Digitization of records of performed autonomous maintenance activities on pc panels of production lines

Master Thesis

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3. Design a compatible solution with regard to user-friendliness, visualization, alerts, system extensions and customization.
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[3] HEIJDEN, J. G. M. van der. Designing management information systems. New York: Oxford University Press, 2009. ISBN 978-0199546329.
[4] MCNURLIN, B. C., a R. H. SPRAGUE, T. X. BUI. Information systems management in practice. 8th ed. Upper Saddle River, N.J.: Prentice Hall, c2009. ISBN 9780132437158.
[5] LEVITT, J. Managing factory maintenance. 2nd ed. New York: Industrial Press, 2005. ISBN 9780831131890.

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Abstract

During the last few years, new trends in technology innovation have emerged. The most essential of these new trends is digitalization of maintenance activities. In this work, it aimed to eliminate the extra workload and decreasing of human factor mistakes of manual, paper-based autonomous maintenance processes. Created platform provides to enable workers to solve deviations much quicker and more efficient. The maintenance platform is all about smooth digital registration and keeps records of maintenance activities. This platform enables maintenance management to have more control over the maintenance activities and to make change easily.

KEYWORDS : Autonomous Maintenance, Digitization, Database Management, PHP, HTML, CSS, Industry 4.0.

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LIST OF ABBREVIATIONS

Abbreviation	Long Name
AM	Autonomous Maintenance
TPM	Total Productive Maintenance
TQC	Total Quality Control
ISO	Industrial Organization for Standardization
PC	Personal Computer
IT	Information Technology
HMAC	Hash-based Message Authentication Code
www	world wide web
CGI	Common Gateway Interface
FTP	File Transfer Protocol
NoSQL	Not only Structured Query Language
RDBMS	Relational Database Management System
SQL	Structured Query Language
ANSI	American National Standards Institute
PHP	Hypertext Preprocessor
HTTP	Hypertext Transfer Protocol
HTML	Hypertext Markup Language
OOP	Object Oriented Programming
XHTML	Extensible Hypertext Markup Language
W3C	World Wide Web Consortium

Abbreviation	Long **Name**
CSS	Cascading Style Sheets
PDO	PHP Data Objects
MD5	Message-Digest Algorithm 5
PDF	Portable Document Format
URL	Uniform Resource Locator
SMTP	Simple Mail Transfer Protocol

1. INTRODUCTION

During the last few years, new trends which are Industry 4.0, Internet of Things, Digitalization in technology innovation have emerged. In this research, the compatibility of these technology innovations with the maintenance procedures is discussed.

Digitalization of maintenance activities has been becoming more and more popular for the companies. Competitive companies are making remarkable investments for digitalization of maintenance activities in order to not fall behind this trend. However, while these investments are being made, companies should need a strong technical backgrounds. Otherwise, these investments will not provide companies with a payback.

Today, poor maintenance strategies can reduce productive capacity of a plant between 5 and 20 percent [1]. Recent studies also show us that unscheduled downtime costs industrial manufacturers an estimated $50 billion for a year [2]. As a result of these numbers, companies focus more about their maintenance strategies.

Targets of this study is described below:

- Remarkable improvement in maximum effectiveness of equipment,
- Cleaner and tidier workplace,
- Increasing of employees' morale,
- Increasing average capacity,
- Increasing production capacity,
- Decreasing maintenance expenses,
- Decreasing maintenance man-hours.

In this work, the digital transformation is applied with designing a compatible solution with regard to clear, user-friendly navigation. This implementation is an essential step in order to complete new maintenance trends with regard of Industry 4.0.

This study will be implemented to welding line of SKODA AUTO s.r.o. The company is working with paper-based maintenance which is shown on Figure 1.1. Our solution or digital platform enables to eliminate disadvantages and limitations of paper-based maintenance.

The platform is a digital-based maintenance which has classified in 2 main sections. One of them is administration panel which is used by maintenance supervisors of the workplace. The second one is user panel which is used by workers of the workplace.

The Figure 1. 1 shows us the current status in the workplace for the maintenance activities in the selected workplace.

Figure 1. 1 Paper-based Maintenance of the Welding Line.

As seen in the Figure 1. 1, the maintenance activities are checked from the paper by the maintenance supervisors, after the paper is filled by the maintenance workers.

The proposed solution basically offers digital-based maintenance which is shown in the Figure 1. 2.
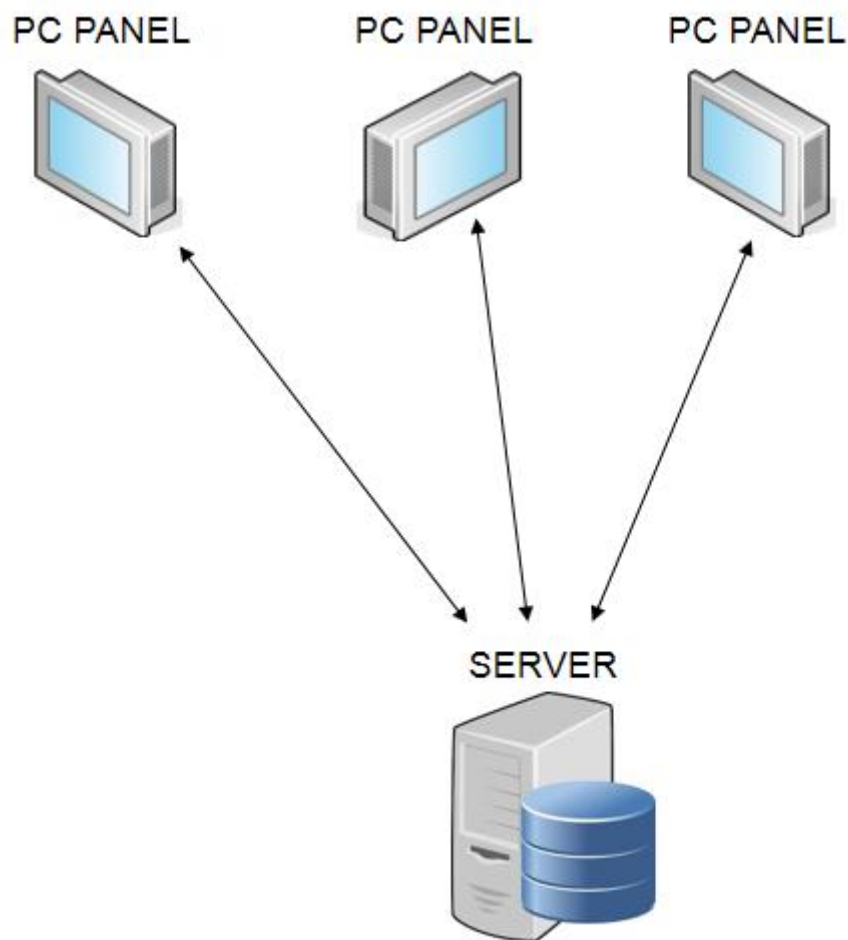
Figure 1. 2 The Desired Status for the Maintenance Activities.

PC Panels are used instead of the maintenance papers. PC Panels display the assigned checklist by the maintenance supervisors. Operation manuals which are image guides for the workers, are displayed in PC Panels.

On the other hand, server side is designed for the supervisors in order to apply PC Panel assignments. The proposed solution covers adding, editing and deleting checklist and operation manual. Also, viewing checklists for the selected date range is possible.

This research basically consists of two main part. The first chapter will explain the technical backgrounds in order to design the proposed solution. The second chapter is going to explain that the how to design the proposed solution.

2. TECHNICAL BACKGROUNDS OF THE DIGITAL SOLUTION

Digital technologies have made many positive changes. It covers the improvement of existing approaches and new ideas for product and service delivery. Many companies need effective tools such as digital transformation framework in order to complete seamless integration.

The implementation of the digital transformation framework includes elements such as project management, personnel productivity, user experience, technology implementation and corporate culture. Businesses benefit greatly from transformation process.

The proposed solution should be capable of creating complex integration solution and adding to make all business solutions effectively and flawlessly work as a single system. For this capability, technical background of the proposed solution should be well understood.

In the first section of this chapter, followings are discussed in order to understand concept Autonomous Maintenance:

- Definition of Autonomous Maintenance,
- Expected actions to perform Autonomous Maintenance,
- Steps of Autonomous Maintenance,
- Advantages and Challenges of performing Autonomous Maintenance.

In the second section, paperless manufacturing and digital transformation are explained. Fields of digital maintenance are investigated in order to achieve successfully implementation of the proposed solution.

The one of the most significant part of the platform is selecting optimal technologies for the proposed solution.

All technologies have trade-offs, therefore the primary focus is understanding what a specific business challenges are and then selecting technologies that best aligns with individual needs of business challenges.

Technical backgrounds have been implemented to the proposed solution with proper technologies.

2.1. AUTONOMOUS MAINTENANCE

Autonomous Maintenance (AM) is defined as a maintenance strategy where machine operators uninterruptedly monitor their equipment, make adjustment and execute minor maintenance activities on their machines. This done rather than assigning a dedicated maintenance specialist to perform maintenance and regularly scheduled upkeep. AM is performed by the operators and not by dedicated maintenance technicians.

AM is the first pillar of the Total Productive Maintenance (TPM) concept. AM is a crucial component of the TPM. TPM was industrialized by Japanese companies, trying to extend the existing concept of Total Quality Control (TQC) with the ideas of predictive and preventive maintenance lists. As a company-wide initiative, TPM is a maintenance strategy which maximizes the effectiveness and longevity of related equipment. To recognize AM properly it needs to be seen as an improvement activity within TPM, rather than production teams taking on maintenance activities. Therefore, when companies begin to implement TPM, they frequently start by pointing AM. This approach is understandable as AM is one of the most important and distinguishing features of the TPM.

The most significant idea of AM is that operators perform routine maintenance tasks and continuously improve their structures. These tasks generally include daily cleaning, inspection, lubrication and tightening required by the equipment. Since operators are closer to their equipment than anyone, it quickly detects abnormalities [3]. One of the main ideas of TPM is that operators will become more important, so some authors state that AM is the most significant and resembles true TPM thinking [4]. Giving an impression of what most authors mean by AM, some clarifications are provided.

Expected actions for performing AM:

- Detect abnormalities and make improvements.
- Understand the functionally and the components of the machines and realize the causes of abnormalities.
- Recognize possible quality concerns and identify their causes.

Whenever the failure requires the intervention of the maintenance division, the operator may be asked to assist the maintenance engineer.

One of the biggest advantages of this work is that in such situations, the operator can quickly and easily report his/her intervention and detected issues. It means that this optimizes the traceability of the encountered faults and helps the team to provide the best and fastest troubleshooting solutions.

On the other hand, the operator should be talented to provide reliable and quick initial diagnosis and troubleshooting in a certain number of failure cases.

The operators' training should begin with strict observance of a definite number of rules, called by the Japanese "the five S":

- *Seiri*; has been translated 'Sort' - storage, elimination of unnecessary effects
- *Seiton*; has been translated 'Set in order' - orders, methods
- *Seisso*; has been translated 'Shine' - inspection, control, workplace cleaning
- *Seiketsu*; has been translated 'Standardize' - standardization, repetition, visualization
- *Shitsuke*; has been translated 'Sustain/Self-discipline' - organize, identification, discipline, morale

If the 5S are properly introduced and strictly applied, working methods for failsafe operations will get extremely optimized. The successful implementation of AM depends on 5 steps, patenting from the Japanese five S.

Equipment has become increasingly sophisticated and complex, and the maintenance function has gradually become separated from the production function, with the result that production and maintenance departments have become isolated in their own camps, with one 'making' and the other 'fixing'. This approach makes equipment much less efficient than it could be, and the need to remedy this culture has led to the emergence of the discipline known as 'Autonomous Maintenance' [5].

This basic precepts or implementation of AM may very slightly depend on each plant's operation.

The steps of AM can be broadly categorized into three main precepts:

- The complications that stop equipment from working, or make it work less effectively, can be completely eliminated.
- When the equipment work better, the people and whole factory work more effectively.

- AM should be presented step by step under the control mechanism and the guidance of management, with each step implemented methodically. It should involve the entire workforce and empower each individual to fulfill employer's potential.
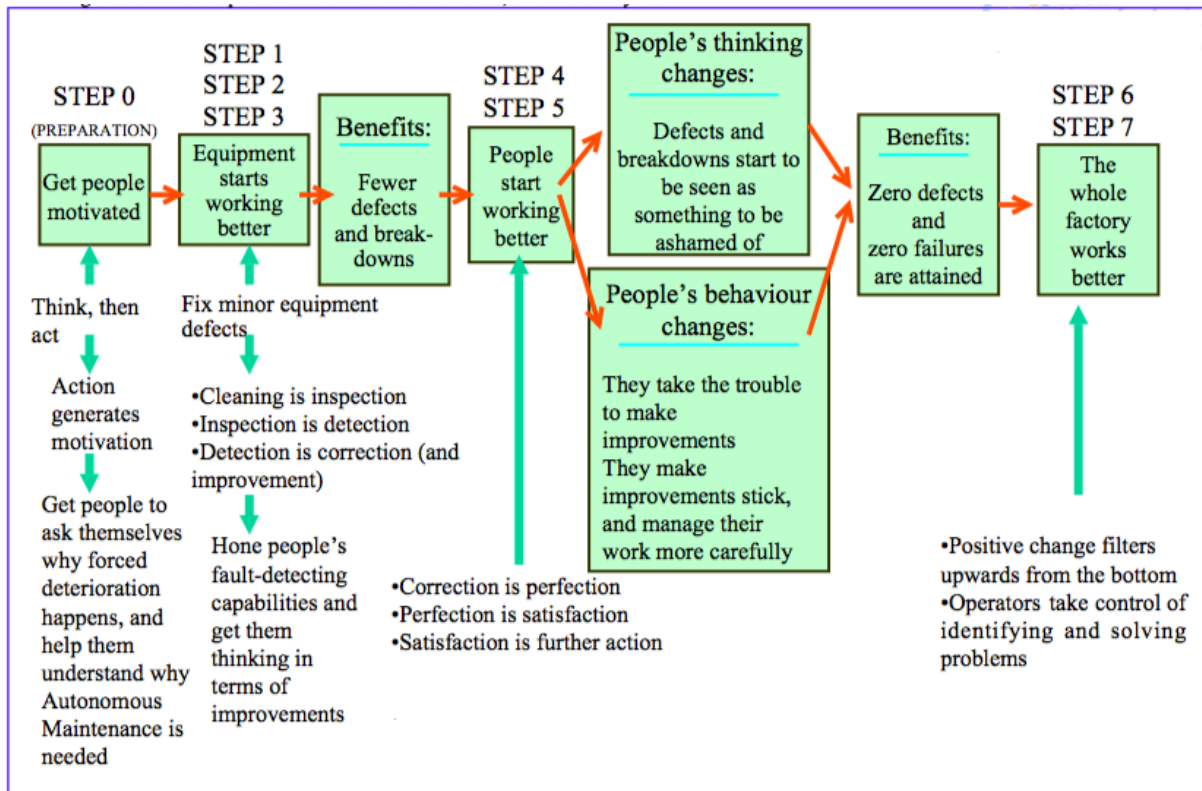
Figure 2. 1 The steps of AM and How They Work [1].

Implementing AM is typically broken down into seven steps.

2.1.1. Increase Operator Knowledge

Sometimes called "step 0", the training level is about informing basic knowledge of components and function of machines. In order to complete properly most important task - machine cleaning, operators should fully understand the purposes of AM and be even able to deliver improvement in equipment reliability. Educated operators should know the inputs and the outputs of their machine. This involves training from maintenance technicians on the technical details of how the components of machine work and their purpose, as well as training on problem-solving skills. As a summary, operators should have four equipment-related skills:

- Detecting abnormalities,
- Correcting and restoring abnormalities,
- Setting optimum equipment conditions,
- Maintaining these optimum equipment conditions [6].

In this purpose, the operation guide manual has been implemented for the operators in the proposed solution which we are working on.

2.1.2. Initial Cleaning and Inspection

The initial cleaning of the machines is crucial for high-quality maintenance. This step is usually performed by all involved teams of the maintenance, production and engineering and includes the thoroughly cleaning of the equipment and surrounding. Basically, initial cleaning means exactly these; removing all foreign matter, for example dust, dirt, oil stains, sludge, rasping and so on, from the mechanisms of machine, moulds, tools, fixture, jigs and other equipment which is used to make the product.

The goal of this step is to fully restore each part of equipment to its full performance by recognizing and eliminating signs of deterioration. Members of teams should take care and perform things like:

- Leak detection,
- Lubrication,
- Control of loosened bolts,
- Correction of defective items,
- Removal of material rests from oil or water,
- Detection of non-apparent cracks,
- Better precision adjustment
- Eliminating of micro-stoppages due to dust, waste,
- Decreasing of fluid contamination rates,
- Removal of dust and dirt,
- Eliminating of conductibility restriction in electrical manufacturing due to oil and dust deposits.

The step mentioned above has a slightly complex structure. Because of this, it could be good idea to document the protocol while conducting this thorough cleaning. Therefore, our solution contains control and management panel in order to issues can be easily traced and operators have something to access that contains easy-to-follow steps.

Main key points of implementation of initial cleaning and inspection is described below:

- The basic instruction should be given required for this step to operator.
- Cleaning plan should be created.
- All unnecessary objects should be removed. Freeing up space in this way is an important step in initial cleaning and inspection.

Figure 2. 2 The Effect of Effective Initial Cleaning in AM [7]

2.1.3. Remove the Causes of Contamination and Improving of Access

After the initial cleaning steps have been performed and the equipment has been restored again, it is extremely important to make sure that equipment doesn't deteriorate again. This can be achieved by eliminating all possible contaminating sources and improving accessibility for maintenance and cleaning.

In this step, safety and all possible security issues are also considered. On the other hand, cleaning or maintaining a running machine is quite dangerous. Therefore, improving the security and visibility through better access points is vital.

A maintenance supervisor should take into consideration the fallowing possible solutions:

- *Establishing and sticking maintain cleaning standards:* The most serious problems cannot have repaired immediately and may require the machine to be shut down for a long time according to the standards. Other problems detected as leaks or damaged parts can be repaired.
- *Achieving permanent cleaning by avoiding soiling:* The main causes for contamination of machine should be eliminated gradually. High-quality sealing and covering of machine are efficient points to start. However, some causes for contamination may request more serious investment in thing like pumps or dedusting or pumps.
- *Promoting cleanliness:* Reiterate cleanliness should be continued during inspections and maintenance.
- *Promoting orderliness:* Making sure tools have specific place and remain there which increases efficiency.

2.1.4. Developing Standards for Cleaning, Lubrications and Inspection

Maintenance employees should use experience of previous steps to determine the optimal cleaning, lubrication of related equipment and to draft preliminary work standards for its applications. Key point is that operators should create their own standards to feel more commitment.

This step can be adjusted as required based on each section of equipment and its operator. Standards should indicate which components of machines should be cleaned and lubricated, how components should be cleaned and lubricated, and all other maintenance tasks to be assigned. Standards can be categorized based on whether the machine is considered not critical and critical:

- When the machines are defined as a *non-critical machine*, operators shall be trained by maintenance engineer who is an expert about maintenance procedures and operator should follow the established standards. After training, operators can establish their own routine.
- When the machines are defined as a critical machine, a team of maintenance engineers dedicated to maintenance methods and production, can be created.

After finalized, all standards which are established should be documented and operators can use easily these standards. These finalized stage which are also best indication for the successful implementation of AM at a plant.

2.1.5. Inspection and Monitoring

After fourth stage, operator have a set of standards to take a guidance. In this case, operators can modify their basic maintenance routine to streamline and improve responsibilities. The maintenance responsibilities of operators are tracked and compared with the maintenance department's own schedules to ensure the duplication of responsibilities are not an issue.

The maintenance department's own schedules are usually through a computerized maintenance management system.

In this work, maintenance management system is created. Maintenance manager can track all of steps of each operator using mentioned maintenance management system.

Unfortunately, basic inspections are overlooked in many manufacturing plants. On the other hand, implementation of basic machine inspection is not so laborious. The machine operators themselves can successfully perform the following basic tasks:

- Checking lubrication levels,
- Tightening bolts,
- Detecting location of leaks,
- Performing mechanical adjustments,
- Identifying possible mechanical problems.

2.1.6. Standardize Visual Maintenance

Standardizing AM and making equipment visual is an essential step for maintaining the integrity of each piece of machinery at workplace. Companies seek to standardize the maintenance work which is applied and also try to make the workplace as visual as possible. Companies should create formal standards for AM and improve the visual management of the machines. In short, visual management means that making thing on the machine as obvious as possible.

Standards basically should cover these things;

- Operating procedures,
- Safety procedures,
- Basic work standards,
- Data recording,
- Managing equipment and tools,
- Managing spare parts,
- Process quality assurance.

2.1.7. Continuous Improvement

The final step of the AM is AM review and continuous improvement. It is necessary to periodically taking the time to step back and control standardized processes to make sure the system is working efficiently and to see where improvement can be applied.

Keeping good records of failures is vital to provide data that maintenance engineers can use when designing future machines, making them even easier to access and maintain [6].

Auditors can be divided into two main groups. The first group consists of the personnel from the AM group itself, and second group consists of the members outside the AM group. Top management should consider any comment and recommendation given by the auditors once they have completed the auditing process to initiate the continuous improvement of tasks [8].

This stage is really essential for implementing of AM. Because, the results of the audit are used for further improvement to achieve the targets of the AM programme and enables to check all of the AM system using of feedback from auditors. On the other hand, these feedbacks enable to distinguish who do their job well. It helps operators to play an active role in process design reviews and contribute their suggestion.

Examples of audit points for evaluation and recommendation:

- Understanding the objectives of AM programme by management group,
- Understanding the objectives of AM programme by execution group,
- The planning of AM activities by management group,
- The implementing of AM activities by execution group,
- The cooperation between management group and execution group,
- The communication between management group and execution group,
- The knowledge transfers from management group to execution group,
- The knowledge gained by execution group in training session and so on.

2.1.8. Importance of Autonomous Maintenance

As described for AM above, involving operators in routine maintenance of critical plant equipment offers major benefits. The most obvious is reduced maintenance labor cost.

The other important advantage is an increase availability of the highly-skilled maintenance workforce. This is especially essential for offsetting the population reduction in the skilled maintenance workforce for those maintenance activities that require greater specialized talents.

The ultimate reason for AM is simply that it reduces cost and improves profitability. Also, it ensures to permit more effective use of maintenance crafts from operators.

