Ecodesign of electronic devices

UNIT 5: Management of the Ecodesign process.

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Chapter summary:

- Project structure
- Project plan
- Project management

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5.1. Managing device development process

After the initial phase in developing electronic devices, the main tasks are determination of device functionalities, targeted customers, and market, consideration of customer requirements, market and execution methods, etc. The following questions can arise: »How will the device function?« or »What functions will it have?« and later can develop questions on project management that is crucial for execution and achieving of the set timeframes. Management also has to optimally distribute workload between employees and departments for achieving high quality of products and the fastest possible execution. The inevitable question here is »How much will the development process cost?« and »How long will development take?«. When projects are undertaken in large companies the questions about price and development time come from the management which manages the company and its profit. In smaller companies and groups these questions are usually asked by the customer. But in every design process, the designer is responsible not only for previously defined device characteristics but also for the work finished in the financial frame and in the given time.

If the design process requires more than one designer, then we come across the following questions and conditions that need to be anticipated. We need to consider how many people we need, what knowledge these people should have, what research and production capacities we need and if we need any special equipment for testing. Depending on these and many other questions, the project organization needs to be clearly defined, and possible discrepancies need to be considered.

Lately, project management has become an advanced and efficient research discipline. The importance of discipline is visible in a quick increase of manager associations, research journals, and new educational programs. In this unit, we will focus on planning and management of designing process through different phases and also how to provide designer goals and financial frame of the project.

5.1.1. Project definition

Project definition can be presented in a simplified way as quantitative part of the whole process where beginning and end are clearly determined, as well as expected results and outcomes. In most of the engineering work, such as project designing and planning studies project constructions are precisely defined. Contrary to the engineering functions, such as network maintenance, production management, teaching, etc. do not belong amongst project activities and project definitions. These activities are usually defined as parallel activities and enable upcoming activities and services.

The attributes that are often related to project definition are:

- Unique product or service, small sized production.
- Measuring instruments and values.
- Use of resources (people, materials, equipment).

- Work is mostly complex, uncertain and/or urgent.

5.2. Approaches to project management

The effort that we put into designing is quantitative part of project work and reflects all attributes of the project structure. For example, take a look at upgrading and improvement of the existing electronic devices. The project will at the beginning have a defined start date and expected due date. The result will be a small number of prototype devices with suitable documentation for mass production. The goal is to ensure improvement that needs to be measurable to guarantee pre-defined criteria and goals. Project work and development will be undertaken by the developer team with equipment, available in the development laboratory. Complexity, uncertainty, and necessity for the work to be finished can vary depending on the devices and market. Nevertheless, we can conclude that every design project and management of it uses methods of project management.

5.2.1. Project organization

Project management differs from each manufacturer, but companies have very similar structures and patterns. In a broader sense, there is always an individual who is responsible for managing company or project. This person is the project leader. He determines a group of people called project or development team that has access to different structures from the inside and outside of the company. Often the development team responsible for developing electronic devices collaborate with hardware and design departments. The synergies between the group and good communication outline the design journey to competitive and high quality products. Image 1 shows a structure for project management.

In larger corporation, designing can have more sophisticated approaches. The project can be divided into multiple parts, and each group is responsible for one part. It is very important that project leader determines one group or individual who coordinates and manages individual parts of the development process. With thoughtful planning, this is relatively simple. Contrary, with poor project structure it can happen that some parts cannot be merged or that this process takes too long to be finished. In larger organizations, it is also common that the company manages several different projects at once and consequently the developer teams also solve several tasks simultaneously. The project leader has to optimally determine needed tasks and a timeframe for these tasks.

In smaller companies where development of new devices is not primary activity, external developer teams are often hired. Device development is not completely transferred to the external contractor but only some tasks. The leader's task is to coordinate external work and work of internal employees. The inclusion of external teams brings better expertise of the development area but on the other hand limits

control and project management. Limitations to the control are related to external project work because it is carried out in another company or laboratory that can be in another city, country or even continent.

