Augmented Reality (AR) Assisted Smart Glasses Case Study for Remote Support Between Two Distant Production Plants

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Abstract

Rapid developments in technology enable us to reach smart glasses and AR technology with a wide range of products and competitive prices. Hence, increase in smart glasses industrial use give an opportunity to whom work distant such as making it possible to see from each other's eyes, which increases the operational efficiency of the companies; since it is costly to make experienced staff traveled to another plant in aspects of travel cost, accommodation cost and the lack of the experienced person in his/her the main responsibility area in factories with different experiences in remote locations. This study is conducted about the application of smart glasses on one of the biggest tire manufacturing company since 2018.

End to end journey of the smart glasses' remote support applications, starting with how the devices are selected and ending with an evaluation of advantages/disadvantages of the smart glasses' technology, is explained in this paper. Moreover, the study covers details and observations of staff training, new product development, and inspections, first-run test on machinery, maintenance, and audits.

Keywords: Smart Glasses, Augmented Reality, Remote Support, IoT, Remote Maintenance, New Product Development, Inspection, Audit, Tire Industry

Introduction

The development of digital trends and smart technologies is making a significant impact on the industry. Computer technology has advanced from mainframes to desktops, then laptops and mobiles, and is now moving onto and into the human body by way of wearable computers. These devices provide unpredictable network access – hands-free, heads-up operation with full mobility (Grupta et al., 2018). Technology supplies smaller and easily accessible devices. With all these developments, Smart glasses started to appear and it has become easily accessible in the market with the developing technologies and the race in the digitalization age.

This introductory part covers that historical developments in smart glasses, the technologies of smart glasses, and application areas in the industry would be examined.

The Brief History of Smart Glasses

The history of smart glasses has come from more than 100 years. The imagination of the human being has always played an accelerating effect on advances in technology. The science fiction stories created laid the foundations of today's technologies and became a point of inspiration for them. Imagine that people could communicate with each other with the help of cables before electricity entered the life of humanity. In the 1840s, the first Morse code telegraphy had invented and humanity had begun to discover how communication would be more effective and faster with the advancing technologies. The journalist Arthur Brehmer in 1910 gathered that It was in light of advances like these that domain experts from different fields to envision the world in 100 years from then in a collection of essays (Ruppelt, 2014). Oppermann & Prinz (2016) illustrated that such notions also reached the mass media before long, as one can see in this 1929 contemporary vision of video telephony depicted in figure 1.

Figure 1 - Video telephony according to a 1929 vision (adapted from Oppermann & Prinz, 2016)

By the end of the 1950s and the beginning of the 1960s, technology in communication channels was developing rapidly. Some of this part comes from the cinema and theater techniques used for entertainment, while some are from the rapid developments in the defense industry. The sector where visual and audio communication is most developed is the entertainment sector. People were showing several of illusions in the theaters. Later these techniques became so simple that it entered people's homes as a small box TV. Humanity quickly accepted this evolving visual and auditory communication. Some theater and cinema techniques contribute to the development of smart glasses. For instance, in 1862, John Henry Pepper (1821-1900) and Henry Dircks (1806-1873) discovered an illusion / simple projection technique, which is called Pepper's ghost. This technique was very common in theater used. The basic trick here is that there are two rooms built on the stage, one that people can see into, the other one (called blue room) that is hidden. For the illusion, you set up a big glass in the main room at 45-degree angle that is able to reflect the view of the blue room towards the audience in order to project 'floating' ghost objects onto the spatiality of the twin room as shown in figure 2 (Wild, n.d.; Secord, 2002). The technique is old, but still in use for modern projection AR (Augmented Reality). With the increasing awareness of television in homes, new ideas started to emerge. Scientists and engineers have dreamed that this technology will be downsized, making it easy to hang on our heads. Many of these interesting designs were protected by their inventors with patents. Some examples are shown in figure 3.

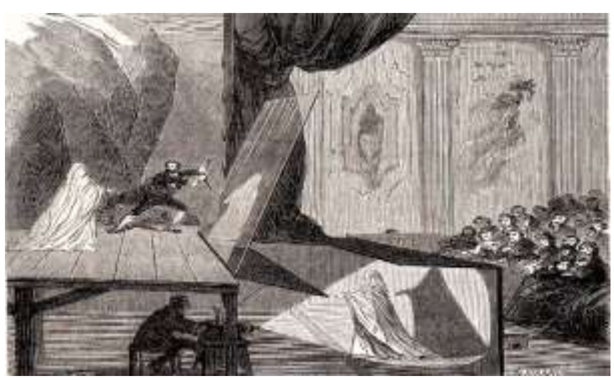

Figure 2 - Pepper's Ghost Technique (Wild, n.d.) (adapted from https://codereality.net/ar-for-eu-book/chapter/historyar/ retrieved on November 8, 2020

The first Stereoscopic Television (TV) Apparatus was patented by Henry McCollum in 1945, which was a head-mounted display. Morten Heiling also patented a stereoscopic television Head-Mounted-Display for individual use in 1960. This device is seen as the mother of all smart glasses, highlighting its importance (together with Heilig's Sensorama for VR) as a milestone in the history of computing (Wild, n.d), which is also illustrated in figure 3. The idea is very close to today's smart glasses technology. Hugo Gernsback, an American science fiction evangelist, introduced his television goggles idea in 1963. The device was compact to place on the head.

