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MEASURMENT OF TIMBERIN IN PERSPECTIVE OF TIME AND HUMAN RESOURCE MANAGEMENT

Piotr CIEPLUCHA

Akademia Wymiaru Sprawiedliwości; piotr.cieplucha@aws.edu.pl, ORCID: 0009-0000-9216-4392

Purpose: The implementation of new work tools is an important factor affecting the way of time and human resources management. As a rule, such actions are preceded by a series of studies that are intended to provide answers to questions regarding the degree of usefulness or the need to modify solutions. The purpose of this paper is to verify the impact of the use of photo-optical measurement of wood raw material on the way forest management is conducted.
Design/methodology/approach: This paper covers the analysis of source documents – reports from tests carried out in connection with the implementation of photo-optical measurement of wood raw material by the State Forests in Poland. The study focused on aspects related to the impact of the new measurement method on the way of time and human resources management in the State Forests.
Findings: The studies of tools and applications for photo-optical measurement of timber material have shown that the use of the method in question can significantly contribute to the reduction of the working time, thus changing the way human resources are managed, both in the State Forests and in companies of the timber industry. An analysis of the tests carried out abroad also yields similar conclusions. Possible errors and shortcomings of individual applications have been addressed by manufacturers over the years. In addition, further development of the tools in question, which we consider as part of precision forestry, is anticipated.
Research limitations/implications: If research is reported on in the paper, this section must be completed and should include suggestions for future research and any identified limitations in the research process. Introducing the necessary modifications, eliminating the shortcomings and integrating the tools with the information systems currently used in the State Forests National Forest Holding are the most important measures to be taken in order to ensure the widespread use of the measurement method in question. The possible decision of the State Forests management to implement the method of photo-optical measurement of timber at the RDSFs, forest districts and Forest Service Companies, will require appropriate internal legislative regulations at the level of the institution.
Practical implications: Process of implementation the photo-optical method in the current forest management should be a priority in the near future, especially with the increasing volume of timber acceptance work.
Social implications: State Forests employees themselves positively evaluated the new opportunities provided by the new photo-optical measurement applications. This was shown by opinion surveys conducted among employees.

Originality/value: This article is the first attempt to verify the impact of the implementation of the photooptical method of measuring wood raw material on the management of time and human resources.
Keywords: photo-optical measurement, forestry, State Forests, time management, human resources management.
Category of the paper: research paper.

1. Introduction

Technological advances generally lead to changes in the way individual entities and processes are managed. The implementation of new solutions in the area discussed herein most often results in a reduction of the time required to perform specific activities, and enables more efficient use of human, organizational and, in the case of production, material resources. The 21st century and the last years of the past century have been a period of rapid development of information technology tools. which play a dominant role in many industries today.

One example is the photo-optical measurement method. Although its roots can be traced back to 19th-century photogrammetry, it started to develop on a wider scale in the 1990s, with the spread and growth of digital techniques. Nowadays, it has more and more applications, especially in forestry and the timber industry. The labour intensity required to measure the logs on a pile so as to determine timber volume has provided the stimulus for the search for more efficient solutions than those used so far (Stempski, 2021, p. 110). An additional advantage is the availability of the tool in question, which, with today's capabilities, can be used with cell phones that have a built-in camera.

The State Forests National Forest Holding (SFNFH) has commissioned a series of tests to demonstrate the feasibility and conditions for implementing photo-optical measurements in forest management. If certain conditions are met, measuring and calculating the parameters of stacked wood using photo-optical measurement (Michalec, Wąsik, 2020, pp. 49-50) may prove to be a more accurate and faster method than traditional measurements. In the conditions prevailing in Poland, applications and methods that are already in use, especially in Germany and Scandinavian countries, were tested. The demand for timber from timber industry companies, which is growing year after year, stimulates the creation of fast and accurate methods for measuring it. Therefore, the State Forests are carrying out research into new tools that can be used in the process in question (Grobelny, Buźniak, Szewczyk, 2018, p. 12). In this regard, it should be noted that so far the State Forests National Forest Holding has not made a final decision on the full and widespread implementation of the method in question. However, the expenditures made to implement the project in question allow us to assume that eventually the senior management of this institution will take further steps in this direction. Timber measurement activities are not highly complex. However, they require a relatively large

amount of time. At present, photo-optical measurements are mainly used in Poland's timber industry to control the volume of the raw material before purchase and to carry out its inventory at the depot (Tomczak, Naskręt, 2022, p. 3).

The implementation of photo-optical measurement of wood raw materials will significantly change the way of managing time and human resources. This change constitutes the optimization of production processes in forest management.

