# The Ergonomic Design of the Tower Simulator Concept for the Training Needs of Air Traffic Control Students


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***Abstract*—The main goal of this paper is to propose an ergonomic concept of the workplace for training students - air traffic controllers at the Faculty of Aeronautics Technical University of Kosice with an emphasis on a complex of ergonomic aspects that affect the efficiency of work, the level of safety, fatigue, and performance. The topic touches on 3D software, programs for modeling and design, through which it is possible to carry out the conceptual design of the simulator workplace. In the process of providing an air traffic control service, the controller as a person is the most important factor for the safety, performance, and quality of the service provided, which mainly depends on his ability, speed, and skills. The tower workplace in real traffic has its local specifics in different phases of the day, geographical orientation, layout, floor plan, and height of the tower. In the case of tower control simulation, we identify the need to design a typified workplace that can also correlate with new trends, where the main task is to create a homogenized remote tower control workplace that would reflect current legislative and ergonomic requirements and would be used in simulated and in real operation. The advantage of this workplace would be its uniformity when applying the design to other simulation centers of tower control.**



***Keywords*—3D model, remote tower, tower control simulator, air traffic control, ergonomic, design.**


## I. INTRODUCTION

Air traffic controllers provide services 24 hours a day, 7 days a week. Their work is closely connected with stress, solving unusual situations, quick decision-making, multitasking, and other factors that affect their work and with which they still have to cope. Mitigating the negative impacts resulting from their work duties is possible through advanced workplace automation. In order to ensure good performance and fulfill the work tasks of air traffic controllers in full, the issue of ergonomics when designing the work environment should be a priority. By virtual analysis of the workplace before its physical design, we can anticipate possible shortcomings that are important for the correct design of workplaces [1]. Nowadays, the ergonomics of the working environment is an important element not only of the working environment but also of social life [2]. The main goal of the article is to propose an ergonomic concept of the workplace for training students - air traffic controllers with an emphasis on the complex ergonomic aspects that affect the efficiency of work, the level of safety, fatigue, and performance, through computer modeling and 3D visualizations using digital software based on a summary of legislative requirements, new trends and a survey of experts' opinions. The research is aimed at finding answers to 2 research questions:

**Research question 1:** Is it possible to use digital 3D software to optimize the workplace of air traffic controllers and solve its shortcomings?

**Research question 2:** What are the possibilities of verification of the proposed model?

The design of workplaces and other different types of workplaces, assuming high performance, must respect the principles protecting health and safety at work. Achieving creativity, high productivity, quality, and flexibility requires an understanding of the factors resulting from the complex interaction of subsystems and the impact of the surrounding environment and the workplace itself on the person (employee), his mental well-being, and performance [3]. In addition to the surrounding work environment, it is also necessary to improve work tools and aids, not only from a functional but also an aesthetic point of view. This requires knowledge sharing and process integration. When designing a workplace, problems associated with the use of anthropometric data necessary for optimal workplace design are solved. The size of the workspace and a suitable working position for work is determined. This is also related to setting the optimal working height and ensuring optimal visual conditions during work, as well as the selection of suitable work seats [4]. Furthermore, when designing a workplace, the layout of the workplace is important. At the workplace, work is designed regarding the principles of the economy of movements, i.e., that the layout of notification and control elements is also proposed. The movement space for the work of the hands (manipulation space) and for the work of the feet (pedipulation space) determines the location of individual elements of the workplace equipment[5]. Excessive sitting while performing work tasks causes musculoskeletal disorders that are quite often encountered by air traffic controllers. It is primarily caused by non-ergonomic sitting, which can cause musculoskeletal problems, load on the upper and lower limbs, upper and lower back pain, and hand and finger movement disorders [6].

## II. THEORETICAL BACKGROUND

In this section, we consider it necessary to first identify the important factors of the work environment of air traffic controllers and to define the basic requirements for work environments in connection with national standards. We focus on one of the most current trends in air traffic control - Remote Tower, as this technology is currently being tested or introduced by several countries. Remote Tower is a new dimension in the provision of ATC services, and therefore it


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is necessary to consider simulators for training personnel for this type of air traffic management. Summarizing new trends, factors of the working environment, and legislative requirements for workplaces will allow us to create a comprehensive idea of the concept of the simulator workplace.