Failure to comply with maintenance principles causes in loss of customers and overall low profitability, as exemplified in Figure 2. 3.
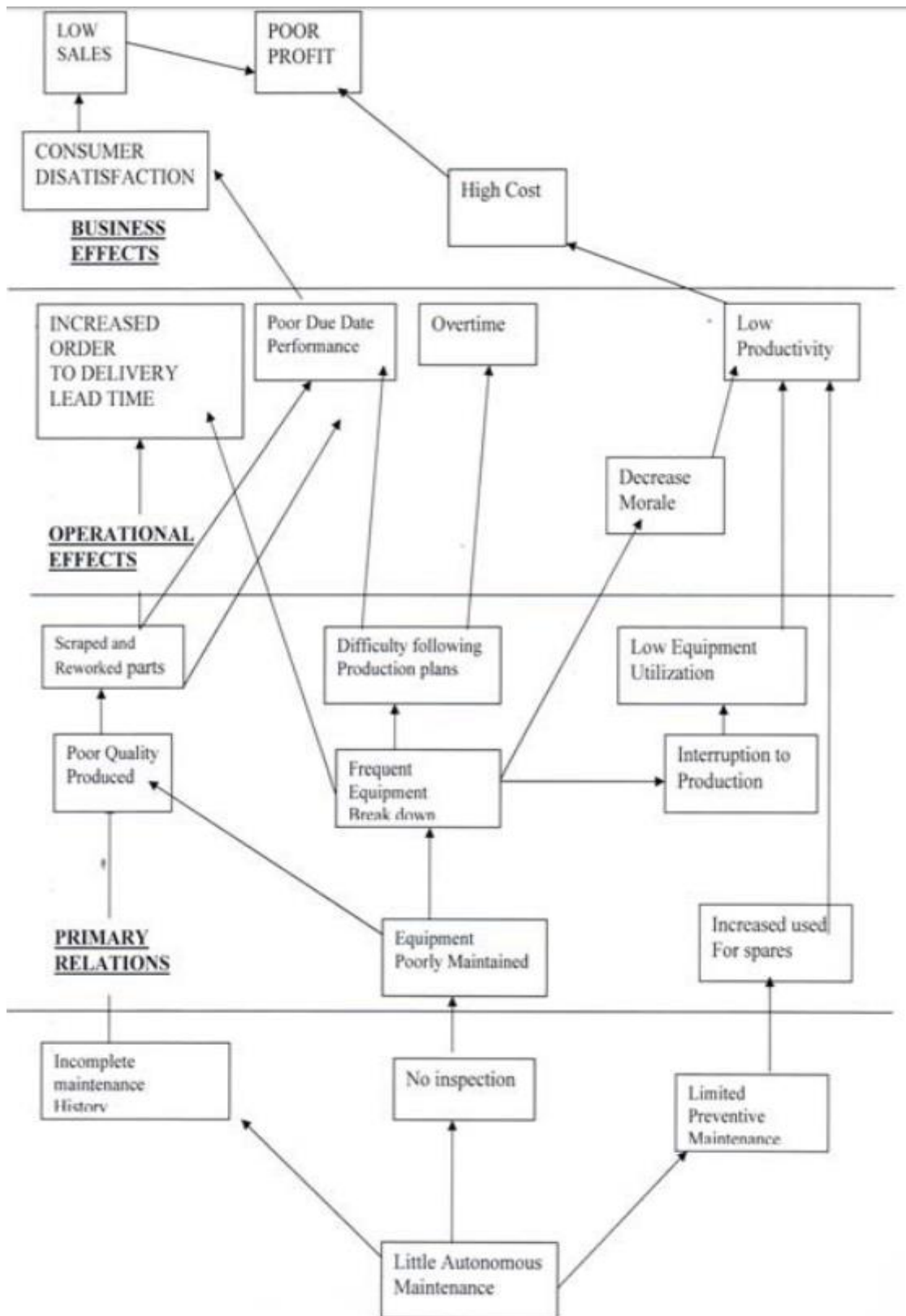
Figure 2. 3 AM and Company Performance [9].

AM can provide more advantages to organization because of the followings:

- Machines can run on, close to the capacity,
- Breakdowns happen rarely,
- Capital expenditure is reduced,
- Products are produced according to the specification,
- Working environment is improved because of cleanliness and pride.

Last but not least, the ability to achieve maximum customer satisfaction by delivering the right quality and quantity of products to customer is one of the major benefits of successfully implementation of AM.

2.1.9. Challenges of AM Implementation

In spite of the numerous benefits of AM, there are a lot of challenges that if not properly addressed will hamper its successful implementation. Because the maintenance strategy which appears easy in theory is actually difficult to actualize.

The implementation of AM is not easy. Implementation of AM brings many demanding tasks and efforts, such as planning, execution and improving based on questions why, where, what and how to do.

Some of these challenges:

- Resistance to change
- Lack of commitment
- Top management pressure
- Lack of knowledge
- Lack of reward programme
- Organizational culture
- Inadequate workshops and trainings

With efficient leadership and management support as well as relevant trainings and workshops, source of challenges will be eliminated and challenges will be overcome.

2.2. DIGITILIZATION

It is not a secret that the role of paper is rapidly decreasing in our lives, both at home and work. Newspaper, books, magazines, workshop drawings, technical specifications of project are obvious examples, which are quickly being replaced by tablets, e-books, computers, PC panels. More accurately, the cost of working in a paper-based environment is likely increase more of the change, quickly making paper old-fashioned.

At work, the decreasing of using paper can be more dramatic, when you compared with at home. The cost of a paper-based work environment is liable for much of the change, and it's rapidly making paper obsolete in the workplace. Companies have been joining the paperless revolution for the last several years for more efficient outputs.

On the other hand, if the paper is stored properly, it can stay for hundreds of years without any of the issues which it has been seen related to changes in digital media storage. Even although paper is still seen by many companies or organizations as a matter of permanent record, there are unfortunately some important restriction and costs. These issues may sound tolerable until we take into account costs related to a significant part of industry requirement like Industrial Organization for Standardization (ISO) document management and certification.

The cost of managing data on paper-based work is higher than people think. Storage of billions of manufacturing document is real. Paper can be misplaced or lost. Information and data of paper can be changed or removed.

When we consider all of processes in workplaces, the majority are still manual. It means the most data is still summarized and written down by operators. As the requirement for data collection increases, significant operator distraction causes to reduce their productivity dramatically. Also, the written data is generally subjective, which varies from operator to operator.

In paperless manufacturing, paper-based is replaced by electronics records. Paperless manufacturing can be defined that the information can be viewed on desktop display units, screens in the workplace. The paperless environment continues across all function of the organization, consist all department, locations and workplaces.

In order to obtain effective paperless environment, a paperless program must be organized and comprehensive. Platform-based solutions that support all connection enables faster response times, because all data has been standardized, which means that optimized performance.

Some of the benefits of paperless shop floor:

- Improved environment for innovation,
- Higher quality
- Lower cost
- Reduced response time
- Eliminate the cost of paper
- Increased productivity and efficiency
- High degree of flexibility

Regarding the previous descriptions in this chapter, we can evaluate that a paperless environment is an essential factor in increasing the speed and decreasing the cost in the workplace. However, there are several other features to a strategy which increase operational flexibility and agility at the plant. Along with the appropriate technology which is platform-based solutions, a comprehensive strategy involves adopting standardized processes and making the required cultural adjustment to achieve goals and targets of organization.

Today's paperless manufacturing projects are now more complex and extensive. As a result, the return on investment associated with them is not only related to the reduction of space required to store documents or the time it takes to find them, but by distinct gains in competitiveness, flexibility, and reactivity [10].

Maybe paperless manufacturing has already been widely discussed, is becoming to the top of the priorities list for many organizations. Nowadays, paperless manufacturing should be integrated in a universal approach to the management of production, taking into account the integration of all systems involved.

Paperless environment is one start point of the digital revolution in manufacturing. Digital revolution is known by many as the Smart Factory or Industry 4.0. digitalization is a critical start for Industry 4.0.

2.2.1. The Digitalization of Modern Manufacturing

According to the Collins English Dictionary, digitalization is the process of converting information into digital format, in which the information is organized into bits [11].

Even although analog data is generally more stable, digital data can more easily be accessed and shared. Therefore, digital data is a favored way preserving information for many organizations.

Smart manufacturing or Industry 4.0 is the application of information and communication technology to every sides of manufacturing are in the center of redesigning modern manufacturing. Convergence of digital technologies with manufacturing industry creates new challenges for global manufacturing competition. Keeping up with rules of this new era has become a sine qua non for competitive companies. These technologies can be applied by every companies across the world, which is why organizations must race to embrace digitalization to stay competitive. Digital connection between designer, workers, managers, consumers, and physical industrial assets will unlock enormous value and change the manufacturing environment forever.

Nowadays, manufacturing isn't only about huge plants and long workplaces anymore. Instead of these, processes are digitized. Drawings of design, maintenance instruction, operations' manuals are not handed down to the workplaces in books. Rather of this, they are being sent to tablets, computers, or any mobile device built specifically for that purpose.

The important point is that processes and systems stay the same when processes are digitized. For example, instead of getting a signature to approve it from the supervisor, an e-signature or login the system with unique name and password might be used on the document.

We are seeing as digitalization transforms in the manufacturing industry is that processes will move a lot faster. Digitalization gives that increasing productivity. It allows projects to run faster and it causes more aggressive deadlines.

Digitalization offers much-needed relief for global manufacturing value chains. At digital environment, data is easier to share files across a network. On the other hand, printing means unnecessary data translation now, and this translation may cause more vulnerability for the organization.

Digitalization can help simple clarity and process enforcement. For instance, specifying that every field in a form needs to be completed. User can not send the form before filling every fields.

Digitalization is not final step of moving Industry 4.0. After processes are digitized, additional essential technologies can be used like Machine Learning, Artificial Intelligence, Internet of Things to achieve new era of manufacturing.

The important digital transformation trends are shown at Figure 2. 4 below.
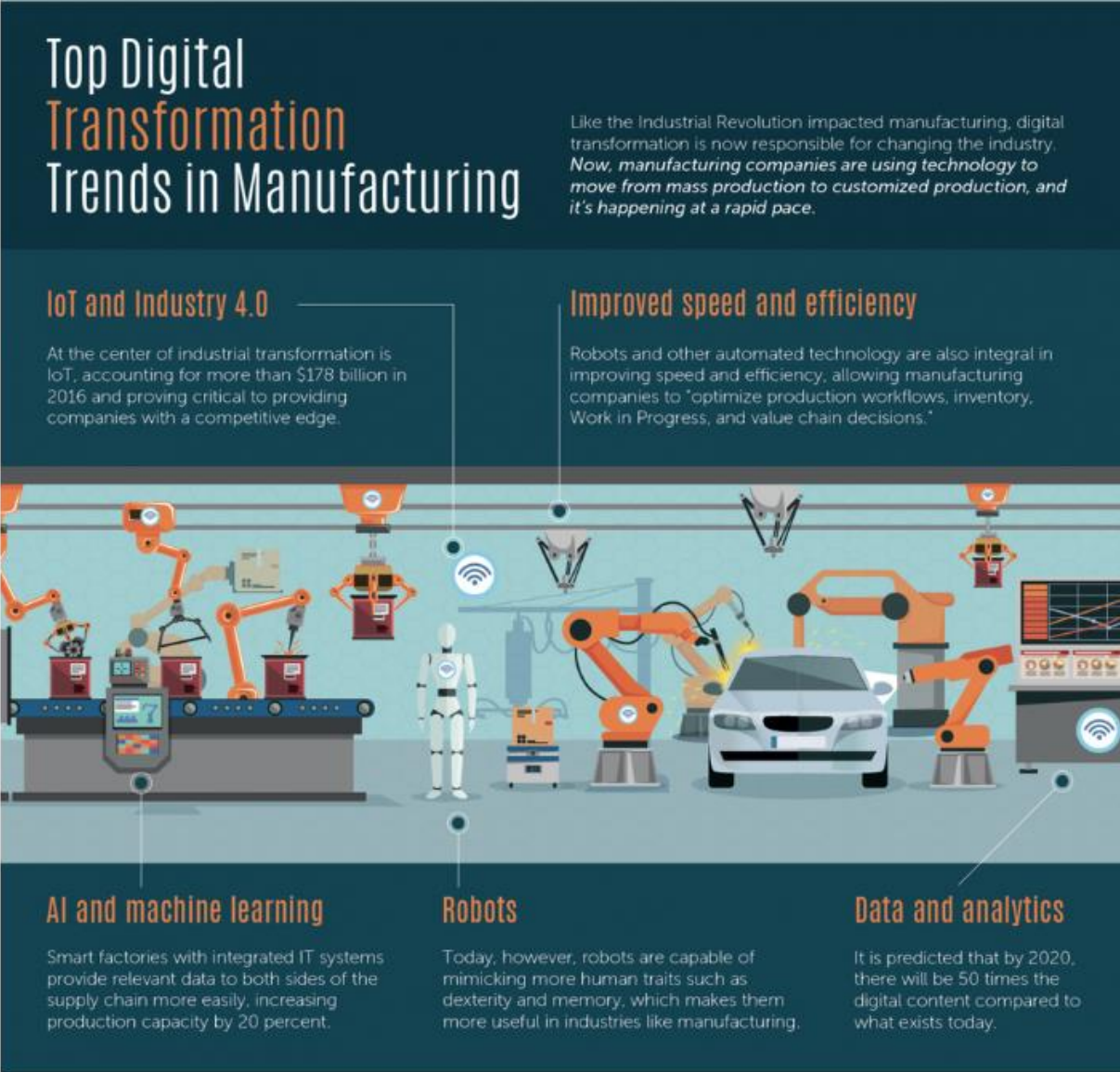
Figure 2. 4 Top Digital Transformation Trends in Manufacturing [12].

Many large manufacturers are starting to implement data analytics to optimize plant activities and operations in order to increasing equipment utilization and product quality while reducing energy consumption.

Workplaces managers have a clearer view of operation flows in a manufacturing network with digital tools, which can help them reducing cost and improve efficiency of factory operations. It also increases quality of products which meet with costumers. Industries in a wide range are using digital technologies in different methods to drive value.

The combination of real-time performance visualization in operators and daily problem solving can led to huge amount of increasing in production rate.

As a summary, digitalization enables to generate, collect and utilize massive amounts of data, along the manufacturing process. Data can be collected with minimum effort which result of digitalization. Monitoring, controlling and manipulation of parameters gets physically detached from the plant through devices which allows for an integrated production [13].

2.2.2. Digital Transformation in Manufacturing Industry

Digital transformation has attracted a lot of attention through the manufacturing industry. Digital transformation causes fundamental changes in manufacturing industry.

Organizations which is applying a digital transformation have achieved higher employee morale and higher costumer revenue. Digital transformation visibly increases the efficiency for companies with a high number of employees.

The manufacturing industry has come a long path from the mechanical processes presented by the Industrial Revolution, and has appreciated the efficiencies of computerized manufacturing processes.

Greater benefit is promised with era of digital information revolution. Valuable data is increasing, and manufacturer must apply it in order to stay the important position in competitiveness.

It is quite clear that the manufacturing industry will transform as the result of the inevitable digitalization of many production processes.

On the other hand, the transformation is difficult process. During this digital transformation, the manufacturing industry should take too many variables into consideration.

A key requirement for truly successful digital transformation is the end-to-end digitalization of processes and drawing up methodology of transformation. This methodology is shown on Figure 2. 5 [14].
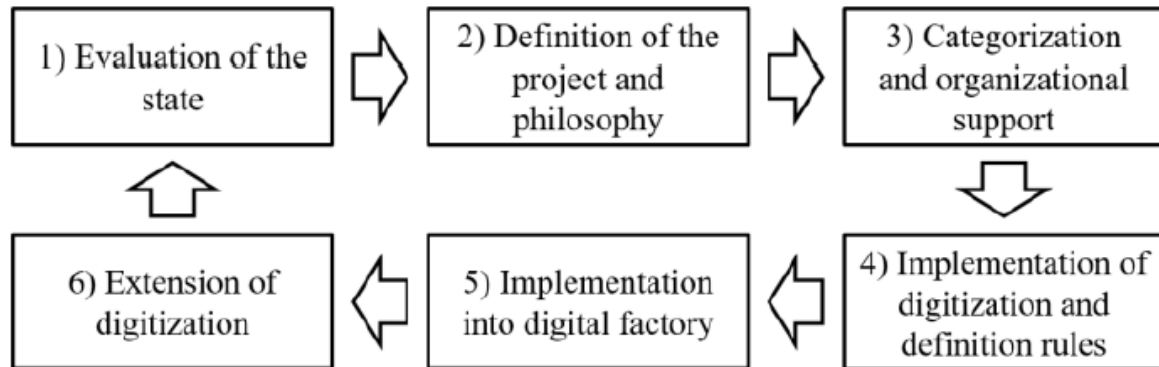
Figure 2. 5 The Phases of Digitalization of the Manufacturing Processes [14].

According to the surveys for manufacturer respondents shared that they are still going through a digital transformation and have more effort to do. Companies have faced challenges while digital transformation processes. What is interesting here is that these challenges are not related to the size of the organizations. According to the researches, the often seen challenges listed were:

- Employee pushback
- Insufficient budget
- Lack of expertise
- Inadequate organizational structure
- Lack of overall digitalization strategy

Humans like to keep routine, and do not want to leave the comfort zone by nature. Undergoing a digital transformation is the epitome of discomfort for employees. Therefore, employees may feel threatened. The key points of avoiding of employee pushback are being consistent and transparent. Keeping employees informed and involved through the whole transformation process.

Organizations must have a strategy. The vision should be clarified, and set goals and targets to reach it. Also whole team in the organization should have target. Journey of digital transformation does not belong to one individual or department. Whole company should be working toward the common goal.

One of the biggest challenge of digital transformation is lack of expertise to lead digitalization initiatives. Digital transformation will bring a lot of technical challenges. It means that in order to solve these technical challenges, companies need the right expertise. Companies should train their workforce to digitally literate. The digital transformation is an essential investment for the organization. It may require changes in more than employees' routines. This could mean changing roles, changing departments, or revising the organizational structure. These changes require considerable courage and effort for companies. The organizational structure should be fluid and flexible.

The digital transformation may require substantial investments in companies. When companies build their strategy, they should use the budget as a reality check to see how much the company can handle. In order to avoid the company at risk over budgetary issues, developing a plan that involves several phases over several years is necessary.

As a generally, for eliminating of these challenges, the organization should build a strong background. In order to reach all of the assistances of a digital transformation with a mindset of continuous improvement and innovation, these challenges which is described above should be eliminated.

2.2.3. Digitalization of Maintenance Activities

Before the explanation of digitalization of maintenance activities, traditional maintenance should be described for better comparison. Traditional maintenance tends to react to faults in equipment or devices after the fact. This traditional, reactive approach (productive maintenance) of identifying faults after they occur is the worst-case scenario for maintenance.

Enterprise maintenance involves preventive and predictive maintenance activities, which has objectives of decreasing unplanned and unscheduled downtime. It means also restriction of reactive maintenance. Because reactive maintenance activities solve problems after they occur, it likely means the machinery functioned in a defective mode during some time and the quality of operations is low when we compared optimal.

On the other hand, preventative maintenance allows operators to perform continuous maintenance. A model uses the power of connected devices and Internet of Things to replace traditional maintenance dynamics; the purely minimizes maintenance downtime [14]. Preventative maintenance activities enable to predict products quality, by detecting equipment failures more quickly.

Type of maintenance activities also directly effect on operation and maintenance costs. A correct maintenance strategy must be chosen and successfully applied to reduce operation and maintenance costs.
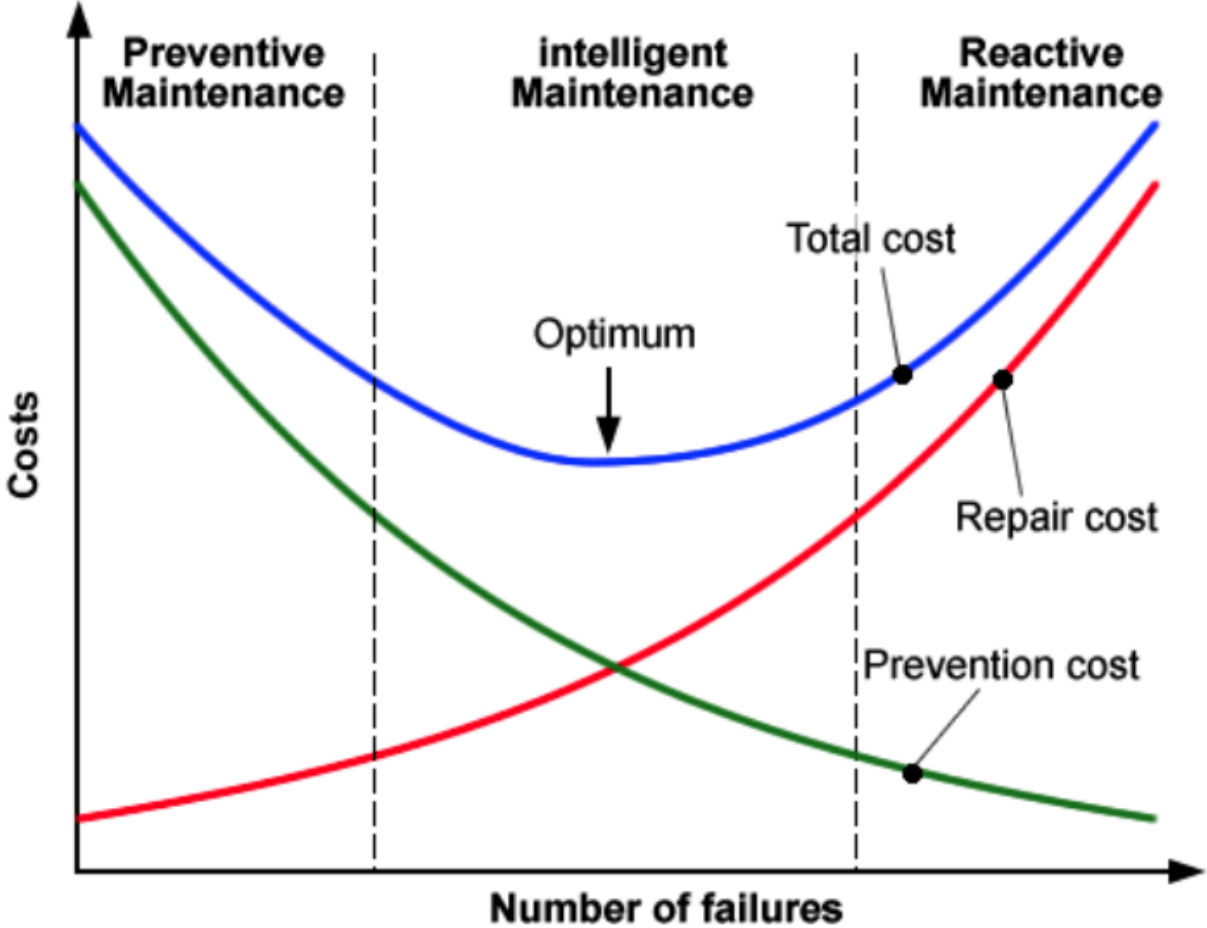
Figure 2. 6 Cost Associated with Maintenance Strategies [15].

The cost associated with maintenance strategies is shown on Figure 2. 6. In reactive maintenance strategy, a greater number of failures will occur. As a result of this repair cost and total cost is increasing. On the contrary, in preventive maintenance strategy, we can see on the graph higher lower repair cost. But total cost still high, due to high prevention cost.

The best solution is combination of the reactive maintenance strategy and the preventive maintenance strategy in order to achieve the optimum total cost.

Maintenance has for long time been one of the essential fields for research on digitalization. Within all maintenance work it should be possible to quickly find the causes of failures, remedies and improvements for future products [16]. For this reason, digital maintenance has been gaining more and more attention in recent years.

Digital maintenance can be described as the field of maintenance where advanced technology is used to provide decision support for operations and maintenance, through the application of advanced information technology [17]. When going from traditional maintenance to digital maintenance, entire organization, working methods and technical solution are changed.

In industries, where maintenance work occurs, it is important to quickly identify the cause of malfunctions and perform preventive maintenance [16].

With digitalization of maintenance, subjective assessments can be reduced when several different people collect data manually. It is really important to make the correct diagnosis in order to save time and money. From that point, digital maintenance enables more efficient maintenance work.

