Adaptive intelligence system for a predictive process for the Industry 4.0 in Tobacco factory

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Abstract. Speaking of the biggest innovations for the manufacturing industry of the day, we are talking about intelligent production systems with "self-aware", "self-contemplative and" self-sustaining "capabilities. Building such an intelligent system that is adapted and predictable provides the aforementioned capabilities in production, processes and machines. The intelligent system is able to combine various technologies and techniques for mixing statistical data, data, and artificial intelligence methods. Cigarette production is selected because it is highly serial. In such production, the use of expert systems in quality management in this area is not sufficiently developed, and with direct management, it generates great savings. Mistakes and errors are inversely proportional to productivity. This paper deals with the application of an intelligent system that uses the key principle of lean production. We need to build an adaptive system for predictive error and reduce the machine's failure time in the cigarette industry.

1. Introduction

Industry development ranges from manual production to Industry 4.0. In Figure 1, development is presented. The first industrial revolution began with mechanization and mechanical energy production in the early 1800s. It then moved from manual labor to the industrial in the textile industry. The other industrial is electrification and allows industrial mass production. The third industrial revolution begins with digitization and automation. Such production systems still do not have the right amount of production. [1]

Industry 4.0 is an initiative launched by the German government. The goal of the initiative is to transform industrial production, introduce digitalization and new technologies. Industry 4.0 is flexible and allows the production of standard products serial. [2] We need such processing:

1. Highly distributed input of industrial data;

2. An industrial large data warehouse;

3. Management of large-scale industrial data;

4. Analytics of industrial data;

5. Management of industrial data

The process of manufacture of cigarettes is selected for several reasons. First of all, because the use of expert systems in quality management in this area is not developed enough and that is through direct management realize big savings.
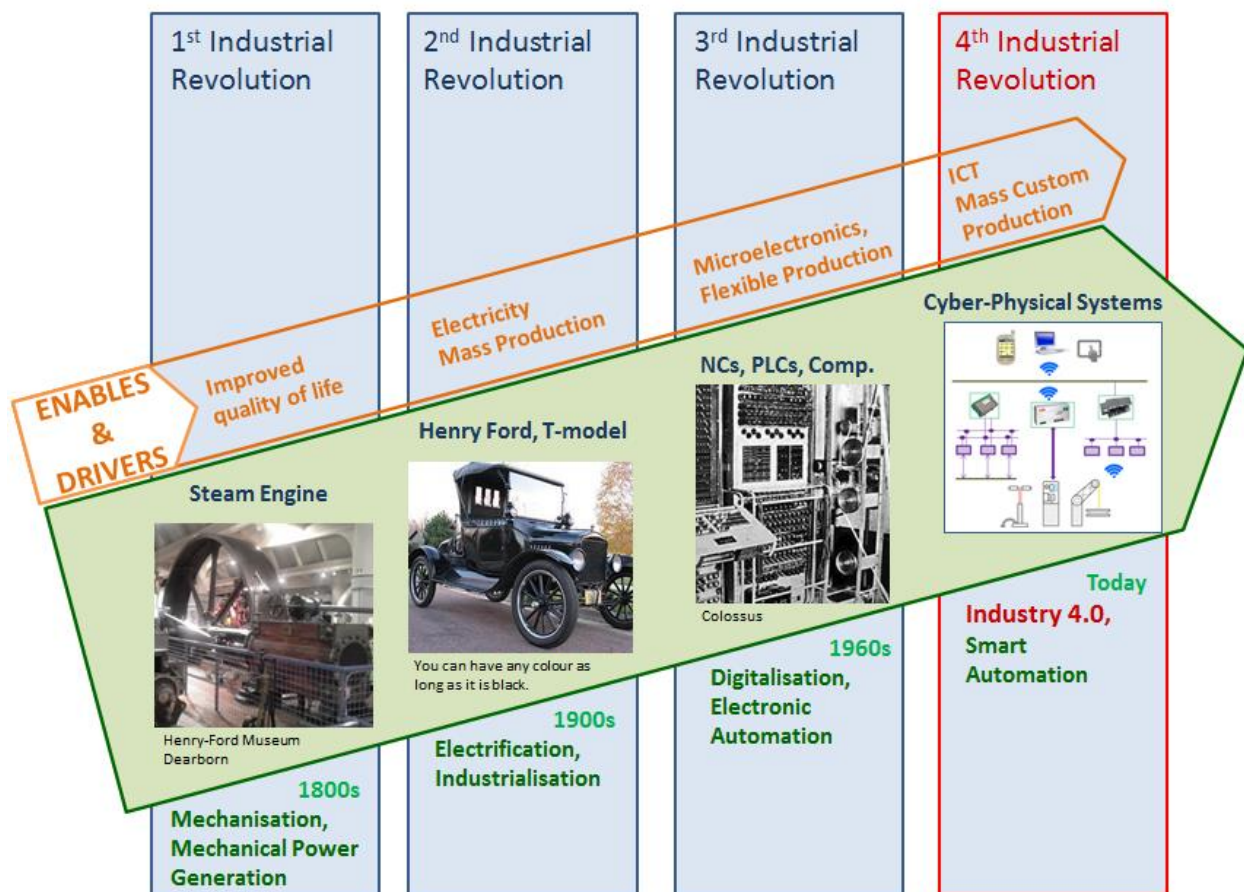