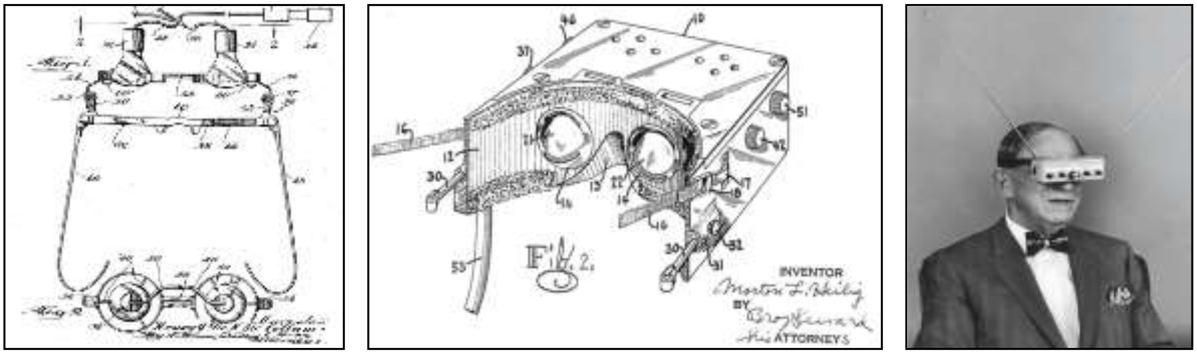

Figure 3 - Henry McCollum's Design(left), Morten Heiling's Design(mid), Hugo Gernsback's Design(right) (Wild, n.d.) (adapted from https://codereality.net/ar-for-eu-book/chapter/historyar/ retrieved on November 8, 2020)

These inventions formed the basis of today's devices. Today's Virtual Reality (VR) Head Mounted Displays have become the inspiration for the Oculus Rift, HTC Vive, or Samsung Gear. Outside of the entertainment industry, developments in the defense industry and industry were accelerating the evolution of smart glasses. Towards the end of the 1950s, Head-up Displays (HUDs) technology was introduced in combat aircraft as shown in figure 4. HUDs are superimposing graphics onto the real world by projecting onto a glass plane in the field of view of the pilot, which means virtual features are shown in the real environment. With the development of HUDS, pilots wouldn't move their heads down to check their vision, so the name 'heads-up' has existed. Augmented Reality (AR) can display on any transparent display, which is a common technique for developing smart glasses.

Figure 4 - Head-up Displays (HUDs) in aviation (adapted from https://www.flyingmag.com/how-it-works-head-up-display/ retrieved on November 20, 2020)

In the late 1960s, technology comes from science fiction to science. There are several academic studies and industrial applications about smart glasses. Ivan Sutherland presented the “Sword of Damocles” in 1968, which was a head-mounted three-dimensional display that was considered the scientific ancestor of the devices we are used to seeing today (Oppermann & Prinz, 2016). As is shown in figure 5, the device consisted of a stereoscopic display and a big mounted structure from the ceiling due to the heavyweight of the system. The system used a mechanical and an ultra-sonic component as a head-tracking system. İt allowed its user to change his view of the 3D world by rotating his head. That would present a simple wire-frame rendered 3D perspective image which changes as the user moves. Because at that time no available general-purpose computer was fast enough to provide a flicker-free dynamic image, Sutherland and his team built additional special-purpose digital matrix multiplier and clipping divider components to reach an interactive frame-rate of 30 frames per second when showing 3000 hardware-accelerated lines (Oppermann & Prinz, 2016; Sutherland,1968). The study of Sutherland demonstrated the main components of all head-mounted display and smart-glass setups to date: a display, a processing unit (connected via cables), and position and orientation sensors (Oppermann & Prinz, 2016). The electrical power in his design obviously came from a socket, which is later on placed with the battery system in the modern technologies.

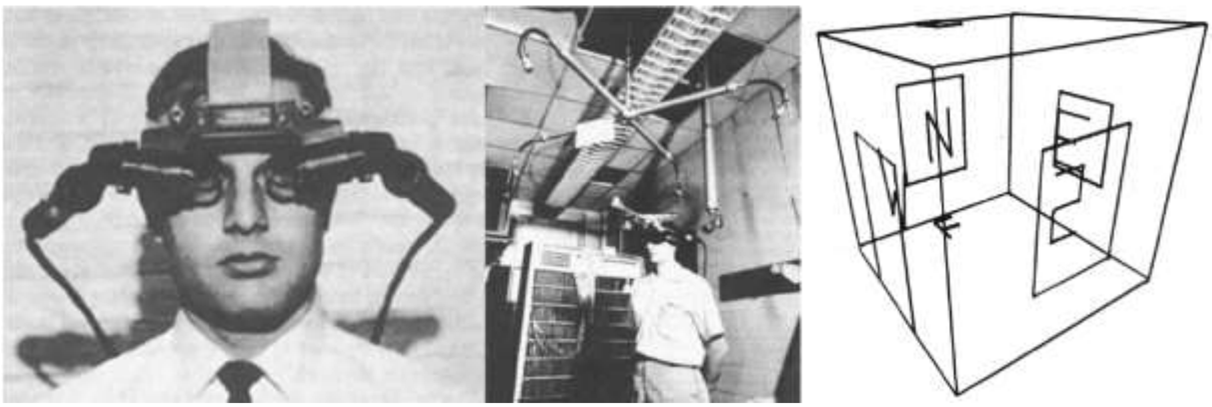

Figure 5 - Ivan Sutherland's 'Sword of Damocles' (adapted from Oppermann & Prinz, 2016)

In 1992, two engineers from Boeing Computer Service, Research and Technology, Thomas P.Caudell and David W Mizell introduced the first industrial use smart glasses. The device was called HUDset which was the first example of implementing head-up, see-through, and head-mounted display. Combined with head position sensing and a real-world registration system, this technology allows a computer-produced diagram to be superimposed and stabilized on a specific position on a real-world object. The successful development of the HUDset technology will enable cost reductions and efficiency improvements in many of the human-involved operations in aircraft manufacturing, by eliminating templates, form-board diagrams, and other masking devices (Caudell & Mizell, 1992). As is illustrated in figure 6, the design of the device is close to nowadays technology.