The collection of data should be efficient in order to obtain reliable output values in digital maintenance. The 6V model in industrial big data is an important approach to the efficiency of data [18]:

- *Volume;* amount of data generated every second by organizations.
- *Velocity;* while data volumes grow, the speed of data creation and use is increasing too.
- *Variety;* data comes in numerous shapes and forms.
- *Veracity;* about ensuring the reliability and validity of the insights derived from data. We can say that it means quality of data.
- *Value;* data is only valuable if it generates some form of payback.
- *Vulnerability;* the provenance of the data, right back to its origin.

Maintenance has always been an important component of Quality Management, but the extended digitalization of operations makes the relationship between maintenance and quality much closer and more symbiotic.

Maintenance engineers gain deeper insights on how maintenance affects quality and how quality affects maintenance, as a result of the availability of large volumes of digital data.

With digitalization maintenance, quality management processes will become more proactive and less reactive when compared with today.

The increased obtainability of digital data about machinery throughout its life cycle makes it possible to continually track and trace the condition of machines and tools, instead of just detecting machines and tools during an inspection [19].

In addition, this traceability with increasing availability of digital data also creates a reliable feedback mechanism for maintenance activities. An important fall of failure can be envisaged in the errors caused by the operators.

Digitalization maintenance can speed up the process with a maintenance platform. Even cutting downtime by the five minutes it takes to retrieve a manual from the office can save organizations hundreds of thousands of euros a year.

Digital maintenance allows the maintenance team to accumulate, sort and analyze detailed and accurate asset data to determine which assets are repaired on a proposed basis and when it would be better to invest in newer, more efficient equipment.

Digital maintenance keeps maintenance team on schedule for planned activities. These preventive strategies keep machines and systems running efficiently and less energy. Consuming less energy means decreasing of costs.

The framework implementation of digital maintenance is shown on Figure 2. 7. When maintenance is digitized, it is important to analyze the main capacities and focus on the issues surrounding them implement the digitalization of maintenance as presented on Figure 2. 7 [20].
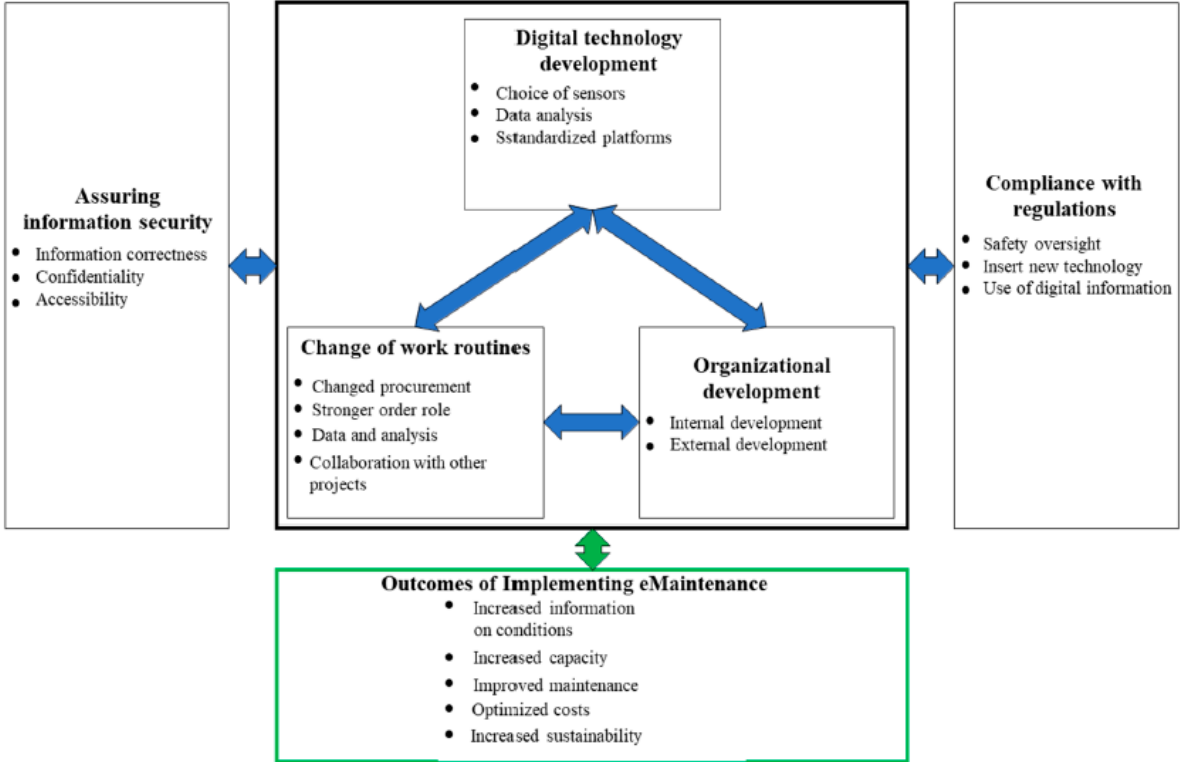
Figure 2. 7 Framework for Implementing Digital Maintenance [20].

In spite of continuously maintenance and monitoring, need for organizational changes, requirement of increased training, digital maintenance is a great opportunity for competitive companies if it is properly implemented. Digital maintenance will continue to develop and generate more precise, quicker diagnostic, allowing organizations to take action at an even faster pace.

2.3. TECHNOLOGIES

Designing of a digital platform, proper technical backgrounds should be known. These technical backgrounds should be applied within selected technologies.

Digital industrial platforms are in the lead of digital transformation, which make the bridge between technological building blocks and industrial applications.

Digital industrial platforms are essential for smart plants, because of taking data from the operators or/and machines, making the data accessible to monitoring and controlling, connecting different users (for instance; workers, engineers, managers) and application developers. In order to develop applications based on that data, the platforms should allow third parties.

Platform owner fulfills a role of information broker to enable a dialogue between customer and vendor which is represented on Figure 2. 8 [21]. On the other hand, in an internal platform at workplaces, this dialogue is designed for communication between user and supervisor or admin.
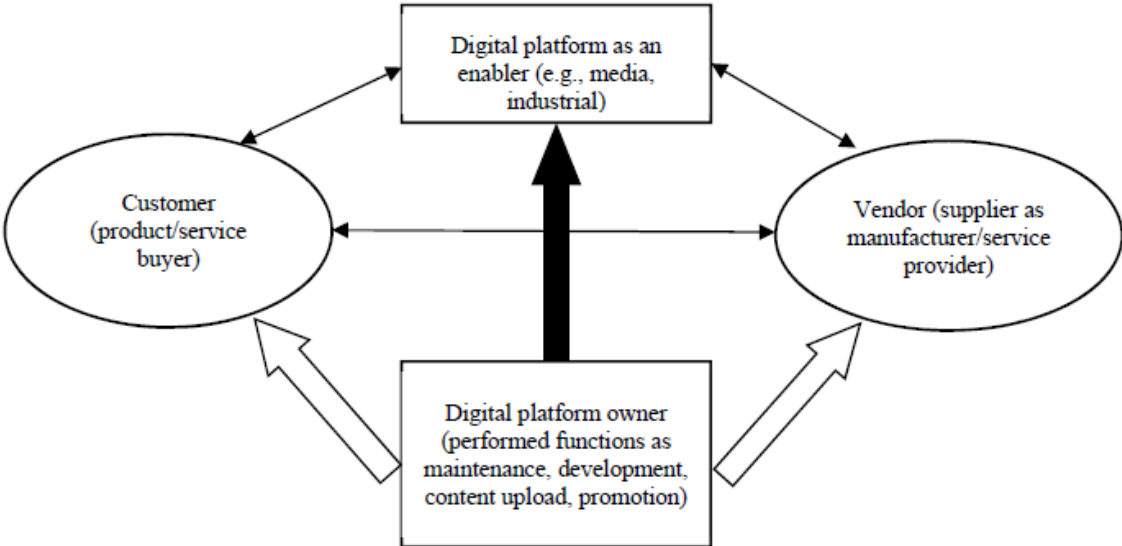
Figure 2. 8 Digital Platform Architecture [21].

Digital platforms are an efficient instrument and component of the digital economy, which enables companies to cooperate, communicate and implement integrated solutions [21].

Digital platform can have various definitions from simple to complex, which can be viewed as technically and socio-technically, it can unit technical elements such as code-bases, technical elements and associated organizational processes [21]. The platforms can be categorized as two types of platforms as technical (for example, software development and production) and non-technical (for example, business to business, business to consumer, consumer to consumer) [22].

Digital platform fulfills the role of an online community, they represent a mixture of interrelated components as software, hardware, operation and networks [23].

Generally, a platform is numerous of participants to connect, interact, generate and exchange value [21].

2.3.1. Server Management

Servers are an essential function in any network. It can refer to the hardware itself, the functioning system that runs on it, or a member of software that provides a specific service, such as e-mail transfer or website hosting. Server can be described that which is a high-performance computer that uses specialized software or operating systems to store data and integrate resources.

Growing organizations in terms of employee, elements or funding require to upgrade to a server-based or client/server system in order to help manage and control the information technology. Growing organizations should consider a server to better manage their workforce and the data which are produced.

The following some key points of having a client-server system:

- A server allows organizations manage the users on a network. Besides users, server-based systems allow workstations to be centrally managed without the need for individual management.
- With more workstation comes more data generated and collected, and the greater need to share files and resources. Sharing a server makes it easier. In addition, servers are also designed with efficient storage and retrieval of data. It is equipped to store a lot of data and allows organizations to add additional storage capacity when it is required.

- While data and workstations are managed more centrally, backing up data will become less disorganized. Server will help to create a better backup system.
- Servers are designed to host several users at the same time. It is equipped to handle more memory and processing power compared to ordinary desktop computer in order to improve performance. Servers enable to improved networked application performance.

The web server can consist of three different forms. First, the web server can refer to the software. Second, the web server can refer to the hardware. Once and for all, the web server can refer the hardware and the software working together.

- On the hardware side, a web server is a computer which stores web server software and component files of a website (for instance, Markup Language documents, images, Cascading Style Sheets, script files).
- On the other hand, on the software side, a web server consists of several parts that control how users access hosted files.

Existing business infrastures include multiple components (for example, database managements servers, Web servers, application servers) distributed across multiple networks and residing on hundreds of servers running multiple operating systems [24] [25].

Due to Information Technology (IT) infrastructures are large and complex, server system management has emerged as an important components of IT services business [26].

The ever-increasing demands for data availability and quality service have increased the importance continuously available service. As a result of this, the industry has encountered server system management costs that exceeded system component costs [27] [28]. In fact, human cost of system management has grown to represent two-third of total system management costs since the 1990s [28]. As a result of this fact, in order to compete in the business service market, organizations require to achieve significant productivity gains.

Basically, server management can be defined as the responsibilities and services that are completed on a server in order to manage it. Server management is about having control or access to a physical, virtual or application server in order to make different types of administrative or maintenance operations [29].

Server management also includes server monitoring and visibility into how a particular server works to improve and optimize performance.

Tasks and services of the server management usually consist of the followings:

- Monitoring of the server and applications running on the server. It is important to get real-time data to check their status and uptime.
- Updating the server and software installed on the server.
- Doing setup and configuration of software and services running on the server.
- Planning the capacity of the server. Organizations never desire to provide an excess of machine capacity.
- Optimizations capabilities in order to improve server efficiency and overall operations.
- Ability to alert an administrator via messaging system to different errors is helpful components.

Critical attributes that should be considered by organizations which are shown on Figure 2.9.

Critical Attributes for Server Management	
Coverage	• Identify what types of servers and applications that will be managed. • Make sure the tool or service covers the server you need to manage
User Interface	• Basic server administration can be done via a simple terminal. • Some tools provide advance visualization capabilities that can make it easier to manage
Alerting	• The ability to set performance or other thresholds that can generate alerts. • Consider different alerting options, including email, SMS and slack
Support	• Server management can be complicated, having support is often critical to success.

Figure 2. 9 Critical Attributes for Server Management [29].

Ensuring that applications run correctly without meeting the security requirements of the infrastructure can have devastating consequences, so the security should be considered as part of initial infrastures setup.

The security issues governing the Web server are complex. The security components include the web server software, the databases, and the any applications that exist in on them [30] [31].

The web server can be decomposed into three components: front-end server, back-end server, and middleware interface software. The middle tier performs as a communication buffer between the back-end and front-end servers [32].

Three components structure of the web server is shown on Figure 2. 10.
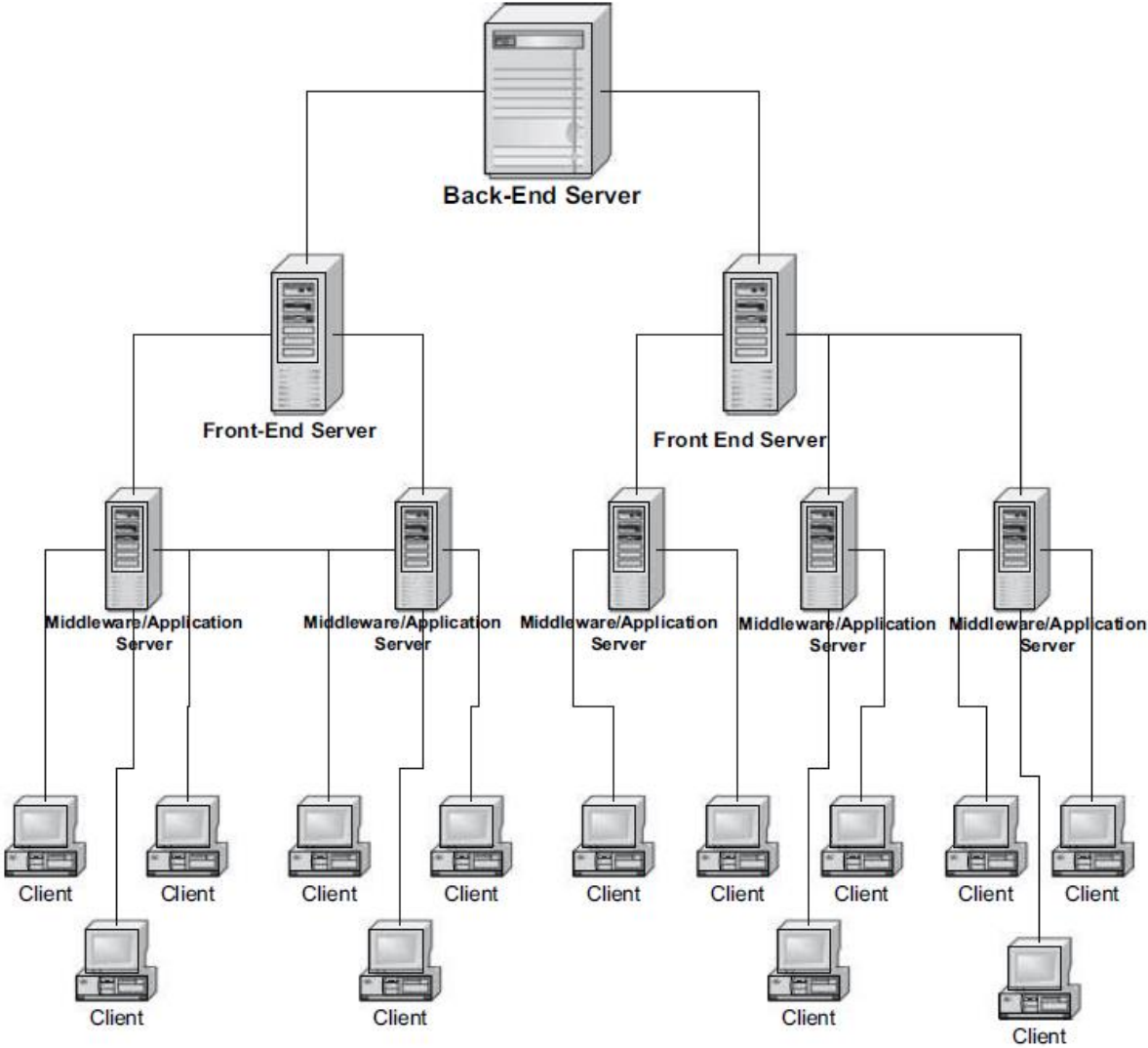
Figure 2. 10 Decomposed the Client/Server Structure [31].

Any one of these components which receive malicious events could cause the security problems. The best way to deal with security issues is to first understand where the system is most vulnerable.

Each decomposed component is examined separately and the type of security required to maximize reliability and confidentiality is determined. Figure 2. 11 depicts the decomposed server components.
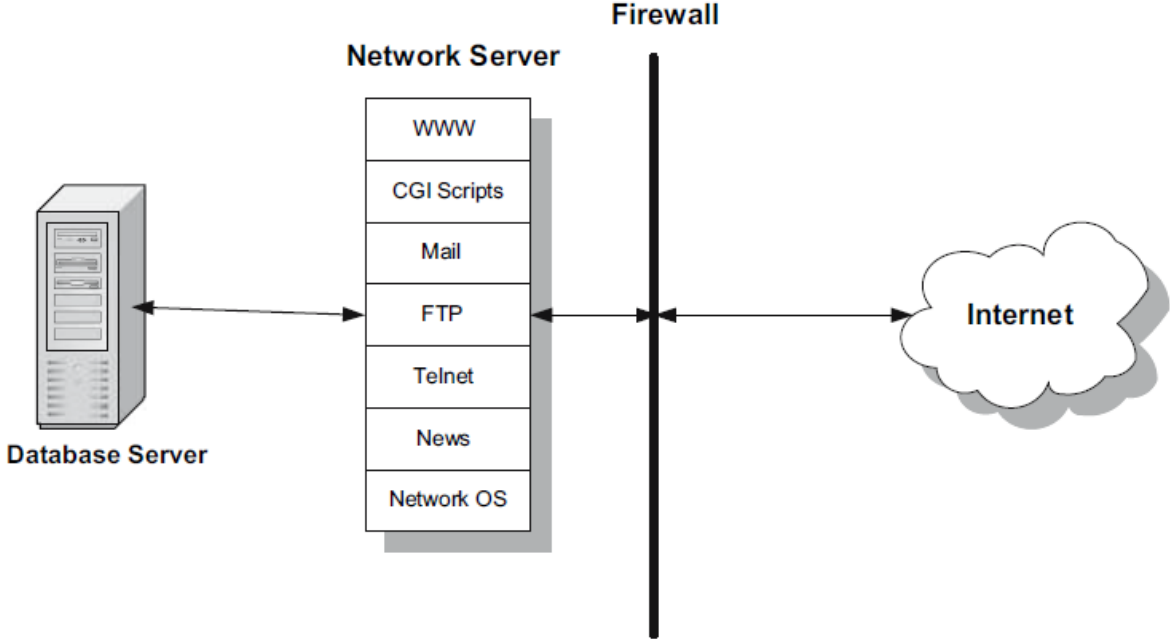
Figure 2. 11 Decomposed Server Components [31].

Database security consists of protection against unauthorized access to sensitive data. Database security will be discussed in the next section.

2.3.2. Database Management

Before the explanation of database, data should be known. Data can be a quantity, symbol or character on which operations are performed. Data is information which is converted into digital form.

The database is a structured collection of records or data stored electronically in a computer system and organized in such a way that it can be quickly searched and data can be rapidly retrieved [33].

Databases have evolved dramatically since their inception in the early 1960s. navigational databases like the hierarchical database (which relied on tree-like model and allowed only a one-to-many relationship), and also the network database (a more flexible model that allowed multiple relationships), were the initial systems used to store and manipulate data [34]. In spite of low complexity, these early system was not flexible.

Relational databases become popular within the 1980s, followed by object-oriented databases in the 1990s.

Recently, Not only Structured Query Language (NoSQL) databases have emerged as a response to the expansion of the internet and the requirement for higher speeds and processing of unstructured data. NoSQL database are mostly used in big data and real time web applications.

Today, cloud databases and self-driving databases (which are cloud-based and use machine learning) are breaking new ground when it comes to how data is collected, stored, managed, and utilized [34].

Relational Database was invented in 1970s by E. F. Codd at IBM [35]. He was unhappy with the available models of data storage. He found that all the available methods were prone to error and redundancy. He worked on these problems and then, published a paper about relational database [36].

A programmer named Larry Ellison read Cood's paper and started work on software in order to put the theories into practice [36]. Ellison's product and company took the name Oracle and his companies has become a successful company in many fields over the years.

In connection with market demands over the years, many other companies are established that have designed systems with a variety of features geared toward a variety of operating systems. These processes made that relational databases are so common in worldwide.

The relational database is a collection of information that systematizes data points with defined relationships for easy access.

The data structures which are consists of data tables, indexes and views remain separate from the physical storage, allowing administrators to edit the physical storage, allowing administrators to edit the physical data storage without affecting the logical data structure in the relational database model [37].

Relational databases enable users to easily categorize and store data that can later be queried and filtered to extract specific information for reports which is the main advantage of relational databases.

Other important advantages of relational database are the followings:

- *Extendibility:* Relational databases are easy to extend and are not reliant on physical structure.
- *Flexibility:* Complex queries can be easily used by users.
- *Accuracy:* Data is stored just once, in order to eliminate data deduplication.
- *Reliable:* Relational database models are mature and well-understood by users.
- *Security:* Data in tables within a Relational Database Management System (RDBMS) can be limited to allow access by only specific users.
- *Collaboration:* Multiple users can access the same database.

Data in a relational database is often organized into tables. Tables can have many columns and rows of data. Rows are often called records. On the other hand, columns are labeled with descriptive name with a specific data type.

Student Name	Age	Faculty
Thomas	25	Manufacturing
Joe	23	IT
Laura	28	Arts

Table 2. 1 A Example of Table Structure.

In the table above, there are three columns which are 'Student Name', 'Age', and 'Faculty'. The 'Student Name' and 'Faculty' column store string data types, whereas 'Age' stores integer data types. The table which is shown on Table 2. 1 has also 3 rows, or record.

Relational Database Management System (RDBMS) is a program that allows users to create, update and manage a relational database.

Popular examples of the RDBMSs include Microsoft SQL Server, Oracle Database, MySQL and IBM DB2.

Most RDBMSs use the Structured Query Language (SQL) in order to access and manipulate the data in tables. SQL became a standard of the American National Standards Institute (ANSI) in 1986, and of the International Organization for Standardization (ISO) in 1987 [38].

SQL statements are used to perform tasks such as followings [33] [36] [38]:

- Executing queries against a database
- Retrieving data from a database
- Inserting records in a database
- Updating records in a database
- Deleting records from a database
- Creating new databases
- Creating new tables in a database
- Creating stored procedures in a database
- Creating views in a database
- Setting permissions on tables, procedures, and views

SQL is the most popular language for interrogating a database in the whole world. Many database product use SQL or variants of SQL. Although most RDBMSs use SQL, most of them have their own additional patented extensions which are usually only use on their system. However, the standard SQL commands like 'SELECT', 'UPDATE', 'INSERT', 'DELETE' can be used accomplish almost every processes that one needs to do with a database.

Some of the most important SQL commands are described in the followings [38]:

- SELECT – extracting data from a database
- UPDATE – updating data in a database
- INSERT INTO – inserting new data into a database
- DELETE – deleting data from a database
- CREATE DATABASE – creating a new database
- ALTER DATABASE – modifying a database
- CREATE TABLE – creating a table
- ALTER TABLE – modifying a table
- DROP TABLE – deleting a table

Most SQL or SQL-like database server products are costly, such as Oracle or Microsoft SQL Server. On the other hand, MySQL is totally free of charge for non-commercial users. MySQL is the one of most popular open sources SQL database according to DB-Engines Ranking (see Table 2. 2).