*A. Factors of the air traffic control work environment*

We can understand the work environment as a set of conditions in which work is performed. These factors affect the health and work performance of a person in the work process and can be influenced by the work regime, rest, and also the technical equipment of the work environment. Important factors that need to be mentioned are:

- Lighting: lighting and color adjustments of the work environment can emphasize or suppress, improve, or worsen human perception. At the workplaces of the airport tower, the lighting changes throughout the day. In the area control and radar control workplace, the light is controlled and maintained at the same rate all the time.

- Colors: they have a great influence on a person's emotional mood. In general, desaturated, and pastel colors should be used on air traffic control displays, while saturated colors are the only choice for important and temporary information [7].

- Microclimatic conditions: include heat, cold, humidity, air flow, and radiant temperature of equipment, material, and walls. Violation of the thermal balance negatively affects the thermoregulatory processes of ATC. As a result, fatigue increases, sensitivity, attention, and flexibility of thinking deteriorate, which is reflected in decision-making processes, performance, and quality of work.

- Noise: Noise in the working environment of ATC is disruptive, unnerving, makes communication difficult, and causes e.g., loss of concentration or increased error rate.

- Ergonomic sitting/working position: air traffic controllers usually spend their work time sitting. Non-ergonomic sitting causes skeletal muscle problems, strain on the upper and lower limbs, upper and lower back pain, hand, and finger movement disorders. In the case of problems with the musculoskeletal system, it is mainly spinal pain [8].

*B. National standards on the issue*

Computers and display units are among the most frequently used elements in the performance of air traffic control tasks. Computers are an everyday part of the working environment of the ATC service. The basic requirements for equipment, work environment, and software for workplaces with display units are defined by the Regulation of the Government of the Slovak Republic № 276/2006 [9]. Regulation of the Government of the Slovak Republic № 391/2006 on minimum safety and health requirements for the workplace defines that the tabletop or work surface must have sufficient dimensions (length at least 1,200 mm and width at least 750 mm), a surface with low light reflectance. At a stable height of the worktable, on which the employee performs most work operations, the height must correspond to body dimensions (650 mm for women, 750 mm for men). If the height of the worktable is adjustable, the adjustment range should be between 650 and 750 mm [10]. In general, the principles of prevention and basic conditions for ensuring safety and health protection at work and for the exclusion of risks and factors conditioning the occurrence of occupational accidents, occupational diseases, and other occupational health damage are defined by Act №124/2006. Act №355/2007 on the protection, promotion, and development of public health defines the requirements for the protection of employees from noise at work, lighting at work, health protection from physical stress at work, and mental workload, which also needs to be considered when planning the workplace concept.

*C. Remote Tower as a current trend in air traffic control*

The renewal of ATM tools is essential for development and optimization in the context of fluent flow in air traffic management. The adoption of next-generation technologies has become essential in supporting congested and complex airspace. New technologies bring a paradigm shift in air traffic management. Digitalization is a priority in this new dimension. New technological trends are aimed at supporting the improvement of the training process of air traffic controllers and increasing the quality of simulator training. Currently, one of the most popular trends in the world is Remote Tower technology. Remote Tower – is a concept that allows air traffic services to be provided at the airport remotely or from any location, without direct visual contact with the tower windows.

Fig. 1. Example of a Remote Tower workplace in Budapest. Source: HungaroControl

The technology allows tower air traffic controllers to perform visual surveillance using digital devices based on direct visual capture and reproduction through cameras. Monitoring takes place with the support of a digital network, and the display from the camera sensors is transmitted to the operator's screen. It is used by navigation service providers in several countries such as Avinor (Norway), NavCanada (Canada), DFS (Germany), Hungarocontrol (Hungary), FAA (USA), LVF (Sweden), LVNL (Netherlands) [11].

The workplace of the Remote Tower is usually one large display for visual presentation and one workplace is used for one control flight operation. The main elements of the workplace controlling the remote tower are flight strips (in digital or paper form), voice communication system, meteorological information (represent a special screen with current weather information, weather forecasts, actual pressure, direction and wind speed and others), radar information in controlled airspace, systems for managing and monitoring the status of flights, airports navigation devices (radar, ILS, PAPI, VOR), warning systems and alarms,

runway lighting, control panel of airport lighting systems and PTZ cameras, data recording and backup systems [12].
We perceive the issue of the working environment of ATCo as part of the agenda of safety and smoothness of air traffic and safety management in aviation, which were addressed by our faculty in separate scientific works [12].