The principal objective of this article is to analyse the results of the research and tests that have been carried out in connection with the intention to introduce the photo-optical method of measurement of timber raw material. Based on the information gathered, conclusions will be drawn on how this process can change the way time and human resources are managed in the State Forests. Accordingly, quantitative methods were used in the analysis of secondary data from studies and surveys carried out by the Office of Forest Expert Analysis and Technology of the State Forests Development and Implementation Centre in Bedoń. These activities were commissioned the General Directorate of the State Forests. At the same time, an analysis was conducted of the results of opinion surveys carried out on a group of foresters who tested the measurement application in two forest districts.

2. The development of photo-optical measurement and its applications

Photogrammetric measurement, from which the photo-optical measurement technique has evolved, is a process of acquiring geometric data on objects using photographs or camera images. It involves using photo analysis techniques to measure the distance, height, area and shape of objects based on their images. A key element of photogrammetric measurement is the use of stereoscopic technology, which involves analysing two or more photos of the same area taken from different viewpoints. In this way, it is possible to reproduce the three-dimensional structure of objects and determine their dimensions and position (Kuczyński, 2014, pp. 15-16).

One of the basic criteria for classifying a measurement is the circumstances in which the photos are taken. Consequently, one can distinguish aerial photogrammetry, which uses special cameras mounted on aircraft, such as planes or drones, to photograph an area from a high altitude. Then, using special software, the photos are processed into three-dimensional terrain models or maps. Terrestrial photogrammetry, on the other hand, is characterized by the use of photographs taken from the ground, such as from a camera on a tripod or a mobile camera. These images are analysed to obtain information about the objects in the photos (Kuczyński, 2014, p. 19). The images taken and photogrammetric data collected are processed with special software, which allows to analyse images, take measurements and generate three-dimensional models of terrain or objects.

The photogrammetric measurement method is widely used in many different fields, which include surveying, cartography, urban planning, archaeology, forestry, construction and production of computer games. This makes it possible to obtain precise data on the shape, size and position of objects from their images. Thus, photogrammetric measurement is an extremely important tool for acquiring geometric data using photographs or images, which is used in various fields of science and in practical applications. In forest management, this method is used to scan forest areas with cameras attached to aircraft. Recently, the use of drones for this purpose has become increasingly popular, as it allows to monitor a variety of parameters related to the functioning of forest areas (Lummitsch et al., 2019, p. 1).

The photogrammetric and photo-optical measurement methods use optical imaging to acquire spatial data, but they differ in terms of their technical details and applications. One should bear in mind that photo-optical measurement, as a technique that uses optical imaging, has its roots in the photogrammetry technology, which was developed in the 19th century (Kuczyński, 2014, p. 23). However, modern photo-optical measurement systems, such as those used in forestry to measure timber, began to be used much later - at the turn of the 20th and 21st centuries, thanks to the development of the digital and mobile technologies.

Photo-optics is the use of optical technologies and photographs to acquire data and take measurements, often in an industrial or terrain context. It uses standard cameras, often integrated with mobile devices (smartphones, tablet computers), to take measurements without the need for special equipment, which is required by the photogrammetric. Image analysis, which is the next stage of the process, is often automated and performed in real time using mobile applications. Photo-optics is used in forestry for measuring timber stacks and assessing the quality of the raw material, as well as for monitoring forest resources. It popular technique is also used in the timber industry, in warehouses and during the transportation of timber. It uses applications that process photos and perform calculations directly on the mobile device (Majerowski et al., 2017, pp. 20-22). The most popular applications include Timbeter, iFovea Pro and Trestima. They can be used on smartphones with the Android and iOS systems. However, there is also software such as LogStackPro and sScale (Dralle) that cannot be used on mobile devices (Tomczak, Naskręt, 2022, p. 4). The latter uses a device attached to the roof of a vehicle. The vehicle used to take measurements with the Dralle software moves at an average speed of 5-10 km/h. Weather conditions do not affect the results in this case (Pachuta, Chojnacki, 2018, p. 16).

The principle of operation of the photo-optical technology involves the use of cameras and sensors to capture images of timber. The measurement is taken on a proper stack of wood (Pachuta, Chojnacki, 2018, p. 14). The measurement itself, regardless of whether it is done by traditional or photo-optical methods, must be taken the basis of established grading rules and formulas that determine, for example, the thickness of the raw material (Ślęzak, 2006, p. 5). The images are then processed by special software that analyses the characteristics of the timber, such as thickness, length, diameter, and even the quality and type of timber. This makes

it possible to quickly and accurately determine the quantity and quality of the timber, which can contribute to more efficient management of forest resources, optimization of production processes in the timber industry and minimization of waste. Photo-optical measurement of timber raw material can use various technologies, such as laser technology, high-resolution cameras, vision systems, and 3D scanning technologies (Cremer et al., 2018, pp. 127-130).