Figure 1. Through the industrial revolutions

All manufacturing organizations are striving to eliminate different types of wastes. Waste minimization is mandatory to stay competitive in any market. Breakdown time that causes delay directly relates to the production capacity of a machine. Artificial Intelligence helps them to generate a system of the expert opinion dealing with machine malfunction and its root causes.

Figure 2. The stages of cigarette manufacture of raw material to the finished product

1. The first phase of the load materials, tobacco, the process of manufacture. Such material is fed into the machine for the production of cigarettes.
2. The second phase of the primary manufacturing process a time which makes the cigarette tobacco.
3. The third stage is fed cigarette paper and tobacco it enters and continues as endless cigarettes.
4. The fourth phase is to cut endless cigarettes and it needs a filter. the glue that sticks natural starch adhesive and at the output we get a cigarette.

Input materials for the production of tobacco, paper, adhesive, filter. These input materials are purchased by different manufacturers, have different levels of quality, and are subject to weather conditions, especially moisture. Since so different raw materials should have a cigarette, which is subject to the established standard. [3]
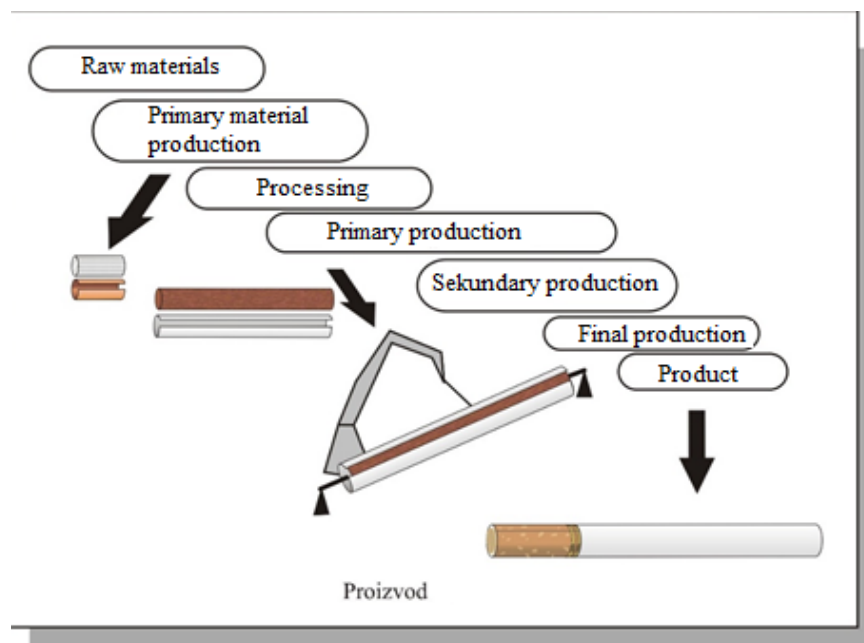
Figure 2. The stages of cigarette manufacture of raw material to the finished product

The targeted experiment was carried out in the tobacco factory Banja Luka. The base has been accompanied by quality cigarettes and his rewriting during the production of the target value.

In a specific example of the tobacco factory Banja Luka, the processing is done on the machine Molins Mark ninth machine Molins Mark 9 provides a reliable, high-quality manufacturing cigarette at high speeds. Programmable logic controllers (PLC) control all the processes on the machine. Speed is 5000 cigarettes per minute for 70 mm length of the cigarette, the length of time the tobacco of 350 meters per minute. The production is the very fast and turbulent process and requires adequate input materials, the appropriate paper, appropriate glue, filter sticks and more. The machine for the production of cigarettes is high certified and allows monitoring the quality of cigarettes through the menu quality. [4]

2. Menu quality

Menu quality offers us a series of commands directed to the ultimate quality of cigarettes produced. That is:

– automatic sampling
– standardization
– adjustment
– Parameterization cigarettes
– Setting classification parameters

2.1. Automatic sampling

To test cigarettes is necessary to take a sample cigarette. A sample is taken from the machine 5 Molins Mak the first step is the automatic sampling. This procedure was developed following scenario:

1. Choosing a target sample (number of cigarettes)
2. Cigarettes will not be disposed of immediately but after 8 seconds. In that time, we have to insert a plastic box for sampling.
3. The targeted sample will be thrown on the usual port for discarding the bad cigarettes.