Fig. 2. Example of a Remote Tower workplace in Leipzig. Source: DFS

## III. Materials and Methods

In Slovakia, the implementation of Remote Tower is very current and we can consider it a trend. LPS SR, a provider of air navigation services in Slovakia, concluded a contract with DFS Aviation Services (DFS Deutsche Flugsicherung; DAS) to provide operational consultancy for the possible integration of Remote Digital Towers in Slovakia. In addition, a Remote Digital Towers solution feasibility study was developed, creating a business study for Remote Digital Towers [13]. This means that soon, we can expect the first attempts to use the technology in real operation. The preparation and training of personnel in Slovakia for this technology are very interesting and relevant for us from the point of view that the Faculty of Aeronautics Technical University of Košice conducts basic theoretical training for air traffic controllers as an approved ATCo training organization. This training also includes practicing practical skills on the simulators that we have, and which need to be modernized in terms of ergonomics. The new workplace could correlate with current trends and be uniform for use in simulated and real operations. A simple adaptation to the environment from a simulated operation to a real one would be ensured by the uniformity of the workplace. Since the tower workplace in real operation has its local specifics (e.g., in different phases of the day, geographical orientation of the tower and its height, floor plan), the typified workplace of the Remote Tower simulator could be beneficial for application in real operation and other simulation centers due to its uniformity.

### *A. The current state of the tower simulator at the Faculty of Aeronautics Technical University of Košice*

Currently, the air traffic control simulator department at the Faculty of Aeronautics does not have a tower simulator. Training of practical skills in tower control takes place in the form of procedural control at radar workplaces. The workplaces consist of a working console, means of communication, radio stations, and two attached monitors in the upper and lower part of the workplace. Monitors are used to display time and airspace maps during procedural control. The height of the worktable is 65 cm, the width 120 cm and the depth 60 cm. Seating is provided by an office chair without armrests. Since our institution is a certified organization for providing basic theoretical ATC training, we are interested in improving our simulation center and creating the concept of a new tower simulator for the needs of training new ATCs with a focus on ergonomics. This workplace forms the input for our research, and we will try to optimize this workplace so that it correlates with current trends in ergonomics and meets the requirements for the mandatory equipment of Remote Tower workplaces.

Fig. 3. Example of ATC simulator workplace at the Faculty of Aeronautics of TUKE. Source: own

Considering this fact, the goal was to obtain an expert opinion about the current ergonomic state of simulators online Google Forms questionnaire to find out what parts of the workplace need to be improved and modernized. Experts evaluated the workplace with the help of ergonomic questions.

### *B. Obtaining an expert opinion on the current ergonomic status of the ATC simulator*

The sample consisted of 25 expert graduates of the certified ATC basic theoretical course at the Faculty of Aeronautics, who hold a class 3 health certificate according to Commission Regulation (EU) 2015/340 [16]. Each of them completed at least 15 hours of practical exercises on the simulator as part of the course and received a rating of more than 75% in the professional subjects of the course. Professional subjects include the Professional Environment subject, which includes the ergonomics of ATCo workplaces. Our goal was to formulate ergonomic questions related to the concept of the tower simulator workplace at the Faculty of Aeronautics. The research of Y. Liu and H. Jin [17] helped us to divide the questions into blocks, the answers to which could help us to find out the critical places of the procedural workplace. One of the important tasks was to find out the anthropometric parameters of the respondents to use this data in the future for verification. We plan that the next step will be the design proposal of the ergonomic workplace and then its verification through simulations using the typical anthropometric parameters of the respondents.

### *C. Structure of the questionnaire*

The questionnaire contained a total of 16 questions aimed at evaluating the hardware structure of the simulator workplace. The first block of 3 questions for the respondents was intended to find out information about the gender, height, and weight of the respondents. The answers from this part of the questionnaire represented numerical values of approximate height, weight, and a verbal answer about gender (male/female). Height scaling was from 150 to 190+ (and more centimeters). Weight scaling from 50 to 90+ (and more

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kilograms). Another block of questions was intended to determine satisfaction with the workplace of the simulator, and these questions had answer variants on a scale from 1 to 5, where 1 meant complete satisfaction with the workplace and 5 complete dissatisfaction. Ergonomic questions and scaling are shown in the table below. All these questions had the same answer options.