However, it is important to keep in mind that despite its many advantages, there are some challenges associated with this technology, such as the need to calibrate the measurement systems and adapt to different types of timber, and the need to continuously improve image analysis algorithms. At the same time, with the advances in science and technology, the technology of photo-optical measurement of timber raw material is constantly developing and becoming more precise and versatile.

3. Studies of the feasibility of using photo-optical measurement in the activities carried out by the State Forests National Forest Holding

3.1. Activities of the State Forests

Forests play an extremely important role in people's lives. They have accompanied humans since the beginning of history and were initially treated as an inexhaustible source of resources and food. It was only with time that forest management began. In Poland, its origins are thought to date back to the First Republic. Currently, we can consider that forests have three basic functions: ecological - by regulating and stabilizing the climate and the water resources, preserving biodiversity and reducing pollution; economic - primarily by being a source of timber; and social, as a place for leisure, tourism and education. The very definition of a forest today is set forth in legislation. The Forests Act of 28 September 1991 (Journal of Laws, no. 101, item 444, 1991) provides that a forest is a land:

1. With a compact area of at least 0.10 hectares, covered with forest vegetation or temporarily deprived of it:
   - designed for forestry production or
   - constituting a nature reserve or being part of a national park, or
   - listed in the Register of Objects of Cultural Heritage.
2. Related to forest management, occupied with the purpose of use for forest management: buildings and structures, water land improvement facilities, forest spatial division lines, forest roads, land under power lines, forest nurseries, timber storage areas, and also used for forest parking lots and tourist facilities.

According to the statutory provisions, supervision of forests owned by the State Treasury is exercised by the minister competent for the environment. Such supervision covers land in national parks, forests under the management of the Agricultural Property Agency and those put under the supervision of the State Forests National Forest Holding. The largest portion of all forests are properties supervised by the latter institution, which regularly undergoes certification (Leśkiewicz, 2018, pp. 86-87).

The State Forests National Forest Holding has been in operation for more than 100 years. The institution is headed by a Director General of State Forests. Together with his deputies, he manages an organization of more than 25,000 employees, supported by staff employed in the Directorate General of State Forests. The central authorities of the Holding manage 17 Regional Directorates of State Forests (RDSF), which include a total of 429 forest districts throughout Poland. At the same time, 7 nationwide institutes (including the State Forests Development and Implementation Centre (SFDIC) in Bedoń, which carried out the research described in this paper) and 15 regional institutes also carry out their tasks. In addition, the State Forests have a uniformed formation - the Forest Guard (www.lasy.gov.pl, 2024).

The Forests Act, which has been in effect since 1991, defines the goals of forest management, which are primarily the preservation and protection of forests, as well as water, soils and the natural equilibrium, while producing timber and harvesting raw materials and by-products of forest use. The above goals are achieved based on the principles of universal protection, sustainability of maintenance, continuity and sustainable use of the functions and expansion of forest resources (Walas, 2015, pp. 356-357).

The operations of the State Forests National Forest Holding consists in generating income from, for example, the sale of timber. At the same time, the Holding provides many services, such as access to the forest, enabling tourism and recreation, free of charge. The Holding also carries out a number of educational activities (Pikus et al., 2018, pp. 44-45).

The most important goal of the operations of the State Forests is the sustainable use of forest resources. This goal is achieved by meeting the needs of the public, while taking care of nature conservation and the ecological equilibrium (Paschalis-Jakubowicz, 2012, p. 7). The basic divisions of forest management are planning (forest organization), culture, use, forest protection and hunting (Matysiak, 2008, p. 24). The management of the institution in question itself is carried out on the basis of forest organization plans. They are the main pillar of the entire system. Forest management also uses the products of technological advances to improve processes (Matysiak, 2008, p. 27). A key role in forest management is played by forest organization companies, which plan and supervise day-to-day forest management activities. This is done by, among other things, conducting analyses and classifications of the tree stand, setting goals of an economic and protective nature, creating strategies for sustainable management and intensity of use, as well as developing breeding programs (Chmielewski, 2015, pp. 118-120).