357 systems in ranking, May 2020

	Rank		DBMS	Database Model	Score		
May 2020	Apr 2020	May 2019			May 2020	Apr 2020	May 2019
1.	1.	1.	Oracle ➕	Relational, Multi-model ℹ	1345.44	+0.02	+59.89
2.	2.	2.	MySQL ➕	Relational, Multi-model ℹ	1282.64	+14.29	+63.67
3.	3.	3.	Microsoft SQL Server ➕	Relational, Multi-model ℹ	1078.30	-5.12	+6.12
4.	4.	4.	PostgreSQL ➕	Relational, Multi-model ℹ	514.80	+4.95	+35.91
5.	5.	5.	MongoDB ➕	Document, Multi-model ℹ	438.99	+0.57	+30.92
6.	6.	6.	IBM Db2 ➕	Relational, Multi-model ℹ	162.64	-2.99	-11.80
7.	7.	7.	Elasticsearch ➕	Search engine, Multi-model ℹ	149.13	+0.22	+0.51
8.	8.	8.	Redis ➕	Key-value, Multi-model ℹ	143.48	-1.33	-4.93
9.	9.	⬆11.	SQLite ➕	Relational	123.03	+0.84	+0.14
10.	10.	⬇9.	Microsoft Access	Relational	119.90	-2.02	-23.88

Table 2. 2 Rank of DBMS According to the Popularity [39].

MySQL has a development background going back to 1979, however it has been available for the public users at 1996. Michael Widenius is a co-founder of MySQL. [40]

MySQL is stable, reliable and powerful solution with a large community of developers who can help to users in order to answer their questions.

MySQL is great choice for companies which want lot of functionality, a good range of interfaces and need something reliable without disturbing wanted flexibility. MySQL is used by high profile web applications including Twitter, YouTube, Facebook, and all of the top five websites.

A database table contains multiple columns with specific data types like string or numeric. MySQL provides more data types aside from just string or numeric. MySQL also supports date/time and spatial data types with sting and numeric data types. Each data type in MySQL is often determined by the subsequent characteristics [41]:

- The kind of values it represents.
- The space that takes up and whether the values is a fixed-length or variable length.
- The values of the data type can be indexed or not.
- How MySQL compares the values of a specific data type.

Some essential data types are shown in the Table 2. 3.

DATE TYPE	SPEC	DATA TYPE	SPEC
CHAR	String (0 - 255)	INT	Integer (-2147483648 to 214748-3647)
VARCHAR	String (0 - 255)	BIGINT	Integer (-9223372036854775808 to 9223372036854775807)
TINYTEXT	String (0 - 255)	FLOAT	Decimal (precise to 23 digits)
TEXT	String (0 - 65535)	DOUBLE	Decimal (24 to 53 digits)
BLOB	String (0 - 65535)	DECIMAL	"DOUBLE" stored as string
MEDIUMTEXT	String (0 - 16777215)	DATE	YYYY-MM-DD
MEDIUMBLOB	String (0 - 16777215)	DATETIME	YYYY-MM-DD HH:MM:SS
LONGTEXT	String (0 - 4294967295)	TIMESTAMP	YYYYMMDDHHMMSS
LONGBLOB	String (0 - 4294967295)	TIME	HH:MM:SS
TINYINT	Integer (-128 to 127)	ENUM	One of preset options
SMALLINT	Integer (-32768 to 32767)	SET	Selection of preset options
MEDIUMINT	Integer (-8388608 to 8388607)	BOOLEAN	TINYINT(1)

Table 2. 3 MySQL Data Types [41].

MySQL is generally used for web applications and often accessed using Hypertext Preprocessor (PHP). In the fallowing section, PHP will be explained with more details.

2.3.3. Hypertext Preprocessor

We cannot imagine our life without computers and also cannot imagine computers without web sites and applications. In order to create, operate and manage the web world, Hypertext Preprocessor (PHP) is mostly used as a server-side language.

Server-side languages allow developers to write programs that add desired features and functionality to web applications. Server-side language is a programming language that is used to develop programs that are executed by the server.

Most large-scale web applications use server-side language in order to dynamically display different data when needed, pulled out of a database stored on a server and after send to the client to be displayed.

The most important advantage of server-side language is that it allows users to tailor web application content for individual users. The dynamic applications can focus content which is more relevant based on user preferences and habits. It can also make applications easier to use by storing personal preferences and data.

Companies specially e-commerce companies use server-side programming to construct search results for products, make targeted product suggestion based on client preferences and previous purchasing history.

Banks use server-side program design to store account data and let only authorized users to view and make operations because of security issues. Also, most large-scale web applications developers such as Instagram, Facebook, Twitter use server-side programming to highlight, share, and control access to remarkable web content.

Some advantages of using server-side languages are listed the followings [42]:

- Efficient delivery and delivery of information
- Customized user experience
- Store sessions for fast surfing
- Notifications and communications
- Controlled access to content
- Analysis of data

Web browsers communicate with web server via the Hypertext Transfer Protocol (HTTP). When client click a link, submit button in a form or operate a search on a web application, an HTTP request is sent from client's browser to the target server.

Web servers wait for client request messages, and reply to the web browser with an HTTP response message. The response contains a status line that indicates whether the request was successful.

Static site returns the same hard-coded content from the server whenever a specific resource is requested. Figure 2. 12 shows a basic web server design for a static site [42].
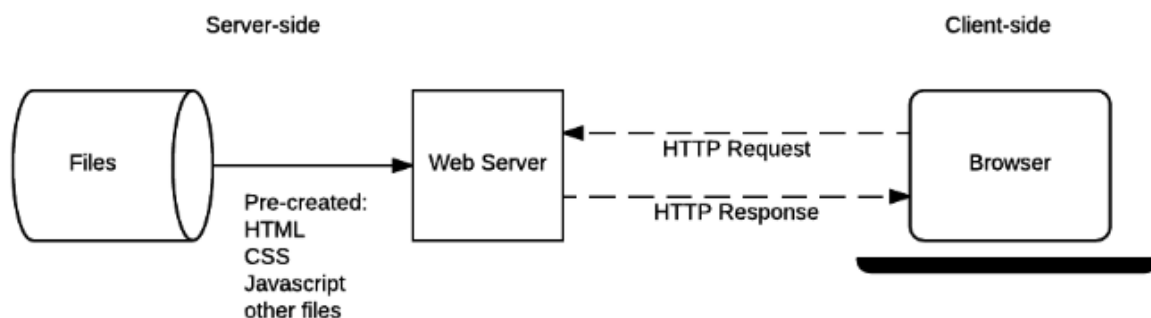
Figure 2. 12 Web Server Architecture for a Static Site [42].

A dynamic site is one where some of the response content is generated dynamically, only when needed [42]. Dynamic sites contain web pages that are generated in real time. And these pages consist of scripting code.

Most of code to support a dynamic site must run on the server. Creating this code is known as server-side language or in other words back end scripting [42].

Figure 2. 13 shows a basic web server design for a dynamic site [42].
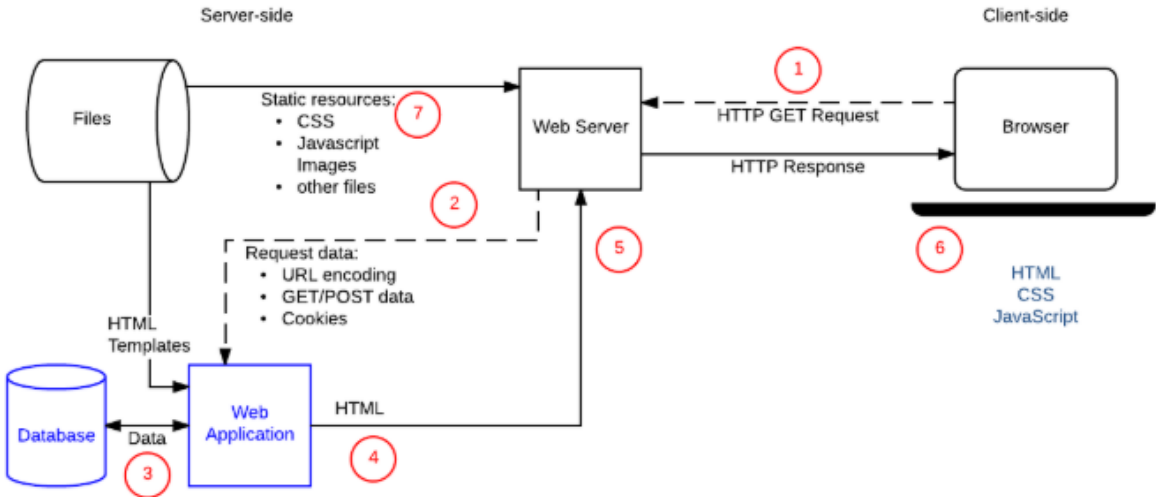
Figure 2. 13 Web Server Architecture for a Dynamic Site [42].

The static site is generally written in Hyper Text Markup Language (HTML) and display to the client what is in the code of the page.

The dynamic site is written using server-side language like PHP and so on. The content of the site is called from other files or from a database using server-side language with dependency of the client's actions.

When the history of PHP is reviewed, PHP1 is created in 1994 by Rasmus Lerdorf [43]. Within the next 6 months at 1995 Rasmus Lerdorf improved added more functionally to PHP1 which is called as PHP2 for this new version [43].

Obviously, PHP is number one server-side programming language in the worldwide. Actually, for a long time PHP programming language was not considered as one of the main languages for large-scale web applications. Developers thought PHP is only sufficient for small web applications. But recently developers realize that importance of PHP. The development pace was fast, stable and efficient.

51

The important point is this changes of popularity is that PHP2 was shared with other developers in order to improve the future of the language. This sharing gave to every developer enjoy with PHP with fixing bugs and improving the future of PHP. From this point PHP became very popular and most used server side scripting language.

```
<!--include /text/header.html-->

<!--getenv HTTP_USER_AGENT-->
<!--ifsubstr $exec_result Mozilla-->
  Hey, you are using Netscape!<p>
<!--endif-->

<!--sql database select * from table where user='$username'-->
<!--ifless $numentries 1-->
  Sorry, that record does not exist<p>
<!--endif exit-->
  Welcome <!--$user-->!<p>
  You have <!--$index:0--> credits left in your account.<p>

<!--include /text/footer.html-->
```

Figure 2. 14 Example of PHP1 Code [43].

Object-oriented source code that was written in the PHP5 was elegant and maintainable [44]. More web applications developers began to use PHP and after satisfactory results made PHP even more popular. Nowadays, PHP is a popular and widely used language which is used by 78.4% of all websites in server-side languages [45].

PHP 78.4%
ASP.NET 10.9%
Java 3.5%
Ruby 3.4%
static files 1.6%
Scala 1.6%
Python 1.4%
JavaScript 0.9%
ColdFusion 0.4%
Perl 0.2%
Erlang 0.1%

W3Techs.com, 8 May 2020

Percentages of websites using various server-side programming languages
Note: a website may use more than one server-side programming language
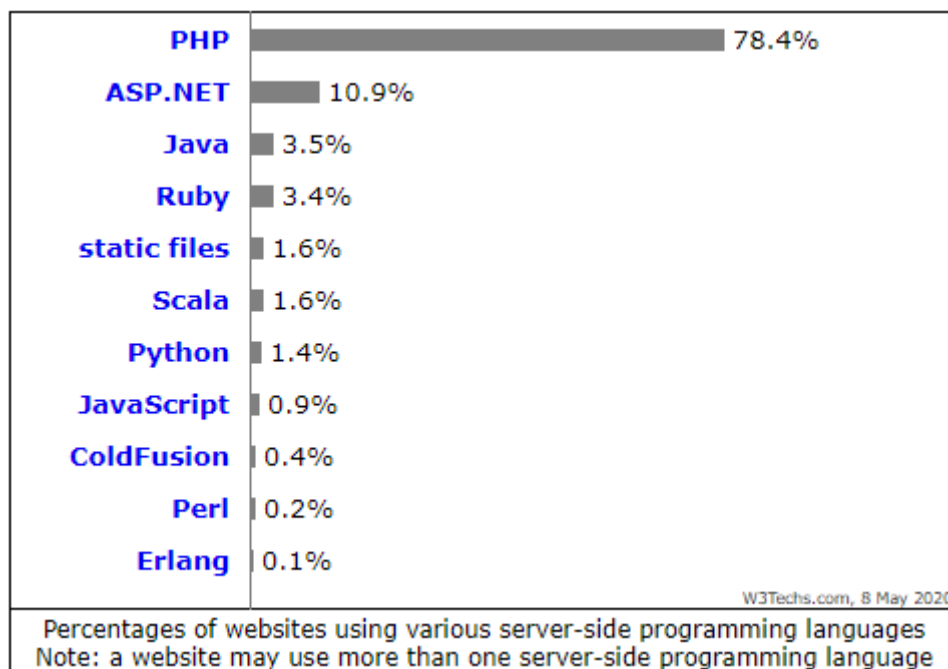
Figure 2. 15 Usage Percentage of Server-Side Programming Languages for Websites [45].

Even although, PHP is a server-side programming language, and generally used for web development but also can be used as a general purpose programming language. PHP is in the list of Top 10 popular programming languages which are shown on Table 2. 4 according to the data of May 2020 [46].

May 2020	May 2019	Change	Programming Language	Ratings	Change
1	2	︿	C	17.07%	+2.82%
2	1	﹀	Java	16.28%	+0.28%
3	4	︿	Python	9.12%	+1.29%
4	3	﹀	C++	6.13%	-1.97%
5	6	︿	C#	4.29%	+0.30%
6	5	﹀	Visual Basic	4.18%	-1.01%
7	7		JavaScript	2.68%	-0.01%
8	9	︿	PHP	2.49%	-0.00%
9	8	﹀	SQL	2.09%	-0.47%
10	21	《	R	1.85%	+0.90%

Table 2. 4 Popularity's Ratings of the Top 10 Programming Languages [46].

In order to better understanding of PHP language, Object Oriented Programming (OOP) should be described.

OOP is a type of programming language discipline added to PHP5, that enables to build complex, reusable web applications.

OOP is a computer programming model that systematizes software design around data, or objects, rather than functions and logic. An object can be defined as a data field that has unique characteristics and behavior [47].

Using OOP, developers can split their problems into smaller problems that are easy to comprehend. Objects are basically small discrete pieces of code which can incorporate data and characteristics together. All objects are connected to each other, they share data among them and solve problems in an application [40] [48].

As a summary of OOP, OOP offers big advantages to all high level programming languages with using code many times. It is used with directly receiving or modifying desired functionality of previous objects and classes.

Basic functions of PHP are described in the followings [49]:

- Generating dynamic page content
- Creating, opening, reading, writing, deleting and closing files on the server
- Collecting form data
- Sending and receiving cookies
- Adding, deleting, modifying data in the database
- Controlling user access
- Encrypting data

Some important advantages of working with PHP are given in the followings:

- In contrast with other languages that are complex syntax, PHP has simple, clean, well-organized syntax.
- PHP is open source language. A large group of PHP developers are ready to support users of PHP.
- Several web applications require easy and good quality database connection. PHP has a built-in-module which helps easily connection of database. Multiple databases can also be integrated with PHP.
- PHP can easily run on various types of platforms. This feature enables to save time and money.
- PHP is stable when compared to other programming languages because of the existence for a long time.

Web applications created using PHP script cannot be considered without Hypertext Markup Language (HTML). In the fallowing section, Hypertext Markup Language will be explained.

2.3.4. Hypertext Markup Language

Web document are created using many different technologies [50]. The main technology of the many different technologies is Hypertext Markup Languages (HTML). Main function of HTML is that telling a web browser how text and other content in a web document should appear.

HTML is hidden from the user by the browser, therefore client rarely experience with HTML directly. On the other hand, developer needs to be intimately familiar with HTML and its features and functions. Because of this, for the web application developer, HTML should be well-known.

Basically HTML describes the structures of a web document which consist of a series of elements. Robert Schifreen describes HTML as language of the web [51].

As the name of HTML suggests, HTML is the markup language for creating web applications. It provides the followings to the web applications in order to describe the structure of text-based information:

- Titles,
- Headings,
- Lists,
- Tables,
- Paragraphs,
- Images and so on.

The origin of HTML dates back 1980, when Tim Berners-Lee, proposed new hypertext system for sharing documents for his companies. Berners-Lee specified HTML and designed the browser and server software in 1990. The first formal document with the description of HTML was published in late 1991 [52].

HTML is a very evolving markup language and has developed with numerous versions updating. Each version has allowed web developer to create easier and efficient web applications.

Extensible Hypertext Markup Language (XHTML) is the part of the family of markup languages. It is extended versions of HTML. XHTML was developed for making HTML more extensible and increase flexibility with working other data formats.

Browsers ignore errors in HTML pages, and try to display the website even there are some error in the markup. Therefore, XHTML comes with a much stricter error handling [53].

History of HTML and XHTML is shown on Figure 2. 16.
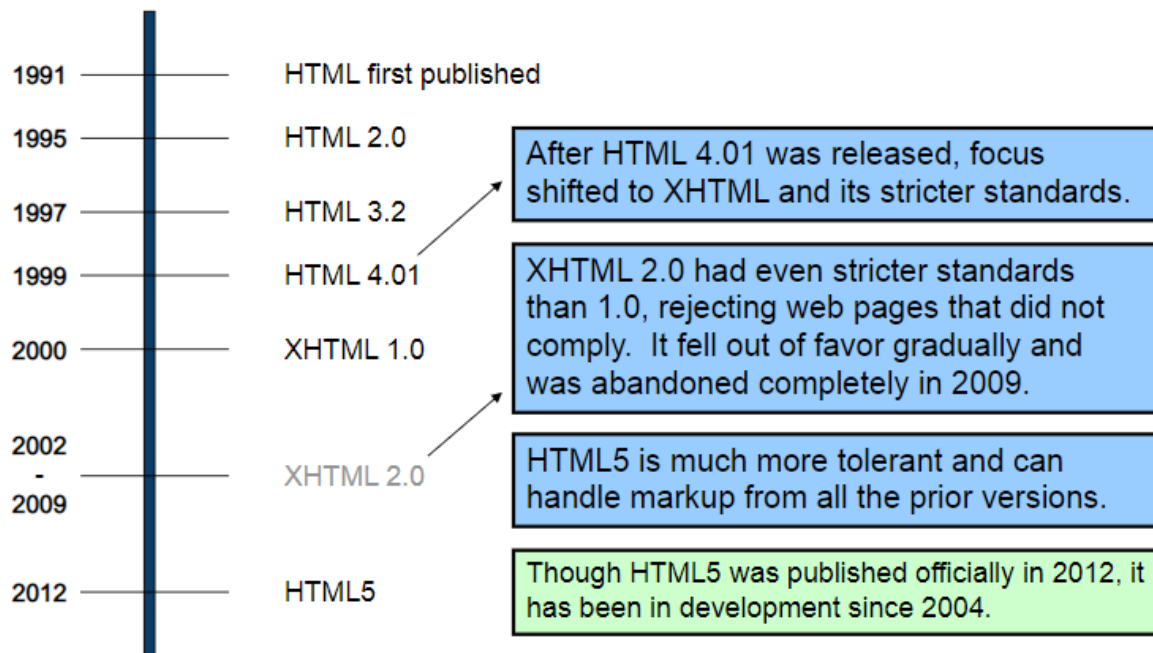
Figure 2. 16 History of HTML & XHTML [54].

Several essential requirements must be considered when telling a computer how to text using HTML. The basic features of these instructions are the following:

- The instructions should follow the standards which are created by organizations such as World Wide Web Consortium (W3C) [50].
- The instructions should be included in the textual document [50].
- The instructions should tell the web browser that where to begin and end, and how to apply the specified format [50].
- The instruction should not be visible to the end user [50].

HTML contains series of codes which are typed into a text-editor. There are the tags. Elements of HTML are represented by tags.

The texts which are typed into a text-editor by developers is saved as a html file using extension of '.html'. A browser reads the and translates the text into a visible form for the end users. Browsers don't display the tags, however use them to render the content of the page [55].

HTML tags generally occur in pairs. The first occurrence turns on a specific effect or marks the beginning of a specific section. The second occurrence turns off the specific effect or marks the end of the specific section [51].

The closing tag is written like opening tag, but with a forward slash inserted before the tag name.

Some basic examples of HTML elements are given the followings:

- The *<html>* element is the root element of an HTML page [55].
- The *<head>* element contains meta information about the document [55].
- The *<title>* elements contains specifies a title for the document [55].
- The *<body>* elements covers the visible page content [55].
- The *<h1>* element defines a heading [55].
- The *<p>* element defines a paragraph [55].

The Figure 2. 17 shows visualization of a page structure [55].

```
<html>
    <head>
        <title>Page title</title>
    </head>
    <body>
        <h1>This is a heading</h1>
        <p>This is a paragraph.</p>
        <p>This is another paragraph.</p>
    </body>
</html>
```
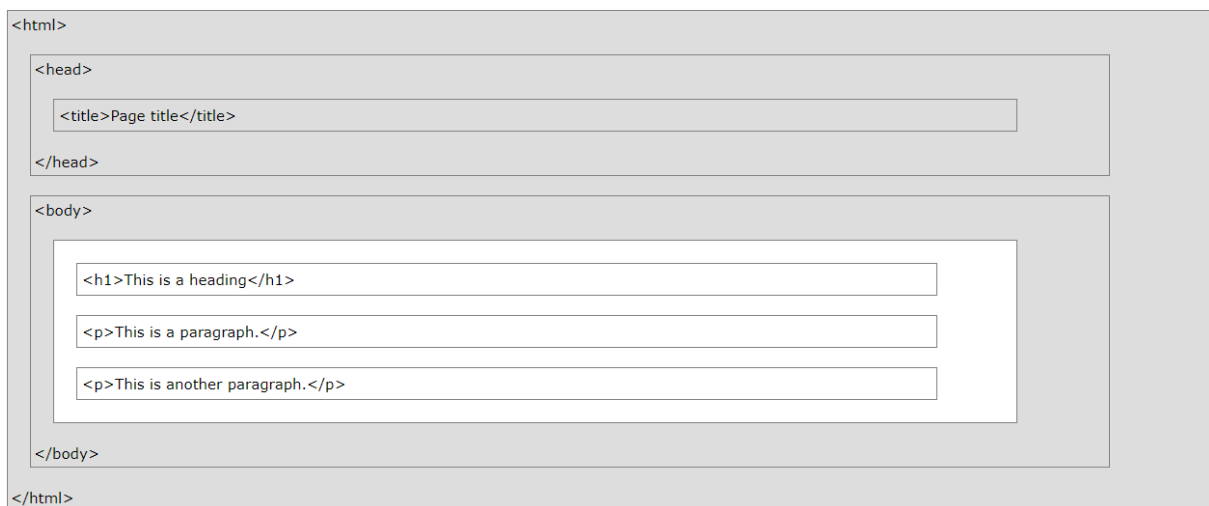
Figure 2. 17 Visualization of an HTML page structure [55].

The end user can only see the content which is inside of tag pairs. For example, considering the page structure which is shown on Figure 2. 17, the browser will only display the followings:

- 'Page title'
- 'This is a heading'
- 'This is a paragraph.'
- 'This is an another paragraph.'

Program developers choose HTML over other alternative program development options due to the important advantageous characteristics of HTML. HTML is one of the best option to develop the web application for the developers.