TABLE 1. ERGONOMIC QUESTIONS OF THE QUESTIONNAIRE. SOURCE: OWN

| Question №: | Answer options (Scaling) |
|---|---|
| 4. I think that the dimensions of the work surface of the table are satisfactory for me. | 1. I completely agree<br>2. I rather agree |
| 5. I think that the height of the worktable is suitable for my physical size. | 3. I don't know<br>4. I rather disagree |
| 6. The space for the legs (pedipulation space) is sufficient. | 5. I completely disagree |
| 7. I think the objects (phone, flight strips, maps) on the table are in sufficient range. | |
| 8. The form of the chair for sitting is satisfactory for me. | |
| 9. The work chair (adjustable height, inclination of the sitting surface, armrests) is satisfactory for me. | |
| 10. I can adjust the chair to my physical size. | |
| 11. I think that a reasonable position of the shoulders and spine is allowed when sitting. | |
| 12. I think the top edge of the monitor is slightly below eye level (eye level at most). | |
| 13. The diagonal of the screen is more than 17'' and it is satisfactory for me. | |
| 14. I can adjust the monitor (adjustable height, tilt of the monitor, rotation of the monitor). | |
| 15. The location of the keyboard allows the upper limbs to rest freely. | |
| 16. I think that the design of the mouse is comfortable to use and enables all functions. | |

## IV. RESULTS

After filling out the questionnaire by the experts, the input data was exported in the form of an Excel file. Using Excel, we decided to process this data and create an overview of the ergonomic situation at the tower workplace in the form of tables and graphs. We assume that, based on these data, it will be possible to find out what needs to be focused on when designing the design of a typical Remote Tower simulator workplace. We will provide a design 3D design of the simulator concept using the PRO100 software, taking into account current trends and mandatory workplace equipment.

### A. Evaluation of questionnaire responses

From the first question via Google Forms, we found that out of 25 respondents, 19 (76%) were men and 6 (24%) were women. The second question was about the height of the respondents. The answer shows that 2 respondents have a height of 150-160 cm, 5 respondents - 160-170 cm, 9 respondents - 170-180 cm, 6 respondents - 180-190 cm, 3 respondents - 190 cm and more. In this part, the result was common for both men and women, which is not entirely clear to us.

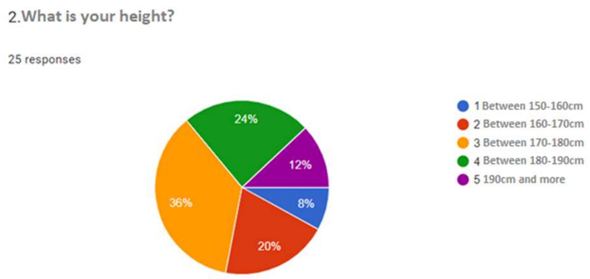


Fig. 4 Evaluation of question № 2. Source: own

The third question was about the weight of our respondents. The answers show that 6 respondents weighed 50-60 kg, 6 respondents - 60-70 kg, 5 respondents - 70-80 kg, 5 respondents - 80-90 kg, 3 respondents - 90 kg and more. From this graph, we cannot identify exactly who had what weight according to gender, and this graph is not completely clear for our evaluation.

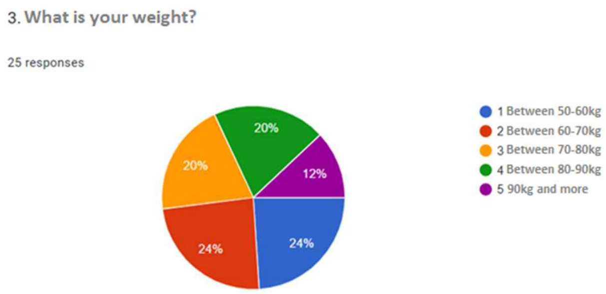


Fig. 5. Evaluation of question № 3. Source: own

The disadvantage of the Google Forms tool is the fact that it exports results to graphs comprehensively without partial specifications. It is convenient for us to do a detailed analysis by manual data processing in the form of a table. We specified all answers using Excel. A Google Forms source file was used in Excel to split the respondent response into male and female, including individual height and weight. Considering the scoring from 1 to 5, it was possible to color separate the questions in the left part of the table, where 1, according to the answer option, was complete satisfaction with the workplace, and 5 indicated dissatisfaction.

