Optimizing the Future: Management Innovation for a Sustainable World

Eds. Gabriela Proştean
Budapest: Trivent, 2026
eISBN 978-615-7058-33-0
Available online at http://trivent-publishing.eu/

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DOI: 10.22618/TP.SIM2025.024

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Keywords
wire; drawing; Six; Sigma; audits; quality

I. Introduction

Drawing is a process of cold plastic deformation of metals and alloys to obtain wires, by forcing the metallic material through a calibrated hole whose cross-section is smaller than the cross-section of the initial material. Following the application of the drawing process, the surface of aluminium and copper wires must be smooth, without oxidation spots, grooves, scratches, cracks, chips, scales, bulges, twists, and excess drawing oil.

In a factory that produces wires by drawing, drawing is divided into two important categories, depending on the wire diameters produced. Heavy drawing is defined as follows, which is obtained by:

- round aluminium wire with diameters 9, 12, 15, 20, 25 mm (heavy aluminium drawing)
- round copper wire with a diameter of 8.0 mm (heavy copper drawing)

For this category of drawing, the raw material is brought from the raw material warehouse, located in the immediate vicinity of the drawing area, using the overhead crane. The wire is placed on the unwinder of each die. From the unwinder, the wire is passed through the range of dies, depending on the desired final diameter. After this operation, the dies are mounted in the die holder. From the final die, the wire is passed to the wire accumulator and then to the double winder. The aluminum wire is drawn starting from the diameters indicated above. The wires obtained from the heavy drawing process constitute a finished product for electrotechnical purposes or by-products used in the construction of other types of insulated or non-insulated electrical conductors. Light drawing is the second category of drawing through which the following is obtained:

- aluminum wire obtained from the heavy drawing process with a maximum diameter of 4.5 mm for T5 (light aluminum drawing);
- copper wire with a diameter of 2.5 mm (light copper drawing);

The raw material is brought from the staging area, after the heavy drawing operation or annealing heat treatment. Six Sigma represents a method of organizing and managing a workspace or workflow and aims to improve efficiency and quality by eliminating waste, improving workflow and eliminating useless processes/activities. Within the wire drawing section, we have thought, realized and implemented elements of Six Sigma as presented below to ensure a predictable, organized and safe workplace. The method is based on the Five Sigma methodology and was empowered by including "safety" as one of the pillars. The Five Sigma process is a structured program to systematically achieve: organization, cleanliness and standardization in the workplace. The content of the Five Sigma is as follows: - seiri (Sorting); - seiton (Stabilizing order); - seiso (Shining); - seiketsu (Standardizing); - shitsuke (Supporting change). To the five pillars, a sixth one was added, which refers to occupational safety. Using the 5 Sigma presented above ensures a safe, clean and profitable workplace. Lean Manufacturing – schematically presents the concept. Lean manufacturing based on Six principles is defined as: 1. Sorting – Organizing; 2. Establishing Arrangement – Order; 3. Shine – Clean; 4. Standardization - Standardized Cleaning; 5. Support – Discipline; Six. Safety - The Only Way to Advance [1-3].

II. Comparative aspects of the application of Six Sigma in the "Metalurgical shop"

The introduction and application of the Six Sigma system is a complex activity, of which several elements will be presented below. Figure 1 presents the application of the SixS method in the metallurgy-heavy wire drawing section.

Fig. 1. Applying Six Sigma in the metallurgy department – cleaning the workplace

Figure 2 presents the application of Six Sigma in the heavy wire drawing section. Figure 2a presents the cleaning and painting of the workplace. Figure 2b presents the establishment of the arrangement of the wire coils and figure 2c presents the standardization. Figure 2d shows workplace cleaning.

a. b. c. d.

Fig. 2. Applying Six Sigma in the heavy wire drawing shop

Within the light wire drawing section, figure 3 presents the cleaning of machines and auxiliary installations as well as their painting.

Fig. 3. Six Sigma - cleaning and painting in workplaces at the light wire drawing shop

Figure 4 also presents the cleaning and painting of the coil supports, the command-and-control cabinets and the auxiliary equipment.

Fig. 4. Six Sigma Application in light wire drawing shop

A. Six Sigma audits

To comply with Six Sigma requirements, periodic audits will be conducted [4,5]. The audit is planned by the area manager, inviting the auditor assigned to the area in charge and support from the continuous improvement department. An action plan for the wire drawing section is presented in figure 5.

