement or fact; a demanding or stimulating situation, ..., etc.» [16, p.66].

Threat is «1. a statement or expression of intention to hurt, destroy, punish, etc. in retaliation or intimidation and 2. an indication of imminent danger, harm, evil etc.» [16, p.62].

We also rely on an important contribution on the topic by Battistelli F. and Galantino M.G., that «the risks are attributable to positive human intention, so that potential harm is an unintended side effect in the production of benefits, threats are

attributable to ill-intentioned actors, deliberately acting to cause damage to others» [15].

4. Current situation with public debts and factors influencing the borrowings

Detailed information about the public debts in different groups of countries is presented in Table 1.

Table 1. General Government Debt in 2018-2028, % of GDP

	Historical information			Projections		
	2018	2020	2022	2024	2026	2028
Advanced economies, average	102.9	122.9	112.3	112.7	114.6	116.3
USA	107.4	133.5	121.3	126.9	132.9	137.5
eurozone	85.7	96.8	91.0	88.3	86.1	84.9
Japan	232.4	258.6	260.1	251.9	251.1	252.8
United Kingdom	85.2	104.6	101.9	105.9	108.5	108.2
Canada	90.8	118.9	107.4	103.3	98.6	94.7
Emerging markets and developing countries, average	53.3	65.9	65.3	70.1	74.3	78.1
China	56.7	70.1	77.0	87.4	95.9	104.3
India	70.4	88.5	81.0	82.3	81.7	80.5
Russia	13.6	19.2	18.9	21.8	20.9	18.2
Brazil	84.8	96.0	85.3	90.3	93.9	96.0
South Africa	51.5	68.9	71.1	75.8	81.6	86.7
Developing countries with low income, average	41.7	48.4	48.4	46.3	43.8	42.0

Source: compiled by the author based on [1, pp. 56, 64, 70].

Despite the fact that in 2022 there was a decrease in the debt to GDP ratio in the majority of countries, except Japan, China, South Africa, the growth of this indicator, according to IMF calculations, will continue in the future. Debt ratios are projected to start going up again in 2023 and continue to increase over the medium term through 2028. The level of public debt is now more elevated and projected to grow faster than foreseen before the pandemic. By 2028 the United States' public debt ratio is projected to exceed 137.5 percent of GDP, significantly surpassing the pandemic peak [1, p.56]. For China, the public debt to GDP ratio is expected to increase continuously to reach 104.3 percent in 2028, that is twice higher than the level observed in 2018 [1, p.64]. In general, the growth of public debt in 2028 compared to 2018 in developing countries (excluding China) will be more moderate than in advanced countries. There will be virtually no change in debt levels in low-income countries, but this indicates problems with access to the capital market rather than a favorable macroeconomic situation.

Public borrowing is carried out in the form of government loans and direct loans. Government loans are characterized by the fact that temporarily free funds of individuals and legal entities are attracted through the issuance and sale of government securities on national and international markets. The main type of securities symbolizing a debt obligation is a bond. Loans are characterized by the fact that lenders directly (without purchasing debt securities) transfer to the borrower the credit resources. Credit relations involve a negotiation process between the lender and the borrower, as a result of which the latter can receive more favorable financial conditions. However, in exchange for these conditions, the creditor will often make additional demands, which can be both economic and political in nature. An example of such obligations with conditionalities are the IMF loans, the provision of which is associated with a specific set of economic measures. In the case of borrowing on the open market using securities, the terms of borrowing depend on the current market conditions. The advantage of this form of debt is a wide range of potential investors, large capacity and the ability to actively manage debt obligations. No form of borrowing is free from potential problems.

Among the factors influencing the public borrowings we can name the negative effects of COVID-19 pandemic and weak recovery growth after this, general decline in economic activity, geopolitical difficulties that affect the state of countries' budgets.

The factor, that influences the situation with the public debt, is the change in the structure of debt in terms of creditors and types of debt. The debt composition has changed in recent years from predominantly bank loans to bonds, leading to higher probability of rapid contagion, as bonds change hand quickly and across borders. In contrast to the previous years, currently low- and middle-income economies have become increasingly indebted to private creditors, especially bondholders. According to the International Debt Statistics, prepared by the World Bank, at the end of 2021, 61 percent of the US\$3.6 trillion in long-term public and publicly guaranteed external debt stock was owed to private creditors—up from 46 percent in 2010. In IDA (International Development Association) eligible countries, the share owed to private creditors rose from 5 percent in 2010 to 21 percent in 2021. [3, p.ix]. The composition of debt owed by IDA countries to official bilateral creditors has also changed significantly. The proportion owed to Paris Club creditors fell to 32 percent at the end of 2021 (US\$64.2 billion), down from 58 percent (US\$48.9 billion) at the end of 2010. Above mentioned decline was compensated by the increase of the amount owed to non-Paris Club creditors (China, India, Saudi Arabia, the United Arab Emirates, and others) up to 68 percent (US\$138.3 billion) in 2021 from 42 percent (US\$35.3 billion) in 2010 [3, p.ix]. Taking into consideration the change in debt composition, debt reduction process for low- and middle-income countries in debt distress can become more challenging as reaching agreements becomes more difficult and time-consuming.

Another aspect of the composition of the debt is the increase of the share of short-term debt. According to the reports, short-term debt accounted for half of the increase in the total net external debt inflows for low- and middle-income countries in 2021, even though it accounts for only 27 percent of the overall external debt stock [3]. Short-term debt inflows are volatile and bear the increased risks of refinancing (roll-over risks).

5. Calibration of risks, challenges and threats in relation to public debt

From our point of view, we can apply the approach from another domain (national security) to the sphere of public debt management. As the answer to the research question, we present our version of the calibration of the risks, challenges and threats in relation to the public debt. We also distinguish between different types

of borrowings and note general risks, challenges and threats, as well as specific ones that are characteristic of certain types of borrowings.