| QUESTION № | | | | | | | | | | | | | | | | TOTAL | RESPONSES FREQUENCY | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | Completely agree | Rather agree | Don't know | Rather disagree | Completely disagree |
| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. | | 1 | 2 | 3 | 4 | 5 |
| Man | 170-180 cm | 70-80 kg | 3 | 2 | 5 | 2 | 1 | 4 | 4 | 4 | 5 | 4 | 2 | 4 | 2 | 42 | 1 | 4 | 1 | 5 | 2 |
| Man | 170-180 cm | 60-70 kg | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 15 | 11 | 2 | 0 | 0 | 0 |
| Man | 180-190 cm | 80-90 kg | 4 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 1 | 20 | 9 | 2 | 1 | 1 | 0 |
| Man | 180-190 cm | 70-80 kg | 3 | 4 | 4 | 2 | 2 | 5 | 5 | 5 | 4 | 4 | 2 | 5 | 2 | 47 | 0 | 4 | 1 | 4 | 4 |
| Man | 160-170 cm | 50-60 kg | 1 | 2 | 2 | 2 | 2 | 4 | 5 | 5 | 4 | 4 | 2 | 4 | 4 | 41 | 1 | 5 | 0 | 5 | 2 |
| Man | 190 cm and more | 90 kg and more | 5 | 2 | 4 | 4 | 1 | 4 | 2 | 3 | 4 | 2 | 1 | 4 | 1 | 37 | 3 | 3 | 1 | 5 | 1 |
| Man | 180-190 cm | 70-80 kg | 3 | 1 | 2 | 2 | 1 | 4 | 4 | 3 | 4 | 2 | 2 | 2 | 2 | 32 | 2 | 6 | 2 | 3 | 0 |
| Man | 160-170 cm | 60-70 kg | 2 | 2 | 2 | 2 | 2 | 5 | 5 | 5 | 4 | 5 | 1 | 3 | 4 | 42 | 1 | 5 | 1 | 2 | 4 |
| Man | 170-180 cm | 60-70 kg | 2 | 1 | 4 | 1 | 1 | 4 | 3 | 1 | 1 | 2 | 5 | 2 | 5 | 32 | 5 | 3 | 1 | 2 | 2 |
| Man | 160-170 cm | 50-60 kg | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 19 | 7 | 6 | 0 | 0 | 0 |
| Man | 170-180 cm | 60-70 kg | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 20 | 8 | 3 | 2 | 0 | 0 |
| Man | 190 cm and more | 90 kg and more | 5 | 2 | 5 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 5 | 1 | 27 | 8 | 2 | 0 | 0 | 3 |
| Man | 180-190 cm | 80-90 kg | 4 | 5 | 3 | 5 | 2 | 3 | 2 | 2 | 1 | 4 | 3 | 3 | 3 | 40 | 1 | 3 | 5 | 2 | 2 |
| Man | 180-190 cm | 80-90 kg | 4 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 5 | 1 | 26 | 7 | 2 | 2 | 1 | 1 |
| Man | 170-180 cm | 80-90 kg | 4 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 4 | 4 | 2 | 3 | 29 | 4 | 5 | 1 | 3 | 0 |
| Man | 170-180 cm | 60-70 kg | 2 | 4 | 4 | 1 | 2 | 1 | 1 | 1 | 3 | 2 | 1 | 5 | 2 | 29 | 5 | 4 | 1 | 2 | 1 |
| Man | 180-190 cm | 50-60 kg | 1 | 2 | 2 | 4 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 19 | 9 | 3 | 0 | 1 | 0 |
| Man | 190 cm and more | 90 kg and more | 5 | 4 | 5 | 2 | 2 | 2 | 2 | 4 | 2 | 4 | 2 | 2 | 4 | 40 | 0 | 7 | 0 | 4 | 2 |
| Man | 170-180 cm | 70-80 kg | 3 | 4 | 4 | 4 | 1 | 1 | 1 | 1 | 1 | 4 | 2 | 3 | 2 | 31 | 5 | 2 | 2 | 4 | 0 |

Fig. 6. Evaluation of questions – male. Source: own

In the left part of the table, the respondents' answers are given, whereas, in the first three columns, we can find out the gender of the respondent, his approximate height, and approximate weight. The answers to ergonomic questions 4 to 16 in the table make it possible to find out the critical places of the workplace and what the respondent was not satisfied with according to the question number. Critical values in this part of the table are highlighted in red, less critical in yellow,