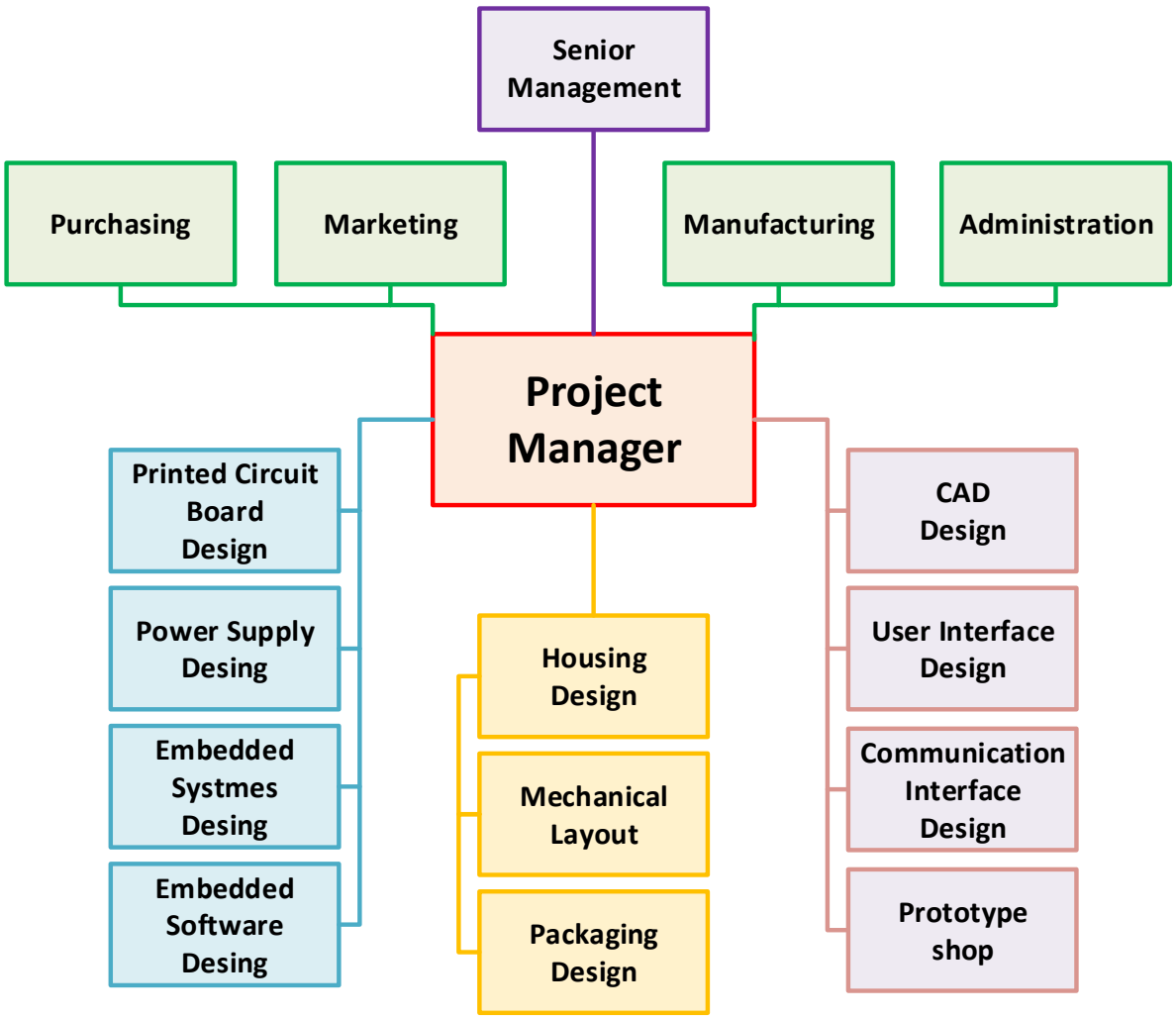

IMAGE 1: ORGANIZATIONAL STRUCTURE IN A COMPANY

Lastly, it is important to point out that lately have been established many larger companies that are essentially specialized only for designing and development of devices. These companies take over complete projects, form development teams or hire contractors. When the project is finished, they take over the next project with the same or different company.

Regardless of the project's nature and type of organization that is working on the project, the structure and management type is more or less the same. It is important to choose a unique group of people with excellent knowledge, competence for achieving the aim of finishing the work.

5.2.2. Elements of project management

The person who is designing a new device is responsible that the device meets the functional requirements and all other criteria. In Ecodesign, it is very important that all the set ecological criteria are met, and ecological certificates are awarded to the product. The person who is leading the designing project (project manager) is responsible for functionalities and everything previously mentioned, as well as that the project is realized in a given timeframe and within financial means. Many see project manager's role as "undermining" of design quality and device functionalities to achieve and reduce the costs of designing and production. Contrary, an experienced and disciplined project manager manages the project to improve product quality and design in the given financial framework. When focusing and leading the development team with the optimal order of tasks and skillfully avoiding tendencies and interests of individuals, this approach leads to achieving goals and accomplishment of all set development requirements.

Project management includes three key elements:

- **Planning:** In the beginning, the project plan defines work that needs to be done, project timeframe, budget, required ecological standards and description of the needed resources (people, equipment, and materials).
- **Control:** When the project starts, its progress is controlled depending on the set plan. The project manager has to routinely control the progress, budget, used resources and how much work still needs to be finished according to the given plan.
- **Management:** Just like the designer can plan to optimize designing, so can the project manager create a plan that optimizes project execution. Different resources, especially people and equipment can be moved between different tasks. Some tasks can be realized within an existing task; others can be done in advance. The project manager also has to determine which skills are needed for certain tasks. Management goal is a realized project within the as short timeframe as possible with the lower possible costs. Reduction of costs does not mean reduction of quality or device standards.

It is very important to point out that management of Ecodesigned projects in regards to environmental friendliness of the device often leads to higher costs. Designing costs and final device price reflect in higher device quality, more development efforts, payment of standardization processes and maintenance of ecological labels and production processes. On the other hand, ecological awareness increases steeply, mainly due to media campaigns and unfortunately due to natural disasters that are results of environmental changes. Health protection is also an important aspect because it enables the ecological products and electronic devices to gain recognition and stay interesting for consumers and sell successfully despite a higher price.

It is obvious that no matter how the project is planned, organized and managed, it cannot be successfully realized without suitable personnel and equipment. For the project to be successful if it is necessary to be supported by experienced and professional personnel.

The same applies to the project manager. He has to have the skills and knowledge of the top-notch managers and be an expert in ecological practices in management. The manager has to forecast and determine certification processes, ecological standards depending on the market where the product will be launched. Depending on the current situation the manager has to be up to date with all ecological novelties and policies. It is also reasonable to forecast trends and development of ecological standards, as well as decide whether the product is ready for the future or it needs to be modified in future.

5.3. Project plan

The main project management task is a set of unambiguous instructions. Clear instructions describe how the project will be managed and executed. The project execution instructions are given in a document named project plan. This document is similar to the requirements analysis that presents the requirements for technical characteristics of the device. Similarly, the project plan instructs how the project will be executed. The requirements analysis answers the questions on the technical sophistication of the device. The project plan answers questions about costs of development, final design price and which resources will be needed and used.

Similarly to the design process that was presented in the previous chapter, so does the project plan present an agreement between the project contractor and the project buyer. In larger corporations, the project plan is an agreement between multiple departments inside the company, administrative services, development group and project manager that initiates the project. The signing of this contract is a pact between these services with which the company commits to invest in development to achieve the desired results. When the complete project is undertaken by an external company, the project plan acts as a legal document and as part of the contract where order payment, disagreements, and adverse circumstances are described.

The project plan can be defined and presented in different forms, depending on its complexity and purpose. The project plan that foresees the construction of a complete communication system for a company, organization or city will be designed over a longer period, for example, several years in comparison to the project plan for a less complex device for counting steps (pedometer). Nevertheless, almost every project plan includes the following steps:

- **Determining tasks:** Includes clear description of different tasks that need to be executed. The tasks have to be clearly defined and easy to understand.
- **Schedule:** Dates and timeframes have to be defined for each task.

- **Resources and requirements:** Evaluation of personnel by experience, knowledge, and skills, used materials and needed equipment.
- **Costs evaluation:** The costs are evaluated depending on the used resources and equipment. It is also important to foresee a crisis budget in case some costs cannot be evaluated precisely or in case of unexpected circumstances.

Details on how to determine these project steps will be presented in the next chapters. Before that, let's see how the project plan is adjusted to the actual design tasks. Image 2 shows how the project plan is developed in parallel with determining of requirements specification when designing a device. While development of requirements and analysis of the new device take place, a preliminary project plan is created. Determination of requirements depending on development costs and timeframe are key figures when designing requirements and device functionalities. Both also enable comparison of all alternative solutions.

After the analysis of device functionalities and before in-depth work and solution finding is often formed a formal document that presents a framework of the project plan. This plan can be completely developed, when device requirements are clearly defined and set, and until then a more downgraded plan needs to be in use that in the end matches to the final plan or even significantly deviates from it. During many iterations of requirements definition, we can see a journey on how to achieve the final goal and successfully finish the project more or less clearly through every repetition.