GYR Logic: G "Activity complete or on target." Y "Activity incomplete - ongoing". R "Activity not started yet"

Item No.	Actions: Date	Actions: Location	Actions: Description	Actions: Photos Before	Recomandation/Corrective action	Responsible for implementation	DEADLINE	GYR Status	Photos After	OBS.
1	6-iun.-22	Trefilare	Training operatori Trefilare+ Sorting Activity (Train the operators for Rod Drawing Area)		Need to cover all the shifts	Teodor /Marin D.	21-iun.-22	G		The training for 2 shifts was done during the Kick off event.Needed for other 1 shift.
2	6-iun.-22	Trefilare	Organizare zona etichete roll + Completare table de 6S Organigrama (Organize the red tagg Area + completed the 6S Area)		To be paint in red the area + update the 6S board	Teodor O.	25-iun.-22	G		Done
3	6-iun.-22	Trefilare	Sortare zilnica la masini (Daily sorting and cleaning activity at the machines)		Sortare zilnica si predare de la schimb la schimb zonele de lucru (Daily activity requirement)	Donciu M./Team opertors	30-iul.-22	G		Activity is done continuously every day .
6	6-iun.-22	L1/L3	Curatenie ulei zona Trefilor L1/L3 (Cleaning oil at L1 Wiredrawing)		Clean and eliminate the cause	Donciu M.	14-iun.-22	G		The Rod drawing around L1 was clenead of oil
7	7-iun.-22	T1	Bobinor T1 legat cu sarma-Improvizata(Take-up T1 wire improvisation)		Find other solution	Chelaru M.	21-iun.-22	G		Done- need to be painted
9	7-iun.-22	L1	Capace motor deteriorate scurgeri ulei - L1(Motor covers damaged -oil leakeges)			Chelaru M.	14-iun.-22	G		The motors was cleaned and covers removed
11	14-iun.-18	T1	Amenajare zona materiale colaci de aluminiu(Arange the area of aluminium coils)		Area to be defined See if is possible to put L profile rows	Donciu M.	30-iun.-22	G		was done
12	6-iun.-22	T1	Panou de comanda deteriorat(Control panel damaged)		Repair or change the panel	Chelaru M.	30-iun.-22	G		Done
13	7-iun.-22	T2	Motor de actionare mergand in gol si legat cu sarma. (engine tided up with wire - improvisations)			Sanda Viorel	4-iul.-22	G		Done
14	6-iun.-22	T1	Suporti adaptori T1 take up (Adaptors take up need supports)			Donciu M.	4-iul.-22	G		Done
15	6-iun.-22	Trefilare	Schimbare sufe in caz de deteriorare (Change the belts in case of damage)		Change with new ones	Marius Costea	4-iul.-22	G		Done
16	6-iun.-22	L1	Gard protectie L1 deteriorat (Protection fence damaged L1)		Need to be repaird	Chelaru M.	21-iun.-22	G		Done

Fig. 5. Action plan for the wire drawing shop

Non-conformities identified during the Six Sigma audit will automatically be assigned as tasks. Activities that are not completed within a reasonable time will be presented in the weekly management meetings. For the Six Sigma audits, a list of responsible people is drawn up. In the continuation of the activities, the graphic tracking of the results from the Six Sigma audits and the closure of non-conformities will be carried out.