Below given are some important advantages of HTML:

- HTML is easy to learn and understand concepts. Developers can easily recognize other developer's code. This features enables that changes in codes if required.
- HTML is free of cost. It is very cost effective due to no cost required to purchase the license.
- Almost all the browsers are supported by HTML if the program optimize for the different browsers. Also, HTML provides an easy optimization according to the browsers.
- It could be written in simple notepad and hence can be simply edited in any text editor.
- HTML is lightweight language.
- HTML can be easily integrated with multiple languages and does not cause any problem. For instance, PHP codes can be written between the HTML and it mixes with PHP very easily.
- A large group of HTML developers are ready to support users of HTML.

On the other hand, HTML has some disadvantages for the developers. These are given the followings:

- HTML can create only static and plain pages, therefore if dynamic pages is required, HTML cannot be used alone. Developers need to know additional languages such as PHP. Code snippets written using PHP or similar languages are then added to the HTML file to generate the dynamic content.
- Using HTML causes to write a lot of code for creating the web applications.
- Security features are not good at HTML.
- Writing long code for creating web application causes some complexity.

HTML has way more advantages when compared to disadvantages. Therefore, comparing the advantages and disadvantages of HTML, it can be inferred that HTML is a good language to use for web development.

HTML is stronger tool when it uses with Cascading Style Sheets (CSS). HTML and CSS are two of the core technologies for building the web applications. For the web designing HTML and CSS are important. When the HTML make the web applications structure, CSS enables developers to make the web applications well-designed.

In the fallowing section, Cascading Style Sheets will be explained.

2.4.5. Cascading Style Sheets

Cascading Style Sheets, fondly referred to as CSS is a simple mechanism which is used for adding style such as fonts, spacing, colors and so on to the applications. CSS enables powerful control over the presentation of an HTML document.

HTML can also offer some rudimentary options for changing the design of the application. However, it is easier way to have all the styling stored in a CSS file in order to maintain and restyling easily.

As developers learn CSS style rules, they will have more control over the style applied to different kinds of content on the applications.

In the early days of the web, there was no way to separate the presentation and the content of the web documents. It means that HTML pages were repetitive and difficult to understand [51].

A few years ago, new revisions of HTML came. Top of the list of new features was something called CSS or HTML Style Sheets. CSS is a separate file that complements one, some or all of the HTML pages on the application. It consists of all the information about the styles of the applications [51].

CSS was first proposed by Hakon Wium Lie on October 10, 1994 [56]. He published a document which proposes a style sheet scheme for HTML documents. Several other style sheet languages for the applications were proposed around same time. These proposals caused that releasing the first W3C CSS Recommendation (CSS 1) in 1996 [57]. Particularly, a proposal by Bert Bos was effective, result of this he became co-author of CSS 1, and is regarded as co-creator of CSS [58].

CSS level 2 specification was developed by the W3C and published as a recommendation in May 1998. The W3C no longer maintains the CSS 2. In order to eliminate limitations of CSS 2, it revised as CSS 2.1 [59].

The term 'CSS 3' denotes to everything published after CSS 2.1. CSS 3 was started in 1998 but it has never been completed. Some modules of CSS 3 are still being developed.

CSS is on its last version as a tool as a whole, therefore dropping the number would be appropriate and referring to everything on only 'CSS'. Each module of CSS levels up independently.

CSS includes of style rules that are deduced and then interpreted by the browser and last applied to the corresponding elements in the document. These style rules follow a specific structure.

The syntax for CSS rules consists of a selector and a declaration.
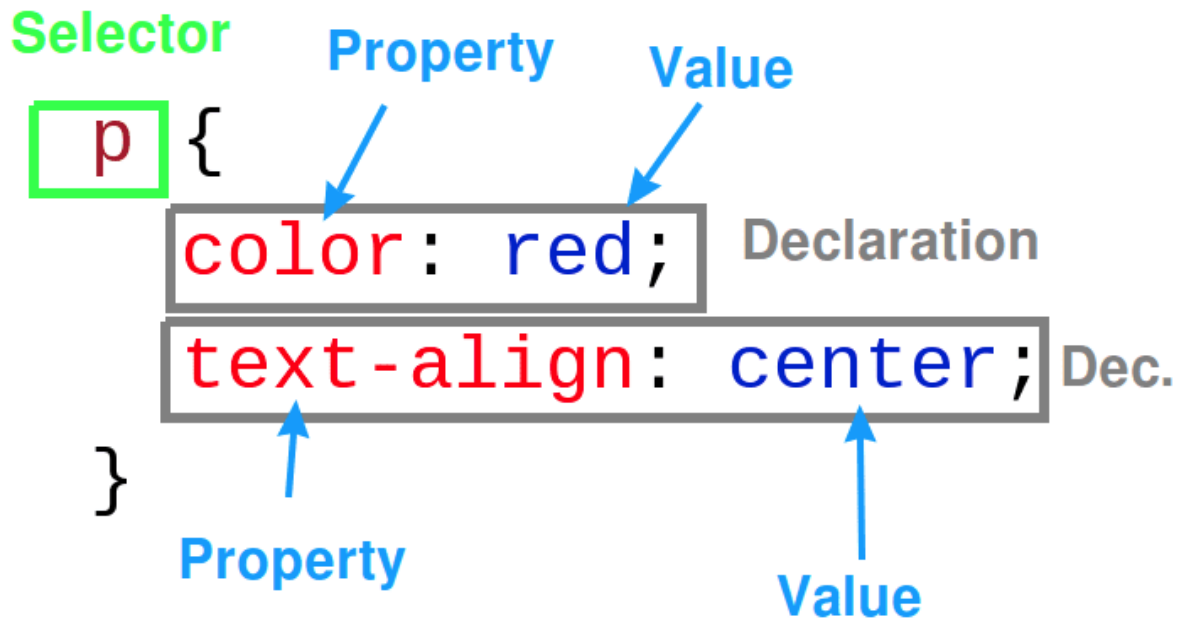
Figure 2. 18 Structure of One CSS Rule-set [60].

The selector points to the HTML element developers want to style. HTML element can be defined in the following ways [60]:

- *ID;* is a unique which is a full name of a HTML element.
- *Tag;* is the type of the HTML element (the example which is shown in Figure 2. 18, paragraph *<p>*).
- *Class;* is defined when writing the HTML code.

The declaration block consists of one or more declarations separated by semicolons. CSS declarations contain a property and a value. For the example as shown in Figure 2. 18, there are the specific property and the assigned value for the property.

Let's explain on the example of Figure 2. 18:

- For the first declaration block; color is property and red is assigned value.
- For the second declaration block; text-align is property and center is assigned value. So, the declaration block means that aligns the text of a HTML element to the center.

CSS declaration always ends with a semicolon and declaration block are inside of the curly braces.

There are three types of CSS categorized by linking ways CSS to HTML which are given the followings:

- Inline CSS
- Internal CSS
- External CSS

Inline CSS declarations that affect a specific HTML element, contained within a style attribute.

The inline CSS is limited. An inline style loses many of possibilities of a style sheet. Because of this reason, it is not suitable for elaborate projects. Also it causes messy code because of combining CSS and HTML.

Using of Internal or Embedded CSS is proper when a single HTML document must be styled uniquely. Internal CSS can be integrated by placing the *<style>* element in the *<head>* section of a page.

Internal CSS affect to whole pages but not to multiple HTML documents.

External CSS is a *'.css'* file with all same CSS rules. Developers can link CSS to HTML by using the *<link>* tag in the page. By this way, developers can style multiple pages according to the planned style.

In addition, external CSS decreases complexity and increases maintainability of a page with separating style from content.

The *<link>* tag contains three attributes:

- *rel* element describes the relationship between the linked document and the HTML doicument.
- *type* element determines what type of data should be taken by an input element [61].
- *href* element refers to a particular file that developer is uploading.

A *'.css'* file can be created with any text editor with having *'.css'* extension.

Simple usages of inline CSS, internal CSS, and external CSS are shown on Figure 2. 19.

Inline CSS

```
<p style="color: blue;">This is a paragraph.</p>
```

Internal CSS

```
<head>
  <style type = text/css>
    body {background-color: blue;}
    p { color: yellow;}
  </style>
</head>
```

External CSS

```
<head>
  <link rel="stylesheet" type="text/css" href="style.css">
</head>
```

Figure 2. 19 Simple Examples of Types of CSS [61].

External CSS is used by 93,6% of all the websites who use CSS [62].

External CSS	93.6%
Inline CSS	89.1%
Embedded CSS	69.9%
	W3Techs.com, 16 May 2020

Percentages of websites using various subcategories of CSS
Note: a website may use more than one subcategory of CSS
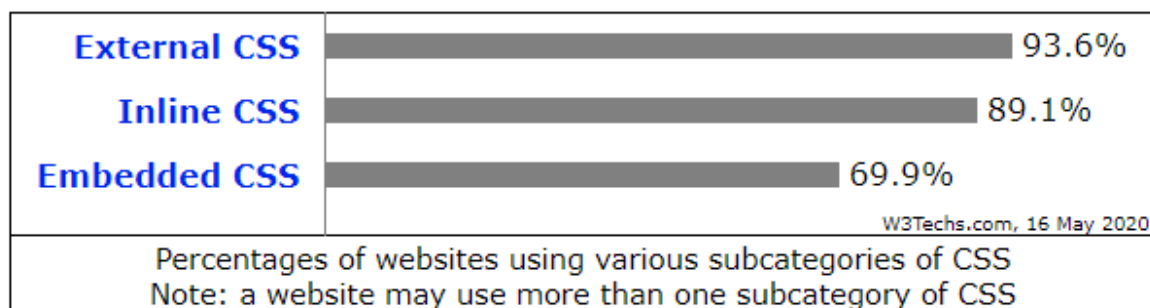
Figure 2. 20 Percentages of Websites Using Various Types of CSS [62].

External CSS is the best option for the complex and large-scale projects with advantageous of optimizing code and consistent style.

On the other hand, linking many external CSS might cause to increase loading time of application. Because of this disadvantages, for styling a single element better to use inline CSS and for styling one-page best option is internal CSS.

Priority order answers the question that which one will be highest priority, if more than one style is defined. Any styles that are defined in the external and internal style sheets are overridden by inline styles because of inline style has the highest priority.

If there are no styles defined either in internal or inline style sheets, then external style sheet could be applied in HTML documents. External style sheet has the least priority.

CSS modularizes the web applications. Modular code in the applications allows the developers greater design consistency and easier maintenance. Some of essential advantages of using CSS are the following:

- CSS allows developers more control over the presentation of the application.
- CSS contains lightweight code and has a simpler structure. It could be cause easy and fast learning process and more importantly optimization benefits of search engine.
- Separating the content from its design language causes dramatically decreasing of file transfer size.
- CSS generally leads to less code behind of the application which reduce download time.
- Its cascading name indicates that we can use multiple styles and that local styles –inline style sheets- are given priority first. Developers can override the declared global style and assign the locally to the tag.
- CSS sheets allow users to customize the web application. CSS sheets can be stored externally and which enable the user to make the desired changes.
- The most important point of the advantages of CSS is saving time. Developers can define the all changes in a single CSS file and they can apply for the other desired pages or elements.

On the other hand, developers are required to consider and test all styles for multiple browsers. Because CSS output might be different with each browser.

In spite of fragmentation and different levels of CSS, CSS is a vice choice for various type of projects with so many advantages.

CSS is an essential tool to effectively guide the users for the front-end developers. CSS can increase the functionality of the application with serving effective guide to the users.

Nowadays, CSS is a leading style sheet language and has been still developed, it means CSS has been hailed as the future of the web applications.

3. IMPLEMENTATION OF THE DIGITAL SOLUTION

For this study, collaboration with SKODA AUTO s.r.o. has been made. SKODA AUTO commonly called Skoda, which is a Czech automobile manufacturer established in 1895 as Laurin & Klement and headquartered in Mlada Boleslav, Czech Republic [63].

Laurin & Klement was acquired by Skoda Works, which itself became owned in 1948 [63]. After 1991, Skoda was gradually privatized and in 2000 Skoda become an entirely owned subsidiary of the German Volkswagen Group [64].

Skoda automobiles are sold in over 100 countries and total global sales reached 1,25 million units in 2018, with an increasing of 4.4% from the previous year [65]. The operating profit was €1.6 billion in 2017, with an increasing of 34.6% over the previous year [66]. As of 2017, Skoda's profit margin was the second highest of all VW Group brands after Porsche [67].

The first vehicle left the factory in Mlada Boleslav in 1905 and millions of others have followed it throughout the company's more than 120 years of existence. The company's registered office and automobile development department have remained in the company's home town, but production has also spread to many other places, cities and countries over time [68].

In 2018, Skoda has reached 1,253,700 units regarding to the Skoda Auto Annual Report 2018 [65].

As a result of these fast, high quality and successful production results lead Skoda to closely follow and implement new trends in automotive sector and even to be creator of these trends.

When looking at from this approach, Skoda Auto which has huge production capacity, should apply this and similar innovations.

All of the operations mentioned during this study are the operations in the welding line of Skoda. Therefore, the system which is implemented will be used in the welding line of the Skoda in Mlada Boleslav.

When the number of workers in the workplace to be applied has been kept in mind, the proposed solution will cause significantly decreasing of workload and saving time.

In this chapter, implementation of the proposed solution will be described. Basically the solution consists of the administration panel for maintenance supervisors and the user panel for maintenance workers.

3.1. PROGRAMMING MATERIAL OF THE DIGITAL SOLUTION

In order to implement the proposed solution for the workplace of Skoda, AppServ has been used. AppServ is a simple package for programming. This package is the version 9.0.0 which consists of the followings:

- Apache Web Server Version 2.4.39
- PHP Script Language Version 7.3.7
- MySQL Database Version 8.0.17
- phpMyAdmin Database Manager Version 4.9.0.1

The Apache Web Server is an effort for developing and maintaining an open-sources HTTP server for modern operating systems [69]. The aims of the Apache Web Server are to provide a secure, well-organized, and extensible server that provides HTTP services.

The Apache Web Server was established in 1995 and it has been the most popular web server since middle of 1996 [69]. Apache is used by 38.4% of all websites [70].
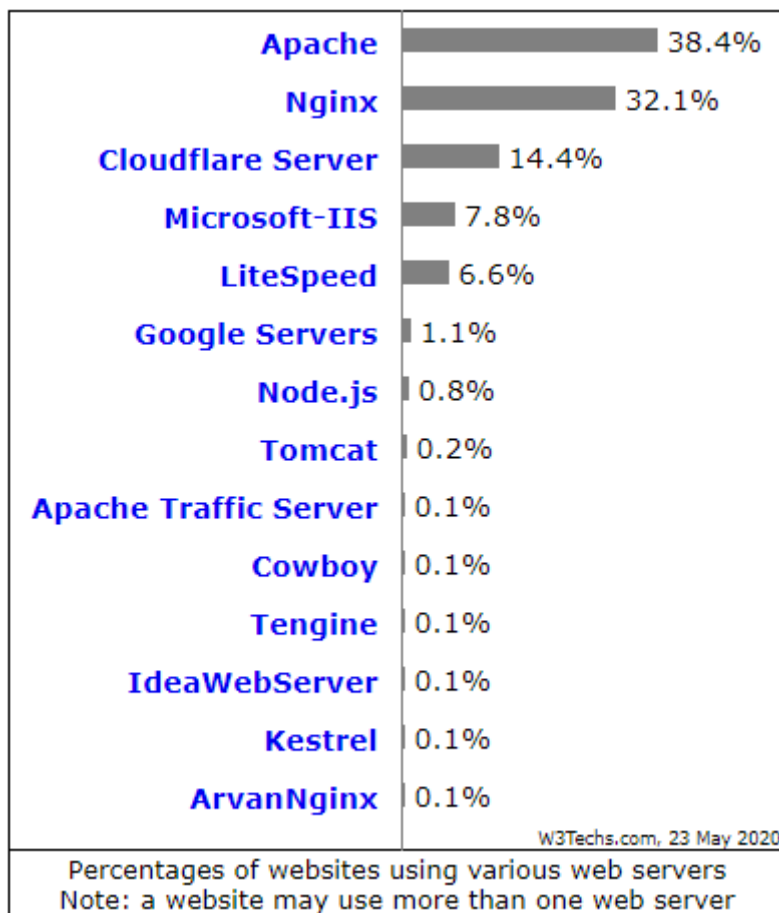

Figure 3. 1 Percentages of Using Web Servers [70].

The Apache Web Server is a project of the Apache Software Foundation [69].

PHP Version 7.3.7 has been used as a server side scripting language during this project. This version is one of the latest versions of the PHP scripting languages. It can be say that the latest version is the most secure version. PHP 7.3 is on average 9% faster than PHP 7.2 [71]. The latest version is generally fastest version and serve the best performance.

The Figure 3. 2 will show current supported versions in PHP and their supporting periods according to the active support and the security support.

Branch	Initial Release		Active Support Until		Security Support Until	
7.2	30 Nov 2017	2 years, 5 months ago	30 Nov 2019	5 months ago	30 Nov 2020	in 6 months
7.3	6 Dec 2018	1 year, 5 months ago	6 Dec 2020	in 6 months	6 Dec 2021	in 1 year, 6 months
7.4	28 Nov 2019	5 months ago	28 Nov 2021	in 1 year, 6 months	28 Nov 2022	in 2 years, 6 months

Figure 3. 2 Current (23.05.2020) Supported PHP Versions [72].

For example, release of PHP 7.1 is no longer supported. Users of version 7.1 should upgrade as soon as possible in order to avoid unpatched security vulnerabilities.

MySQL Database was discussed in the '2.3.2. Database Management' section before. MySQL Database Version 8.0.17 has been used for the proposed solution, is one of the latest release of the Oracle Corporation.

phpMyAdmin is a free software tool written in PHP server side scripting language, intended to take over the administration of MySQL [73].

phpMyAdmin supports a wide range of operations such as managing database, tables, relations, columns, indexes, users, permissions on MySQL. These operations can be performed via user interface of the phpMyAdmin. Some advantages of phpMyAdmin are given followings:

- Multi server administration
- Exporting data in various formats
- Global database searching
- Simple interface
- One of the most commonly installed by developers
- Accessibility from any computer
- Language support with 72 languages option
- Stable and flexible code base

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3.2. THE CONNECTION TO THE DATABASE

In order to run the pages, data in the MySQL database must be accessed. Before accessing data in the MySQL database, we need to be able to connect server.

There are three types in PHP in order to connect MySQL database through backend [74]:

- MySQL
- MySQLi
- PDO

In the proposed solution, MySQLi is preferred because of better set a functions and extensions. MySQLi uses as a connector function to link the PHP to the MySQL.

MySQLi extension is the improved extension of the MySQL. The 'i' which end of MySQLi stands for improved [74].

The MySQLi extension has a lot of advantages. The key improvements over the MySQL extension are given in the followings:

- Supporting for the multiple statements
- Supporting for the prepared statement
- Supporting for the transactions
- Embedded server support
- Object oriented interface
- Improved debugging capabilities
- Enhanced security
- Faster

Steps of the creating MySQL database at the localhost are given in the followings:

- Creating database
- Creating the folder for PHP files
- Creating database connection file with *'.php'* extension
- Creating file to check the database connection
- Running the created file

Before the connection, the database has been created. Creating database model is most essential part of the proposed solution. This data model, is a model that organizes elements or tables of data and standardizes how they relate to one another.

The data model for proposed solution is shown on Figure 3. 3.
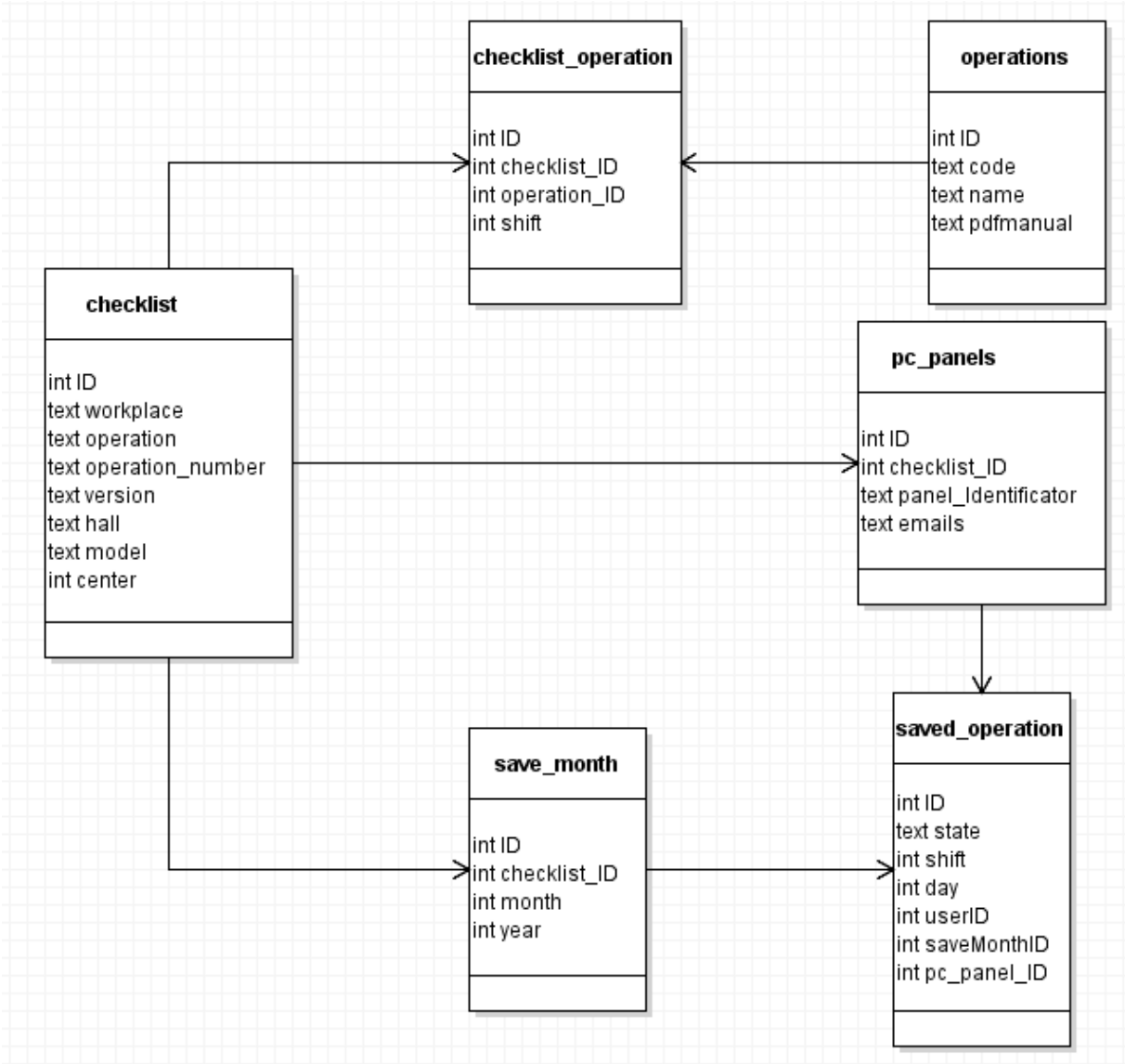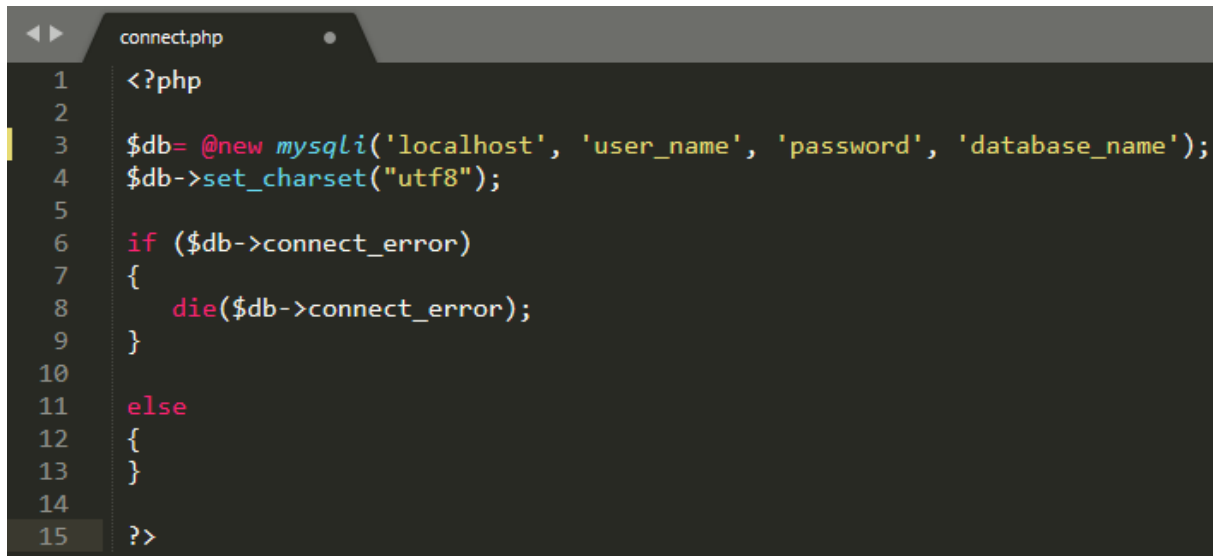
Figure 3. 3 The Data Model.