4. Once the ejected target sample (normally about 106 cigarettes) ceases ejection of cigarettes on the basis of the sample and continues to eject bad cigarettes on the basis of weight and of low quality.

The second step of the dynamic calibration of the machine, comprising:

1. Check that Spec. Weight = Tobacco Cigarette + paper + Adhesive
2. Perform standardization.
3. Take a sample from the output of cigarette machines (100 cigarettes per sample)
4. Reject filters.
5. Measure the distance.
6. subtract 0.5 grams (5 IU per mg of the road paths 100) for possible deviation.
7. type in reading.
8. Repeat the procedure at least 2 times.
9. Meet the mean
10. Enter the translated value in the computer.

The third step is the input of machine parameters that the cigarette produced as follows:

FILE NAME	LONG.brn
NUMBER OF BRENDA	1234
NAME BRAND	LONG
SPEC. WEIGHT	898.0 mg
LENGTH OF TIME	63
START the door strike to reject CIGARETTE	2
Pulse width OPENING DOORS FOR REJECTING CIGARETTE	0
OFFSET A	236
OFFSET B	238
SCOPE histogram	125

2.2. The coefficient production facilities cigarettes

When the cigarette producer wants to launch another cigarette, he usually deals with the parameters that influence the placement of cigarettes in the market. In the paper are analyzed all the parameters and grouped them into three groups:

- Environmental factors
- Managerial factors
- Financial factors

2.2.1. Environmental factors are:

- The life cycle of the product, a rating 1-introduced, 0-increasing, 2-long products
- Conditions for production of cigarettes, a ratings-1 intermediate, 3-perfect, 2-monopoly
- Rating laboratory measurements and data acquisition, and rating: 4-excellent, 3 = good, 2 medium, 1-bad
- Do you perform measurements in the last 12 months and the rating: 3-order, one-I do not know, 0-no?
- Were there any technological advancement in the industry, and the score 3-big, 2-important, 1-slightly
- Were there any changes that affect the target cigarette, rating: 3-very adversely, 2-negative, 1-slight, 0-convenient.
- Do you expect that the cigarettes produce more and score 4-to 1-I do not know 0-no?
- Do you expect that the economy will grow following the introduction of the cigarettes and score: 4-order, one-I do not know, 0-no?

2.2.2. *Production factors are:*

- What is the culture of data acquisition, and 3 ratings-good, two-compatible with the environment, 1-I do not know, 0-poor?
- Is analyzed the production of the last 12 months and the rating: 4-to 1-I do not know, 0-no
- Is it in the past realized the target of cigarettes and if so, what are your impressions and rating: 3-unfavorable, 2 good, 1 is not checked, 0-poor?
- How do you assess the internal control of production cigarette companies, rating: 3 very good, 2 medium, 1-poor, 0-no?
- How to control the satisfactory production process, a ratings-3 is very good, 2 good, 1 or less is applicable, not-applicable 0
- How do you assess the conditions under which the products cigarettes and 4 ratings-growing, 1-invariant, 0-declining?
- Are there any negative publicity about the new cigarettes, rating: 3-order, one-I do not know, 0-no
- What is budgeting for a cigarette, and 3 ratings-centric, 2 good, 1-I do not know, 0-no
- What is the strategy of the company related to this for a cigarette, and 3 ratings-medium, 2 good, 1-I do not know, 0-no?
- What is the price of cigarettes, a 3 ratings-medium, 2 good, 1-I do not know, 0-no?
- How do you assess the quality of the cigarettes, and rating: 4 excellent, 1-good, 0-I do not know?
- How is the acquisition of data for export of products, and the score 3-good, two-compatible with the environment, 1-I do not know, 0-poor