In 2011, The Google Glass prototype assembled standard eyeglasses with the lens replaced by a HUD (Miller, 2013). The first prototype was engineered/designed as weighed 3.6 kg. By 2013 they were lighter than the average pair of sunglasses (Sparkes, 2014). Thanks to Google, the availability of smart glasses in the market has increased, and most importantly their prices are affordable. After Google, many players participated in the race of smart glasses development such as Microsoft, ODG, Epson.

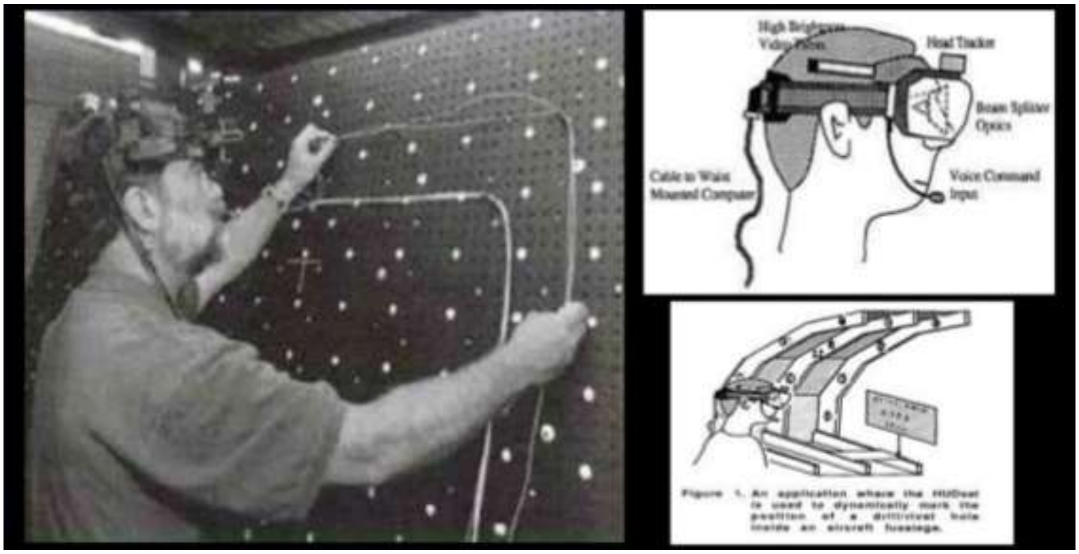

Figure 6 - First smart glasses application in Boeing by T. P. Caudell and D. W. Mizell (adapted from : https://www.timetoast.com/timelines/educacion-oblicua retrieved on November 26, 2020)

Types of Smart Glasses and The Differences of VR, AR, MR & XR

The technologies behind Smart Glasses are similar to a smartphone, however, Smart glasses are still one of the most complicated & fancy wearable technology. As a smartphone, Smart glasses have also certain sections such as wireless connectivity, GPS/Navigation, activity tracking, camera & video call, hands-free use, interactive assistants, etc. Figure 7 illustrates the basic components of ordinary smart glasses.

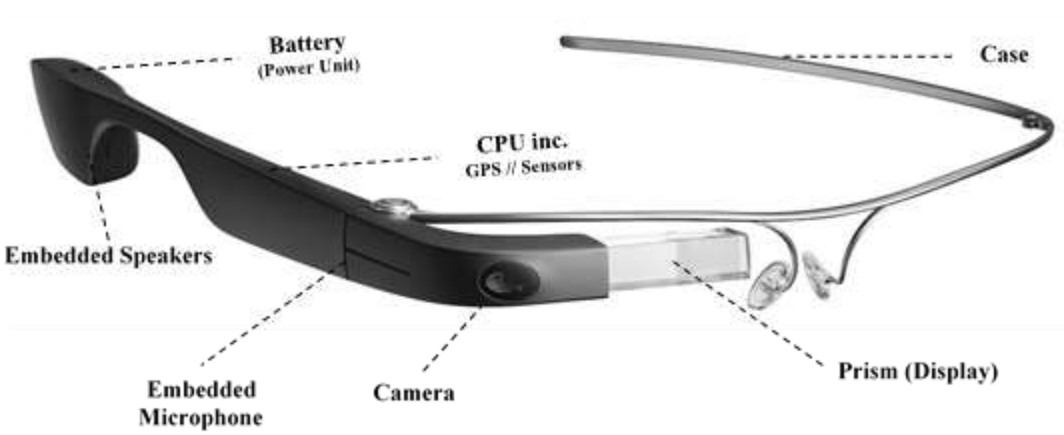

Figure 7 - Basic components of smart glasses (Symbolic illustration of Google Glass 1st Generation)

The smart glasses technology has been evolving significantly. Devices become faster, more user-friendly (ergonomic) and less impractical than their first generations. This technology takes the advantage of using augmented reality (AR) features, which gives an opportunity to merge the virtual environment with real surroundings.