For each table, there is one primary key. Primary key is defined as *'ID'* in order to uniquely identifies each record in each table. The databases use the keys to compare and to create relationship between records.

Data is stored in the tables and the selected rows are used to link these tables on the relationships to be established. The unique identifier, such as *'ID'* in our database is used to establish the relationships between these tables which is shown on Figure 3. 3.

The database model only consists of integer and text data types. With this approach, we are avoiding creating a complex structure.

Created database connection file in PHP is shown on Figure 3. 4.

```php
connect.php
1    <?php
2
3    $db= @new mysqli('localhost', 'user_name', 'password', 'database_name');
4    $db->set_charset("utf8");
5
6    if ($db->connect_error)
7    {
8        die($db->connect_error);
9    }
10
11   else
12   {
13   }
14
15   ?>
```

Figure 3. 4 Database Connection File in PHP Language.

The database connection file has been created separate. Because, multiple files have been created to insert data and select data from the database. With this method, we don't need to write same code in order to connect the database for all files.

This connection file which is shown on Figure 3. 3 is included for other files by using PHP custom function include (*include 'connect.php';*) on the top of the code. This function calls and uses the connection functions in the connection file.

Here is the explanation of the variable what we have used in *'@new mysqli'* function which was shown on Figure 3. 4:

- *'localhost'* is the host where the server is running. In proposed solution, the server is running at localhost.
- *'user_name'* is the username which is used to access the phpMyAdmin.
- *'password'* is the password which is used to access the phpMyAdmin.
- *'database_name'* is the database name which has been created in the phpMyAdmin.

The *'connect_error'* which is shown on line 6 of the Figure 3. 3 returns the error description from last error about connection.

3.3. THE USER PANEL

The user panel is designed for maintenance workers which are working at the workplaces of Skoda's welding line.

Modern web applications need to have higher user expectations and greater demands than ever before when competition is considering with increasing availability of techonology. Modern web applications are expected to be available at any moment from anywhere, and usable from virtually any technological device or any screen size.

Web applications must provide security, flexibility and scalability to meet greatly increasing of demand from users. Applications are especially designed for the industry, should be suitable for designed a complex structure using rich user experiences.

While designing this project, the employees were considered as the targeted group and their demands were taken into consideration. The characterizations of the proposed solution are designed according to the possible demands from the users. Some considered characteristics are described in following:

- *Functionally:* The proposed solution is designed to serve a purpose, usually to solve the problem.
- *Organizing information:* How information is organized and presented to the client on the solution is vital for well usability. In order to achieve good usability, the proposed solution has been planned sections and categories carefully. The information has been presented in a way that it is easy for users to find.
- *Effective navigation:* Well-organized navigation is one of the most important aspects of the proposed solution. An effective navigation has been created with the help of CSS and HTML.
- *Relevant content:* There is no extra content on the proposed solution that is not relevant to the users.
- *Modern:* Current trends and technologies have been used in the proposed solution.
- *Performance:* Performance and speed are essential properties for the proposed solution. The solution has been designed to be as fast as possible for users.
- *Security:* Security is major concern when designing the proposed solution. The solution follows industry standard and guidelines. For example, user passwords are encrypted and not displayed in plain text in login page of the user panel.

Responsibilities of the maintenance workers of the workplace is shown on Figure 3. 5.
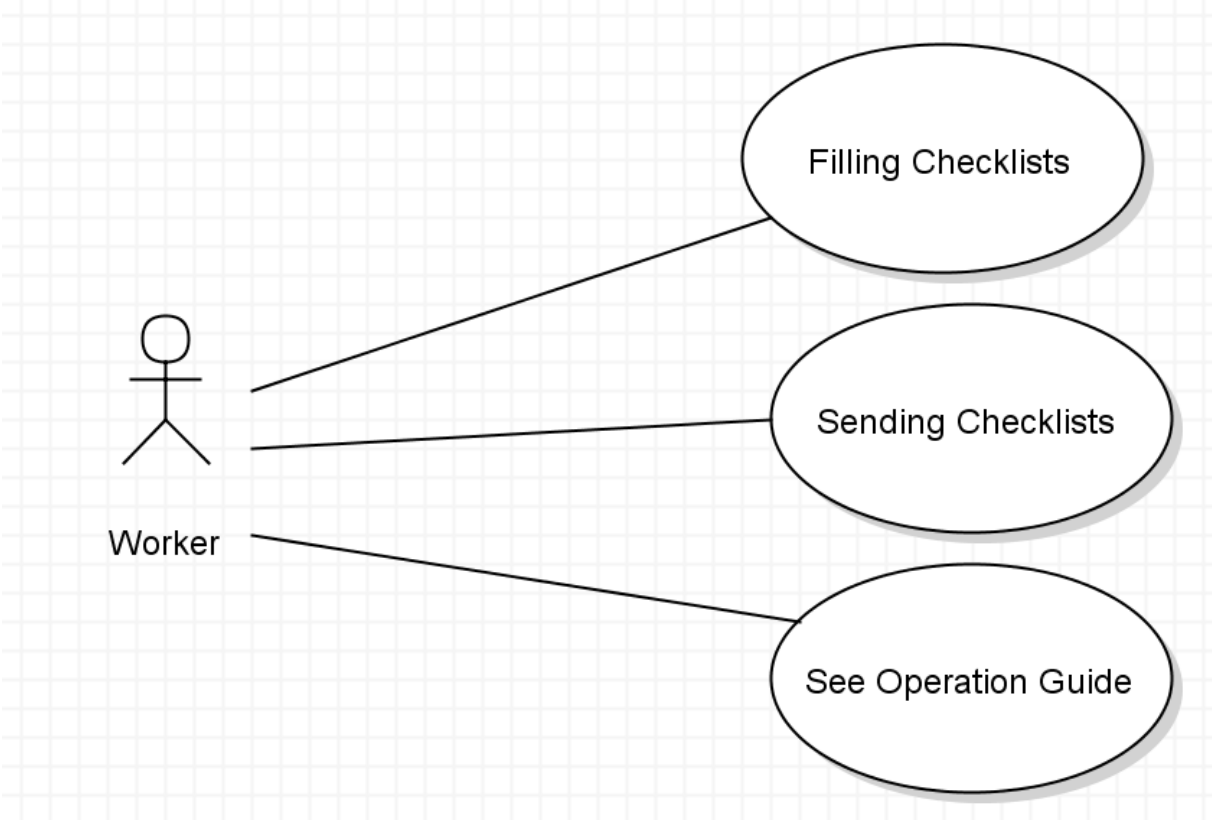

Figure 3. 5 Use Cases of Maintenance Workers.

Workers are required to fill related checklist after finishing maintenance operations. After filling the checklist, they are required to send this checklist to the maintenance supervisors.

Before the doing the maintenance operations of the workplaces, workers should check the operation and maintenance manual in order to maintain correctly and safely. An operation and maintenance manual is a comprehensive sheet that provides all the necessary details to help maintenance workers keep everything running smoothly.

The operation guide is prepared separately for each operation. The operation guide describes the maintenance workers how to do each maintenance operation separately and safely.

The operation guide can be accessed in the autonomous maintenance sheet using hyperlink on the operations.

These three use cases will be discussed with more detail in the chapter of the 'Autonomous Maintenance Digital Sheet'. Because these responsibilities can be completed in the digital environment which is created.

3.3.1. Login Page of the User Panel

The first step for implementing the user panel is creating of login page with PHP scripting language. After looking over the requirements for user login, it necessary to create a database table for users. In our case, these users will be the maintenance workers in the selected workplace. Database table for workers is shown on Figure 3. 6.
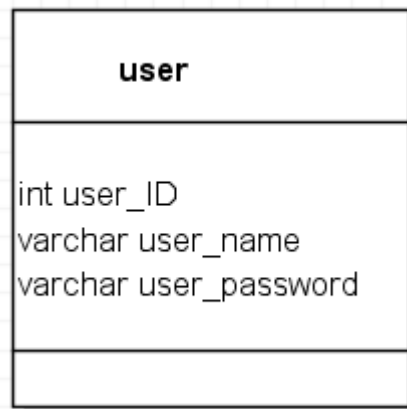

Figure 3. 6 The Users Table.

The *'user'* table consists of the user ID, user name and user password. The primary key of this table is the user ID. The user ID is unique and auto-incremental. Auto-increment allows a unique number to be produced automatically when a new worker is inserted into a table.

The user name contains the name of the maintenance workers who logs on to the system. In order to log in to the system, the user name must be entered.

The second requirement in order to log in to the system is the user password. For the password, Message-Digest Algorithm 5 (MD5) is used. MD5 is a cryptographic hash function. It generates a value with is a 128-bit, regardless of the data entered. MD5 has been implemented with basic function of PHP which is shown on Figure 3. 7.

```php
$user_name=$_POST['user_name'];
$user_password=md5($_POST['user_password']);
```

Figure 3. 7 MD5 Function.

Figure 3. 8 shows the query in order to access the autonomous maintenance digital sheet.

```sql
"SELECT * FROM user WHERE user_name='$user_name' AND user_password='$user_password'";
```

Figure 3. 8 SQL Query for the User Login.

The user name and the user password entered by the workers are sent with HTTP *'POST'* method. The values entered must match the user name and the user password in the database in order to log in the system.

The user login page is arranged as Czech languages because of using local languages of the workers of Skoda. The user login page is shown on Figure 3. 9.
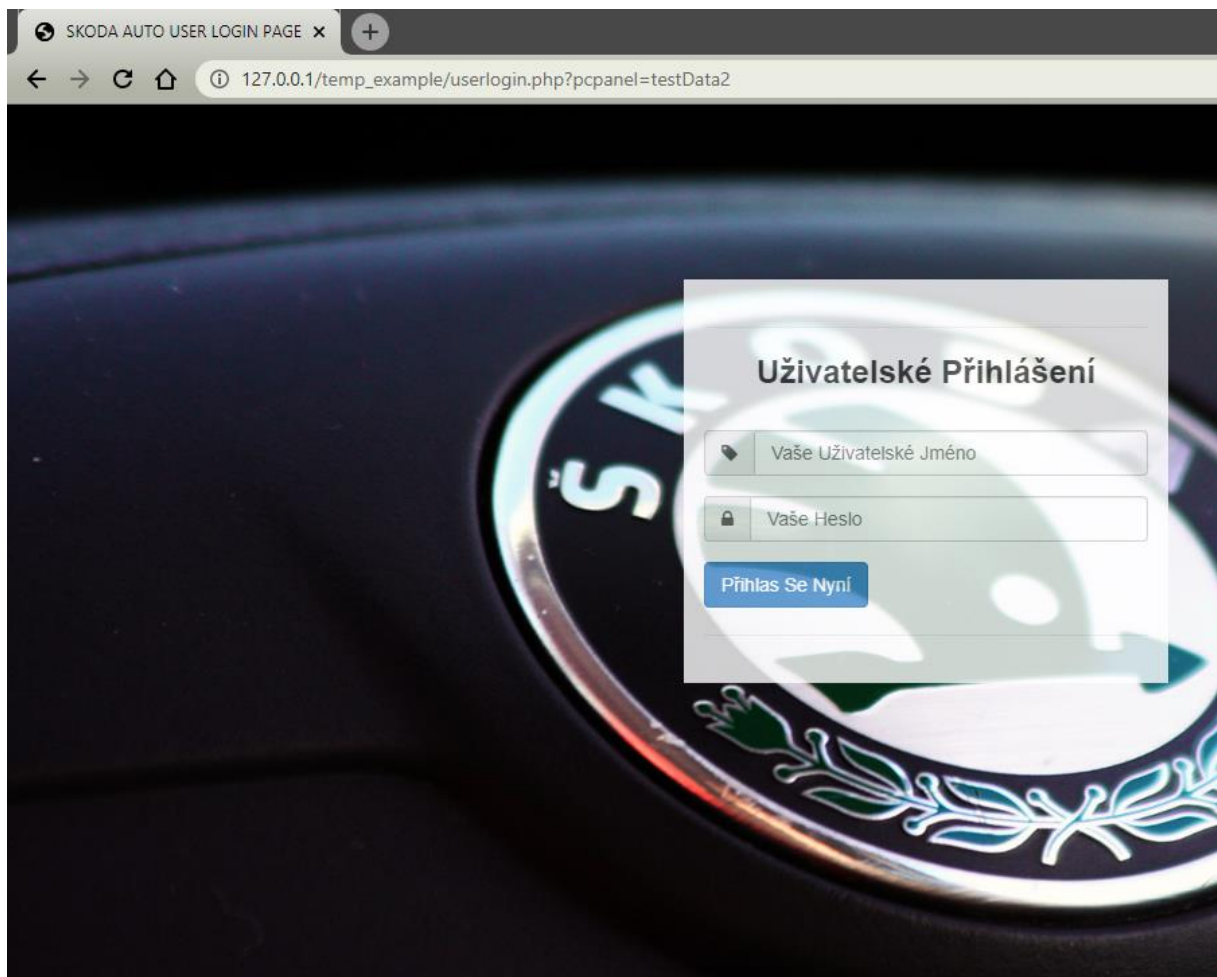
Figure 3. 9 Designed User Login Page for the Workers.

The white field in the user login page is the form. When the workers access to the page, they are interacting with this form. The form is used to get input from the workers about the user name and user password.

When the workers fill out the form which is shown on Figure 3. 9 and click the submit button, the form data is sent for processing to related PHP file. The form data is sent with the *'POST'* method.

In order to design the user login page, external, internal and inline CSS types has been used.

3.3.2. The Autonomous Maintenance Digital Sheet

The autonomous maintenance digital sheet is main part of the proposed solution. The digital based sheet consists of all tables of the data model and relationships between each other.

The language of the page has been arranged as Czech which are local language of the workers of Skoda.

All elements of the page are dynamic which are created by queries of SQL and various functions of PHP and jQuery. JQuery is a fast, clean, and feature-rich JavaScript library. Like the login page, as a designing tool is external, internal and inline CSS types has been used.

While explaining this section, the data model will be divided into sections. Thus, the relationship between the database table will be better understood.

First section is relationship between assigned checklist and the maintenance operation as shown on Figure 3. 10.
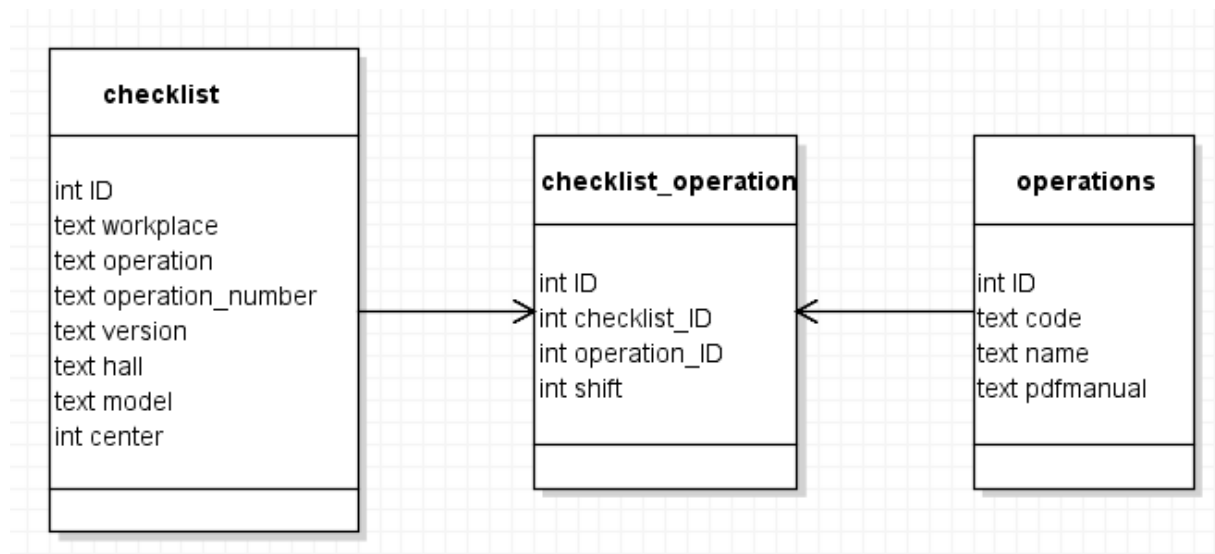
Figure 3. 10 The Relationship Between Checklist and Operations.

The *'checklist'* database table is the main table for relationships between data models. It consists of the assigned operation and information of the selected workplace.

The data of its primary key which is *'ID'* is stored as *'checklist_ID'* which is element of the *'checklist_operation'* database table. The *'checklist_operation'* has the *'shift'* column. As the name suggest, shifts in the workplace are stored in this column. There are three shifts in the selected workplace of Skoda.

The data of *'operation_ID'* column is received from the primary key (*'ID'*) of the *'operations'* database table. The *'operations'* database table consists of code and name of the operation. Also, the operation manual is stored in this database table as Portable Document Format (PDF) file.

The digital sheet is designed as two tables which have different content due to design restrictions. First part of the AM digital sheet is shown in the Figure 3. 11.

ŠKODA	AUTONOMNI UDRZBA SVAROVNA PF 1-K		ŠKODA
Pracoviste: Podlaha UB2-GEO		Operace: 1800-1833	
Datum: 2020/05/28	Verze: 16.06	Hala: M13	Model: B	Stredisko: 3536
Kontrola spravne funkce a cisto y zarizenina pracovisti, zamerte se na cinnosti:			
pri ranni (06:00-14:00)	pri odpoledni (14:00-22:00)	pri nocni (22:00-06:00)	
35A Kontrola nanasecho zafizeni	46A Kontrola robotovy ch klesti	60A Kontrola el. senzoru	
37A Kontrola rob. nanaseci pistole	48A Kontrola grelferu	61A Kontrola mech. upinky	

Figure 3. 11 The First Table of the Digital Sheet.

As seen on Figure 3. 11, information about the workplace are given in first three rows. The next rows contain operations which are applied for each shift separately. As described before in this section, there are three shifts in the workplace. First shift is the morning shift which is stored as *'0'* (integer) in the database. Second shift is the afternoon shift which is stored as *'1'* (integer) in the database. Third shift is the night shift which is stored as *'2'* (integer) in the database.

The supervisor can define different or same operations for each shift. Operations which are seen on bottom of the Figure 3. 11 is designed blue text. Actually, these operation descriptions are linked to PDF file for the operation manuals. After the maintenance worker clicks on this blue text, he or she will see image guide for the selected operation.

It is very important for this system to implement on actual date. PHP is a very effective tool regarding this issue as it is in many issues. The Figure 3. 12 proves that PHP provides the actual date with simply function.

```php
echo "<td colspan='".$colspanLengthDatum."'>Datum: ";
echo date("Y/m/d");
echo "</td>";
```

Figure 3. 12 The Function of the Actual Date in PHP.

Second relationship of the data models for the maintenance digital sheet is about sending maintenance activities by workers. This relationship is shown in the Figure 3. 13.

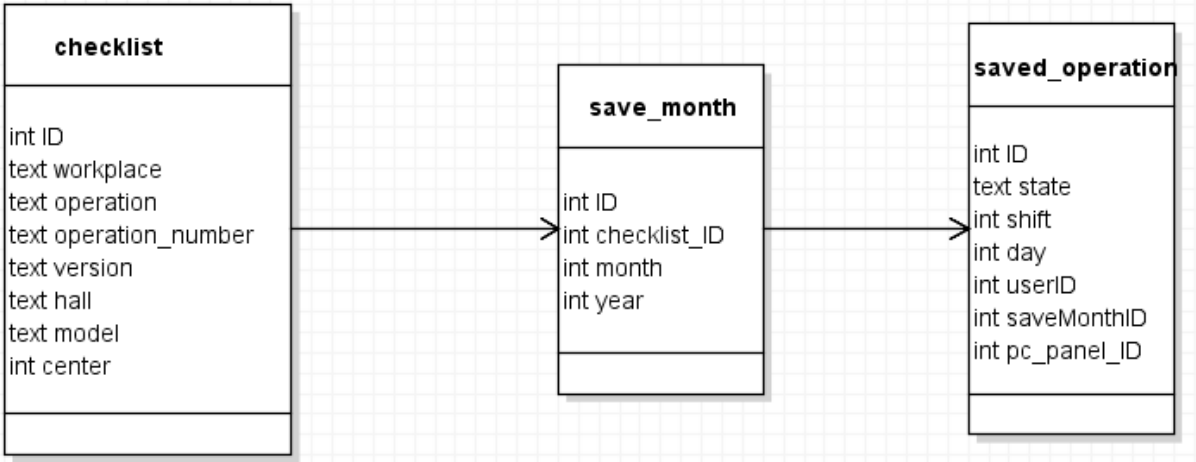**Figure 3. 13** The Relationship Between Checklist and Saved Operations.

The primary key of *'checklist'* database table is connected with *'checklist_ID'* column of the *'save_month'* database table. The *'save_month'* database table consists of actual month and actual year.

The primary key of the *'save_month'* is stored in the *'saveMonthID'* column in the *'saved_operation'* database table. The column of *'pc_panel_ID'* is received from the primary key of the *'pc_panels'* database table.

This table gives information of the saved operation to the maintenance supervisors. This is essential table because of that the activity's output is stored in this database table. The second table is designed to obtain this information from the worker.

	pri ranni (06:00-14:00)			pri odpoledni (14:00-22:00)			pri nocni (22:00-06:00)		
	35A Kontrola nanasecho zafizeni			46A Kontrola robotovy ch klesti			60A Kontrola el. senzoru		
	37A Kontrola rob. nanaseci pistole			48A Kontrola grelferu			61A Kontrola mech. upinky		
	Cinnost		Provedl	Cinnost		Provedl	Cinnost		Provedl
Den	35A	37A	Name	46A	48A	Name	60A	61A	Name
1.	☐	☐		☐	☐		☐	☐	
2.	☐	☐		☐	☐		☐	☐	
3.	☐	☐		☐	☐		☐	☐	
4.	☐	☐		☐	☐		☐	☐	
5.	☐	☐		☐	☐		☐	☐	
6.	☐	☐		☐	☐		☐	☐	

Figure 3. 14 The Second Table of the Digital Sheet.