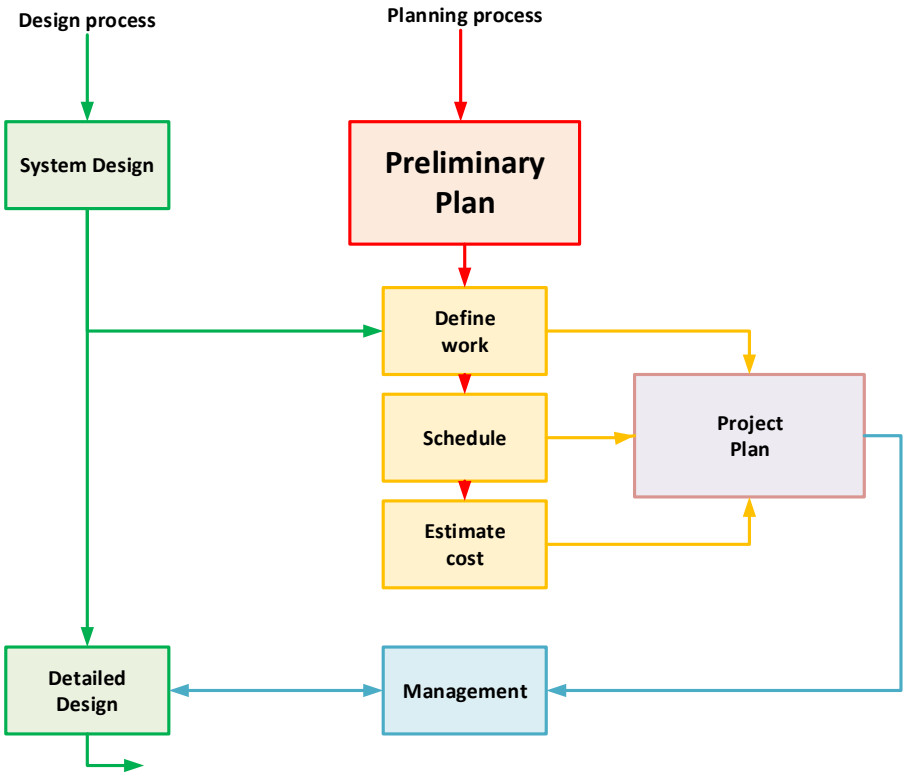

IMAGE 2: PLANNING PROCESS

The sequences in which the components of the project plan are defined are also presented in the image 2. Planning work is an iterative process where we initially define work and tasks, then determine timeframes and then foresee the costs and budget. When determining which tasks need to be done, the tasks need to be revised depending on the requirements. The similar iterative process takes place in determining timeframes of tasks, as well as in determining prices and budget. The project plan can be identified as the simplest and the cheapest way of finishing the set work.

At the end of this process, when the plan is finished, the planning materials give instructions on how to manage and finish the project.

5.4. Tasks determination

The first step to the determination of project plan is determination of tasks and work that needs to be finished during device development. Many information on task determination can be found in the block diagram of the new device. For easier presentation of the project planning concept, we will use a block diagram of a device for managing low flow for laboratory measurements. The block scheme of device is presented in image 3. The device functionalities will not be described in detail but will be used for task determination.

In this point of contact, the block diagram presents the final version of device functionalities where are also defined all requirements. Now is the time to start with organizing work and developing the project plan. Table 1 presents an approach on how to define a project. The table gives basic information on what will be done when it will be finished, who will do the tasks and the costs. For many smaller projects are added additional requirements. Let us analyze the following limitations of table 1.

Task description: In the table are stated different tasks and their description. The disadvantage is that there is no description of the foreseen final results of individual tasks. There is also no description of the expected initial state before the tasks are started.

Terms: The terms in the table present when a task will be finished. The terms are usually time milestones. It is not stated when a certain task starts and how long it takes. In task description, it is important when task realization starts and how long it takes. In task description, it is important to determine how much effort is needed and how much time we need to finish the task. When determining the task timeframe elapsed time has higher importance and also how much time we need to finish. In this definition is a differentiation between the two approaches as will be seen with the following steps.

Resources: Human resources are determined, but other tasks for which there are responsible and their involvement are not defined. Needs for other human resources are not presented.

Precedent: At the end, the interconnection of tasks is not described. For example, designing of communication part and system management can be designed separately. But the testing and measurements cannot be implemented before these two tasks are

not completed. The interconnection of tasks, task order and interdependence of tasks are called “priority tasks or advantage”.

Description of required tasks in device design	
Schedule	
Activities	*Date*
Completion of system design	June 19
Designing primary board	August 18
Designing power supply	August 20
Designing interface	September 10
Validation and testing	September 20
Final design revision	September 25
Production prototype	October 5
Personel	
System designer and manager	J. Moge
PCB designer	J. Moge and D. Steyer
Packaging designer	K. Janovec
Technical support	H. Glover
Budget	
Material	2300€
Equipment	700€
Total	3000€
Project beginning: 9. May	

TABLE 1: DESCRIPTION OF PROJECT TASKS

As previously mentioned, management of less complex projects does not need a precise description of tasks, work and needed time for implementation. Presentation of work as seen in table 1 is enough. We can take a look at more complex designing, for which a more detailed overview of tasks has to be done. An example of a detailed overview of tasks is shown in table 2 and 3. Both give information that is needed in the first step of device development. The main limitations of table 1 are lack of information about precedents, task precisions and that the time for doing a certain activity is too long. Otherwise, it is very difficult to determine work that could describe certain activities, which applies especially to the beginners. Someone can finish a certain task as a complete activity, and someone else can split the same task into several individual activities. When evaluating the tasks we need to choose a balanced approach that splits work into key activities. Naturally, the distribution depends on manager’s experience, group of technicians and engineers, as well as on the project alone. There are no set rules on how to approach the problem, but we can suggest a few guidelines that can be very useful.