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and non-critical in green. Points for the questions are counted in the TOTAL column. The maximum value of dissatisfaction in questions 4 to 16 is 65 points (13 questions of 5 points max). Values above 32 points are important for us, as they represent half the level of satisfaction with the workplace. The second part Responses Frequency indicates the frequency of the response. The color marking of the frequency is based on the same principle, so that the red value does not represent a critical value for us, but highlights in red the largest answer number, as it was in the first part of the table. In this case, we are interested in columns 4 and 5. Among the six male respondents, the greatest dissatisfaction was in questions 9 to 13. These are questions about the work chair and the sitting position, the position of the monitors along with their dimensions. The respondents had approximately the same weight of 70-80 kg, the difference was only in their heights. In seven male respondents in question no. 4, we identified dissatisfaction with the dimensions of the work surface. Five expressed dissatisfaction with the work desk question. Eight were not satisfied with the pedipulation space.

| QUESTION № | | | | | | | | | | | | | | | | TOTAL | RESPONSES FREQUENCY | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | Completely agree | Rather agree | Don't know | Rather disagree | Completely disagree |
| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 15. | 16. | | 1 | 2 | 3 | 4 | 5 |
| woman | 150-160 cm | 50-60 kg | 1 | 2 | 2 | 2 | 2 | 4 | 5 | 5 | 5 | 4 | 2 | 4 | 1 | 39 | 2 | 5 | 0 | 3 | 3 |
| woman | 170-180 cm | 50-60 kg | 1 | 4 | 4 | 4 | 2 | 2 | 2 | 3 | 1 | 1 | 3 | 3 | 2 | 32 | 3 | 4 | 3 | 3 | 0 |
| woman | 160-170 cm | 60-70 kg | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 21 | 5 | 8 | 0 | 0 | 0 |
| woman | 160-170 cm | 70-80 kg | 3 | 2 | 4 | 4 | 2 | 1 | 1 | 1 | 2 | 2 | 1 | 3 | 3 | 29 | 4 | 4 | 3 | 2 | 0 |
| woman | 170-180 cm | 80-90 kg | 4 | 1 | 3 | 2 | 1 | 2 | 2 | 2 | 1 | 3 | 1 | 1 | 1 | 24 | 6 | 4 | 2 | 1 | 0 |
| woman | 150-160 cm | 50-60 kg | 1 | 1 | 3 | 2 | 3 | 2 | 2 | 1 | 2 | 2 | 3 | 1 | 2 | 25 | 4 | 6 | 3 | 0 | 0 |

Fig. 7. Evaluation of questions – female. Source: own

Women had less dissatisfaction with the hardware equipment of the workplace. Only one woman had the same answers to questions no. 9 to 13 as the group of men. Some of them were mainly dissatisfied with the height of the desktop, insufficient pedipulation space and reach to objects on the table. Almost all the women in question no. 4 were satisfied with the height of the tables, except for one. In both cases, we consider it necessary to incorporate the dissatisfaction of the questionnaire respondents into the resulting 3D design and approach this task more comprehensively.

## V. Discussion

From the available sources and graphic materials, we analyzed the Remote Tower workplaces from Avinor in Norway, Hungarocontrol in Hungary, DFS in Germany, LVF in Sweden. The analysis allowed us to summarize all mandatory workplace elements and information that must be displayed on air traffic controllers' screens. The modeling of the new workplace was carried out using the PRO100 software. We chose this software due to its availability and ease of use. Most design operations can be done quickly. Each object has exact dimensions. Answers from the questionnaire point to a lack of desk space and its height did not suit several respondents. In a new concept, we have created a new desktop with a round shape using the PRO100. The dimensions are based on the dimensions of the premises of our simulation center, and PRO100 allows you to change them in online mode, and the object will also change automatically. The desktop will have the possibility of height adjustment from 70 cm to 145 cm, which will allow working while standing. The lack of pedipulation space can be solved by increasing the depth of the table to 71.5 cm.