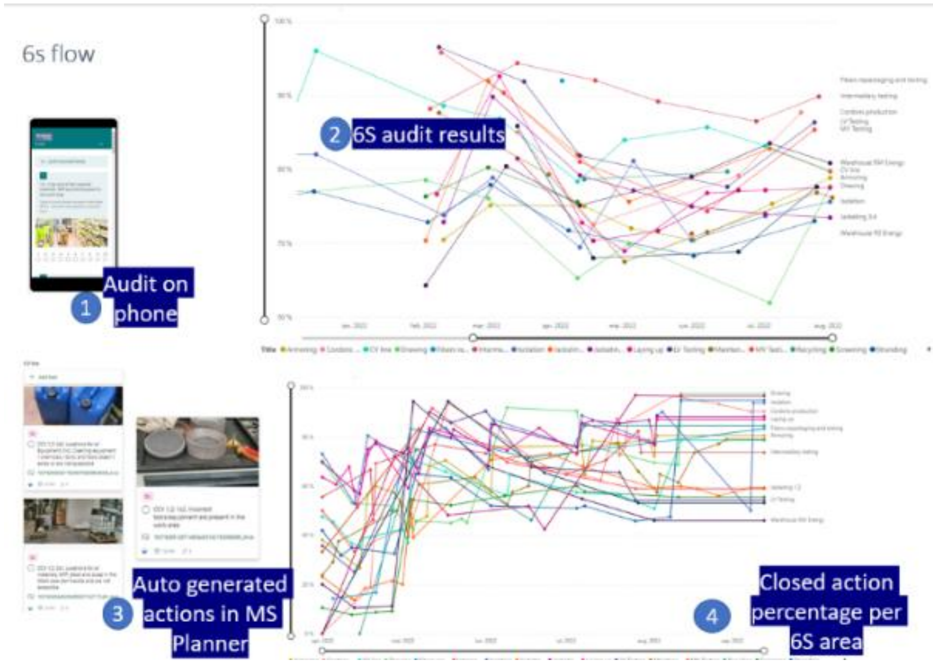

Fig. 6. Graphical tracking of results from Six Sigma audits

Fig. 7 presents the flow of actions to be done within Six Sigma activities.

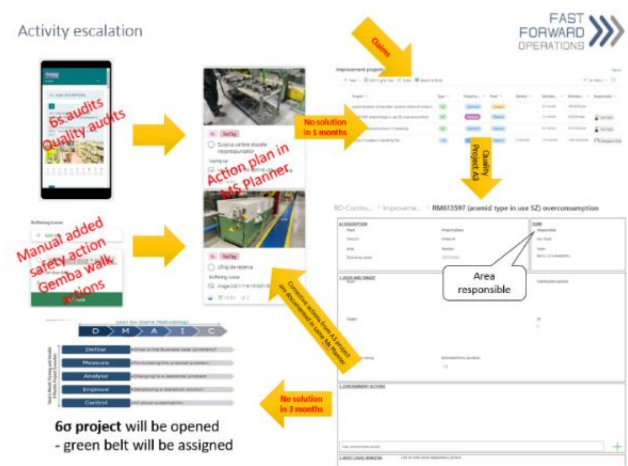

Fig. 7. Flow of actions within Six Sigma activities

As a result of the Six Sigma audit, each area manager within the company must close the non-conformities in the Planner within one month. Figure 8 presents examples of applying the 6S methodology in the Energy factory.

Fig. 8. Six Sigma improvements

Each area manager within the company must close the non-conformities in the Planner within 1 month. Figure 9 shows examples of applying the Six Sigma methodology in the wire-drawing shop as a result of the activity during Six Sigma audits.