A detailed description of the required tasks in designing device	
Task description	**Inputs**
1. ***System designing:*** Overview and revision of the solution. Upgrading of system specifications.	Preliminary system designing
2. ***Designing basic board:*** Similar design, testing on a test board, debugging.	System specifications
3. ***Power supply:*** Similar design, testing on a test board, debugging.	System specifications
4. ***Housing:*** Detailed description of the housing design, designing front plate, testing, and evaluation.	System specifications
5. ***Integration and testing:*** Device composition, testing depending on system specification.	Basic board, power supply, and chosen housing
6. ***Finishing design:*** Overview of the test results, overview of documentation.	Integration and testing results
7. ***Prototype:*** Production of the final prototype and documentation.	Final designing
8. ***Project management:*** Overview of all the work, overview of all expenditures, following the schedule, reporting.	
Project beginning: 9. May	

TABLE 2: DETAILED DESCRIPTION OF PROJECT WORK

- When designing work plan, we can use two different approaches. The first approach is “top-down” where we first determine the basic tasks, and then we split them further and add a detailed task description. The second approach is “bottom-up” where we first determine all smaller tasks which need to be done and then combine them and simplify into meaningful groups.
- Individual blocsk in the block diagram of tasks need to be evaluated as individual tasks. Also, where it is visible that multiple blocks present a separate module (for example PCB for power supply or basic board) individual modules need to be considered as individual tasks.

- A part of the task that an individual performs independently is sensible to evaluate as an individual task. If the task is very long or complex, it needs to be divided into sets of multiple tasks. A rough estimation if the task is complex and long is if an individual cannot track the progress or manage the whole performance process. If this is the case, then the tasks need to be split into several smaller tasks.
- The work that leads to an intermediate milestone can be considered as an individual task, especially if the milestone is somewhere in the middle of the task.
- The beginning of the task depends on the inputs which are determined by the performance of other tasks. The task beginning depends on other inputs.
- In the end, it is important to have a compromise between the complexity of the task classification ad transparency. Too many tasks increase the amount of work in administration and the development team. On the other hand, too loosely defined tasks decrease transparency. This approach can lead to a large deviation from the planned path.

Project personnel, description and hours per task

	Work description	Work (days)	Needed time (weeks)
1.	Approved plan of design.	SE: 4	3
2.	***Basic circuit:*** Scheme, components, circuit description.	DE: 13 TE: 10 DO:10	5
3.	***Power supply:*** Scheme, components, circuit description.	DE:10 TE: 7 DO:4	2
4.	***Housing:*** Housing design, 3D modeling, materials.	PE:6 TE:4 DO:4 SE:1	3
5.	***Integration and testing:*** Complete testing, presentation of test results and preparation of documentation.	DE:3 PS:1 TE:2	1.5
6.	***Design finish:*** Product description, documentation revision.	SE:2 PE:1 DE:1 PS:1 TE:2 DO:3	1.5
7.	***Prototype:*** Working prototype and test results.	PS:7 TE:3 DE:2	2
8.	***Project management:*** Reports.		
		SE:15	13

Project beginning: 9. May

Abbreviations: SE=Senior engineer, DE= design engineer, PE= packaging designer, TE= laboratory technician-engineer, DO= CAD-designer, PS= prototyping department.

TABLE 3: DESCRIPTION OF PROJECT PERSONNEL, REQUIRED TASKS AND PROJECT TIMEFRAMES

5.5. Work planning - schedule

Work planning is the main step towards efficient management and device development. In this chapter, we will present some of the most common planning techniques that have evolved in the last decades. Planning can be managed manually and lately, it is increasingly done with dedicated software.

5.5.1 Network diagram

Work planning can be divided into two parts. The first presents use of network diagram and the second use of line diagram. A network diagram is already established and will be further presented here. Network diagram structure is used by different methods, such as CPM (Critical Path Method), PERT (Program Evaluation and Review Technique). The purpose of network diagram is a graphical presentation of individual tasks. It is also used to determine independence of tasks and their priority. With unequivocal presentation of tasks it is possible to optimize these tasks and increase the efficiency of the design process.

Image 3 and 4 present two types of network diagram for development of previously mentioned laboratory equipment. Image 3 presents AOA (Activity on Arrow) type of network diagram where tasks are displayed as circles which are connected with arrows. Each circles carries information on current, past time. Each connection presents duration of a certain task. The diagram also presents timing of tasks and used time.

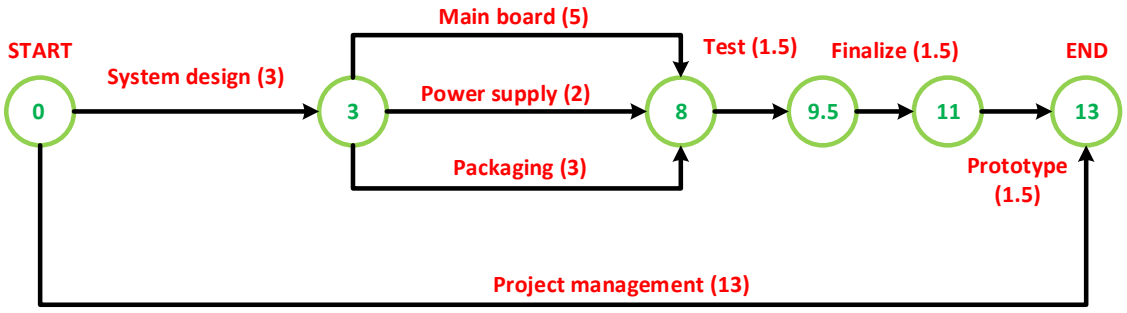

IMAGE 3: AOA NETWORK DIAGRAM

Image 4 presents a widely used network diagram type AON (Activity on Node). The tasks are presented as blocks connected with arrows. Task activity is written in each block. The diagram also presents start and end of the project, as well as the variable time. Variable (loose) time is the free time that is left from the set time in the schedule.