3.2. The first tests of commercially available tools for photo-optical measurement of raw materials - an attempt to implement foreign solutions (2015)

With the worldwide popularization of photo-optical timber measurement tools and applications, the management of the State Forests commissioned the staff of the Office of Forest Expert Analysis and Technology of the State Forests Development and Implementation Centre in Bedoń to carry out field tests of three measurement systems for roundwood: sScale (Dralle A/S), iFOVEA (FOVEA GmbH) and AFoRS (Scheller Systemtechnik GmbH).

The tests were conducted between April and June 2015. They included the use of five measurement devices on mobile systems and one device of the sScale system. (Jodłowski et al., 2015, p. 4). The minimum quantity of timber measured was 2500 m³ per device. The tests were conducted under different weather and lighting conditions, taking into account different tree species (pine, spruce, birch, oak and beech) and different wood stacking configurations (Jodłowski et al., 2015, p. 11). The field tests were carried out in the Karwin, Nowa Sól and Świeradów Forest Districts, as well as in the area of the RDSF in Piła (Jodłowski et al., 2015, p. 12).

As part of the results of the field tests, the following characteristics of the tools tested were determined:

a) sScale - uses two industrial monochrome cameras to create a 3D image of the stack. The measurement is fast and is also possible at night thanks to LED lamps;
b) iFOVEA - the measurement is taken by iOS system devices; panoramic images are processed directly on the mobile device;
c) AFoRS - the measurement is taken with a smartphone with the Android system; the images are sent to a server for analysis.

The final test report includes an assessment of the functionality and effectiveness of the three measurement systems and recommendations for their use in practice. In addition, the report contains detailed statistical analyses concerning, among other things, the determination of volume and analyses of the time of measurement of stacked timber and the thickness of timber logs, and the effect of weather conditions and stacking on the results of measurements and on their repeatability (Jodłowski et al., 2015, pp. 14-38), In addition, it provides recommendations for the use of photo-optical measurement systems under different field conditions and for specific tree species. The document allows for formulating recommendations regarding the use of photo-optical measurement systems in forestry under the conditions prevailing in Poland and provides specific recommendations for their use, both at the operational level in forest ranges and for larger operations at a forestry district level.

All three photo-optical methods of timber measurement (sScale, iFOVEA, AFoRS) that were tested showed practical suitability for both stacked and logged timber under the conditions prevailing in Poland. The AFoRS and iFOVEA mobile applications, designed for use at the forest range level, received good ratings. Notably, iFOVEA was rated slightly higher by field users, so it is recommended for use in practice if a choice has to be made. It is also worth

considering the development of a national solution that would combine the functionalities of both applications. In contrast, the sScale system, designed for the acceptance of large masses of timber, is recommended at the forest district and higher levels. One sScale set per regional directorate would solve the problem of timber acceptance, especially for large stacks shipped to a single customer or in the event of natural disasters. This system should be used intensively to reduce the cost of acceptance (Jodłowski et al., 2015, pp. 39-47). At the same time, the statistical analyses have shown that the accuracy of the determination of the thickness and volume of timber stacks largely depends on the experience and diligence of those taking the measurements.

Two years after the report in question was drafted, the Director General of the State Forests issued decisions to put the photo-optical method into practice, although this was due to the exceptional situation at the time (Decisions No. 211, 223, 225 of the Director General of the State Forests, 2017). The first use of photo-optical measurements in forest management in Poland took place as a result of the damage caused by the Eunica storm. The timber accepted in connection with the disaster amounted to about 8.5 million cubic meters. At that time, the management of the National Forests decided to use the Dralle software based on the sScale system. The measurements were taken with the equipment attached to the roof of a vehicle. Another study commissioned by the Directorate General of State Forests, was conducted by the staff of the State Forests Development and Implementation Centre in Bedoń in 2020. Its objective was to test the technical, legislative and usability capabilities of the Timbeter software, which is used for photo-optical measurement of stacked wood, integrated with the Leśnik+ application (Sarzyński et al., 2021, p. 5). The tests were conducted in the Nowe Ramuki and Zdrojowa Góra Forest Districts. The activities performed included an examination the information-technology details of the application (API, integration with Leśnik+) and a determination and identification of the technical details of the mobile devices used for measurements. In addition, the repeatability of measurements and the labour intensity of the process were tested.

The tests in the Nowe Ramuki Forest District lasted from 1 March to 31 August 2020. 1,391 timber measurements, with a total volume of 21,781.77 m³, were conducted using PointMobile PM85 recorders and Samsung Galaxy XCover 4s smartphones. The most important problems encountered during the tests included the inability to record the results in the State Forests' Information System (SILP) and the difficulty in recording the actual volume of the timber in the inventory (Sarzyński et al., 2021, pp. 6-9).