According to design shape there are two different smart glasses, one of them is monocular smart glasses, the second one is binocular smart glasses. Figure 8 demonstrates the main shape difference of the monocular and binocular type smart glasses.

Figure 7 - Vuzix M300 Monocular Smart Glasses (left) & ODG R7 Binocular Smart Glasses (right) (adapted from: https://www.aniwaa.com/vr-ar/ retrieved on November 21, 2020)

Monocular smart glasses are head-mounted displays where the display section (HUDs or mini-projector) is positioned on one of the glasses' lenses, so it is called monocular. The best-known examples of devices in this category include Google Glass, RealWear HMT-1, Vuzix M300, etc. The simple way of describing monocular smart glasses is that it is like having a see-through smartphone in front of your eyes. However, augmented information is located just out of your line of sight, which means you can concentrate on the task at hand, but the display is always available for additional information at a glance. Furthermore, the other eye is free to concentrate on the physical world. According to smartglasseshub.com (2020), as an example, monocular HMDs can be used by a surgeon to keep track of a patient's vitals. When users need a limited set of data on view, an economic and light solution, they can prefer the monocular smart glasses. By the way, this type of smart glasses is more suitable for focusing on mission-critical business applications and studies.

Binocular smart glasses come with two transparent displays (HUDs), giving users a dual (stereoscopic) vision. These types of glasses have an optical engine in front of each eye makes it possible to augment a huge part of the total field of view of the wearer. According to smartglasseshub.com (2020), similar to monocular glasses, this type also displays the information just out of the line of sight of the user, but to both eyes. The best-known examples of devices in this category include ODG, Microsoft Hololens, Epson Moverio BT-300, etc. If users require a large viewing area or 3D-vision experience, they can prefer the binocular types of smart glasses.

Apart from the types of smart glasses, whenever there is talk about smart glasses, there is confusion, which comes from the difference between virtual reality (VR), augmented reality (AR) mixed reality (MR), and extended reality (XR) concepts. It is important that these new technologies come from different areas and the use of purpose is exactly different for each. These are using some similar technologies. For instance, 3-D options and artificial intelligence (AI) are crucial to all of them, however, they have certain differences from each other.

When Jaron Lanier founded the first company to sell virtual reality goggles and gloves, the virtual world became more popular (Rheingold, 1991). According to Lanier, VR could be used in several areas by wearing goggles and gloves such as surgical simulation or training, interior design, and prototyping, virtual sets for television production, video-game, etc (Lanier, n.d.). Virtual reality is to describe a three-dimensional, computer-generated environment in which the user can immerse. In other words, using reality headsets to generate realistic sounds, images, and other sensations that replicate a real environment or create an imaginary/virtual environment. VR is the simplest way to immerse the user into the virtual world. However, augmented reality (AR), does not give a complete immersion. It adds virtual objects and figures to a live view done by using the camera on any smart device. These virtual objects and figures are augmented by computer-based sensory data. In other words, users experience the virtual objects in the real environment. Mixed reality (MR) is the combination of AR and VR elements, it is also known as hybrid reality. This technology creates the intersection of the real and virtual world. Milgram and Kishino (1994) in their virtuality continuum described that mixed reality consists of a real environment, augmented reality, augmented virtuality, and virtual environment. The main characteristic of mixed reality is that the virtual content and real-world content are able to react to each other in real-time. When extended reality (XR) is considered, it appears just a generalized term. Extended reality (XR) covers all its descriptive forms like the augmented reality (AR), virtual reality (VR), mixed reality (MR).

To sum up, VR is immersing people into a completely virtual environment; AR is creating an overlay of virtual content, but can’t interact with the environment; MR is mixed of virtual reality and reality, it creates virtual objects that can interact with the actual environment. XR brings all three Realities (AR, VR, MR) together under one term, hence many times XR is called an umbrella term. Table 1 also summarizes and compares VR, AR, and MR technologies.

Table 1 - Short summary of VR, AR and MR

VIRTUAL REALITY (VR)	**AUGMENTED REALITY (AR)**	**MIXED REALITY MR)**
VR implies a ***complete immersion*** experience that shuts out the physical world. **i.e.** There is ***no real surroundings***, all features are virtual  ***Sample shape of VR glasses**** There is ***no physical contact*** with real environment. Users are exposed ***in virtual world***  ***Surrounded by virtual environment**** **Head-Mounted Devices (HMD) :** Samsung VR, HTC Vive, Oculus Rift Common use in video gaming, trainings, simulation	According to Shiner from Planetary Science Institute (n.d.), AR is an ***interactive*** experience of a physical surroundings where the objects that reside in the real-world are "***augmented***" by computer-generated perceptual information. **i.e.** ***Real world environment***, but objects are ***virtual.***  ***Virtual object in a real world*** ***No physical*** contact between the objects and surrounding  ***Sample shape of AR glasses**** The major ***distinction*** between AR & VR is that ***AR*** is still based in the physical world surrounding, VR is not. **Head-Mounted Smart Glasses:** ODG R7, Epson Moverio, Google Glass Common use in Several Industries : Production, Oil & Gases, Aero etc.	MR comes in as a ***subcategory of AR*** that distinguishes itself in the blending of ***reality*** and the ***virtual world*** into a true hybrid **i.e** it combines elements of both AR and VR, ***real-world and digital objects interact.***  ***Virtual object with real world properties in a real environment**** It is possible to generate ***physical contact*** between the virtual objects and real surrounding.  ***Sample shape of MR glasses**** **Head-Mounted MR- Smart Glasses:** Microsoft HoloLens, Meta 2 Common use in Engineering Design Study
*Figures are used symbolically.		

