The main goal of this paper is to analyse production line LITROBA and propose improvements for this line. The paper is divided into three main sections. First section consists of two smaller parts, which treat about method FMEA and about selected product, which is throttle valve. Second section is about branches of production line LITROBA and is concentrated on the manual workstations and in this section is used FMEA method as the basic part for the third section. Third section deals with the proposal of robot utilization in the selected production line and there are calculated benefits that will arise from this proposal.

KEYWORDS
FMEA, production line, throttle valve, ESD floor, automation, 3D model

1 INTRODUCTION
Nowadays, every production company is trying to achieve the best results and deliver the highest quality products to its customers. Of course, the higher the quality of the product, the greater the number of pieces produced is requested by the customer. To achieve this, the company needs a team of skilled people and well-established processes in production lines. Because everything goes ahead and technology is not the exception. Thus, in some cases, an automatic robot replaces human work. The main objective will be to specify and propose process improvements of the selected production line in the company so that it will be able to compete with other production lines and other plants involved in the production of throttle valves. The analysis will be carried out on a semi-automatic line called LITROBA, which deals with the production of throttle valves.

2 DESCRIPTION OF THE FMEA PROCESS AND INTRODUCTION OF THE PRODUCED PRODUCT
Failure Mode and Effects Analysis (FMEA) is a systemic approach to detecting potential failures or errors that may arise in the design of a product or process [Pantazopoulos 2005]. FMEA is a method, by which it is possible to prevent or minimize the risks that arise during the construction of the management system, the product development and its construction, in the preparation of new technologies, the process development, respectively preparation of production itself [Altunatas 2019]. The "LITROBA" line produces an electronic throttle valves. The throttle valve is a very important part of the engine that serves to regulate the operation of the engine by opening and closing and reducing or increasing the power of the input gases. The throttle valve is located in the engine's intake tract and is usually controlled by pressing the accelerator pedal. It is used by carburettor engines, but also by fuel injection engines. The composition of the throttle valve is shown in Fig. 1.

Figure 1: The composition of the throttle valve

3 INTRODUCTION OF THE PRODUCTION LINE LITROBA
The production line LITROBA is located in a production automotive company. This line is semi-automatic and its main product are throttle valves [Banduka 2016]. On this production line, there are three operators and they load components into the production line. The entire production line is built on the ESD floor, due to the possible generation of antistatic energy in the product. The operator entering the production line must pass the ESD tourniquet and wear ESD shoes. In Fig. 2 shows a 3D model of a production line.

The whole production process consists of getting machined pieces to the production line. It all starts from the machining itself, where the castings are inserted into the machine tools and parts are machined and then into these parts are subsequently inserted the components. After the machine tool, the work pieces go to the washing machine, where they are washed in hot emulsion, so that they are free of dirt and aluminium clasps that arise during machining and can thus affect the throttle valve function. In addition, another major part of the throttle valve is the TPS covers, which are produced in the ESD zone and are supplied as components to the production line [Cibulka 2018]. TPS abbreviation means "Throttle Position Sensor" which in translation is a sensor that controls the entire throttle valve. This sensor is programmed on each flap separately to control the timing of opening and closing the throttle valve. The non-contact type of TPS works on the principle of the Hell effect or inductive sensors, in general the magnet or inductive loop is a dynamic part, which is mounted on the throttle valve of shaft transmission and the circuit board to processing sensors and signals and is mounted in the ETC transmission housing. ETC is stationary [Piechowski
The 2D model of the production line shows three operators in four working positions. The production line is divided into 3 branches, from which empty pallets are returned to the operator station.

Figure 2: 3D model of production line

The first branch of the production line ends at station 80, the second branch ends at station 130, and the third branch ends with packaging of the finished product (Fig. 3).

Figure 3: Model of production line with three operators

3.1 DESCRIPTION OF THE FIRST BRANCH OF THE PRODUCTION LINE IN TERMS OF MANUAL WORK

Manual Operator Station 1 (component loading, station 10) includes a linear conveyor, safety light barriers, all necessary components, an LCD monitor, a stop button Bosh Rexroth and a Datametrix code reader [Chin 2009], [Cibulka 2018]. Within the operator station 1, a plastic case is also loaded into the work piece, as shown in Fig. 4.