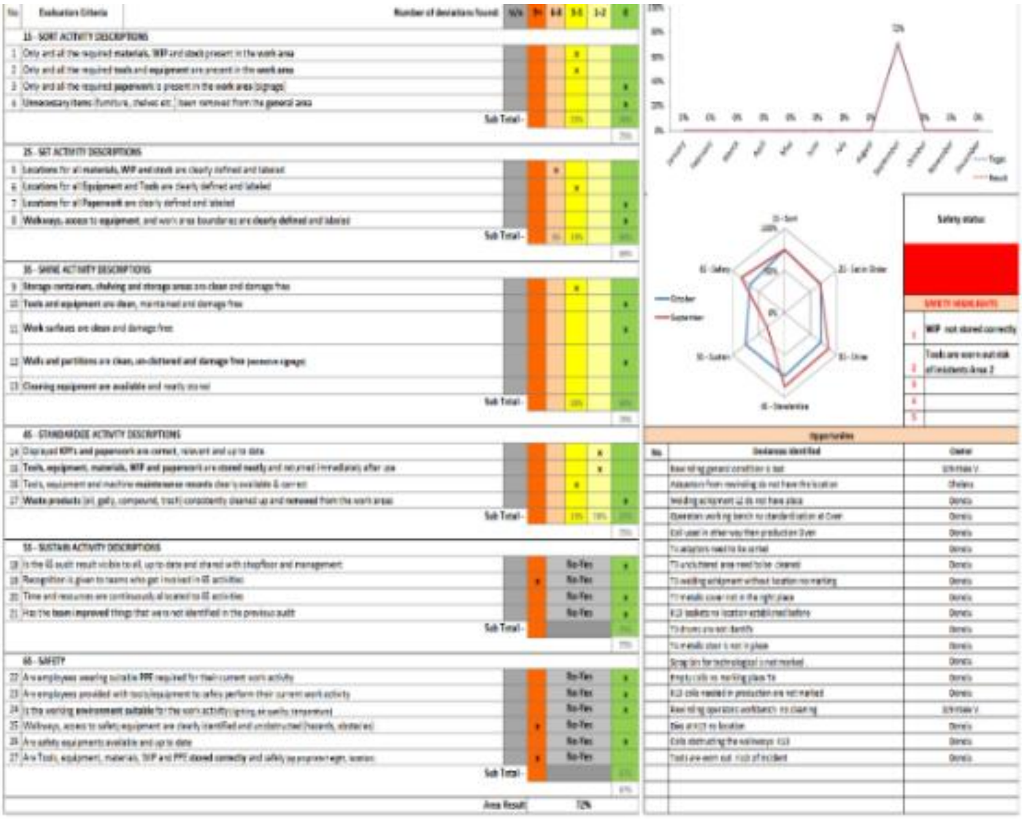

Fig. 9. Six Sigma audit presentation format

A part of the result of the Six Sigma audits in the wire drawing area is presented in figure 10.

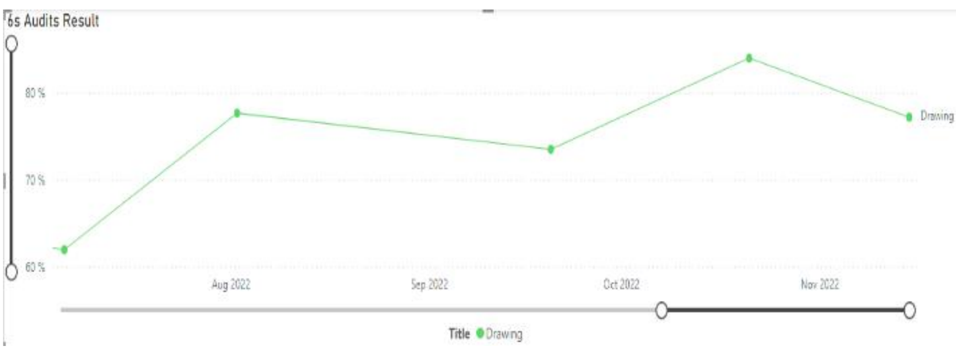

Fig. 10. Six Sigma audit result represented graphically

As can be seen from figure 27, a level of fulfilment is found as follows: July- 62%; August-77%; September-74%; October-84%; November-79%. Tips for a successful implementation of Six Sigma can be:

- establishing a calendar for support activities and respecting it;
- communicating with employees to empower their sense of involvement and listening to what they have to say;
- involving employees in supporting Six Sigma improvements;
- taking advantage of the tools used daily (checklist), analyzing what the opportunities are
- reinforcing the idea that audits are an opportunity for improvement, so as not to highlight weaknesses;
- using the network with other facilities of the Group and HQ;
- encouraging operators to develop daily with the support of the 6S Council;

Communication of the results of the 6S audits is done monthly by e-mail to all company management, as can be seen in figure 11.