The tests in the Zdrojowa Góra Forest District were conducted from 25 September to 20 December 2020. 14,211.86 m³ of timber were measured (including 12,192.76 m³ of stacked timber and 2,019.1 m³ of logs). In the tests, the latest version of the Timbeter application was used, which had been changed in terms of diameter measurement (Sarzyński et al., 2021, pp. 10-12).

The tests showed the need for further modifications to the Timbeter application to improve its accuracy and functionality. The need to improve the integration of measurement data with the Leśnik+ system was also identified. It was noted that photo-optical measurements can significantly reduce the time required to take wood measurements, but need further improvement in terms of automation and accuracy. On the other hand, the need to solve problems related to measurement conditions (e.g., adverse weather conditions) and to improve the usability of the application was pointed out (Sarzyński et al., 2021, pp. 16, 25-26).

The summary report from the tests indicated that photo-optical timber measurements have the potential to improve the measurement processes in forestry, but need further work to improve their accuracy, integration with management systems and usability. The recommendations included in the document include continued testing and development of the Timbeter application, as well as possible changes in internal regulations to allow full use of this type of technology in the State Forests National Forest Holding. These changes concern further integration with the Leśnik+ system and the use of measurement devices with parameters higher than those specified by the provided of the Timbeter application. The report points out the need to focus on improving the equipment used for measurement, control over application updates, and the need for proper preparation of the timber for measurement. Other important recommendations include further development and testing of the technology, and adjustment of the regulations to its specifications (Sarzyński et al., 2021, pp. 91-94).

3.3. Successive research on the functionality and application of photo-optical measurement tools (2020)

Another study commissioned by the Directorate General of State Forests, was conducted by the staff of the State Forests Development and Implementation Centre in Bedoń in 2020. Its objective was to test the technical, legislative and usability capabilities of the Timbeter software, which is used for photo-optical measurement of stacked wood, integrated with the Leśnik+ application. The tests were conducted in the Nowe Ramuki and Zdrojowa Góra Forest Districts. The activities performed included an examination the information-technology details of the application (API, integration with Leśnik+) and a determination and identification of the technical details of the mobile devices used for measurements. In addition, the repeatability of measurements and the labour intensity of the process were tested.

The tests in the Nowe Ramuki Forest District lasted from 1 March to 31 August 2020. 1391 timber measurements, with a total volume of 21,781.77 m³, were conducted using PointMobile PM85 recorders and Samsung Galaxy XCover 4s smartphones. The most important problems encountered during the tests included the inability to record the results in the State Forests' Information System (SILP) and the difficulty in recording the actual volume of the timber in the inventory.

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4. The possible impact of the use of photo-optical measurement of timber on the change in the way time and human resources are managed in the State Forests

The use of photo-optical measurement of timber can have a significant impact on time and human resource management in the context of forestry and the timber industry.

Traditional timber measurement methods, such as manual measurement, can be time-consuming and manpower-intensive. The new possibilities offered by precision forestry have caused significant changes in this area (Dhanashri, 2023, p. 4748). The use of photo-optical measurement systems allows for the rapid and automatic collection of data on timber, which significantly reduces the time required for measurements.

In the timber industry, effective management of people's work time is key to optimizing the production processes. Photo-optical measuring systems can be used to automate the processes of sorting and processing of timber, thus increasing productivity and reducing the time required to perform specific tasks (Bieniok, 1997, pp. 131-135).

The use of automated measuring systems eliminates or significantly reduces the risk of human error that can occur when using traditional measurement methods. This, in turn, can lead to a reduction in the amount of time and resources needed to correct errors. Studies and comparative analyses of traditional and photo-optical measurement methods show that under certain conditions the accuracy of both methods is comparable. The photo-optical method, on the other hand, may be attractive to entities conducting large-scale operations (Cremer, Ferreol et al., 2021, pp. 3-4).

By quickly and accurately collecting data on timber resources, forest managers can more efficiently plan wood harvesting operations, allocate human resources and machinery, and minimize the time required to move between locations. This involves setting a new standardization of the working time (Cremer, Ferreol et al., 2021, pp. 138-142). A measurement helps determine what the use of the timber may be in further production processes. It is also possible to assign a serial number to individual batches of timber, which allows to accurately track the path the timber follows from growth to use in the final product (Lummitsch et al., 2019, p. 3).