Operator station 2 (or station 80) has a second operator, which inserts the manual components into the station, and at the same time ends the first branch of the line and after loading all components passes to branch no. 2.

Figure 4: Loading the plastic case into the work piece
3.2 DESCRIPTION OF THE SECOND BRANCH OF THE PRODUCTION LINE IN TERMS OF MANUAL WORK

Within second branch of the production line, the operator takes the loaded components and puts the piece into the operator station no. 3 (Fig. 5). This station is manual and is connected next to the second operator station. Station 90 (throttle valve loading) contains same parts as previous station (station 80) and potentiometer [Shaker 2018].

Figure 5: The throttle valve-loading model and displaying its insertion

3.3 DESCRIPTION OF THE THIRD BRANCH OF THE PRODUCTION LINE IN TERMS OF MANUAL WORK

At operator station no. 4, 6 pieces of metal clips are loaded on the work piece to hold the attached TPS cover on the work piece [CKrasaephol 2018]. A linear conveyor is used to feed seals and clips to station 140. The operator station (manually loading of the seal and clips) includes a linear conveyor, a seal presence camera, a clips presence camera, and a stop button Bosch Rexroth. Fig. 6 shows a 3D model of loading metal clips and a system of its pushing [Gawdzinska 2017].

Figure 6: 3D model of metal clips loading and their pressing system

Due to the nature of the paper, we don’t describe the other stations of the production line, because they carry out operations where no human element is required and we focus on human element [Dudek 2017], [Cibulka 2018].

| Process description / Functions | Potential possible error | Potential consequence of error | Severity | Potential reason / cause of error | Prevention (preventive measures) | Occurrence | Detection (problem detected) | Detection | RPN |
|--------------------------------|--------------------------|-------------------------------|----------|----------------------------------|---------------------------------|------------|-------------------------------|-----------|-----|
| Inserting the double spring into the workpiece | Component error | Delay in production | 8 | Operator failure | Training of operators | 3 | 100% control by camera | 2 | 48 |
| | Component has been reversed | Delay in production | 8 | Operator failure | Training of operators | 3 | 100% control by camera | 2 | 48 |
| | Placing upside - down | Product’s functionality affected | 8 | Operator failure | Poka yoke (only one way to insert component) | 1 | 100% control by camera | 2 | 16 |
| | Placing of 2 components | Product’s functionality affected | 8 | Operator failure | Training of operators | 4 | 100% control by camera | 2 | 64 |
| Inserting the shaft into the workpiece | Component error | Delay in production | 8 | Operator failure | Training of operators | 3 | 100% control by camera | 2 | 48 |
| | Component not placed correctly | Delay in production | 8 | Operator failure | Training of operators | 3 | 100% control by camera | 2 | 48 |
| | Placing upside - down | Product’s functionality affected | 8 | Operator failure | Training of operators | 3 | 100% control by camera | 2 | 48 |
| | Placing of 2 components | Product’s functionality affected | 8 | Operator failure | Training of operators | 4 | 100% control by camera | 2 | 64 |
| Loading of double wheel | Component error | Delay in production | 8 | Operator failure | Training of operators | 3 | 100% control by operator | 2 | 48 |
| | Component not placed correctly | Delay in production | 8 | Operator failure | Training of operators | 3 | 100% control by operator | 2 | 48 |
| | Placing upside - down | Product’s functionality affected | 8 | Operator failure | Training of operators | 3 | 100% control by operator | 2 | 48 |
| | Inserting 2 components simultaneously | Product functionality not affected | 8 | Operator failure | Training of operators | 4 | 100% control by operator | 2 | 64 |

Table 1: Analysis of possible occurrence and impact of errors – FMEA
Tab. 1 shows the FMEA document, which is implemented directly on the production line, because it will help us to identify the causes of errors and their possible impact on the production line LITROBA.