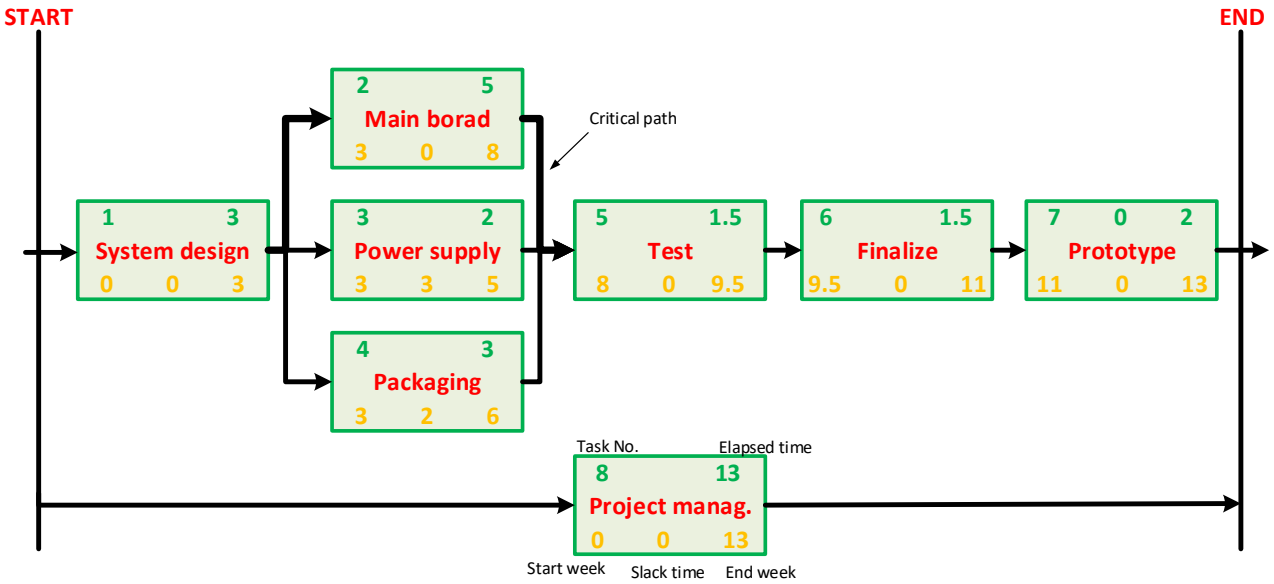

IMAGE 4: AON NETWORK DIAGRAM

No matter which diagram is selected for presentation of project development, it is important that the network diagram presents all tasks, used time and duration of the project. The following attributes present the key elements of the network diagram.

- **Precedence:** Dependency between task beginning and ending is clearly visible in a well-designed network diagram. From our diagram, it is clear that the testing cannot be started until the main board is not finished. The tasks that can be done in parallel or sequentially need to be clearly presented in the network diagram.
- **Critical path:** a sequence of tasks that need to be executed and determined duration of the project are named critical path. This path is in the diagram presented with a thick line. From the diagram, it is clear that design duration for power supply part and housing depend on design of the main board. This part cannot be shortened meaning design of main board determines the critical path. Optimization of the critical path is possible only if we can shorten the main board designing. In project management, this is possible if we assign multiple resources to this task.
- **Variable time–loose time:** Variable time is calculated at the end of network diagram construction. It presents how much time we have left for a certain task without shortening the duration of the complete project. In the diagram, we can see that tasks 3 and 4 have variable time because the processing is finished before task 2. Variable time enables that certain parallel tasks can be started later than others. Ideal network diagram has tasks defined in a way that none of the tasks has variable time which is very difficult to achieve.

5.5.2 Overview of the project plan

As previously mentioned, the development of project plan is an iterative process. After finishing the network diagram and overview of all tasks, it is highly likely that we have the possibility to improve the schedule or remove certain tasks.

Let's take a look at the development tasks for the laboratory measurement instrument and network diagram on the image 4. Depending on the critical path, duration of main board production and the testing process we have two possibilities for improving task order. The first is dividing of the main board production task into an additional task named digital production of printed matter. The new task controls the production, layout, and appearance of the main board. This way the process retains production reliability and control over main board production. The key advantage of optimization is faster main board production.

With dividing main task production and shortening of processing time the critical path is transferred to the task of production/design of housing. After an overview of the diagram in image 4, we can see that device testing (5) is not closely related to housing production (4). Device housing can be finished in the process of finalizing and production of the final prototype. In this case, the housing task can be moved to the finalize task(6). The optimized network diagram is shown in image 5.

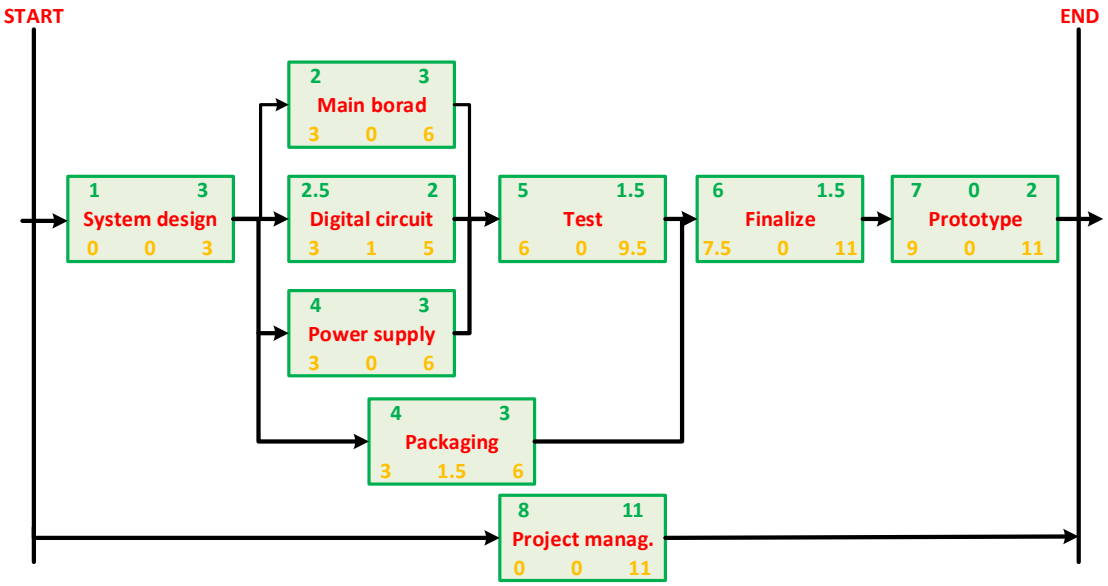

IMAGE 5: OPTIMIZED NETWORK DIAGRAM

Depending on the optimization of the network diagram in image 5 it is clear that the device development process is shorter (from 13 to 11). We need to emphasize that shortening duration causes the emergence of more resources in the production of the main board. The additional resource can be substituted with designers who do the

power supply's work which increases the risk of overload. On the other hand, with the incorporation of new resources, we increase the development costs. The task optimization also causes increased risk at testing and matching of electronics with the housing.

The housing task matches the electronic part in finalizing of design and prototype. When the housing and electronic part are not compatible, a new design has to be performed which significantly prolongs development duration. Optimization efficiency is greatly dependent on the experiences of the person who is developing the project plan.

5.5.3 Column diagram

Timing diagram and Gantt diagram are types of column diagrams. Both methods present individual tasks as columns on the timeline axis.

Image 6 presents column diagram of laboratory device development. Network diagram, as well as column diagram, clearly show the start and end of the project, as well as the duration of each task. The timeline can be divided into days, weeks, months, etc., depending on the project size.