Risks in public debt sphere. Risk implies uncertainty. As Brauch H.G. mentions, risk is present only to the extent that uncertainty involves some feature of the world, stemming from natural events or human activities that impacts human reality. Risk, in human terms, exists when humans have a stake in outcomes and is close to a situation or event in which something of human value has been put at stake and where the outcome is uncertain [16, p.82]. Risk is inherent in all economic processes. We cannot take advantage of the opportunities available for government borrowing without incurring certain of the risks noted below.

IMF provides some guidelines in connection to risks, important for public debt management. So, according to IMF, risks of public debt are as follows:

-market risk (the risk of an increase in the cost of debt due to changes in market variables such as interest rates and exchange rates). The most common types of market risk are the interest rate and currency risks. Interest rate risk is the risk of an increase in the cost of debt due to changes in interest rates. Currency risk is the risk of an increase in the cost of debt due to changes in exchange rates;

- refinancing risk, or rollover risk (the risk that the debt will need to be refinanced at high cost; in extreme cases, the debt cannot be refinanced at all);

- liquidity risk (means a situation where the volume of liquid assets decreases rapidly as a result of an unexpected flow of cash liabilities and / or possible difficulties in raising funds through short-term borrowing);

- credit risk (risk of non-performance by a counterparty of obligations under loans, financial contracts, etc.);

- settlement risk (the risk that a counterparty will not deliver a security in accordance with the terms of the contract after the country (other counterparty) has already made a payment in accordance with the agreement);

- operational risk. This includes a number of different types of risk: transactional errors at various stages of execution and transaction posting; deficiencies or failures in internal controls or systems and services; reputational risk; legal risk; violations of security measures; natural disasters affecting the debt manager's ability to operate [18, p.14].

To our mind, above mentioned risks relate to all types of public borrowings.

Challenges in public debt sphere. Challenges to economic security are understood as a set of factors that, under certain conditions, can lead to a threat to economic security.

From our point of view, in case of challenges, it is necessary to differentiate between general challenges, that relate to all types of borrowings and challenges, that are specific to some types of borrowings.

As for general challenges, they are as follows:

- significant decrease in state budget revenues and an increase in government spending;

- realization of contingent budget obligations;

- the significant deterioration in borrowing conditions;

- challenges in the field of cybersecurity.

One of the main challenges in public debt sphere is the significant decrease in state budget revenues and an increase in government spending. This situation has fully manifested itself during the pandemic, that has negatively affected public debts. The major drivers of the significant growth of the public debts in different countries were as follows: sharp contraction in economic activity, the rises in the primary deficits and as a consequence – necessity to increase borrowing. As a result, public

debt reached record levels during the pandemic, in both advanced economies and low- and middle-income countries.

The COVID-19 pandemic has had a negative impact on economic activity across the board, with international interactions coming to a near standstill as countries impose strict travel restrictions to stop the spread of the virus. The pandemic-induced recession has led to soaring unemployment, falling real wages, shrinking fiscal revenues and a weakening banking sector. The pandemic and measures to contain it caused for a certain period of time the sharp decline in demand and a drop in oil prices. As a result, exporters of oil and manufactured goods were hit particularly hard.

The pandemic will continue to be one of the defining challenges for entering the trajectory of sustainable development and creating conditions for ensuring dynamic development in the medium term. Countries are emerging from pandemic restrictions at different speed, some industries still can not recover. New waves of the pandemic, new strains or new emergences of infectious diseases cannot be ruled out. In this case governments will be forced to financially mitigate the consequences of the pandemic by increasing the debt burden.

Escalation of the geopolitical tensions in the global economy can hinder bilateral contacts and the establishment of productive economic partnerships. It can cause the tighter global financial conditions, higher inflation, lower growth, and higher stress on public finances and, as a result, have adverse implications for various countries' debt dynamics. Continuation of the geopolitical tensions may lead to further increases in different types of spending, including defense spending. Public debt will also increase because of the fiscal support to address negative effects from disruptions to international trade.

Another example of the challenges in public debt sphere is the issue of contingent liabilities. According to the IMF, «contingent liabilities are the obligations that are not explicitly recorded on government balance sheets and that arise only in the event of a particular discrete situation, such as a crisis» [1, p. 31].

There is a steady increase in contingent obligations in the world economy. Large contingent liabilities are accumulated by now as the governments provided exceptional support during the COVID-19 pandemic and by the sovereign-bank nexus. Currently large banks have huge holdings of government debt from different countries; banks and governments have become more interdependent. Negative changes in demographics, including declining fertility and aging populations are the factors, that negatively influence the public budgets, especially in the developed countries. The complete comprehensive account of all contingent obligations accumulated by the governments is absent, that results in the failure of the authorities to manage effectively contingent liabilities and associated risks.

Another example of the challenge in public debt sphere is the significant deterioration in borrowing conditions as a result of external and internal factors. Currently, after years of low interest rates, tighter monetary policy and the increase of the key rates are challenging the public debt management.

Additional problems with the cost of debt can be caused by the additional spending, connected with the debts (numerous commissions, including commissions for negotiations, participation, management, reservation of funds, one-time special bank commissions, commissions for guarantees, overestimation of the necessary amount of the collateral). All this should be clear to the borrower.

We should also pay attention to the challenges in the field of cybersecurity. The ongoing processes of technological change affect all aspects of life and create uncertainty about the future. The sphere of public debt is under the transformations under the effect of new technologies, that have not only advantages, but also

drawbacks, such as the need for harmonization and common standards; problems of integrating new ones with existing processes and systems; the necessity to provide cybersecurity [19]. Challenges in cybersecurity can be demonstrated in different ways:

- from the point of view of the impact on network equipment, cyber challenges can be associated with denials of service and modernization, interception of equipment control, unauthorized data collection, disruption of critical communication infrastructure;

- as for challenges for routing, cyber challenges can result in unavailability of Internet resources, distortion of traffic routes, and network congestion;

- from the point of view of data processing, one may encounter denial of service and updating of user devices, de-anonymization and localization of users, unauthorized data collection;

- as for the challenges for services, cyber challenges similar to problems with data processing consist of de-anonymization and localization of users, unauthorized collection of data, as well as failure of «libraries», and the introduction of «bookmarks» in programs;

- when distributing harmful information, the challenges are associated with large-scale harm to the well-being of citizens.