As you can see in the Figure 3. 14, the name fields are empty. Because, the name field is only active for the current time. User can only fill data of the current time. The next Figure is created on May 29th during the morning shift.
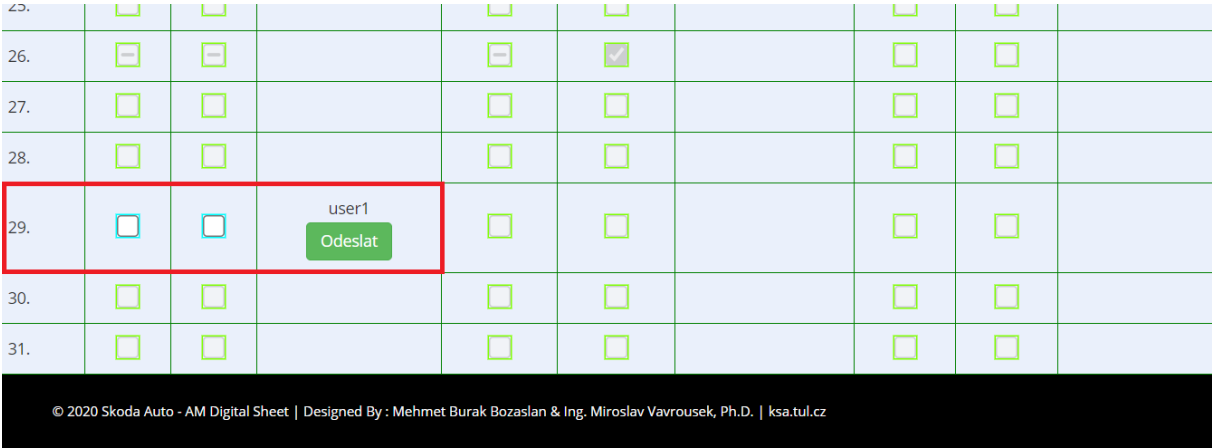

Figure 3. 15 Review of the Area to Fill by the Workers.

The maintenance workers can only fill elements which are in red line. Another fields are not allowed to fill it. Workers should fill these two checkboxes and after it, they should press "Send" button which is shown as green color. After sending information will be sent. The maintenance supervisors can display that followings:

- Which user filled it (*'userID'*).
- What are the states of the maintenance operations (*'state'*).
- Which day did worker send it (*'day'*).
- Which shift did check it (*'shift'*).

If we check the Figure 3. 15, we can realize that 26th day is filled before in the digital sheet for May. Filled checkboxes have been seen in the digital paper. This is significant information for workers as well as supervisor.

Above the "Send" button, user name has been seen. This information is received from *'users'* database table with the PHP global variable *'$_SESSION'*. This variable hold information about one single user, and are available to all pages in one application. The codes for "Send" button and user name are shown on the Figure 3. 16.

```
echo "<td colspan='2' align='center'><div class='inner-text'>";
echo $_SESSION['user_name'];
echo "</div><input class='btn btn-success' type='submit' name='senddata' value='Odeslat'></td>";
echo "</form>";
```

Figure 3. 16 PHP Codes for Button and User Name.

States of checkboxes are another important data for the maintenance supervisor. Supervisor can obtain the situation of the operation with state values. Checkboxes has been designed as three states which are shown in the Figure 3. 17.
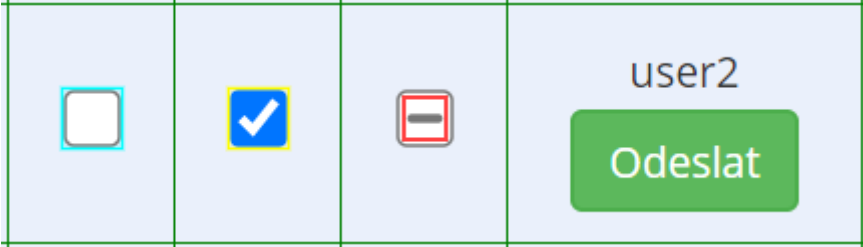

Figure 3. 17 Three-states Checkboxes.

The first state describes that the selected operation is not checked. This state has been arranged as a default. Unchecked state is stored as *"0"* (text) in the database table.

The second state represents that the selected operation is checked by the worker. Checked state is stored as *"1"* (text) in the database table.

The third state declares that there is a problem in the selected operation. Intermediate state is stored as *"2"* (text) in the database table. If workers send this value, the alert system will be active and the maintenance supervisor will automatically receive an e-mail regarding to the value which has been sent.

States are stored as text data type in the *'saved_operation'* database table due to obtain a string from state values. For instance, for the Figure 3. 17, if the *'user2'* send these values, it will be saved as *"012"* in the *'state'* column.

These checkboxes are really complex structure. They are good examples for combination of PHP, HTML, CSS and jQuery. A piece of code for checkboxes is shown on the Figure 3. 18.

```
if ($filledDataDayShift[$y] == '0')
{
  echo "<td align='center'><input name='check".strval($indexCheckbox)."' type='checkbox'
    id='check".strval($indexCheckbox)."' class='tristate'>";
  echo "<input name='check".strval($indexCheckbox)."a' style='display:none;'
    type='checkbox'>";
  echo "<input name='check".strval($indexCheckbox)."b' style='display:none;'
    type='checkbox'></td>";
}
```

Figure 3. 18 A Piece of Code for the Unchecked Checkbox.

As seen in the Figure 3. 18, there are two hidden checkboxes are designed due to obtaining three state checkboxes.

The relationship between checklist and PC Panel will be discussed in this section. The data model for checklist, PC Panel and their relationship is shown in the Figure 3. 19.
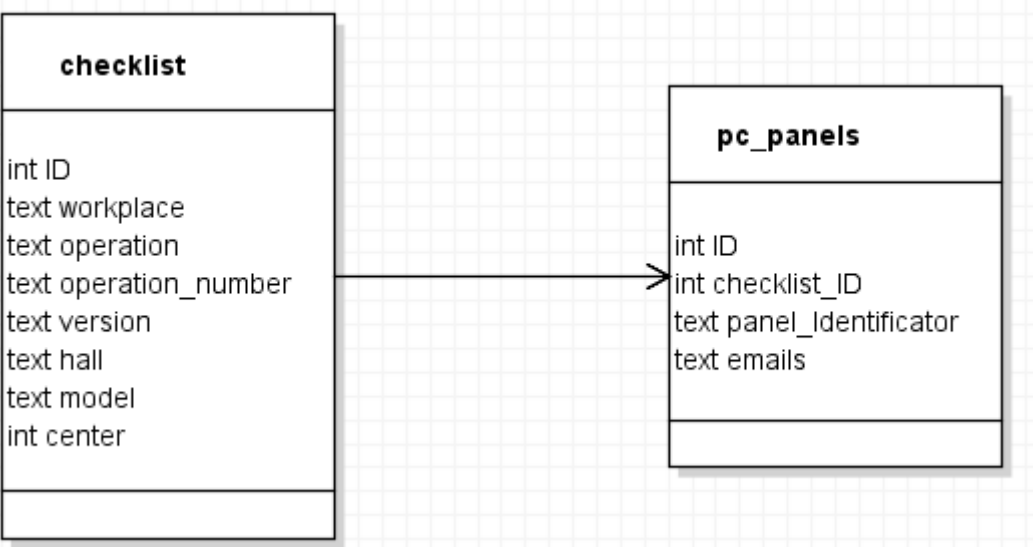

Figure 3. 19 The Relationship Between Checklist and PC Panel.

The primary key of *'checklist'* database table is connected with *'checklist_ID'* column of the *'pc_panels'* database table. The *'pc_panels'* database table contains panel identificator which is stored as text. Also for the alert system, list of e-mails of the supervisors is defined in the *'pc_panels'* database table.

In order to implement PC Panel to the proposed solution, PHP *'$_GET'* super global variable has been used. This is used in order to collect data sent in the Uniform Resource Locator (URL).

```php
if ($pcVariable = $db -> prepare("SELECT * FROM pc_panels WHERE panel_identificator='".$_GET['panel']."'"))
{
  $pcVariable->execute();
  $pcResult = $pcVariable->get_result();

  while ($pcRow = $pcResult->fetch_assoc())
  {
    $checklist_ID = $pcRow['checklist_ID'];
  }
}
```

```php
header('Location:../../table.php?panel='.$_POST['pcpanel']);
```

```
127.0.0.1/temp_example/table.php?panel=testData2
```

Figure 3. 20 The Code Blocks for Implementing PC Panel.

The URL and the code blocks is shown in the Figure 3. 20 in order to implement PC Panel to the digital sheet. Before the user login, workers can select assigned PC Panel by the maintenance supervisors. Supervisors assign different checklist for each PC Panel.

3.4. THE ADMINISTRATION PANEL

The administration panel is also called control panel that is a web-based interface provided by a hosting service that enables users to manage their services and servers. The control panel should provide tools for managing an application, in our cases managing the AM digital sheet.

In short, the admin panel is where content created and managed. Admin panel is one of the most significant modules of a web application. If admin panel is powerful, managing the system would be easy.

For creating the administration panel, the requirements of the Skoda have been taken into consideration. According to these requirement, a rich, useful and easily understandable structure has been created. The most important priority has been the basic needs of the Skoda.

The admin panel is designed for maintenance supervisors which are working at the workplaces of Skoda's welding line. Responsibilities of maintenance supervisors are given in the Figure 3. 21.
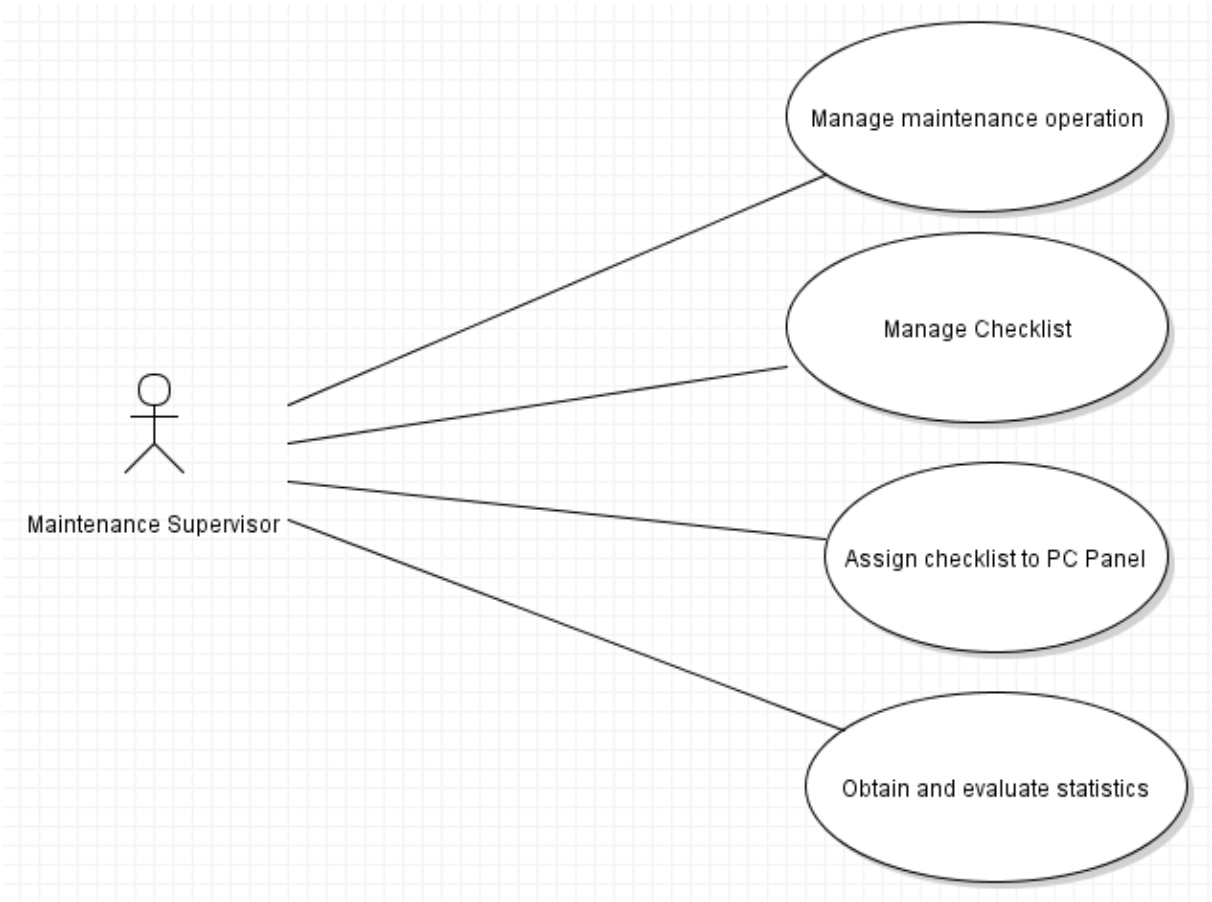

Figure 3. 21 Use Cases of Maintenance Supervisors.

The administration panel should be functional in order to complete the admin's responsibilities. While designing, this functionality has been focused on, and easy-to-understand instructions have been made to use this functionality properly. For example, warning texts, remarkable button colors, guidance texts have been used for this purpose.

What the maintenance supervisor can do by using the administration panel has been given below:

- Supervisor can add a new operation.
- Supervisor can delete the desired operation.
- Supervisor can edit the desired operation.
- Supervisor can manage the operation manuals (editing, deleting, adding).
- Supervisor can add a new checklist for the workers.
- Supervisor can delete the desired checklist from the database.
- Supervisor can modify the desired checklist.
- Supervisor can add a new PC Panel.
- Supervisor can delete the desired PC Panel.
- Supervisor can edit the desired PC Panel.
- Supervisor can assign checklist to PC Panel by changing ID of the checklist.
- Supervisor can see that which operations have a problem with alert mail system.
- Supervisor can obtain some statistics with regards to the selected date range and can evaluate these statistics by using the related database.
- New users -in our case, workers- can be added to the system.
- Users -in our case, workers- can be deleted from the system.
- User password and user name for login can be modified.

As a summary, the maintenance supervisor has been having a high level of control over the AM digital sheet. They can easily track all maintenance activities of workers in the workplace.

The administration panel consists of two main part. First one is login page, second is the main page which are displayed after successful login.

Generally, the maintenance supervisor will use the sidebar elements of the admin panel. Because, he or she will complete responsibilities from the sidebar. They will be discussed the followings.

3.4.1. Login Page of the Administration Panel

The first step for implementing the control panel is designing of login page for the maintenance supervisor. Steps of designing the login page of the administration panel is really similar with the user login page. After looking over the requirements for admin login, it necessary to create a database table for admins. In our case, these admins will be the maintenance supervisor which are working at the selected workplace. Database table for supervisors is shown on Figure 3. 6.

Figure 3. 22 The Admins Table.

The *'admin'* database table consists of the admin ID, admin name and admin password like the *'user'* database table. The primary key of *'admin'* database table is the admin ID. The admin ID is unique and auto-incremental. Auto-increment allows a unique number to be produced automatically when a new supervisor is inserted into a table.

The admin name contains the name of the maintenance workers who logs on to the system. In order to log in to the system, the user name must be entered.

The second requirement in order to log in to the system is the admin password. For the password, MD5 is used for the security. MD5 was described in the user login page. For the user password and admin password, same approach has been used.

When comparing the *'user'* database table and *'admin'* database table, one difference could be realized. For the *'admin'* database table, there is one additional elements which is *'admin_aut'* with *'enum'* data type. Enumerated data type has been used in order to represent admin roles in the database.

The proposed solution allows to assign admins different roles so that it is allowed or restricted access to specific function. It is called authorization. For the authorization of the admin, two values are used in the databased. Admin has been restricted or admin has been allowed.

In order to access to the admin panel, login is required. It means that the login page will be first page for the maintenance supervisor. After admin name and admin password are correctly filled, they can access to the control panel. The admin login page is shown on the Figure 3. 23.
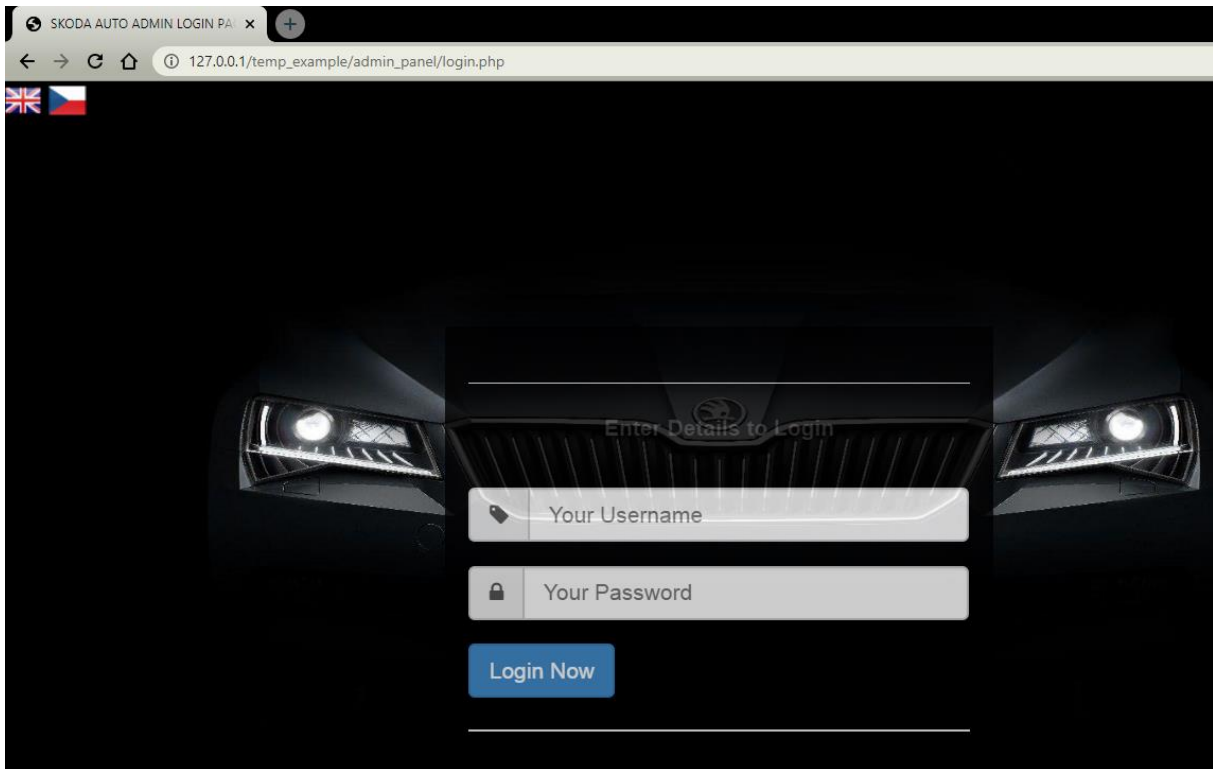
Figure 3. 23 Designed Admin Login Page for the Supervisors.

Skoda is a global company who has many employees from different countries. Because of this reason, a multi-language support system has been created for the administration panel unlike of the user panel. As the global language English, as the local language Czech have been implemented as needed by an international company.

There are various ways in order to implement multi-language support for an application. The multi-language support is provided by managing language configuration with files containing texts in Czech and English languages instead of having duplicate pages or creating database for the language contexts.

By implementing localization with the files, it eliminates inconsistency among the duplicate pages and complexity which is came with creating database.

The first thing to implement the multi-language support is to create a couple of files which consist of the text for Czech and English languages. This step is shown on the Figure 3.24 and the Figure 3.25.

```
//index.php
$lang['TEXT1'] = 'Welcome to the admin panel of SKODA AUTO';
$lang['TEXT2'] = 'You can use the side elements to use your portal.';
```

Figure 3. 24 A Part of the Language File for English.

```
//index.php
$lang['TEXT1'] = 'Vitejte v administracnim panelu udzby SKODA AUTO';
$lang['TEXT2'] = 'Vice v bocnim menu.';
```

Figure 3. 25 A Part of the Language File for Czech.

The second step of the implementation, a file which is shown in the Figure 3. 26 has been included containing a piece of code that gets the desired language.

```php
1    <?php
2        session_start();
3
4        if(isset($_GET['lang']))
5        {
6            $lang = $_GET['lang'];
7            $_SESSION['lang'] = $lang;
8            setcookie("lang", $lang, time() + (3600 * 24 * 30));
9        }
10
11       else if(isset($_SESSION['lang']))
12       {
13           $lang = $_SESSION['lang'];
14       }
15
16       else if(isset($_COOKIE['lang']))
17       {
18           $lang = $_COOKIE['lang'];
19       }
20
21       else
22       {
23           $lang = 'en';
24       }
25
26       switch ($lang)
27       {
28           case 'en':
29           //English
30           $lang_file = 'lang.en.php';
31           break;
32
33           case 'cz':
34           //Czech
35           $lang_file = 'lang.cz.php';
36           break;
37
38           // Default English
39           default:
40           $lang_file = 'lang.en.php';
41       }
42
43       include_once 'languages/'.$lang_file;
44   ?>
```

Figure 3. 26 Common Language Configuration PHP File.

After determining value of *'lang'* variable, *'switch'* has been used to compare value of *'lang'* variable with some different values, and run a different piece of code depending on which value it equals to. PHP global variable *'$_SESSION'* is used to register the value of *'lang'* variable.

In addition, another PHP global variable *'$_COOKIE'* has been used to store the selected language in the computer during 30 days. When the supervisors will come back, they will see the administration panel in the language which they previously selected.

We have output the values inside the administration panel PHP file. After the implementation steps of the multi-language support, when we call other language file, different text will be seen every time.

There are flags in the upper left corner of the admin login page for the language options. The admin can choose the desired language by clicking on the flag. If the supervisor would like to change the language, they have to click the flag before login to the main page of the administration panel.

3.4.2. Home Page of the Administration Panel

The supervisor will be redirected to the home page of the administration panel after a successful login of administration login page. All of the responsibilities that are defined on the maintenance supervisor can be completed here.