The use of modern technologies, such as photo-optical measuring systems, requires appropriate training of the staff. Therefore, human resource management also includes providing adequate training and skill development for employees so that they can use these technologies effectively. Taking these arguments into account, photo-optical measurement of timber can help improve operational efficiency, optimize human work time, and better manage human resources in the forestry sector and the timber industry.

In terms of human resource management, photo-optical measurement of timber should bring the following results:

a) Reduced workforce requirements - photo-optical systems automate the measurement processes, thus reducing the need for multiple foresters to engage in manual timber measurements. As a result, fewer workers are needed to perform these tasks. At the same time, the introduction of modern technologies makes it necessary to train workers in the operation of photo-optical systems. Instead of a large number of workers performing simple measurements, fewer skilled technology operators are needed.
b) Improved productivity thanks to:
    - faster measurement - photo-optical tools enable fast and precise measurements, allowing more work to be done in less time. Workers can focus on other important tasks, which increases the overall productivity (Kozioł, 2000, p. 19);

- reduction of human errors - automated measurement systems reduce the risk of human errors, thus leading to more reliable data and less need for repeated measurements.

At the same time, one should bear in mind that the application of precision forestry has socio-economic implications. The changes in job requirements, economic viability and social acceptance of changes in human resource management (Dhanashri, 2023, pp. 4750-52).

c) Improved working conditions - operations with photo-optical systems are less physically demanding compared to traditional measurement methods, which can help improve the working conditions and reduce the risk of injury.

Table 1.
Duration of individual activities during an 8-hour work shift at the positions of forester and deputy forester

Timber acceptance	
One-man forest range	44.9 minutes
Two-man forest range (forester)	35.2 minutes
Deputy forester	65.4 minutes
On average, about 10% of the working time under standard conditions	

Source: (Grzywiński et al., 2017, p. 27).

In terms of time management, the following elements that can be influenced by photo-optical measurement can be distinguished:

a) Reduction of the measurement time:
   - instant results - photo-optical tools, such as mobile applications, provide instant measurement results, which reduces the time needed for analysis and calculations. This allows for faster operational decisions,
   - no need for repeated measurements - thanks to greater precision and accuracy, photo-optical measurements minimize the need for repeated measurements, thus saving time.

b) Forestry project management:
   - planning and monitoring - automated measurement systems enable better planning and monitoring of forestry projects. Measurement data is quickly available and can be easily integrated into resource management systems for more efficient project management;
   - optimization of logistics - fast measurements allow better coordination of logistics, including timber transportation, which reduces the time needed for loading and unloading and minimizes downtime.

c) Real-time data management - photo-optical tools enable real-time data collection, which allows for real-time updating of the forest resource database. This provides an accurate and up-to-date picture of the available resources, which is crucial for effective management.

Studies conducted in 2015 in the conditions prevailing in Poland showed that the photo-optical measurement method requires less time than measurements conducted using traditional methods (Jodłowski et al., 2016, p. 306). The tests compared the traditional method and operations performed using the AFoRS, iFOVEA and Dralle applications.