Now let's turn to the specific challenges, that are observed in case of borrowing in the form of credits from international organizations and banks, as well as foreign governments.

Significant debt to international financial organizations (such as the IMF and World Bank), foreign banks and governments under bilateral loan obligations can significantly limit a country's sovereignty, especially if the country's interests do not coincide with the interests of the relevant creditors.

Loans from international financial organizations come with a number of challenges for the borrower. Among such we can name the necessity to follow the requirements about special economic programs (for example, when the country borrows from the IMF or the World Bank).

Additionally, as the challenges we can name the need to fulfill the conditions of the membership in the global financial and economic organizations (including the provision of information on the state of the country's economy, the provision of financial resources to unfriendly states (for example, as part of membership in the IMF). Thus, in case of loans from the international financial and economic organizations, we can observe conditionality of their financial resources. When restructuring debt, it is necessary to reach agreements with all creditors and to have uniformity in the applicable terms of settlement with all creditors (for instance, IMF-World Bank-Paris club).

The problem of debt dependence concerns not only low-income countries, but also countries of the European Union, which have also experienced debt crises and restrictions on their sovereignty in decision-making. This is due to the presence of supranational bodies that have control and enforcement mechanisms for the execution of decisions. An example of these actions is the anti-crisis policy imposed on Greece.

Another negative phenomenon associated with participation in international financial organizations is the lack of involvement of participating countries in making decisions about the recipient of borrowings. This problem is revealed by A.V. Navoi, who comes to the conclusion that Russia essentially generates resources for IMF loan programs, that are implemented, among other things, in favor of unfriendly countries [20].

Additional challenge, connected with the participation of the country in international financial institutions is the necessity to provide statistical and other information about the economy. A.V. Navoi proves, that this situation is becoming increasingly burdensome. Thus, due to the growth of the supervisory and control functions of the IMF, Russia is becoming increasingly burdened with obligations to provide statistical and other information to the IMF, participate in mutual inspections, and receive technical missions. Thus, in 2021, the volume of assessment activities carried out was 4 times higher than the scale of activities within the framework of FSAP (Financial Sector Assessment Program), for 2011 [21, p. 139]. It should be noted, that additionally to FSAP [22] there are several such programs within which different countries provide significant volume of information: NSDP, SDDS, SDDS+, e-GDDS [23].

Thus, the International Monetary Fund's Dissemination Standards Bulletin Board (DSBB) provides access to the National Summary Data Page (NSDP), Special Data Dissemination Standard Plus (SDDS Plus), the Special Data Dissemination Standard (SDDS), the Enhanced General Data Dissemination System (e-GDDS), and the Data Quality Reference (DQRS) sites.

- The National Summary Data Page (NSDP) is a «data portal» for countries participating in SDDS Plus, SDDS, and e-GDDS. The NSDPs allow users to access data, view metadata, or browse links to online datasets for all available categories for a country, even if these categories are compiled by multiple statistical agencies.
- The SDDS was established in 1996 to guide countries that have, or that might seek, access to international capital markets in the dissemination of economic and financial data to the public.
- The SDDS Plus was established in 2012 to reinforce and supplement the Fund's Data Standards Initiatives. It builds on the SDDS and its purpose is to assist member countries with regard to the publication of economic and financial statistical data. The main reason for the developing SDDS Plus is addressing data gaps revealed during the global crisis.
- The e-GDDS was established in 2015 to guide countries in data dissemination by supporting transparency and encouraging statistical development. This site provides information on data produced and disseminated by member countries that participate in the e-GDDS.
- Additionally, there is the Data Quality Reference Site (DQRS), which provides access to contributions in the field and includes a selection of articles and other sources related to data quality issues [23].

Thus, the difficulties, additional obligations and disadvantages of participating in certain international organizations can outweigh the advantages of participating in them.

One of the challenges, connected with credits, is the reduction in the value of the collateral and requirements for its replenishment. As the experience of Russian companies and banks during the global financial and economic crisis has shown, it is possible to encounter demands from foreign lenders for Russian borrowers to increase the collateral or repay the loan early due to the depreciation of the collateral. During the world financial and economic crisis, the fall in the share price of the Russian banks and corporations on the national stock market reached 70%. The rate of the depositary receipts of Russian companies on foreign stock markets, primarily the UK and the USA markets, as well as Russian Eurobonds (long-term debt obligations with maturity up to 30 years, that are denominated in a currency not native to the country where it is issued) and euronotes (that are similar to the eurobonds, but with shorter

maturity, typically 2-10 years), has decreased due to the risk of non-repayment on time. As a result of the depreciation of the pledged shares, the collateral for Rosneft's loan decreased, for example, from 4.9 to 2.1 billion dollars in September 2009. A similar situation arose with other Russian companies UC RUSAL (secured by shares of Norilsk Nickel), AFK Sistema (loan secured by shares of MTS), Altimo (loan secured by shares of Vypelcom). The risk of increasing costs for insuring external borrowings is associated, in particular, with the inclusion in the loan agreement of a clause on increasing the insurance premium index for the risk of the default. Its basic indicator is the cost of the CDS (credit default swap) contract. The borrower pays this premium in exchange for a commitment to pay it under certain conditions if the debtor defaults. These indices, combined with the LIBOR rate, served as a guide to the cost of the loan for borrowers. Due to the fall in Gazprom's share price, the insurance premium to LIBOR on its external debt increased from May to early September 2008, and on September 12-19, 2008 it increased by another 50% and reached its maximum - 1200 points. Subsequently, in mid-2009, the cost of CDS on Gazprom loans decreased, but it was twice the pre-crisis level [14, p.118].