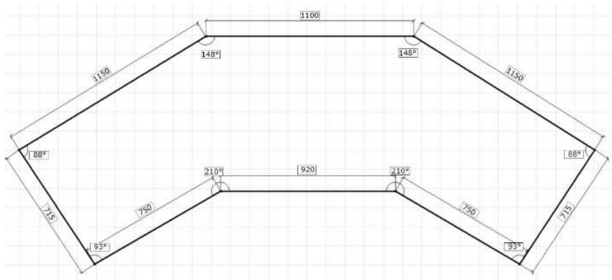

Fig. 8. The dimensions of the work surface of the table. Source: own

The next step is the modeling of systems and equipment that must be present at the Remote Tower workplace. When modeling, our priority is a seven-monitor display with a location in front of the work desk with a basic display of the airport's runways. The three-monitor display serves as an alternate display with the option to switch the screen to other airport cameras.


Fig. 9. Ergonomic 3D model of the Remote Tower simulator. Source: own

The main display on desktop is provided by three 32-inch height-adjustable monitors. The air traffic controller can zoom in or switch the display at any time. To increase situational awareness, a 32-inch touch display is placed in the center of the work surface, which, in addition to radar data, contains the view from the ground radar at the airport and digital flight strips.

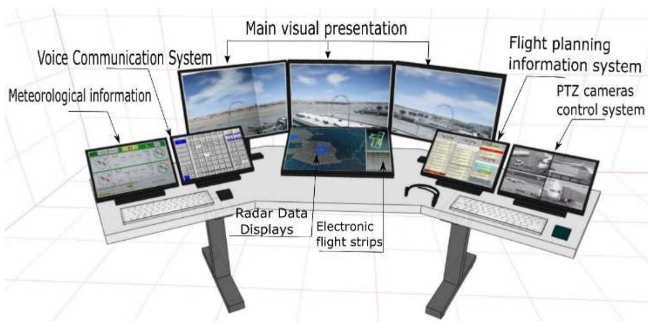

Fig. 10. Remote Tower workplace equipment. Source: own

A secondary element of the workplace model is a touch voice communication system. The device is a 17-inch monitor and consists of digital stations and represents individual working frequencies intended for flight coordination. Another mandatory element of the tower simulator is the meteorological information system, intended for obtaining an overview of the current weather at the airport. This system in our model is a 17-inch monitor with information on wind direction and speed, runway in use, current QNH, and other

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relevant information. Operational flight planning information is available in the flight plan information system. This system in our model is designed as a touch 17-inch monitor. In this system, in addition to flight plans, it is possible to receive detailed messages regarding airspace management, detailed notes about flights via the AFTN network. For camera control, the last element of the model is the proposed PTZ camera control system. It is intended for obtaining additional information from aircraft stands, taxiways at night, or in fog and is a substitute for binoculars. The model of this system is presented with a 17-inch overview monitor with the option of dividing the display according to the number of cameras. The main philosophy of this design is to have all the printed maps, manual flight strips, printed regulations, and other staff in digital form in one place.

## VI. CONCLUSION

The great advantage of 3D tools is that during the design and subsequent analysis of workplace concepts, it is possible to optimize ergonomics, specific shapes, and geometry even before the start of production itself, facilitate the imagination of models, significantly reduce the time needed for design and adapt the dimensions of objects according to needs. The working position of 3D Remote Tower concept will be able to be adapted with respect to anthropometric parameters, through the height adjustment of the table and monitors. The layout of the displays depends on the frequency of viewing information from them. The main three-monitor display is in the center of the field of view. Meteorological information is on the edge, as it has a lower tracking frequency than, for example, radar information, which is in the center of the field of view on the tilting monitor. The voice communication device is located as close as possible, and its usability, both in simulated and real operation, is quite high. With the help of the PRO100 software, we found out how it is possible to design a workplace model using 3D visualizations. We found that the dimensions and shape of the object can be changed in online mode so that the object will automatically change. For us, it is very important, as the dimensions and shape of the objects in the future can be adapted to the dimensions of the spaces in which they can be placed. The data from the questionnaire helped us to determine the mean height and weight of women and men to further achieve the figure model and validate our proposed workplace. For men, the most frequent height was 170-180cm and weight 70-80kg. Due to the smaller representation of women, we will determine 160-170 cm height and 50-60 kg weight as the middle value. We plan to carry out the verification in further research using the Siemens Tecnomatix Jack ergonomic software. Simulations of ergonomic risks in the upper limbs, neck, and trunk by the RULA method using typical models (male/female) can help in verifying the correctness of the desk and monitor concept design.

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