In contrast to immersive virtual reality (VR) headsets, smart glasses give a sense or experience of physical and digital worlds simultaneously, which connects users between the real and virtual world. Behind that experience, there are some advanced technologies such as Optical Head-Mounted Display (OHMD), Augmented Reality (AR) assisted Heads Up Display Glasses (HUD). The use of smart glasses will increase day by day in globalizing and growing industries.

Especially augmented reality (AR) assisted smart glasses will be both a communication channel and a training channel for us.

Literature and Industrial Survey

In this section, smart glasses augmented reality (AR), and virtual reality (VR) applications in the literature and industries are investigated. As a result of the literature survey, the cases and similarities with BRISA are focused on. With the detection of these similarities, road maps have been determined and the relevant details are explained in the 'materials and methods' section. Smart glasses, AR, and VR technologies have been a crucial part of our business life for the last few years. These technologies are used in every field we can think of, from civil aviation to the defense industry, from the energy sector to medical science, from sales consultancy to after-sales services, etc.

As it is mentioned before, Caudell and Mizell (1992) created the first example of the smart glasses concept and augmented reality as part of the aviation industry at BOEING. Today, many aviation companies use smart glasses technology frequently. Fink (2019) wrote an article from Forbes business magazine titled 'How Boeing Uses Upskill Skylight AR To Boost Productivity'. In his article, Fink (2019) emphasized how complex and time consuming the wiring process was in the aviation industry by Paul Davies of Boeing Research & Technology. According to the Boeing claim, this process was simplified with the use of smart glasses and provided a time saving of up to 30%, which means that the use of smart glasses was increasing speed and accuracy of wiring, i.e. optimizing inspection and production. Another example comes from GE Aviation on after-sales maintenance operation. Martin (2018) explained how GE Aviation was used as smart glasses. The main purpose of GE Aviation was to make sure that every bolt in the product was tightened correctly and as in the standards. Maintenance instructions are provided by smart glasses, so they are guided videos, animations, and pictures of the standards. To sum up, there was a significant reduction in maintenance error and between 8% and 12% maintenance capacity-up.

Smart glasses are also sometimes encountered in industries where there are operational high-risk factors, such as oil and gas, energy, etc. Nagamatsu et al. (2003) studied experimental prototypes about smart glasses. They tested the maintenance performance of nuclear power plants and communication between workers and technical staff. The study shows head-mounted display (HMD) – i.e. smart glasses technology with augmented reality assist is a useful tool for remote support and communication during maintenance activities.

The literature studies showed that AR and VR technologies can be used effectively in tire production. The applications at one of the famous tire production factories were an example of this development. Olive & Thouvenin (2011) showed how virtual environments were used in workers' training. By using VR technology, they claimed that there was a 25%-time reduction in training and a 62.5% reduction in machine down-time.

All the researches made showed that the technology can be applied to almost every field. The key will be to determine why users need this technology. With the changing conditions of use, the outputs and the challenges faced were changing.

Materials and Methods

Material and methods section explains why the smart glasses technology was needed in BRISA and the work done after the need was determined. The work done includes the preparation of the connection infrastructure of the system and the selection of the appropriate glasses to be selected.

Problem Definition & Aim of the Study

Brisa Izmit plant was established in 1974, nearly 40 years later the new plant was constructed in Aksaray City, Turkey. There is approximately 600 km distance between these two plants and this physical distance affected both effective communication and the time to reach the problem when the problem occurred. Especially, during Brisa Aksaray factory ramp-up, both the know-how transfer, experience, and engineering support of the Izmit factory were frequently needed.

Currently, when the problem occurred, traditional methods were used such as sharing a photo, phone conferences, e-mail about the problem. All these kind of communication staff causes a reduction in operational excellence. If there is a need for an on-plant operation, the plant team loses a day to solve the problem due to the distance between the two plants. Hence, there is a considered newly proposed method, which is using augmented reality (AR) assisted smart glasses. The main aim of Brisa' is to shorten the time to reach the problem. The main advantage of this system is time and cost-saving operation.

There were three different motivations behind this study. Firstly, smart glasses could offer a hand-free experience, which increases multi-tasking operations. The second motivation is that smart glasses offer mobility and remote connectivity. The last one is being a pioneer in the Turkish tire industry as Brisa.

Network Properties of the System

The most critical point in using smart glasses is to have the appropriate network infrastructure. The network structure used can consist of locally controlled servers or remotely accessible cloud solutions. Considering the users' needs, they need to determine which structures are suitable for them. The positive and negative aspects of local servers and cloud solutions on each other were examined in the studies. Network preference has been made by considering usage scenarios and company policies.