As for challenges of the borrowings in the form of securities' issuance, they include the dependence on the conditions of the capital market (both national or international).

The next example of the challenges are the massive sales of debt obligations on the debt market (national or international). Usually it happens under the conditions of increased uncertainty and especially in crisis.

Threats in public debt sphere. Threats in the majority of the methodological publications devoted to the conceptual-categorical apparatus are recognized as a set of conditions and factors that create a direct or indirect possibility of causing damage to the national interests. As general threats, that relate to all types of borrowing, we can name as follows:

- sanctions (freezing of the debtor's international assets, blocking of accounts);
- obstruction of the settlement of public debt.

Serious threat in the sphere of debt is the obstruction of the settlement of indebtedness. For countries with excessive levels of public debt, a solution to the problem is impossible without debt restructuring. In many cases the active usage of debt settlement methods (writing off part of the debt, conversion, securitization, debt repurchase at a discount) [24].

Even before the crisis associated with the COVID-19 pandemic, negative trends related to debt to commercial creditors appeared. Thus, commercial creditors are increasingly able to obtain an inordinately large share of debt repayment during debt restructuring [10, p.14]. This is supported by examples from the experience of resolving the debt crisis of the 1980s years in countries with emerging markets, as well as the European debt crisis of 2010. Official creditors are forced to take on the burden of problems associated with helping the debtor; bear the costs associated with write-offs. As noted by J. Bulow et al., another problem is associated with the use of new tactics of disagreement and litigation on the part of private investors. There is a protracted nature of debt crises; it takes an average of 7 years to overcome an episode of default and, as a rule, several rounds of restructuring take place [10, p.16]. Private creditors have little incentive to follow the lead of formal creditors. At the same time, about 18% of the debt of countries entitled to take advantage of the moratorium on debt payments falls on commercial creditors (the corresponding figure in 2010 was 5%) [25].

The most negative scenario for the debtor is when the creditor opposes debt restructuring and demands full payment of the debt from the borrower. In previous years, there have been examples of predatory behavior by some creditors where government bonds were purchased at a significant discount, but these investors subsequently blocked decisions regarding debt restructuring.

Among threats, that are connected with bilateral credits we consider the loss of strategically important assets pledged to secure debts, including the loss of the country's infrastructure facilities.

As for the specific threats, that relate to public borrowings on the securities markets, they are as follows:

- ban on the purchase of debt obligations;
- creating a situation conducive to a real or technical default on debt obligations, including denial of access to the necessary infrastructure of the international debt market.

Let's analyze the creation of a situation conducive to a real or technical default on debt obligations, including denial of access to the necessary infrastructure of the international debt market, that can be viewed as a threat. The example of such a situation is the case of Russia's external public debt. On May 25, 2022, the license of the US Treasury expired, which gave the Russian ministry of finance and the Bank of Russia the right to conduct transactions related to payments on the country's debt obligations. The American authorities did not extend it. The Russian ministry of finance made the payment in advance - on May 20, 2022 - in original currencies, but the money did not reach the holders of Russian Eurobonds. But the creditors did not receive money because of the actions of international settlement and clearing systems. They did not make the necessary transfers, although they received the money in advance and had all the legal and financial capabilities. On June 22, 2022 Decree of the President of the Russian Federation № 394 «On the temporary procedure for the execution of government debt obligations to non-residents and foreign creditors, expressed in government securities, the nominal value of which is indicated in foreign currency» was signed. In the above mentioned document there was the clarification of the procedure for payments on Eurobonds in rubles. The document recognized obligations under sovereign Eurobonds as properly fulfilled if they are paid in rubles in an amount equivalent to their value in foreign currency. At the same time, in order to receive ruble payments, foreign bond holders were to waive future claims against Russia. From the point of view of Western rating agencies, Russia defaulted, from the point of view of Russia, it did not. Russian Finance Minister A. Siluanov emphasizes that the use of the new mechanism for paying off debt under Eurobonds does not mean a default on external debt, since foreign counterparties refuse to make payments in foreign currency. Financial markets are faced with a unique situation: a borrower facing default has the resources and desire to repay creditors, but is unable to do so due to sanctions. As a practical matter, it is not preferable for investors to initiate lengthy and costly legal proceedings against a borrower, that is willing to service the debt, and in a situation where those investors are prohibited from receiving payments due to them. According to the Ministry of Finance of Russia, the United States and the European Union are creating artificial barriers to servicing Russian foreign debt in order to «label default». At the same time, according to the position of Bloomberg, Credit Derivatives Determination Committees (CDDS) and Moody's, Russia defaulted on its public debt. So, the question is ambiguous and will be settled in the court.

The summary of the risks, challenges and threats, discussed above is presented in the Table 2.

Table 2. List of risks, challenges, threats in public debt sphere

Risks	Challenges	Threats
<i>risks relate to all types of public borrowings:</i>	<i>general challenges, that relate to all types of public borrowings:</i>	<i>general threats that relate to all types of public borrowings:</i>
market risk, including interest rate risk and currency risks	significant decrease in state budget revenues and an increase in government spending	sanctions (freezing of the debtor's international assets, blocking of accounts)
	realization of contingent budget obligations	obstruction of the settlement of public debt
	significant deterioration in borrowing conditions	<i>threats that relate to bilateral international credits and debts to international financial organizations:</i>
	additional spending, connected with the debts (numerous commissions, including commissions for negotiations, participation, management, reservation of funds, one-time special bank commissions, commissions for guarantees, overestimation of the necessary amount of the collateral)	loss of strategically important assets pledged to secure debts, including the loss of the country's infrastructure facilities
refinancing risk	challenges in the field of cybersecurity	<i>threats, that relate to public borrowings on the securities markets:</i>
	<i>challenges, that relate to bilateral international credits and debts to international financial organizations:</i>	ban on the purchase of debt obligations
liquidity risk		creating a situation conducive to a real or technical default on debt obligations, including denial of access to the necessary infrastructure of the international debt market
credit risk	imposition of additional conditions by the creditors on debtor countries	
settlement risk		
operational risk	the need to fulfill the conditions of membership in organizations (including the provision of information on the state of the country's economy, the provision of financial resources to unfriendly states (for example, as part of membership in the IMF)	
	reduction in the value of the collateral and requirements for its replenishment	
	<i>Challenges, that relate to public borrowings on the securities markets:</i>	
	unfavorable conditions of the capital market	
	massive sales of debt obligations on the debt market (international and national)	

Source: compiled by the author. In part of the risks, the materials of IMF were used [18].