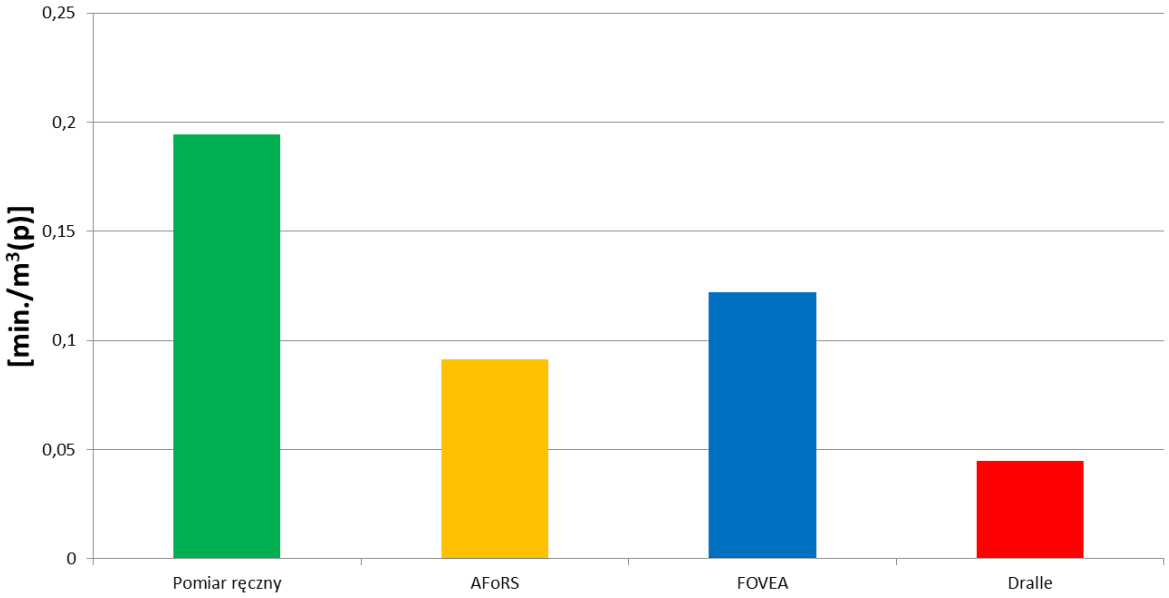

Figure 1. The average time of measurement of 1 stere of stacked wood (the tests were conducted in 2015).

Source: (Jodłowski et al., 2016, p. 306).

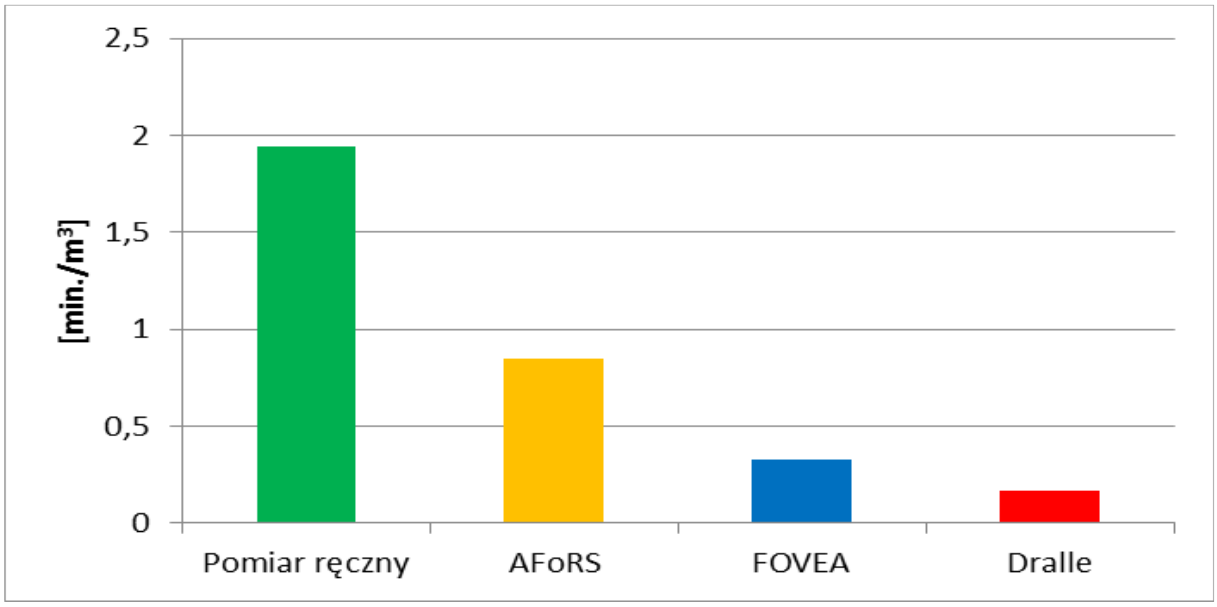

Figure 2. The average time of measurement of 1 stere of log wood (the tests were conducted in 2015).

Source: (Jodłowski et al., 2016, p. 306).

The tests conducted by the staff of Office of Forest Expert Analysis and Technology of the State Forests Development and Implementation Centre in Bedoń in 2020 showed that the use of the Timbeter application influences forestry time management. A chronometric study was conducted to gain a thorough understanding of the differences between traditional measurement

and photo-optical measurement of timber (Sarzyński et al., 2021, p. 26). This study showed the total difference in times between these methods and allowed for a thorough verification of the differences arising from their characteristics.

Timber measurement, whether traditional or photo-optical, is an operation constituting a part of the timber acceptance process. The analysis showed that a photo-optical measurement requires a similar amount of work as the traditional methods. The chronometric observations concerned a measurement operation consisting of procedures performed directly on a single stack of wood to calculate its volume in cubic meters (Sarzyński et al., 2021, pp. 33-35).

On the other hand, during the tests performed on the Timbeter application, technical problems were noted, such as crushing of the application and difficulties associated with taking measurement images in the vertical position. These problems can affect work efficiency and the time it takes to complete a task (Sarzyński et al., 2021, pp. 29-30).