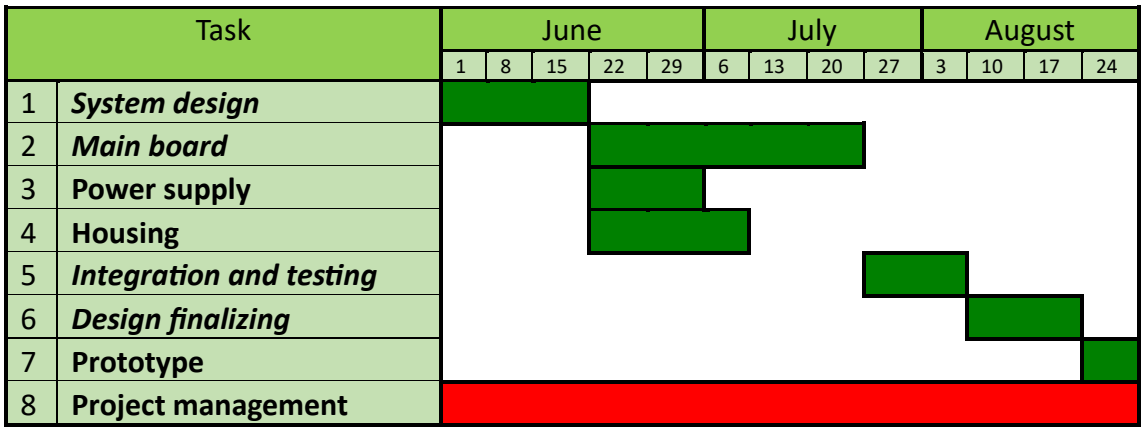

IMAGE 6: COLUMN DIAGRAM

Colum diagram has evolved from the network diagram. In a normal path of column diagram development, it follows the development of optimal network diagram. In less complex project column diagram is usually designed immediately. The advantage of this diagram is that it is easy to understand and transparent. Very often it is used in different project presentations. On the other hand, the advantage of network diagram is precisely in the determination of critical path and a better overview of changes of the project plan. Therefore, the network diagram is used more as a tool for optimization and configuration than the column diagram that is more suitable for presentations of the project plan.

Network and column diagrams are in management of larger projects supported by many computer programs which can be automatically optimized and continuously monitor project development.

5.5.4 Schedule

Determination of schedule is the second part in the establishment of the project plan. First, individual tasks need to be divided. Determination and the extent of the tasks are key for the efficiency of the project plan and determination of the schedule. As previously mentioned, this process is iterative. The iterative process occurs in cycles where we always do a revision after the final plan version and evaluate the strategy efficiency. The main goal of the integration process is improvement of the current plan version. The schedule that marks start and end of the project,as well as chronology and duration of individual tasks is a great indicator of device development process. Also, each project group member can see how their tasks are connected to other members and which dates are set for task finalization. The schedule also determines the priority of tasks and serves as a tool for presentation of workflow to the management of the company or the buyer.

Some common problems of the project plan and schedules, which need to be often revised will be presented in the following points:

- The project plan contains too many tasks, therefore, the schedule is incomprehensible, difficult to follow and too complex.
- The plan contains tasks which cover the understanding of project workflow.
- The project tasks are disproportionate. Some tasks are precisely defined, others are too general. A common mistake is that the hardware tasks are precisely defined, and information on software are only brief.
- The schedule inaccurately defines tasks that are intended for a group or an individual group member. It is also not clear who is responsible for each task.

In designing schedule and project plan, we need to be aware of two things. The first is that the project management has to be intended only for the project and not contrary. We know many stories where project management has gotten out of control. Often also happens that the costs increase enormously over the planned budget. The second thing is that we need to be careful as the project plan has no guarantee that it is correct. For example, if we have inaccurately evaluated the project timeframes, it means that the column diagram is also inaccurate.

5.6. Planning resources and evaluation of costs

In the end, let us focus on two key steps in managing project, which are evaluation of resources and preparation of project budget. Both are closely related. If we propose a new resource, then this also leads to increase in costs.

5.6.1 Cost management practices

Table 1 shows costs of development of laboratory device. But each financial service would quickly decline such cost evaluation. The table 1 does not include the costs of employees, such as developers, engineers, technicians, graphical designers, etc.

A very important data in cost evaluation are costs of personnel. For the implementation of a project, we need differently qualified people of versatile profiles. Such companies employ different types of engineers, designers, programmers, which are of different expertise and with different levels of experience. Often the employees are categorized into main developers, assistants, and technicians. These profiles are mainly differentiated by experience, knowledge, education and by how long they have been working. The salary consists of gross salary and additional bonuses, such as insurance, pension, transportation costs, equipment, etc. In project management, we can see direct and indirect costs. Direct costs are related to all duties in salaries, and the indirect costs are general costs that arise when operating.

Large and middle-sized companies usually have several departments for which they monitor separate personnel costs. Production and development are usually the departments that are marked as cost centers. Other departments that are not cost centers have their costs distributed across different departments and are often labeled as general costs. Often these are management, marketing, financial services, etc. are departments that are cost centers and which create general costs depends on the company structure and the industry they work in.

For evaluation of costs and preparation of project budget, it is important what percentage of costs will be drawn from cost centers and what share will be from general costs. If we continue with the previous example of a project for laboratory equipment, we can see the needed resources:

- Personnel: Companies usually determine the payment depending on the hours or days worked, for each employee profile separately.
- Laboratory and equipment: Larger companies are able to select the location or place where the project will be executed. We can forecast that the department for designing electrical schemes and production will be the main cost centers, therefore, we can include them in the cost evaluation.
- External services: If the project needs external consultants or rented equipment, these costs also need to be included in the project costs.
- Materials and suppliers: Some materials needed can be included as general costs. Such materials are materials that are regularly supplied by the

company (PCB boards, soldering wire, stationary, etc.). other materials that are ordered specifically for a certain project are electronic elements that are evaluated as project costs.

5.6.2 Evaluation of human resources

In most projects, the personnel costs are the largest costs of the whole project. The evaluation of suitable employee profile for the project execution is the basis for a precise evaluation of the complete costs. The availability of personnel with specific skills and their number has a key effect on the determination of a schedule for certain tasks. When the human resources evaluation is set, we need to review the initial steps of project plan development to preserve the evaluation precision.

For evaluation of human resources, we can use multiple methods. A common approach to larger project is to have an overview of all tasks and schedule and to assign a number of people to the tasks, so the project can be finished. Another approach, also often used in larger companies that work on several projects at once is to find the employee that is currently free or has less workload. Then we try to determine how to organize the project plan. In smaller companies we often have a limited number of qualified employee and, therefore, we choose the “halfway” approach. This approach means that during or in the middle of the project we check the tasks that have not been done and depending on the employee workload inform them who will do the tasks.