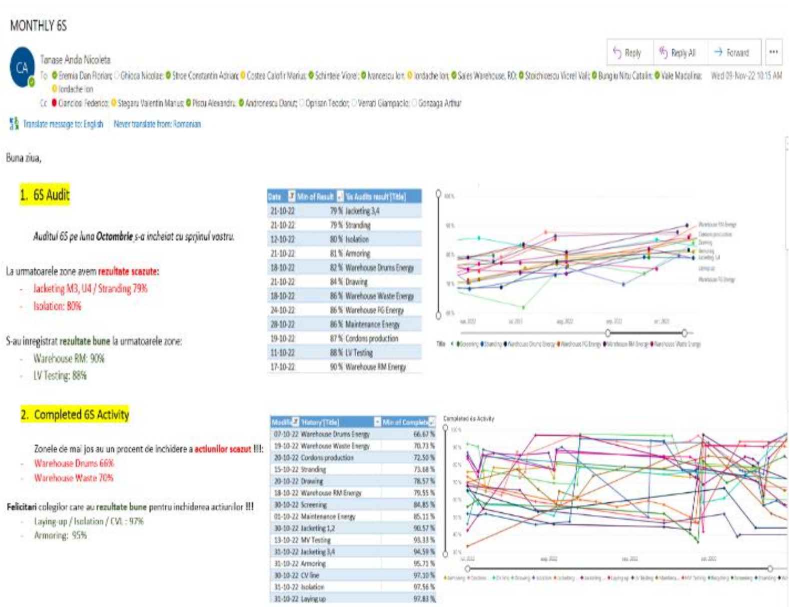

Fig. 11. Communicating Six Sigma audit results

B. Process data analysis during manufacturing

The technological process data monitored in the production of electrical cables is a function of the technological stage. For metallurgy, wire drawing and cabling processes, the most important process data are: electrical resistance, mechanical resistance, elongation and weight. Quality parameters (tensile strength and elongation) are monitored by the Quality Department. The parameters monitored by the Production Department are electrical resistance and weight, as presented in figure 12. Here are presented the data for each column:

- ID - individual numerical code for each entry;

- date when the entry was made;
- material - each product has a unique 8-digit SAP code. For example - power cables start with the number 2. Fiber optic cables start with 6;
- operation - the different manufacturing stages are recorded in SAP by numerical values. For example, 10 is Wire Drawing, 20 is Cabling, etc.
- semi-finished product - the semi-finished product at the respective operation. For example, Al 150 RMC means round multi-wire aluminium conductor with a cross section of 150 mm;
- weight: value measured with an electronic balance;
- nominal electrical resistance and measured electrical resistance;

1171	05.01.2019	20224596	0010	AL 240 SMC	634,09	125	126,31
1172	05.01.2019	20224596	0010	AL 240 SMC		125	127,81
1173	05.01.2019	20021135	0010	AL 70 RMC		443	446,2
1174	05.01.2019	20224744	0010	AL 120 SMC		253	261,41
1175	05.01.2019	20224744	0010	AL 120 SMC	307,07	253	258,55
1178	05.01.2019	20224596	0010	AL 240 SMC		125	127,19
1179	05.01.2019	20021135	0010	AL 70 RMC		443	446,38
1180	05.01.2019	20021135	0010	AL 70 RMC		443	449,13
1181	05.01.2019	20021135	0010	AL 70 RMC		443	449,13
1182	05.01.2019	20224744	0010	AL 120 SMC		253	256,29
1183	05.01.2019	20021135	0010	AL 70 RMC		443	446,4
1184	06.01.2019	20224744	0010	AL 120 SMC		253	258,57
1185	06.01.2019	20224596	0010	AL 240 SMC	613,29	125	126,72
1186	06.01.2019	20224744	0010	AL 120 SMC		253	257,2
1187	06.01.2019	20021135	0010	AL 70 RMC		443	446,49
1188	06.01.2019	20236430	0010	AL 150 RMC	364,69	206	208,79
1189	06.01.2019	20021135	0010	AL 70 RMC		443	449,43
1190	06.01.2019	20224744	0010	AL 120 SMC		253	258
1191	06.01.2019	20021135	0010	AL 70 RMC		443	446,43
1192	07.01.2019	20021135	0010	AL 70 RMC	169,65	443	451,53
1193	07.01.2019	20236430	0010	AL 150 RMC		206	209,35
1194	07.01.2019	20236430	0010	AL 150RMC		206	209,34

Fig. 12. Presentation of process data for the wire drawing operation

C. Overall equipment effectiveness (OEE) analysis wire drawing

Very often, in industry, bottlenecks occur that are crucial to discover. Their identification is carried out based on analyses, provided by reports, such as:
- job performance.
- operator performance.
- production cycle study.
- machine and equipment utilization.
- downtime history.

All these elements allow production managers to make optimal decisions.