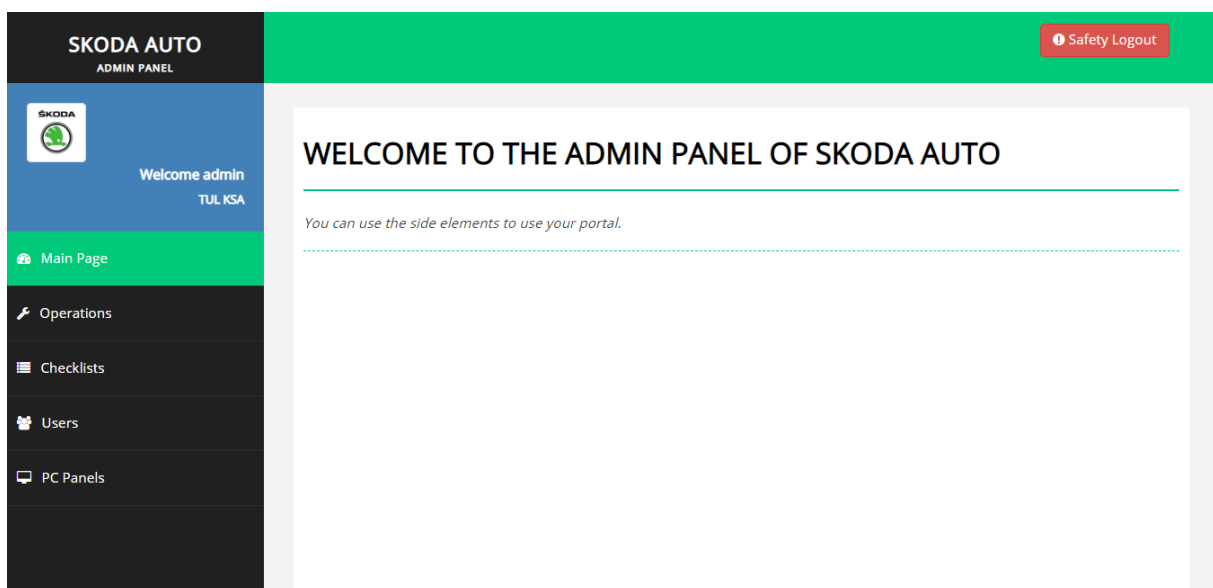The home page of the administration panel is shown on the Figure 3. 27.

Figure 3. 27 Home Page of the Administration Panel.

The home page of the administration panel consists of "Safety Logout" button, usage instruction of the panel and sidebar. If the supervisor presses the "Safety Logout" button which is located on the top right corner of the panel, he or she will exit the panel and be directed to the admin login page of the administration panel. The maintenance supervisor should use sidebar elements in order to complete assigned tasks. These elements located on the left side of the page. The following Figure 3. 28 shows us the sidebar elements of the admin panel.
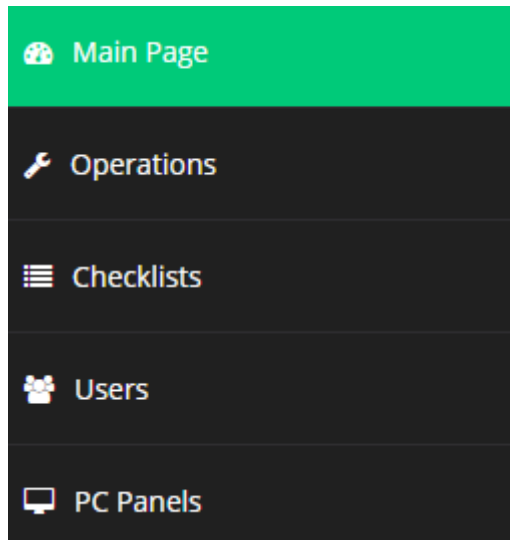

Figure 3. 28 The Sidebar Elements of the Administration Panel.

When the supervisors complete the login process, the main page will come. There is no function assigned here. Sections of the sidebar has been designed with this code block which is shown on the Figure 3. 29.

```php
<li> <a class="<?php if(basename($_SERVER['REQUEST_URI']) == 'index.php'){echo 'active-menu'; }else
    { echo ''; } ?>" href="index.php"><i class="fa fa-dashboard"></i><?php echo $lang['MAIN PAGE'];
?>></a>
</li>

<li> <a class="<?php if(basename($_SERVER['REQUEST_URI']) == 'operations.php'){echo 'active-menu'; }
    else { echo ''; } ?>" href="operations.php"><i class="fa fa-wrench"></i><?php echo $lang['
    OPERATIONS']; ?>></a>
</li>

<li> <a class="<?php if(basename($_SERVER['REQUEST_URI']) == 'checklist.php'){echo 'active-menu'; }
    else { echo ''; } ?>" href="checklist.php"><i class="fa fa-list"></i><?php echo $lang['CHECKLIST
    ']; ?>></a>
</li>

<li> <a class="<?php if(basename($_SERVER['REQUEST_URI']) == 'user.php'){echo 'active-menu'; }else {
    echo ''; } ?>" href="user.php"><i class="fa fa-users"></i><?php echo $lang['USER']; ?>></a>
</li>

<li> <a class="<?php if(basename($_SERVER['REQUEST_URI']) == 'pcpanel.php'){echo 'active-menu'; }
    else { echo ''; } ?>" href="pcpanel.php"><i class="fa fa-desktop"></i><?php echo $lang['PC PANEL
    ']; ?>></a>
</li>
```

Figure 3. 29 Main Code of the Sidebar Elements.

Transition between the sidebar elements are designed with the code blocks which are shown in the Figure 3. 29. The page that is active with help of the CSS tool is marked green color. The maintenance supervisor just clicks on an element to activate it. The background of this process is based on using the HTML *'href'* attribute. This attribute calls to the code block of the page to be activated.

The sidebar elements are connected with *'checklist'*, *'operations'*, *'pc_panels'* and *'user'* database tables. Generally, the maintenance supervisor can manage these database tables regarding to the responsibilities. These management possibilities are adding a new data, deleting the existing data and modifying the existing data. After arrangement by using administration panel, the database tables will be effected according to the applied arrangement.

Since the design approach of each element is very similar, only one element which is named as Operations has been explained in detail. Figures related to the other element have been given for general review.

When the supervisor clicks the Operations menu of the sidebar, he or she will see functions of Operations menu as depicted in the Figure 3. 30.

OPERATIONS

You can edit operations from this page.

Add Operation

Operations					
#	Operation Code	Operation Name	Operation PDF		
5	35A	Kontrola nanasecho zafizeni		Edit	Delete
6	37A	Kontrola rob. nanaseci pistole		Edit	Delete

Figure 3. 30 Operations Menu of the Administration Panel.

The maintenance supervisors can modify the *'operations'* database table from this page. As described before, the *'operations'* database table consists of operation code, operation name and operation manual. The supervisor can manage all of these columns in the database table.

The maintenance supervisor can add a new operation by clicking "Add Operation" button which is marked green.

After clicking the "Add Operation" button, the supervisor sees the output of the adding operation code block. This page is shown in the Figure 3. 31.

ADDING OPERATION

You can add operation from this panel.

Manual PDF Upload

Select file

Operation Code

Enter Operation Code

Operation Name

Enter Operation Name

Save

Figure 3. 31 The Adding Operation Section of the Administration Panel.

The maintenance supervisor can implement a new operation manual to the system by using this interface. Operation code and operation name are the other fields which are required to be filled. The primary key of the *'operations'* table will be updated automatically.

After completing the filling in the given form, the admin must click "Save" button in order to add a new record to the *'operations'* database table.

For the adding a new record in the table, the *'INSERT INTO'* statement has been used. By this way, the supervisor can insert a new record to the database table. The implementation of the SQL *'INSERT INTO'* statement for the 'operations' database table is shown in the Figure 3. 32.

```
("INSERT INTO operations (code, name, pdfmanual) VALUES ('".$_POST['code']."', '".$_POST['name']."','".$imgurl."')");
```

Figure 3. 32 The SQL Statement to Insert a New Record in PHP for Operations Menu.

The supervisor will get feedback from the system for better navigation after saving operation. This feedback gives information about that the activities which is completed in the panel has been successful or not.

In the Operations menu, the supervisor can see the existing records in the database table. The next of the records, there are two more button. One of them "Edit" button which is marked blue color. After clicking the "Edit" button, the supervisor sees the output of the editing operation code block. This page is shown in the Figure 3. 33.

Figure 3. 33 The Editing Operation Section of the Administration Panel.

The maintenance supervisor can modify the existing records in the *'operations'* database table by using this interface.

After completing filling the required fields in the given form, the admin must click "Edit" button in order to change the targeted record in the *'operations'* database table.

For the updating the existing record in the table, the SQL *'UPDATE'* command has been used with PHP. By this way, the supervisor can modify the targeted records in the database table. The implementation of the SQL *'UPDATE'* statement for the *'operations'* database table is shown in the Figure 3. 34.

```
("UPDATE operations SET code='".$_POST['code']."',name='".$_POST['name']."',pdfmanual='".$_POST['pdfmanual']
    ."' WHERE ID='$ID'");
```

Figure 3. 34 The SQL Statement to Edit the Records in PHP for Operations Menu.

The 'WHERE' clause specifies which record that will be updated. After the process, the desired records will be updated in the database table. Therefore, after changes of the existing records, the AM digital sheet will be updated.

The last button in the administration panel is the "Delete" button. The maintenance supervisor uses this button, when they want to delete any records from the *'operations'* database table. This button will delete all data of the desired row. There is no undo of deletion. Creating of the "Delete" button is shown in the Figure 3. 35.

```
<td><a href="netting/process.php?ID=<?php echo $row['ID']; ?>
&deleteoperation=ok"> <button class="btn btn-danger"><?php echo $
    lang['DEL']; ?></button></a></td>
```

Figure 3. 35 Input of the "Delete" Button.

In order to delete the existing record in a table, the SQL *'DELETE'* statement has been used. Like SQL *'UPDATE'* command, the 'WHERE' clause specifies which record will be deleted from the database. For the deleting any record in the *'operations'* table, the code block which is shown Figure 3. 36 has been used.

```
if($_GET['deleteoperation']=="ok")
{
    $deleteoperation= $db -> prepare("DELETE FROM operations WHERE ID='".$_GET['ID']."'");

    $deleteoperation -> execute();

    if($deleteoperation -> affected_rows)
    {
        header ('Location:../operations.php?state=ok');
    }

    else
    {
        header ('Location:../operations.php?state=no');
    }
}
```

Figure 3. 36 The SQL Statement to Delete the Record in PHP for Operations Menu.

The rest of the menus have almost same design approach in the proposed solution. Because of this reason, they will not be explained in detail. Only a few differences are existed, when comparing with the Operation menu. the most notable of these differences is in the Checklist menu. This difference which is shown on Figure 3. 37 is multiple selection features for the assigned operation to the checklist.
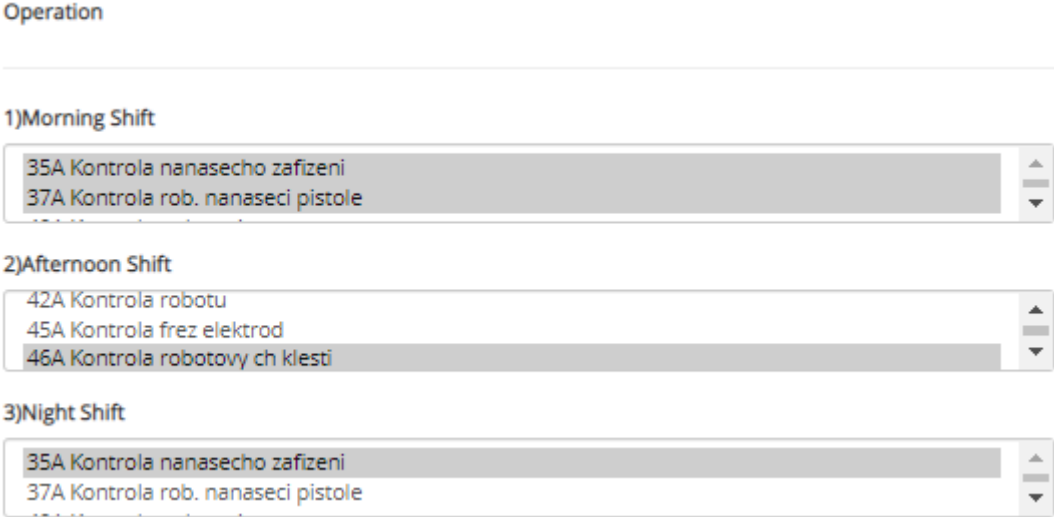
Figure 3. 37 Multiple Selection Features for the Checklist Element.

The assigned operation may be more than one for each shift. Therefore, the admin panel must be able to multiple selection features. Also, operation previously assigned are marked in gray color. Checklist menu is used in order to arrange *'checklist'* database table. The records of this table can be deleted, modified using "Delete" and "Edit" button. Also like the other menus, new record can be created by using "Add Checklist" button. The review of the Checklist menu is shown on the Figure 3. 38.

Figure 3. 38 Checklist Menu of the Administration Panel.

The another element of the sidebar is Users menu. The maintenance supervisor can add a new user. With other words, the maintenance workers can be added from the Users menu with clicking the "Add User" button. Users page is shown in the Figure 3. 39 (user password is hidden for the review).
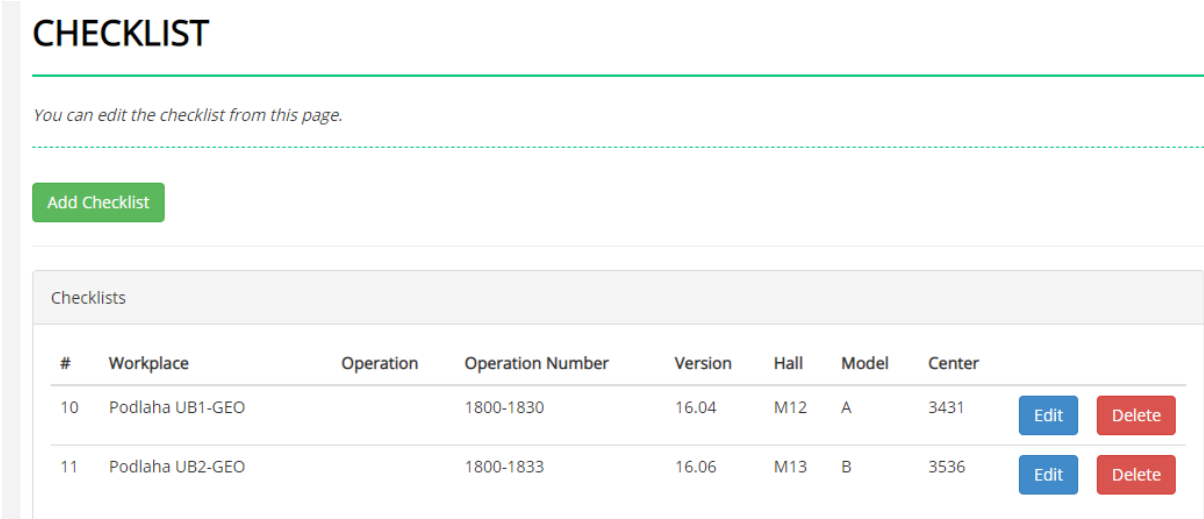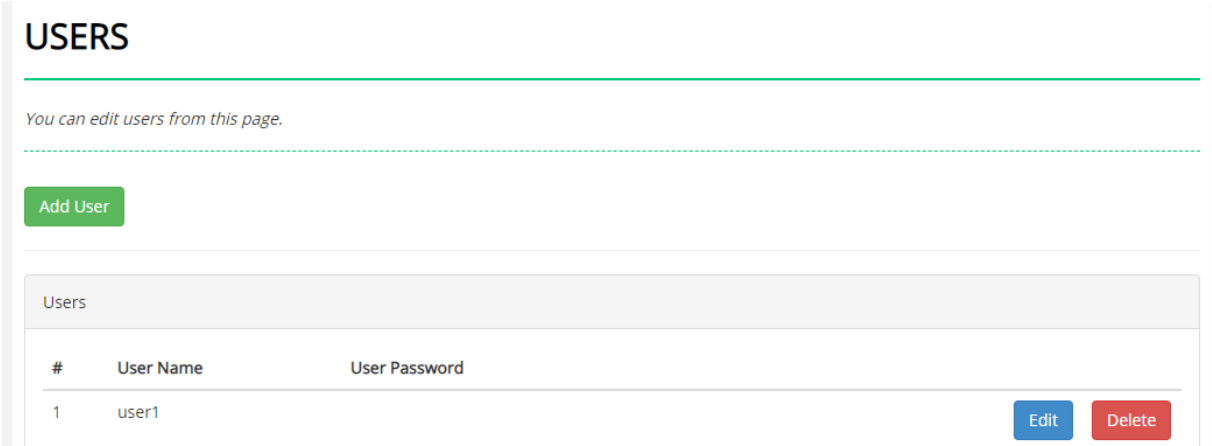

Figure 3. 39 Users Menu of the Administration Panel.

In addition, the supervisor can delete or modify the existing record of the *'user'* database table. They can change the user name and/or user password with using "Edit" button. Deleting all records of the desired row is also available for the supervisor.

Same features had been implemented for the PC Panels menu. PC Panel menu is shown in the Figure 3. 40.

Figure 3. 40 PC Panels Menu of the Administration Panel.

The supervisor can define the desired checklist to the PC Panel with modifying in this menu. As the exact opposite records can be deleted from the *'pc_panels'* database table.

Another important possibility is about the modifying e-mails for the alert system. The supervisor can add more than one emails to the system for the alert system. The maintenance supervisor should follow the instruction which is given in the placeholder of e-mail form in order to successfully add e-mail as shown in the Figure 3. 41.

E-mail

Enter the email; enter the second email; enter the third email
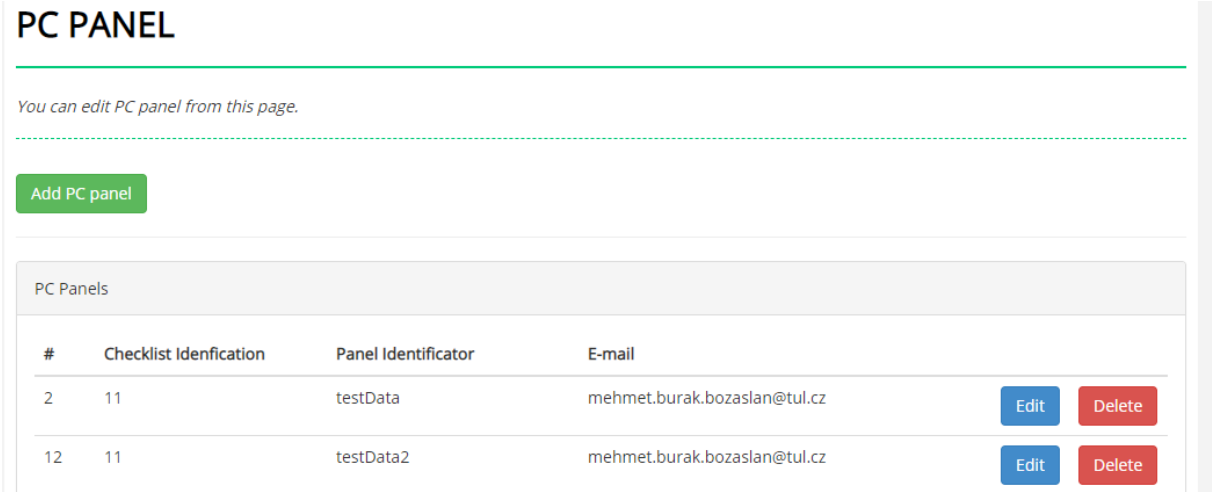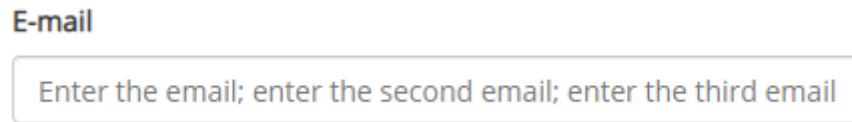
Figure 3. 41 The Instruction to Add a New Mail Address.

In summary, the administrator can make many changes on the system using described sidebar elements of the administration panel. Many table registered in the database can be managed here.

3.5. THE ALERT SYSTEM

Some operations may have problems due to various reason. The maintenance workers are required to report these problems to the maintenance supervisors. For this requirement, the proposed solution has the alert system.

The third state of the checkboxes declares that there is a problem in the selected operation. Intermediate state is stored in the *'saved_operation'* database table. If workers send this value, the alert system will be active and the supervisor will automatically receive an e-mail regarding to the value which has been sent.

In order to achieve solution, PHPMailer library has been used in order to send e-mail to the assigned a list of e-mails. The list of e-mails is stored in the *'pc_panels'* database table.

In the library, Simple Mail Transfer Protocol (SMTP) server has been used in order to send e-mail. An SMTP server processes e-mail, relays the message to the decided -by the SMTP-server.

In the received e-mail, the maintenance supervisor should see information about the operation and the PC Panel to solve the problem. The e-mail consists of followings:

- The subject
- Title of the body
- Content of the body
- Footer

Input of title of body and input of the PC Panel information is shown in the Figure 3. 42. The supervisor will see identification name and number of the PC Panel which is detected a problem.

```php
$body = "Fault alert for the autonomous maintenance operation:\r\n\r\n\r\n";

$body= $body."The problem is detected at the PC Panel ID - ".$_POST['pc_panel_ID'].", ".$
    PCpanelIden."\r\n\r\n";
```

Figure 3. 42 The Code Block for Title of the Body and Data of the PC Panel.

The information of the problematic operation is indispensable in the content of the e-mail. The code and the name of the problematic operation has been provided with the code block which is shown on the Figure 3. 43.

```php
for ($x=0; $x < count($operation_code) ; $x++)
{
    if($state[$x] == '2' )
    {
        $body = $body.$operation_code[$x][0]." ".$operation_code[$x][2]."\r\n";
    }
}
```

Figure 3. 43 The Code Block for the Problematic Operation.

Last section of the e-mail contains the actual date and time. The code block for the footer of the e-mail is shown on the Figure 3. 44.

```php
$body = $body."\r\n"."Please check the operation(s) listed above";
$date = date("Y/m/d");
$time = date('H:i');
$body = $body."\r\n\r\n".$date."    ".$time;
```

Figure 3. 44 The Code Block for the Footer.

As a result of running these code block which are shown on last three figures, the alert mail is received is shown on the Figure 3. 45.

```
Fault alert for the autonomous maintenance operation:

The problem is detected at the PC Panel ID - 12, testData2

60A Kontrola el. senzoru
61A Kontrola mech. upinky

Please check the operation(s) listed above

2020/06/03    23:34
```

Figure 3. 45 The Example of the Received Mail.

The supervisor can obtain all required information from the created alert system for the operation which has a problem. These information goes directly to the mail addresses which is stored in the *'pc_panels'* database table.

4. CONCLUSIONS & FUTURE WORK

This digital solution presented a novel set of design principles of transformation from paper-based autonomous maintenance to digital autonomous maintenance. This transformation has been completed thanks to complementary languages, design tools and the relevant technical infrastructure.

The administration panel which has been created for the supervisors of the maintenance activities completely ready for use. This compatible solution offers the supervisors user-friendly and easy manageable platform. On the other hand, the user panel, with its user-friendly, easy-to-navigate features, allows the workers to easily filling checklists and after that sending to the database system after the related maintenance activities. Also, before the maintenance activities, workers can see the operation manual of assigned maintenance operation.

There are numerous possibilities for future work that can be done.

The proposed solution has been designed for only the welding line of Skoda. The next step of the proposed solution can be the implementing to all workplaces of Skoda. The framework can stay same which has been created for the welding line. The proposed solution can be integrated into the maintenance activities of other production lines with only a few simple technical changes. Therefore, the system can provide equality for all production lines of Skoda. A central system to be designed will be able to approach all maintenance activities as a whole. In this way, the data obtained will be more consistent and comprehensive and it will be more efficient to obtain statistics.

Another improvement on this work might be a smart card system instead of login page. A smart card system can be used to speed up the entry process to the proposed solution and increase the traceability of employees. When the employees try to login the autonomous maintenance sheet, the data in his/her smart card is checked with the related data in the database and if matched, the employee is allowed to login the autonomous maintenance sheet. These possibilities will bring considerable fluency to the proposed solution.

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