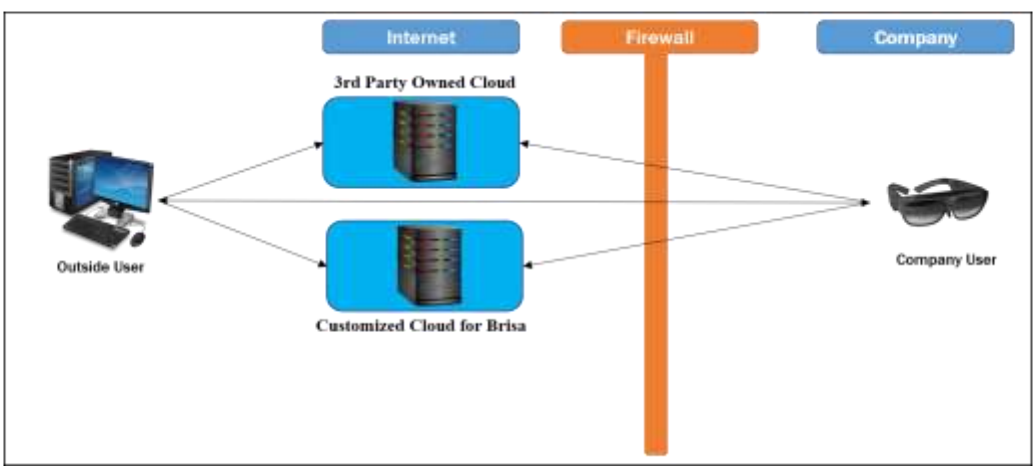

Figure 9 – Cloud solution for smart glasses

As is shown in figure 9, smart glasses working on cloud solutions can use the structures in the cloud for data transfer and data storage. The greatest convenience brought by cloud systems, whether inside or outside the company, parties can easily connect. Connection security is provided by solutions on the cloud. The company connection is still controlled by the company's firewall. If figure 9 is compared with figure 10; there is a certain difference in connection outside of the company. Outside users must be authorized by the company's VPN and connect to the system. After these evaluations, pros and cons table was created, which is shown in table 2.

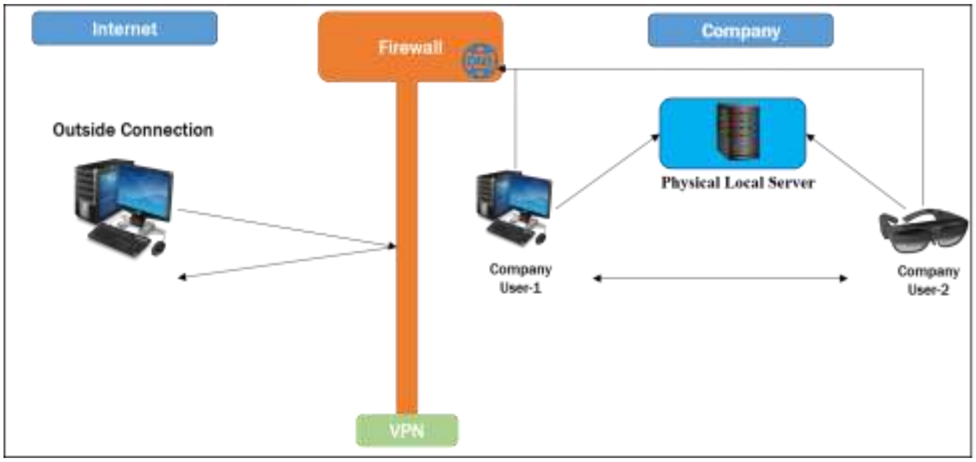

Figure 10 - On-Premise (Local Server) solution for smart glasses

Table 2 – Comparison table of Cloud & On-premise solution

Cloud Solutions		**On-Premise Solutions**	
Pros	Cons	Pros	Cons
Reduction in IT staff responsibility	Internet connection determines user experience	Operating without internet	Requirement extra IT support
Eliminate capital expense	Access is based on connection	Lower monthly internet cost (Local Hub)	Increase in maintenance cost for server
Adjust to company budget	Cost may have baloon effects	Easy to control the required hardware	Need capital investment
Optional - regular backup	Trust in data security	Providing data security No 3rd party	Risk of sudden data loss

Considering all the pros and cons, the local server (on-premise) solution was chosen due to data privacy policy and image quality change with internet speed. After the decision of which network infrastructure is used, there should be some connectivity check.

- Checking Wi-Fi standards: 802.11a, 802.11b, 802.11g, 802.11n, and 802.11ac
- Control the Bandwidth for each production area
- Check wireless signal power for each production area
- Study for surrounding: steel construction & steel cage around machinery

Methodology of Smart Glasses Selection

When it came to choosing smart glasses, a very complicated process was going on. To do this, it was not enough to just look at the specification documents, so when choosing smart glasses, attention should be paid to the ergonomics of use of the device as well as the technologies used. For this purpose, some literature studies have been done. In these studies, some solutions were sought for how to choose smart glasses. After deep research in the literature, some options were formed.

Palmarini et al. (2017) studied augmented reality and they evaluated results by applying a questionnaire to users. This questionnaire measures the AR feasibility on work, AR –hardware system performance, visual quality, etc. After that point, the questionnaire method is chosen. The biggest problems are how users evaluate the system and which users will attend this study. Another study was shedding light on how to evaluate the system. Nagamatsu et al. (2003) from Japan, evaluated their study by scoring four different categories, namely ease of work, understandability of AR indication, communication, the whole system.

Studies were primarily made on who will evaluate the system. The first assumption was that only experts/engineers would be involved in the study and would use the system. When the evaluations were made, it was determined that the choices and comments were not made objectively. Instead, individuals were selected to evaluate systems and devices from two different user pools, which is the second scenario (a method used). These profiles are experts in management/engineering and experts in the workforce such as top graded technicians, foremen, supervisors, etc. The main purpose of these is to eliminate the occurring bias on the professional teams by including the non-expert team. Shortly, smart glasses are evaluated by expert and non-expert groups.

Inspiring from the study of Nagamatsu et al. (2003), four different categories are selected. These four main parameters are hardware specification, AR assistance, ergonomy, and pricing. Users were asked to rate nine different parameters based on 4 main categories from 1 (one) to 5 (five). 1 (one) point indicates that the feature is very weak and 5 (five) points indicate that the related feature is the strongest. Five different devices are evaluated. The below figure shows the result of the questionnaire.