The use of Timbeter in forest management also affects human resource management. Measuring timber with the application is less labour-intensive compared to traditional measurement methods. This allows field workers to perform their tasks more efficiently, thus resulting in better time management and increased productivity (Sarzyński et al., 2021, pp. 37-40). It should be kept in mind that the introduction of the new technology involves the need to train workers in the use of the application. Foresters must learn to use the new tools, which may require additional time and resources at the beginning of the implementation (Sarzyński et al., 2021, p. 55).

The report from the study conducted in 2020 showed that the use of the Timbeter application in forest management has a positive impact on human resource management thanks to reduced labour intensity, improved productivity and requirements associated with adaptation to new technologies. However, it is necessary to take into account and solve technical problems in order to fully realize the potential of the application in human resource management (Sarzyński et al., 2021, pp. 91-93).

Photo-optical measurement methods also have implications for other areas of management. Precision forestry reduces costs and minimizes the risks associated with manual data collection, especially in forest areas that are endangered or difficult to access. The use of modern robotics and technology improves the efficiency and accuracy of measurement and monitoring, reduces labour costs and improves data quality. The latter aspect enables decision-makers to obtain better information which, in practice, contributes to more informed and sustainable forest management (Dhanashri, 2023, p. 4749).

5. A survey of foresters' opinions on photo-optical measurement applications

As part of the tests of the Timbeter application conducted in 2020, a survey of foresters' opinions was also carried out. Those who used the tool in the tests rated its usefulness and possible shortcomings (Sarzyński et al., 2021, pp. 83-85):

a) Intuitive use - operation of the application is relatively intuitive, and entering measurement parameters does not cause any major problems. It is also easy to take photos as part of the measurement.
b) Technical problems - the equipment used for the tests, such as the Huawei P smartphone with 3 GB RAM, proved too weak to take photos for the application. With wide stacks that required multiple images, the application sometimes paused, requiring the stack to be split into several panoramic photos. The application also had problems with the quality of images in partial light and shadow conditions, requiring manual adjustments. Moreover, at low temperatures (below +5°C), the application was unable to record the measurement and closed down.
c) Deficiencies in functionality - the respondents said that there was no automatic assignment of conversion factors to tree species and grades, which made the data entry process difficult and lengthy. Several economically important species were also missing from the application's glossary.
d) Measurement quality - the respondents felt that an advantage of the application was the ability to obtain measurement results similar to those obtained using traditional measurement methods, especially with a dense stack with a level front surface. However, the narrow roads and the need to take multiple photos to measure long stacks were significant impediments.

The Timbeter application received mixed reviews from the users. On the one hand, its intuitiveness and potential to facilitate work were appreciated, but on the other hand, the need to improve the equipment, the functionality and the accuracy of measurements under different conditions was pointed out. The users mostly thought that the photo-optical measurement method facilitated their work, especially with large coniferous tree stacks and logs. Despite the technical problems and functional deficiencies, the method offers a promising future for timber acceptance procedures.

6. Conclusion

The studies of tools and applications for photo-optical measurement of timber material have shown that the use of the method in question can significantly contribute to the reduction of the working time, thus changing the way human resources are managed, both in the State Forests and in companies of the timber industry. An analysis of the tests carried out abroad also yields similar conclusions. Possible errors and shortcomings of individual applications have been addressed by manufacturers over the years. In addition, further development of the tools in question, which we consider as part of precision forestry, is anticipated. The technology discussed herein will be further developed based on the development of laser scanning technology (Lummitsch et al., 2019, pp. 3-4).

Therefore, it seems reasonable to implement the photo-optical method in the current forest management, especially with the increasing volume of timber acceptance work (Tarkowska, 2011, pp. 16-17). State Forests employees themselves positively evaluated the new opportunities provided by the new photo-optical measurement applications.

Increasing work efficiency by eliminating human errors and accurate measurement, as well as reducing the need for employees and general improvement of working conditions are the most important advantages of the described method in human resources management. In turn, in terms of time management, process optimization is manifested by a visible reduction in measurement time, immediate results, no need to repeat measurements and real time data management. Moreover, the use of photo-optical measurement affects the planning and monitoring of processes and the optimization of logistics.

Introducing the necessary modifications, eliminating the shortcomings and integrating the tools with the information systems currently used in the State Forests National Forest Holding are the most important measures to be taken in order to ensure the widespread use of the measurement method in question. The possible decision of the State Forests' management to implement the method of photo-optical measurement of timber at the RDSFs, forest districts and Forest Service Companies, will require appropriate internal legislative regulations at the level of the institution.

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