4 PROPOSAL FOR PROCESSES IMPROVEMENT ON THE LITROBA PRODUCTION LINE

As the FMEA analysis indicated several problems related to manual work, we propose to introduce full automation of the LITROBA production line [Geramian 2018]. Instead of manual insertion of the shaft into the work piece, we propose to implement the IRB 6700 robot (Fig. 7) from ABB in the production station 80 and the gripper from SCHUNK. SHUNK will supply this robot with a gripper that is managed by a control panel and a program designed for the robot. Grippers with four fingers have an advantage over conventional centric grippers, for example, when rolled work pieces are stored in tablets. The gripper processes the work pieces by controlled and reliable process (despite disturbing contours) [Yazdi 2019].

Gripper will be programmed to insert the shaft into the work piece accurately [Feng 2018]. This reduces the cycle time of the production line by almost 10 seconds and avoids the errors most commonly occurred on a production line. There, the operator has to insert the shaft with rotational movement and sometimes this is a problem as the shaft is inserted through the double metal spring and the operator still doesn’t insert the shaft properly. With the operator, the shaft insertion cycle time was 35 seconds, and when the robot will be load, a shaft insertion time will be 27 seconds, which is 8 seconds faster than in the current state. Using the automatic robot for shaft insertion not only speeds up cycle time, but it also increases production line production and eliminates errors after incorrect shaft insertion.

Figure 7: Automatic robot IRB 6700 and gripper

Fig. 8 shows the cycle times before and after the introduction of the robot. Production line cycle time is set to 27 second tact. The station 80 has a high cycle time due to the operator. After the robot introduction, the cycle times will reduce by 10%, which makes smoother production [Hidayat 2018], [Lo 2018].

It is assumed with 2-shift work and this makes a net working time of 22.5 hours per day. The nominal time fund is calculated according to a coefficient (working days per year x hours per day). In Tab. 3 are evaluated costs and revenues, which have to be taken into account, if the company want to buy a new automatic robot IRB 6700. The price of this robot is 85 000 EUR. The installation costs of the robot and the introduction of a robotic gripper, which will cost 2500 EUR, will also have to be taken into account. The total cost of introducing the robot has risen to almost 90 000 EUR.

Figure 8: Cycle times of station 80 at present and after the introduction of the robot
In the third part of the paper, we analyzed in detail, the production processes on the LITROBA production line using manual work, while we investigated and monitored possible improvements at selected stations. By analyzing the production line, we found that it is possible to optimize and improve processes at station 80, where is located the operator. In the third part of the paper, we proposed a change for station 80 by adding a robot and we calculated the economic benefits of this proposal. Next, we evaluated the benefits of implementation of the robot by installing it in station 80. At the beginning, we monitored and measured the operator’s output (how it can feed the shaft into the machine), but after analysis we proved that automation of this workplace is necessary.

### Acknowledgements
This work has been supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic (KEGA 032EU-4/2020)

### Table 2: Time fund of machine utilization

| Workstation                        | Nominal time fund (hours per day) | Usable time fund (hours per day) | Total time loss coefficient |
|------------------------------------|-----------------------------------|----------------------------------|-----------------------------|
| Repairs and maintenance of machine| 15 minutes                        | 35 minutes                       | 0,74                        |
| TOTAL                              | 50 minutes                        | 5139,225                         | 1,08                        |

### Table 3: Financial evaluation of the robot’s contribution

| 5 CONCLUSIONS |
|---------------|
| In the first part of the paper, we described the basis of the FMEA method and the produced product – throttle valve. In the second part of the paper, we analyzed in detail, the production processes on the LITROBA production line using manual work, while we investigated and monitored possible improvements at selected stations. By analyzing the production line, we found that it is possible to optimize and improve processes at station 80, where is located the operator. In the third part of the paper, we proposed a change for station 80 by adding a robot and we calculated the economic benefits of this proposal. Next, we evaluated the benefits of implementation of the robot by installing it in station 80. At the beginning, we monitored and measured the operator’s output (how it can feed the shaft into the work piece), but after analysis we proved that automation of this workplace is necessary. |

### Acknowledgements
This work has been supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic (KEGA 032EU-4/2020)
REFERENCES

[Altunatas 2019] Altuntaş, S. and Kansu, S. An innovative and integrated approach based on SERVQUAL, QFD and FMEA for service quality improvement. A case study.