There is a need for a critical analysis of the list of the risks, challenges and threats to this or that country's national interests in the sphere of the public debt. It can be stated that currently the real situation in different countries of the world is such that challenges and threats to state economic security, including in the public debt sphere, are constantly changing and undergoing the transformations. It is necessary to regularly assess the completeness of the list of the risks, challenges and threats in the public debt sphere. The list of risks, challenges and threats should not be very general and should take into account the specifics of a particular country, as well as new phenomena and problems in the field of public debt management.

Each of the stages of «risks», «challenges» and «threats» in the sphere of public debt can be expressed by various indicators, characterizing the public debt management. Both quantitative and qualitative measurement of the conditions corresponding to risks, challenges and threats constitute an important part of the policy of ensuring national security and sovereignty.

6. Conclusion and the directions of the further research

Our answer to the research question is that the approach from another domain (security sphere) can be applied to the sphere of public debt management; and we have provided our vision of the possible calibration of risks, challenges and threats in relation to the public debt.

We also differentiated the types of borrowings and noted general risks, challenges and threats, as well as specific ones that are characteristic of certain types of debts. It was shown, that the international credits are characterized by the conditionality. In the case of borrowing on the open market using securities, the terms of borrowing depend on the current market conditions and the debtor can face significant deterioration of the situation.

In general, the challenges and threats in the area of public debt are complex. Acute indebtedness problems destabilize the entire economy of the country, that means they negatively affect national independence, create a threat to state sovereignty.

Governments search for new approaches, that provide the necessary balance between the implementation of the national interests and participation in international economic relations. So, one of the priority tasks in the field of economic security is timely forecasting of the risks and challenges and prevention of the transformation of them into the threats to the economic systems. The suggested framework of risks-challenges-threats can be helpful for the public debt problem prevention. Timely identification of risks, challenges and threats contributes to the effective management of public debt. This distinction between different conditions makes it possible to counteract the degeneration of risks into challenges, and challenges into threats. It is necessary to strive to translate threats into challenges, and challenges into risks.

As for the difficulties of the application of the suggested framework and its drawbacks, it is necessary to take into account, that risks, challenges and threats in reality can intersect and combine. In the process of the construction of this «risks, challenges and threats» framework those who do it may be subjective and have their own preferences. In this regard, an important direction for the development of this approach is such an area of improvement as getting rid of subjectivity and striving for more objective conclusions. Thus, it is necessary to further develop the criteria for classifying and distinguishing between risk, challenge, or threat. One of the directions for improving the approach is the use of various methods of collective expert assessments, which allow one to generalize the opinion of several specialists.

The findings of this paper can be useful, first of all, to the financial authorities dealing with public debt (Ministry of Finance, Central Bank, as well as the Debt Agency (if it exists in the public debt management system)).