A very useful tool for determining human resources is an employee histogram. It is defined together with column diagram where the number of participants in a given period is clearly visible and also their operational time. In image 7 is visible a sum of people who in a given moment can cooperate on the project. The employee histogram is a useful tool for a project designer, for evaluation of human resources, task assignments, and schedule determination. In the image, we can also see employee distribution on certain days when the workload is the lowest at the beginning and at the end of the project. To a large extent, the increase of employees in the third weeks is unwanted. This could be the key condition to revise the tasks and determine a new schedule. From the histogram is visible use of human resources where it makes sense to adjust the project plan to allocate the employees proportionately. Experienced project task planners usually stick to the principle to maintain the employee workload at 80-90%. This means that with the selected human resources they can cover the unexpected problems (issues in development, sick leave, etc.).

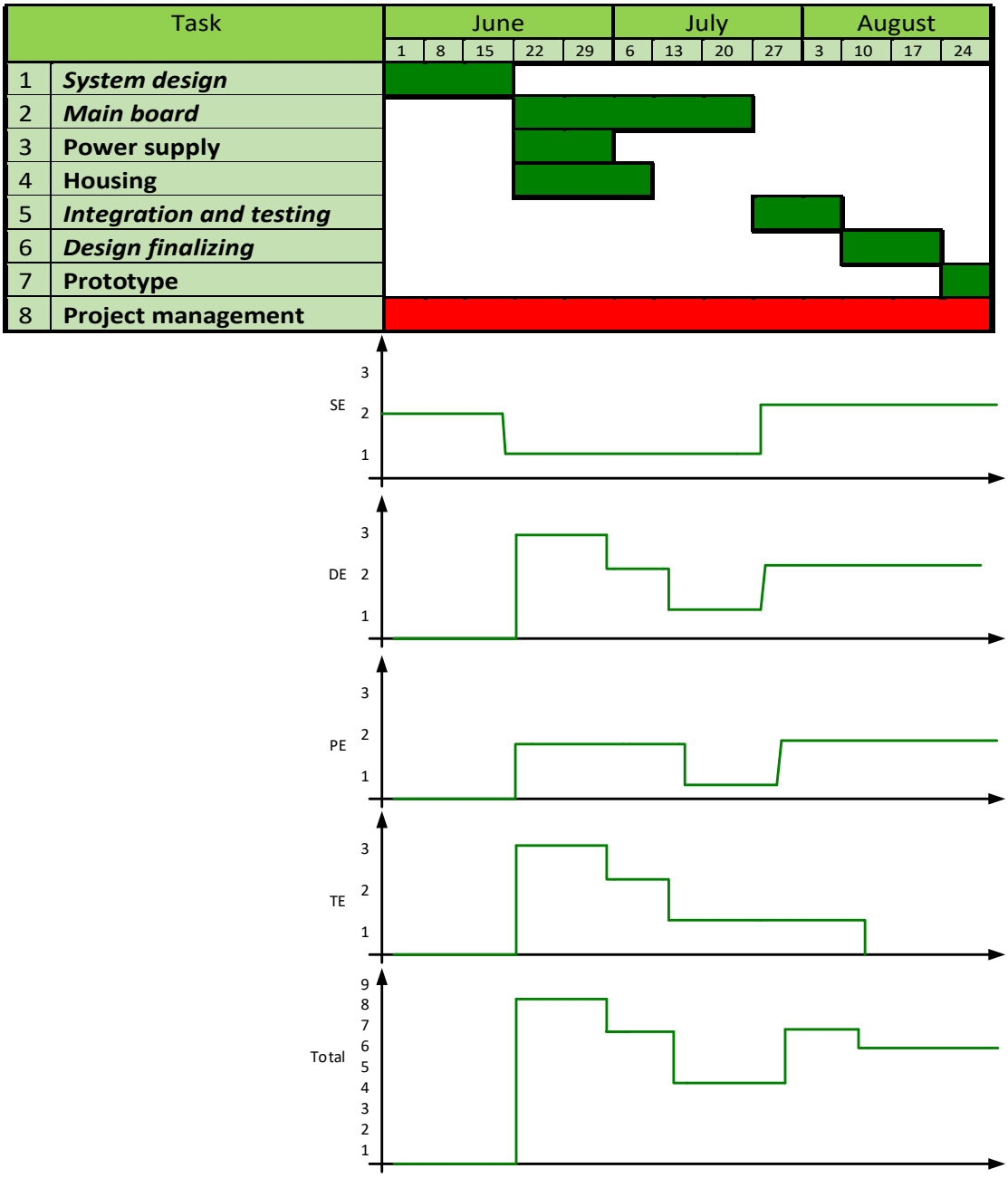

IMAGE 7: EMPLOYEE HISTOGRAM

5.6.3 Budget preparation

After assignment of human resources, it is easy to calculate the project costs. These are based on costs of personnel, which consist of precisely calculated hourly rate, used materials and rented equipment, if needed. With budget preparation, the use of money is easily visible. It is also important that we review the partial use of money in weeks. On the given example, we can see that the highest money use was in week three when the most employees were hired. Also, in this case, we want to lower the work

costs we can optimize the tasks and replace the schedule. Optimization of tasks or even new planning of the project plan is required if the evaluated project costs exceed the level of available costs.

5.7. Project management

When a project plan is set and finished, the next step follows and this is project implementation. When the activity is redirected from task assignment and planning to real implementation, the leader's (main engineer, manager) activity also redirects to control and ongoing project implementation monitoring.

In project management are present three basic functions: monitoring, reporting, and ongoing problem-solving. All three functions are closely related. Project management requires that during project implementation all three functions are considered and continuously studied. Progress and project efficiency are evaluated according to the set plan. The project leader tries to answer these four questions while managing the project:

- Is the project efficiency guaranteed? Does design meet the set criteria)
- Are the resources used efficiently? Do we need more or fewer resources?
- Does project implementation follow the schedule?
- Do the costs correspond to the budget? Will the final price be the same as forecasted?

5.7.1 Monitoring efficiency

Monitoring project efficiency requires evaluation if the project work follows the set requirements that are defined by requirements specification. Every designer is responsible for the task that he is doing according to the schedule. Efficiency management has to be set in a way that some manoeuvre space is available in case of unexpected problems. Despite possible problems, the project efficiency needs to be met. Efficiency monitoring is done through informal communication with group members who are responsible for individual tasks through revision and partial test that come with the tasks.

5.7.2 Task progress

The project leader is also responsible for monitoring of task progress. It can be monitored by group members who are responsible for it and who cooperate on the task. Often the progress can be monitored through weekly or monthly reports.