[Banduka 2016] Banduka, N., Veža, I., and Bilić, B. An integrated lean approach to Process Failure Mode and Effect Analysis (PFMEA): A case study from automotive industry. Advances in Production Engineering & Management, 11(4).

[Cibulka 2018] Cibulka, J. Intensification of FMEA-based processes. Diploma work. TU SJF Kosice.

[Chin 2009] Chin, K. S., Wang, Y. M., Poon, G. K. K., and Yang, J. B. Failure mode and effects analysis using a group-based evidential reasoning approach. Computers & Operations Research, 36(6), 1768-1779.

[CKrasaephol 2018] Krasaephol, S., and Chutima, P. February. Quality control process improvement of flexible printed circuit board by FMEA. In IOP Conference Series: Materials Science and Engineering (Vol. 311, No. 1, p. 012009). IOP Publishing.

[Dudek 2017] Dudek-Burlikowska, M. Monitoring of the production process in a metallurgical company using FMEA method. Archives of Metallurgy and Materials, 62(4), 2089-2094.

[Feng 2018] Feng, X., Qian, Y., Li, Z., Wang, L., and Wu, M. Functional Model-Driven FMEA Method and Its System Implementation. In 2018 12th International Conference on Reliability, Maintainability, and Safety (ICRMS) (pp. 345-350). IEEE.

[Gawdzinska 2017] Gawdzinska, K., Chybowski, L., Przetakiewicz, W., and Laskowski, R. Application of FMEA in the Quality Estimation of Metal Matrix Composite Castings Produced by Squeeze Infiltration. Archives of Metallurgy and Materials, 62(4), 2171-2182.

[Geramian 2018] Geramian, A., Shahin, A., Minaei, B. And Antony, J. Enhanced FMEA: An integrative approach of fuzzy logic-based FMEA and collective process capability analysis. Journal of the Operational Research Society, 1-13.

[Hidayat 2018] Hidayat, A. A., and Kholil, M. The Implementation of FTA (Fault Tree Analysis) and FMEA (Failure Mode And Effect Analysis) Methods to Improve the Quality of Jumbo Roll Products. In IOP Conference Series: Materials Science and Engineering (Vol. 453, No. 1, p. 012019). IOP Publishing.

[Lo 2018] Lo, H. W., and Liou, J. J. A novel multiple-criteria decision-making-based FMEA model for risk assessment. Applied Soft Computing, 73, 684-696.

[Piechowski 2018] Piechowski, M., Szafer, P., Wyczolkowski, R., and Gladysia, V. (2018, August). Concept of the FMEA method-based model supporting proactive and preventive maintenance activities. In IOP Conference Series: Materials Science and Engineering (Vol. 400, No. 6, p. 062023). IOP Publishing.

[Pantazopoulos 2005] Pantazopoulos, G., and Tsinopoulos, G.. Process failure modes and effects analysis (PFMEA): A structured approach for quality improvement in the metal forming industry. Journal of Failure Analysis and Prevention, 5(2), 5-10.

[Shaker 2018] Shaker, F., Shahin, A.. and Jahanyan, S. Developing a two-phase QFD for improving FMEA: an integrative approach. International Journal of Quality & Reliability Management.

[Yazdi 2019] Yazdi, M. (2019). Improving failure mode and effect analysis (FMEA) with consideration of uncertainty handling as an interactive approach. International Journal on Interactive Design and Manufacturing (IJIDeM), 13(2), 441-458.

CONTACTS

Ing. Peter Malega, PhD.
Technical University of Kosice, Fakulty of Mechanical Engineering
Institute of management, industrial and digital engineering
Letna 9, 040 01 Kosice, Slovak republic
tel.: 00421 55 602 3236, peter.malega@tuke.sk
www.tuke.sk

Assoc. prof. Naqib Daneshjo, PhD.
University of Economics in Bratislava, Faculty of Business Economics with seat in Kosice
Department of Commercial Business
Tajovskeho 13, 041 30 Kosice, Slovak republic
tel.: 00421 55 722 3248, daneshjo47@gmail.com
www.euke.sk