References

1. Fiscal Monitor. Climate Crossroads: Fiscal Policies in a Warming World. International Monetary Fund. October 2023. <https://www.imf.org/en/Publications/FM/Issues/2023/10/10/fiscal-monitor-october-2023>, last accessed: 2023/10/26.
2. Global Financial Stability Report: Safeguarding Financial Stability amid High Inflation and Geopolitical Risks. International Monetary Fund. April 2023. <https://www.imf.org/en/Publications/GFSR/Issues/2023/04/11/global-financial-stability-report-april-2023>, last accessed: 2023/09/01.
3. International Debt Statistics 2022: Updated International Debt Statistics. World Bank. <https://openknowledge.worldbank.org/entities/publication/47f55cbf-ee14-531a-8acb-8e2406f4354d>, last accessed: 2023/09/01.
4. Antipova, T.: Insights from Some Governments' Budget Functional Expenditures for the Fifteen Years: 2005–2019. In: T. Antipova (Ed.): ICCS 2021, LNNS 315, 1–11 (2022). https://doi.org/10.1007/978-3-030-85799-8_6.
5. Antipova, T.: Organizational model for public sector auditing bearing in mind time factor. In: Rocha, Á., Abreu, A., de Carvalho, J., Liberato, D., González, E., Liberato, P. (eds.) *Advances in Tourism, Technology and Smart Systems*. SIST, vol. 171, pp. 297–305. Springer, Singapore (2020). https://doi.org/10.1007/978-981-15-2024-2_27.
6. Citizen Public Debt Audit Experience and methods. Auditoría Ciudadana de la Deuda Pública: experiencias y métodos. Maria Lucia Fattorelli [Brasilia: Inove Editora, 2013] and [Geneva, Liège: CETIM/CADTM éd., 2013]. 2014 for the English Edition (2013 for the original Spanish edition). http://www.cadtm.org/IMG/pdf/Audit_ENGLISH_text.pdf. Accessed 1 Mar 2021.
7. Batubara, F. R., Ubacht, J., Janssen, M.: Challenges of Blockchain Technology Adoption for e-government: A Systematic Literature Review. In: *Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age*. (2018). pp. 1–9, <https://doi.org/10.1145/3209281.3209317>.
8. Faber, A.S.C., Budding, G.T.: How to Be Open About Spending: Innovating in Public Sector Reporting in the Information Age. *Advances in Intelligent Systems and Computing*, 724, pp. 137–147 (2018), https://doi.org/10.1007/978-3-319-74980-8_13.
9. Veruhs, A.I.: Relation of categories «risk», «challenge» «threat» in the theory of national security. *Philosophical and humanities: collection. scientific articles*. - Minsk: RIVSH, 2018. - pp. 24-30. - (Scientific works of the Republican Institute of Higher Education; Issue 17). <http://elib.bsu.by/handle/123456789/207168>, last accessed: 2023/09/01.
10. Bulow J., Reinhart C., Rogoff K., Trebish C.: The debt pandemic / *Finance and development*. 2020. September. pp.12-16.
11. Reinhart, C., Reinhart, V., Rogoff, K.: Dealing with debt. *J. Int. Econ.* 96 (Supplement 1), pp. S43-55 (2015).
12. Abbas, A., Pienkowski, A., and K. Rogoff: *Sovereign Debt: A Guide for Economists and Practitioners*. Oxford University Press, New York (2019).
13. Kose, M. A., Nagle, P., Ohnsorge, F., Sugawara, N.: *Global Waves of Debt: Causes and Consequences*. Advance Edition. Washington, DC: World Bank. License: Creative Commons Attribution CC BY 3.0 IGO (2020).
14. Krasavina, L.N.: Risks in the sphere of external borrowings and problems of the Russian debt policy modernization / *Problems of forecasting*, №4, pp.116-123, (2010).
15. Battistelli, F., Galantino, M.G.: Dangers, risks and threats: An alternative conceptualization to the catch-all concept of risk / *Current Sociology*, Vol. 67(1), pp. 64–78. (2019) [ps://doi.org/10.1177/0011392118793675](https://doi.org/10.1177/0011392118793675).
16. Brauch, H.G., et al. (eds.): *Coping with Global Environmental Change, Disasters and Security*, Hexagon Series on Human 61 and Environmental Security and Peace 5, Springer-Verlag Berlin Heidelberg. (2011). DOI 10.1007/978-3-642-17776-7_2.
17. *Forecasted challenges and threats to national security of the Russian Federation and directions for their neutralization* / Edited by A.S. Korzhevsky; editorial board: V.V. Tolstykh, I.A. Kopylov. – M.: Russian state Humanitarian University, 2021. – 604 pp.
18. Revised Guidelines for Public Debt management. International Monetary Fund. April 1, 2014. <https://www.imf.org/en/Publications/Policy-Papers/Issues/2016/12/31/Revised-Guidelines-for-Public-Debt-Management-PP4855>, last accessed: 2023/09/01.
19. Tsvirko, S.E.: Digital technologies for prudent public debt management In: T. Antipova (Ed.): ICCS 2021, LNNS 315, 108–117, (2022). DOI: 10.1007/978-3-030-85799-8_10.

20. Navoi, A.V.: The Russian Federation and the International Monetary Fund: Prospects for Financial Relations at the Present Stage / *National Interests: Priorities and Security*, 2023, vol. 19, iss. 3, pp. 562–577. <https://doi.org/10.24891/ni.19.3.562>
21. Navoi, A.V.: Transforming Russia's Participation in the Global Financial Architecture in the Face of Geopolitical Challenges. *National Interests: Priorities and Security*, 2023, vol. 19, iss. 1, pp. 128–145. <https://doi.org/10.24891/ni.19.1.128>
22. Financial Sector Assessment program (FSAP) <https://www.imf.org/en/About/Factsheets/Sheets/2023/financial-sector-assessment-program-FSAP>, last accessed: 2023/10/28.
23. Dissemination Standards Bulletin Board (DSBB). <https://dsbb.imf.org>, last accessed: 2023/10/28.
24. Tsvirko, S.E.: The state of global public debt and new approaches towards debt management/ *Theoretical and applied economics*, №3, pp.46-57, (2021). DOI: 10.25136/2409-8647.2021.3.36610
25. Financing for Development in the Era of COVID-19 and Beyond (2020). UN. September 2020. URL: <https://www.un.org/en/coronavirus/financing-development>, last accessed: 2023/09/01.

Gender Differences in Perception of Artificial Intelligence-Based Tools

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Abstract. Participation of girls in Science, Technology, Engineering, and Mathematics (STEM) subjects at the higher education (HE) level continues to lag behind that of boys and consequently may affect artificial intelligence proliferation in Ghana. Numerous factors affect girls' engagement in science, one of which is the mistaken belief among girls that STEM subjects are better suited for boys. This study investigates the gender differences in AI-based tools which have become integral for teaching and learning in HE schools. Based on results from 128 students in higher education in Ghana, this article argues that gender is a significant determinant of students' use of AI-based tools in education. The results further revealed a significant disparity in the overall levels of perceived innovation characteristics based on gender. This study urges managers of Higher Education Institutions (HEIs) to implement policies and measures aimed at facilitating women's engagement and greater familiarity with AI technologies.

Keywords: Gender, Perception, Artificial intelligence.

1. Introduction

Participation of girls in Science, Technology, Engineering, and Mathematics (STEM) subjects at the higher education (HE) level continues to lag behind that of boys and consequently may affect artificial intelligence proliferation in Ghana. Numerous factors affect girls' engagement in science, one of which is the mistaken belief among girls that STEM subjects are better suited for boys. Despite the surge in artificial intelligence (AI) based tools like ChatGPT [1], one obvious question is whether males and females in higher education are equally as likely to use AI tools for their learning and research.

In recent times, the disparity in digital technology use between genders has indeed diminished; however, women still face persistent disadvantages. For instance, in today's low- and middle-income countries, a gender gap of 8 percent exists in terms of phone ownership, rising to 20 percent when it comes to smartphones [2](Highet, Skelly & Tyers, 2017). Available data reveals substantial gender disparities in ICT access, encompassing its reach, usage frequency, and information quality [11]. This digital gender gap is most prominent in the Global South, with one in five men utilizing the Internet compared to only one in seven women. For example, in Africa, women lag behind men by 25% in Internet adoption. Overall, women are 21% less likely than men to own a mobile device, the primary gateway to internet access in some developing countries [3].