Overall Equipment Effectiveness (OEE) is a key performance measure used in production. OEE calculations help evaluate the efficiency of equipment or

processes. They provide information about how well a machine or production line works. OEE is calculated by measuring three crucial factors:
- Availability - represents the percentage of time that equipment is available and ready for production. It weighs downtime due to breakdowns, changes, and planned maintenance. The formula for calculating availability is:
Availability = Actual Production Time / Potential Production Time X 100%
- Performance - performance evaluates the speed at which the equipment is operating compared to its maximum potential speed. It takes into account factors such as machine slowdowns, idling and minor stops. The formula for calculating performance is:
Performance = Equipment Operating Speed / Potential Operating Speed X 100%
- Quality - Quality measures the ratio of good quality output to total output. It takes into account defects, rework and scrap. The formula for calculating quality is:
Quality = Good quality output / Total production quality X 100%
Once the availability, performance and quality calculations are completed, they are multiplied together to obtain the Overall Equipment Effectiveness (OEE). The OEE formula is as follows:
OEE = availability x performance X quality x 100%

Monitoring machine performance allows managers involved in production to analyze, interpret and make decisions according to the data received to maximize their efficiency. Among the indicators monitored by managers is OEE (Overall Equipment Effectiveness), along with its three components: availability, performance, and quality. Sometimes, when there are automated data acquisition processes in real time, obtaining OEE is within reach of anyone who has the right to access such data. Practically in this case, the responsibility for calculating OEE falls to the software program that acquires the data from the machine. This method is preferable because it leaves no room for negligence and interpretations regarding the collected data. The second advantage is that the same rules are applied in data collection and decisions are made under the same conditions, so that comparisons can be made regarding the evolution of the machine. In the case of manual data recording, there are situations when the data is “filtered” which leads to a lower accuracy of the information obtained. In this case, there must be a person responsible for recording the data necessary for the OEE calculation. Generally, this responsibility falls on the team leader who, at the end of the work shift, processes it and sends it to higher levels: foremen, workshop heads, and section heads. From a quality management perspective, drawing a Pareto chart is very important because it provides essential data on product quality. A Pareto chart is a way to visually classify the causes contributing to a given result. This chart is like a bar chart, in which they are arranged in descending order of magnitude. Pareto charts are used for problem analysis, process improvement, root cause analysis, and process redesign. This type of chart helps to:

- identify which causes contribute the most to the result;
- identify what is truly important versus what is not;
- prioritizing problems;
- identifying where action needs to be taken.

In quality, the Pareto chart is used to understand the causes of poor results. Thus, it can be seen quite clearly what contributed to the appearance of a problem. The following characteristics make a Pareto chart an excellent visualization tool:

- it is easy to understand and interpret – a Pareto chart is very simple to read and interpret;
- it is simple to create;
- no sophisticated software is needed to create a Pareto chart; all you need is Excel;
- it helps to separate essential but limited causes from multiple but non-essential causes.

Using the Pareto chart, the key causes that lead to most problems can be separated and thus, attention can be focused on a limited number of causes. Figure 13 presents the "Overall Equipment Effectiveness" report for one of the wire drawing machines compared to a calendar month.

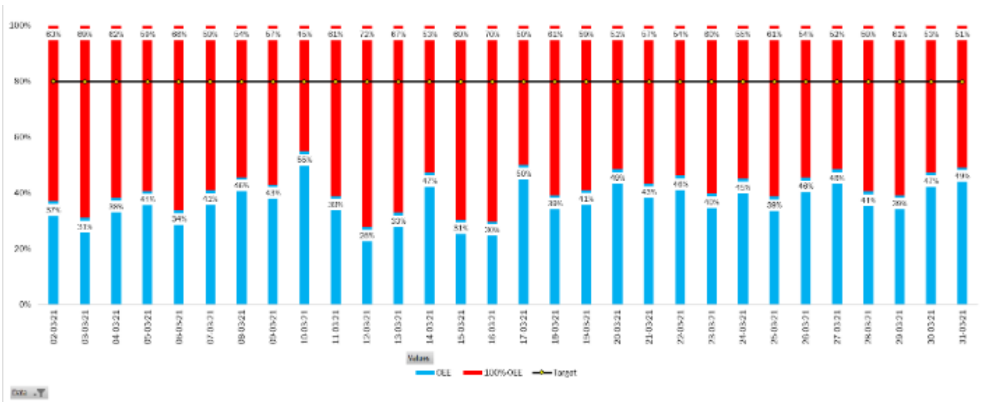

Fig. 13. „Overall equipment effectiveness" report for a calendar month

II. Conclusions

The article presents the Six Sigma method of organizing and managing work activities in an electrical cable manufacturing company within the framework of improving the quality management system. It presents several work stages carried out in this context and the Six Sigma audit, which attempts to highlight the resulting advantages and benefits.

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