Criteria	Candidate 1	ODG R7	Candidate 2	Candidate 3	Candidate 4
Display quality	3	4	4	4	4
Battery life	5	3	3	4	3
AR assistance	1	5	5	4	1
Auto-focus	4	4	4	3	3
Hands-free	4	5	5	2	3
Microphone	4	5	5	3	3
See through capability	4	4	5	3	3
Hardware (Ram-CPU-Storage)	2	5	5	3	2
Price	4	3	1	5	5
SCORE	3.45	4.20	4.10	3.45	3.00

Figure 11 – Result of questionnaire

Finally, ODG R7 is selected. This device is ruggedized while working under harsh conditions, it is a really good solution. ODG R7 smart glasses are binocular type and it is very good at see-through capability. By the way, during the evaluation, the technical team also evaluated 'Microsoft HoloLens', but it did not include the questionnaire study. Microsoft HoloLens is an advanced and complicated device. It is eliminated two main reasons. One of them is a complicated design. The main purpose of the study covers all types of employees such as non-expert technicians, workers, engineers, etc. Microsoft HoloLens has lots of sensors so control of them is very hard. It is too complicated for a non-expert team. The second weakness is the safety issue. Smart glasses are heavier than the others and it is also blocking the worker's view. During the operation, it can create a safety risk for employees. Figure 12 demonstrates the side and front view of ODG R7. The design of ODG R7 is like safety glasses.

Figure 12 – Side and front view of ODG R7

Results

This section will cover the case scenarios for smart glasses and positive effects on Brisa's operational excellence. Smart glasses are used in six different cases. These scenarios are staff training, new product development activities, product inspection, machinery first run test, maintenance operation, and audits activities.

The main purpose of staff training is know-how transfer from the Izmit side to the Aksaray side and on the job employee training. Izmit Plant has experienced for more than 40 years in tire production, Aksaray plant started regular production in 2018, Up to this point, lots of employees joined the company. Tire production is a process that requires quite good hand skills. For that, technicians undergo continuous training. This training includes both how to make the tire and how to use the complex machines used during tire production. Therefore, this training must be given by experienced and experts in their field. For this one-on-one training, an authorized employee from the Izmit factory; needs to visit the Aksaray factory. During this journey, a full day is lost on the road and there is also a large amount of accommodation cost.

The second activity is new product development. During the Aksaray ramp-up stage, Smart glasses are used for collaborating product development activities were carried out with experienced product development engineers in Izmit. Evaluating the cross-section analysis of the developed tires, engineers in Izmit and Aksaray are connected to each other with smart glasses. This communication channel benefits both the reduction in scrap ratio of the factory and equalized quality of İzmit and Aksaray products developed. Figure 13 illustrates the new product development activities.

Figure 13 – Smart glasses use in new product development activities

The third one is product inspection. Product inspection is the most critical key element for Brisa's production philosophy. Every cured tire is controlled by an inspector for visual control. Inspector peer competence is very important, so technicians are trained regularly to ensure this alignment. During the ramp-up stage of the Aksaray plant, this process has become more critical. All critical training was given physically. Smart glasses were used to repeat the training and to give one-on-one training to the technician in Aksaray by the authorized person in Izmit. In this study, the Aksaray technician inspects the tires visually and records the results. The smart glasses were worn by the Aksaray technician and the examinations were carried out together with the expert technician in Izmit. As a result of the study, the consistency of the decisions made was checked. Studies have shown that the Aksaray factory was a very rigid and risk-free structure in its decisions since it was in the ramp-up stage. Therefore, in some cases, they could label tires as scrap, however, those tires were OK. In a study, the Aksaray technician decided that 51 tires were scrap after the visual inspection. Using smart glasses, these 51 tires were re-examined and 22 were found to be suitable for use. By preventing wrong scrap decisions; thousands of Turkish Liras are saved.

Smart glasses are also used for machinery first run test. It is very useful for the quality, technology, and engineering teams. During the first run, the technician wear smart glasses, the expert team has a check-sheet to control the machine. The technician goes to the control point, checks the items collaborating with the expert team. The most critical feature of smart glasses for this purpose is augmented navigation. The expert can show the check-sheet and control points on the glasses' screen, which makes it easier to control all items. Smart glasses eliminate the extra accommodations for the first run test.

Maintenance is the most popular scenario for smart glasses, and it is also studied. The technician wears smart glasses and the technical center drives the technician. Maintenance technician receives step by step operational instruction according to maintenance standards. Computer side (not smart-glasses), expert, can share files such as PDF, images, to-do list and checklist to smart glasses' displays. The most important advantage is the hands-free operation. While the technician is operating, the expert and technician talk with each other. During the maintenance activity, the expert uses augmented (AR) based instructions such as marking critical points, highlighting machine components so human errors can be reduced. Figure 14 demonstrates that Aksaray technician fixed the control panel, an engineer from Izmit helped and instructed him. The critical outputs of the maintenance study are reduction in downtime period, reduction in production loss, and a good opportunity for operational excellence.

Figure 14 - Smart glasses use in new product development activities

The last category is smart glasses in audit activity. In 2020; there is pandemic (Covid-19) so industries start to change how they do business. As is known, during the audit, a group of people would visit the relevant departments and examine the control items one by one This habit has been changed. The employee goes to the site where the audit will be occurred by wearing smart glasses. Auditors check the required audit items at the computer. They can easily communicate and have the opportunity to share views simultaneously through online video streaming.