The primary scale for monitoring task progress is in percentage. The percentage does not mark time or how many resources were used but mark what percentage of a certain task has been finished. Often this is a subjective evaluation that cannot be precise inside 10%.

The most common way to determine progress is to define the current use of resources depending on the implementation time and compare it to the evaluated resources needed for finishing the task. For example, if 10 days are used for finishing the task, and we have 20 days left, this means that the task is finished in 33%. This type does not differentiate between work (effort) that is a measurement of used resources and used time that presents the timeframe of the task. Due to this, this approach should not be considered too rigorously.

As is visible in image 7, most work has been finished between June 22 and July 13 which is not the project median. We can see that if we want to assess task progress, we need to ask: “Is the task currently completed to the extent the project plan forecasts?”. If the answer is no, then the project is behind or in advance. Both anomalies are expressed in percentage evaluation of the task completion.

In percentage task evaluation we cannot avoid percentage evaluation of resources. For example, if task progress is 30% and we have used 50% resources, this means that the completed task has used more resources than we predicted. In this case, the task has to be split into several resources, for example, number of people or extend the task duration.

5.7.3 The state of the schedule

After certain time intervals, when the task status is defined in percentage, we can check the schedule progress. This means we check if the task implementation corresponds to the set schedule. Image 8 presents project status in a given time period.

The dashed vertical line represents time when we evaluate project status. The green color marks how far the task is completed. From the image is visible that in the fourth week task 1 has been completed fully. Tasks 2, 3 and 4 were in the implementation phase. Task 2 was in advance comparing to the schedule and is completed 40% from the predicted 20%. Task 3 has not yet started, meaning it is behind the schedule. It is not on the critical path, so it has enough variable time to be implemented until the end of week 8. Tasks 4 and 8 correspond to the schedule. Task 8 presents project management and is often in accordance with the schedule. Tasks 5, 6 and 7 have not yet started.

For the project leader, task 3 is currently the biggest warning because it is the only task that deviates from the set plan. His task is to find the cause of this anomaly and determine the critical time when the task has to start. In the given example, the critical time for start is week 6. If this will not be met, then the project implementation will prolong.

Task		June					July				August			
		1	8	15	22	29	6	13	20	27	3	10	17	24
1	***System design***													
2	***Main board***													
3	**Power supply**													
4	**Housing**													
5	***Integration and testing***													
6	***Design finish***													
7	**Prototype**													
8	**Project management**													

TABLE 4: PROJECT PROGRESS AFTER THE FOURTH WEEK OF IMPLEMENTATION

5.7.4 Budget state

Checking of budget status is done according to the given time intervals and has to give answers to the three following questions:

- Do the expenses correspond to the set plan?
- Are the expenses used where we predicted?
- Will the final project expenses correspond to the evaluated expenses?

Often in budget status more specific data need to be given, such as how much we have used for personnel, materials, and equipment. Often the financial report is presented in the form of S-curve as seen in image 9. This curve originates from the form that presents costs of a typical project. In the beginning, the costs increase slowly, over time when the project costs are the highest, and towards the end, the costs are decreasing. The S-curve presents the predicted use of resources during the project, current use and forecasted use until the end of the project. From the graph, we can see if the current budget status is within limits or if we have exceeded the planned costs. The forecast determines what will be the final costs evaluation in relation to the previous and current cost status.

For evaluating the budget status, we can use other methods, such as column diagram, tables, etc., which will not be presented in detail.

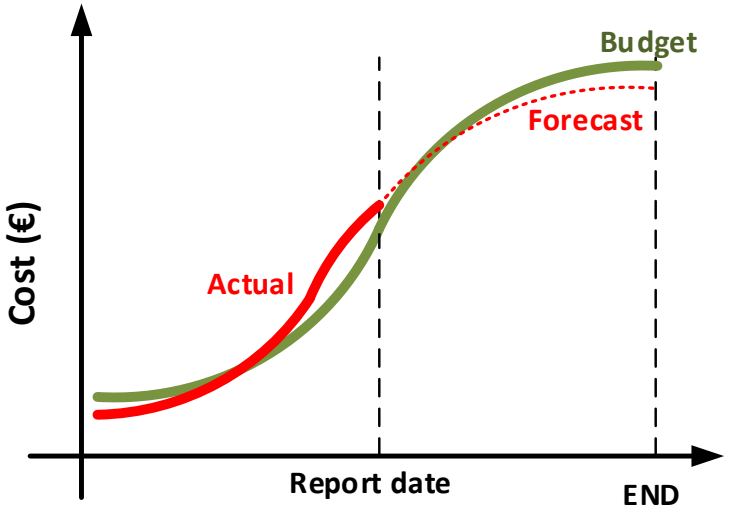

IMAGE 7: S-CURVE OF THE BUDGET STATUS

5.7.5 Reports

After the set time intervals reports of the current project, status needs to be prepared. The time interval can vary depending on the type and project duration common reporting interval for shorter projects is a month for lengthier projects three times per year or once per six months.

The reports serve several functions and are managed by multiple people. It is important for group members who execute the tasks to gain insights into the complete project and influence the implementation. The report is also important for company management or the buyer because it enables overview over current execution and offers a consistent evaluation regarding achieving quality and use of budget. The report is important for accounting, human resources service, and marketing department. In the end, the report is important for the project leader to gain a clearer picture of project management and to determine the most critical activities.

The report has to contain a few key points. The beginning is related to the summary of work and achievements. We also need to describe the possible replacements or changes of plan, new tasks, and personnel. Under the second point, problems that could happen or are currently happening in the project need to be described. It needs o be evaluated how much these problems are influencing the project quality or the quality of products. When the problems are solved, it is sensible to describe how we solved the problems and if the requirements for new resources have risen and if we have solved the existing structure that is defined by the project plan. The report continues with a description of further tasks. In this part, we describe which tasks

will be started until the next reporting period and give an evaluation on how the current state is affecting the further implementation. The report is finished with a short description of work in relation to the schedule and the evaluated current costs. In this part, we can add column diagrams (image 8) and budget evaluation (image 9).

Key points for the project report:

- Description of the finished work.
- Problems that can arise or are already existing.
- Work plan for the future until the new reporting period.
- Schedule, budget evaluation, and budget status.

It is important to note that the final reports are different from other reports. In the final report, all project results need to be described and noted if all criteria were met as written in the technical specification. This means if the device meets all the environmental criteria, presented in the beginning and how this corresponds to the test results. The key is to precisely present the project structure, and its implementation. We also need a precise analysis of financial construction, especially if we exceed the predicted budget during the project. We need to specify the reasons for exceeding the financial limit.