While it's commonly assumed that this gender gap will naturally fade as digital technologies become more universally accessible [4], the truth is that men and women interact with digital services, including AI tools, in distinct ways. This divergence is influenced by various factors, with gendered effort and performance expectancy being a prominent element [5], and these expectations evolve at a much slower pace than technology does. Consequently, women may be downloading and visiting AI tools, but men are more likely to use them.

Higher education institutions (HEI) view women as one of the fastest-growing population segments and issues that affect their use of technology tend to affect the institutions' huge investments in educational technologies. Thus, if HEIs are equipped with the understanding of what promotes or demotivates female students from using AI-based tools, the right approach may be taken to address their expectations and meet this growing segment of AI users.

The purpose of this study is to explore the gender differences in AI-based tools which have become integral for teaching and learning in schools. Thus, the paper examines whether gender is a significant determinant for using AI tools in HEIs. The impact of gender on perception of AI tool adoption is also investigated.

2. Information Technology and Gender

For a long period, men have been associated with technology, whereas women are frequently portrayed as more passive users [6]. From the education standpoint, females have been unrepresented and noticed to have less interest in technology and technology-related application programs. Surprisingly, a growing body of evidence indicates that, in contrast to common assumptions, women are not avoiding computers.

If gender is a significant determinant of AI use, it is useful to recognize why this may be possible. The unified theory of acceptance and use of theory (UTAUT) and diffusion of innovation (DOI) theory [7] is concerned with the use and acceptance of innovation and how innovation propagates through and education system. An aspect of the theories argues that the perception of certain characteristics of technology determines its use and adoption. Usability and user experience (ease of use), perceived value (performance expectancy) and social influence are three key concepts of UTAUT that are widely supported constructs. Compatibility and perceived complexity are also mostly widely support constructs of DOI that influence use [8]. Other perceptions that determine use have also been proposed to include training and support and outcome visibility. The following constructs summarise the theory constructs of interest:

- **Usability and User Experience:** The degree to which the technology or innovation is easy to use and user-friendly. If a technology is intuitive and requires minimal training, people are more likely to embrace it.
- **Perceived Value and Benefits:** The degree to which users perceive clear benefits (e.g. increased efficiency or improved productivity) from adopting the technology.
- **Social Influence:** The degree to which the influence of peers, colleagues, and social networks can impact technology use.
- **Compatibility:** The degree to which the technology is compatible with existing systems, processes, and infrastructure.
- **Training and Support:** Adequate training and ongoing support are crucial for successful technology use and adoption.
- **Perceived Complexity and Risk:** The degree to which the technology is perceived as overly complex or risky. Users are less likely to adopt or use a complex or risky technology and HEIs must ensure that perceived risks is mitigated through clear communication.
- **Outcome visibility:** *The degree to which the technology clearly shows or proves the results or outcomes of use.*

Given the substantial evidence that potential users' perceptions of technology influence their adoption decisions [9], gaining an understanding of how these

perceptions of AI-based tools in education vary between males and females could offer insights into disparities in usage intentions.

This study seeks to investigate whether gender is a significant predictor of the use of AI tools and how perceptions of AI tools differ according to gender in HEIs. The survey's measurement scales were validated through a pilot study's data, demonstrating satisfactory psychometric properties across all scales. Subsequently, the instrument was administered to 188 participants, aged between 17 and 32 years.

3. Is Gender a Predictor of AI Use?

As shown in Table 1, a regression analysis was conducted to ascertain the significance of gender as a predictor for AI use in education. Gender is a significant determinant of students' use of AI-based tools in education. The male students were more likely (mean AI use = 3.14) than female students (mean AI use = 2.73) to use AI-based tools for learning and research.

Also significant are technology familiarity, AI usage experience, attitude towards technology and purpose of AI use ($p < 0.001$). The items of these constructs prove that familiarity and attitude toward technology do in some sense matter to the use of AI-based tools in education. Students who are more likely to use AI tools to enhance their learning experience are those with a greater AI usage experience and have a clear purpose for using the AI. Demographic characteristics such as age, length of education and web browser use were not significant predictors of AI use in education. Not surprisingly, the results also indicate that having access to the internet is a significant predictor of whether students are more likely to use AI-based tools for learning and research. Two main constructs (i.e. technology familiarity and attitude towards technology) were highly significant and AI developers and educational institutions must prioritise these and their delivery of AI-based tools.

Table 1. Regression analysis

Characteristics	Significance	Outcome
Gender	0.010	Significant
Length of education	0.112	Non-significant
Technology familiarity	< 0.001	Highly Significant
Age	0.251	Non-significant
AI usage experience	0.020	Significant
Prior technology use	0.029	Significant
Access to internet	0.018	Significant
Attitude towards technology	< 0.001	Highly Significant
Purpose of AI use	0.031	Significant
Web browser use	0.430	Non-significant

4. Do perceptions of users differ?

To examine the connection between gender and perceived innovation characteristics, a multivariate analysis of covariance (MANCOVA) was conducted. This analysis helps us determine whether there are any significant differences in the perceived characteristics based on gender. As depicted, the results reveal a significant disparity in the overall levels of perceived innovation characteristics based on gender ($p < 0.001$). Furthermore, usability and user experience, perceived value and benefits, social influence, compatibility, training and support, and perceived complexity and risk significantly differ by gender, while outcome visibility ($p = 0.521$) did not. In each instance, men perceived AI-based tools in learning more positively than women. Based on the analysis, men are more likely to intend to use AI-based tools in education for learning and research, and men's perceptions of the

characteristics of AI tools are more favourable than women. Reasons for the differences in use intentions may be due to these factors: technology familiarity and practices and attitude towards technology in general. Further research is needed to investigate the validity of these influential differences in education, however, this research provides a starting point for elaboration in the era of AI tools.