Six different scenarios were studied for two years. With people getting to know the technology, it started to get attention, however, figure 15 shows the performance follow-up of the first four months and the early adopter in the company. Smart glasses were more commonly used by the new product development team and a quality team. During the ramp-up stage of Aksaray in 2018, the most preferable activities were collaborative new product development studies, quality studies, and staff training. In 2019; machinery first run test and maintenance operation became more preferable. In 2020, Covid-19 pandemic changed our priorities; remote assistance and audit activities become more popular.

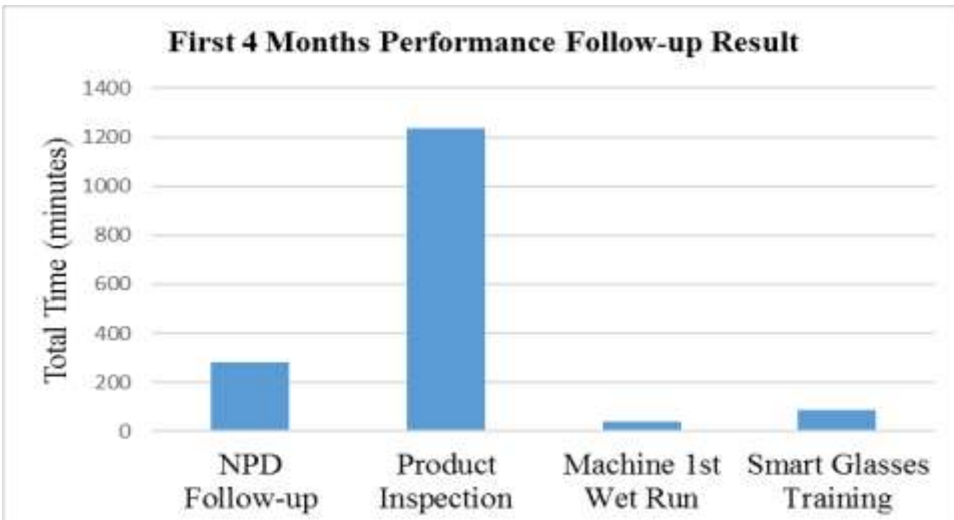

Figure 15 – The use of smart glasses for first four months

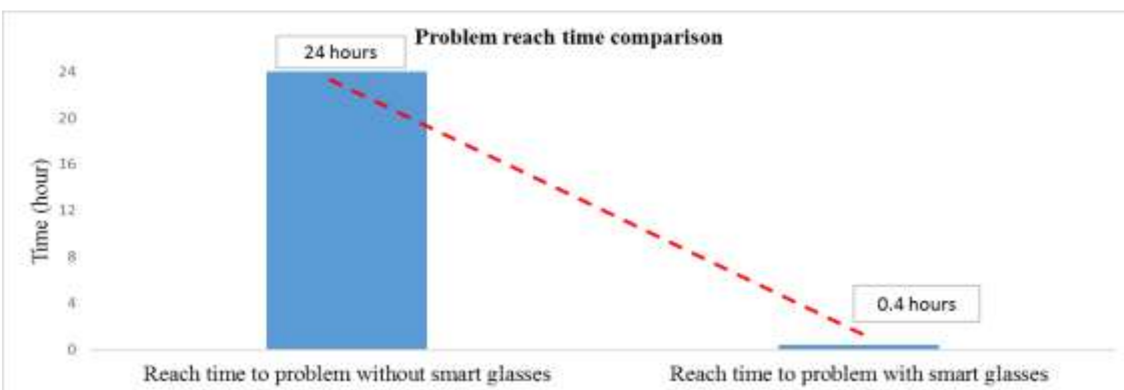

Figure 16 – Time comparison to reach problem

Figure 16 compares the performance of smart glasses. Before smart glasses, when a problem occurred, an expert from the Izmit plant traveled to the Aksaray plant. Up to reach the problem, nearly 24 hours passed. When smart glasses are used, this long period is shortened to 0.4 hours. To sum up, this study resulted in a 40% transfer and accommodation reduction for business trips and a reduction in 50% downtime/production loss due to this transfer time.

Discussion

This study is very important because it was a pioneering work in the Turkish tire industry. The project started in 2018, and different scenarios were put into use every year. Its most important achievement was to make the transfer of know-how between factories located in two different cities dynamically and shorten the time to reach the problem when it has occurred. It was used between 2018 and 2019 to support a factory that was in the process of ramp-up. However, with the global pandemic at the beginning of 2020, it was started to investigate how to use this technology differently. During this period, the concept of home-office entered our lives and it became popular. Efforts were made to make our smart glasses suitable for this purpose. For this, there have been changes in the current network infrastructure. Engineers would be able to connect with their workplaces with smart glasses. While they were working from home, the technician was able to transmit live video streaming from the field, and with continuous communication, both downtime and production losses were prevented.

Papagiannis (2020) from world economic forum said that augmented reality and smart glasses have positive effects on mankind. Papagiannis claimed that AR and smart glasses were no longer just a technology; they were about defining how we wanted to live in the real world with these new technologies and how we would design experiences that are meaningful and could enrich the future of humanity. Smart glasses studies are very crucial due to Covid-19. There may be some lock-down period and loss of workforce, so the sustainability and attainability of production and technology know-how are so important. Collaborating with smart glasses is a big advantage for those lock-downs and working from far away.

Regardless of the distances worked, with smart glasses this means only a few minutes. Smart glasses allow quick access to information. Besides remote assistance options save time and resources, i.e. it prevents additional business trips.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Note

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