Table 2. MANCOVA outcome

Dependent variables	Significance	Outcome
Usability and User Experience	<0.001	Significant
Perceived Value and Benefits	<0.001	Significant
Social Influence	<0.001	Significant
Compatibility	<0.001	Significant
Training and Support	<0.001	Significant
Perceived Complexity and Risk	<0.001	Significant
Outcome visibility	<0.001	Significant

Generally, men think of AI and educational technology tools as more of a social learning activity than women. Thus, the traditional gender-role differences tend to describe female students as less technology-oriented, which has been stated in the literature. Also, the socialization that technology or engineering is for boys may result in less interest in computing. This attitude may degrade women towards computers, although their use is permissible to all. Since AI tools are an extension of modern-day computing, this unfavourable attitude may extend to it, thereby impacting perceptions of usability and user experience, value and benefit, complexity and risk, and compatibility. Ghana, for instance, has constructed Science, Technology, Engineering and Mathematics (STEM) high education schools to propel females' interest and interestingly, these STEM schools are located in remote communities. Although society may play its socialization to the detriment of less interest in technology, the government can change the narrative of society.

Failure to actively promote the fair and comprehensive participation of girls and women in shaping the digital and AI future of the educational system, we are essentially laying the groundwork for a digital landscape that will be devoid of richness, innovation, and fairness. We must prioritize bridging the gender gap within the AI ecosystem and make certain that the future of work is characterized by equity and inclusivity.

5. Recommendations

The outcome of the study shows that females view AI-based learning tools as less favourable than males in education. However, educational institutions can follow the following recommendations to improve female students' perception of AI-based tools.

To improve women's perception of the usability user experience, and complexity of AI-based tools is to reduce the risk of unease of use and improve the performance of AI outcomes [10] involved in using AI. If female students are aware of the ease of use of technology and the satisfactory outcome of AI tools, it lowers the risk of not using the AI tools. AI-based tools are to make life easier than before, hence new AI tools may find that following this outcome will increase the user base and success of their AI developments. Also, just like the Ghana government initiative, girls and women in STEM fields should be promoted, supported and highlighted in communities. Gender stereotypes should not exist in the education environment and all efforts should be geared towards more applied research of how AI-based tools are impacting the educational systems in general and highlighting women's role and work precisely.

This study urges managers of Higher Education Institutions (HEIs) to implement policies and measures aimed at facilitating women's engagement and greater familiarity with AI technologies.

6. Conclusion

This study investigates the gender differences in AI-based tools which have become integral for teaching and learning in HE schools. Based on results from 128 students in higher education in Ghana, this article argues that gender is a significant determinant of students' use of AI-based tools in education. The results further revealed a significant disparity in the overall levels of perceived innovation characteristics based on gender.

References

1. Ofosu-Ampong, K., Acheampong, B., Kevor, MO, & Amankwah-Sarfo, F. (2023). Acceptance of Artificial Intelligence (ChatGPT) in Education: Trust, Innovativeness and Psychological Need of Students. *Information and Knowledge Management*, 13(4), 37-47.
2. Highet, C., Skelly, H. and Alexandra T. (2017). *Gender and Information Communication Technology (ICT) Survey Toolkit*. Washington DC: USAID, <https://2012-2017.usaid.gov/documents/15396/gender-and-ict-toolkit>
3. Treuthart, M. P. (2019). Connectivity: The Global Gender Digital Divide and Its Implications for Women's Human Rights and Equality. *Gonzaga Journal of International Law*, 23, 1.
4. Bryant, J. (2022a) Digital technologies and inclusion in humanitarian response. HPG report. London: ODI
5. Eccles, J. S. (2015). Gendered socialization of STEM interests in the family. *International Journal of Gender, Science and Technology*, 7(2), 116-132.
6. Alfadda, H. A., & Mahdi, H. S. (2021). Measuring students' use of zoom application in language course based on the technology acceptance model (TAM). *Journal of Psycholinguistic Research*, 50(4), 883-900.
7. Kiwanuka, A. (2015). Acceptance process: The missing link between UTAUT and diffusion of innovation theory. *American Journal of Information Systems*, 3(2), 40-44.
8. Duan, Y., He, Q., Feng, W., Li, D., & Fu, Z. (2010). A study on e-learning take-up intention from an innovation adoption perspective: A case in China. *Computers & Education*, 55(1), 237-246.
9. Emre, D. (2019). Prospective teachers' perceptions of barriers to technology integration in education. *Contemporary Educational Technology*, 10(4), 381-398.
10. Huang, J., Saleh, S., & Liu, Y. (2021). A review on artificial intelligence in education. *Academic Journal of Interdisciplinary Studies*, 10(206).
11. Ofosu-Ampong, K., Boateng, R., Kolog, E. A., & Anning-Dorson, T. (2020, June). Examining Information Quality and Perceived Learning Performance in a Gamified Environment. In *2020 IEEE 22nd Conference on Business Informatics (CBI)* (Vol. 2, pp. 1-9). IEEE.

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Aims and Objectives

Published online by Institute of Cited Scientists (ICS), Cyprus, two times a year since 2020, Journal of Digital Art & Humanities (JDAH) is an international peer-reviewed journal which aims at the latest ideas, innovations, trends, experiences and concerns in the field of the arts & humanities. Our journal bridges the humanities, artistic, and scientific disciplines. It is a nexus for information exchange among academia and industry addressing theory, criticism, and practice.

The main goal of this journal is to efficiently disseminate original findings generated by human brain with utilizing modern information/digital technologies with multidisciplinary approach.

Topics to be discussed in this journal include (but are not limited to) the following: Art Exhibit Review; Digital Art; Digital Painting; Excerpts from Digital Technology & Applied Science; Gender differences; Public Health and Statistics in Digital Age; Record Review of Social Media; Record Review of Information Systems; Script of Digital Public Administration.

This special Issue mostly consists of selected papers presented on the International Conference on Digital Science (DSIC 2023) that was hold in Agia Napa, Cyprus on October 20-22, 2023.

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