2.2.3. *Financial factors are:*

- How do you assess the effects of given cigarettes and score 6-over 5 million, 3 between 1 and 5 million 0-over 1 million KM?
- What is the coefficient of demand for a given cigarette, rating: 3-excellent, 2 very good, 1 good, 0-bad?
- How do you compare the demand of target setting in the books last year, 3-growing, 1-dropping, 0-I do not know?
- What is the target price of cigarettes compared to the same in the environment, 3 excellent, 2 good, 1-sufficient, 0-poor?
- What is the target price of cigarettes with the environment in comparison with values from a year earlier, 5-over or equal to 50% increase, 3-dropping less than 50%, 1-I do not know, 0 - Bad?
- How the changed price cigarettes in the past month, 3 less than 0.3 hp per box, 2-more than 0.3 hp per box, 1- more than 0.2 per box, 0- less than 0.2 per box
- How much has changed price cigarettes when last month compared with the previous, and 4 ratings more than 50% decline, 3 less than 50% and falling, one I do not know, 0 on the rise
- How is growth in sales last month, rating: 3 more than 300%, 2- between 100% and 300%, 1 - less than 100% and more than 0%, 0-I do not know
- How increased supply/demand last month compared to the last three months, and the answer: 3-over 200%, 2-between 200 and 100%, 1-less than 100% and greater than 0%, 0-I do not know

Replies are summed weights and divided as follows.

Environmental factors:

stage set		bad 0-11
		fair 12 to 19
		good 20-24
		excellent 25-27

Factors of production:
stage set   bad 0-14
                   fair from 15 to 27
                   good 28-34
                   excellent 35-39
Factors Finance:
stage set   bad 0-18
                   fair 19-34
                   good 35-49
                   excellent 50-55
Answers to the questions are grouped into stage sets: excellent, good, fair and poor.
Customer responses can be again.

3. Expert System

The last phase of the expert system gives value by a factor of convenience sale of those cigarettes, its quality and comparing the same with cigarettes of similar quality from the region and beyond.

The task is to make a quality cigarette, which has optimum quality for this class of cigarettes and the price of which can enter the market. Here we introduce the coefficient benefits.[5]

Based on the combination of four 64 values for each group and 3 groups, giving a final Expert System Suitability cigarette. In Figure 3 we have a Use Case diagram coefficient facilities manufacturing cigarette. Feedback related to the ten groups of replies: [6]

-2 (does not correspond to a),
-1 (transient or unacceptable),
0 (indifferent),
1 (transient but not so attractive)
2 (poor attractive)
3 (can be a good target)
4 (a good cause)
5 (very good cause)
6 (excellent target),
7 (dried objective).

In the final step, all three factors have identical weight. Financial factors have greater weight, but environmental factors and management factors.
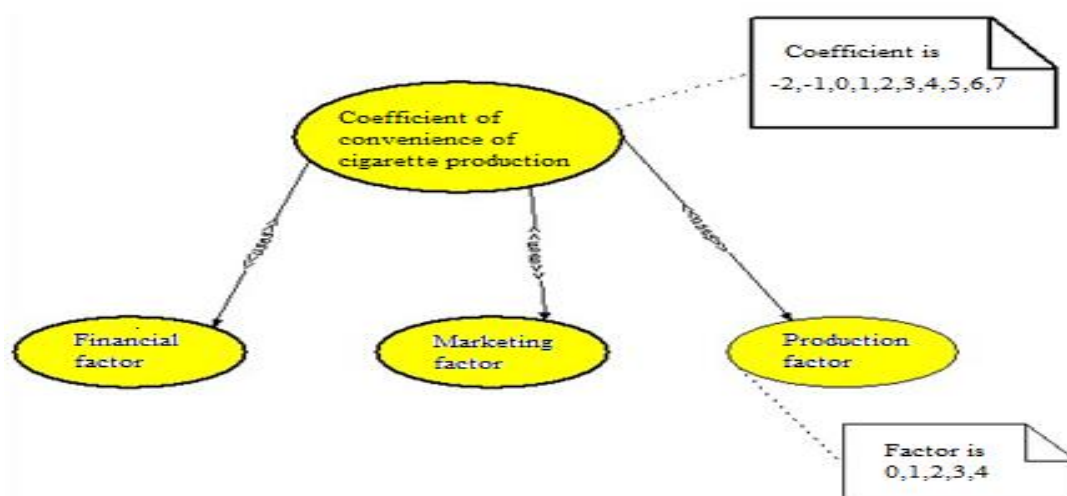

Figure 3. Use Case Diagram connection coefficient benefits of cigarette manufacture with the factors of production

On the basis of these claims is **modeled** USE - CASE diagram coefficient convenience cigarettes.
In Figure 3 we see that the coefficient of facilities used three factors:

    1. Financial factor
    2. Marketing factors
   **3.** Production factor

The factors are further decomposed Use Case diagrams.
In Figure 4 see USE-CASE model of financial factors. Financial expert answers a set of questions and from this set is decided and calculated the weight of financial factors.
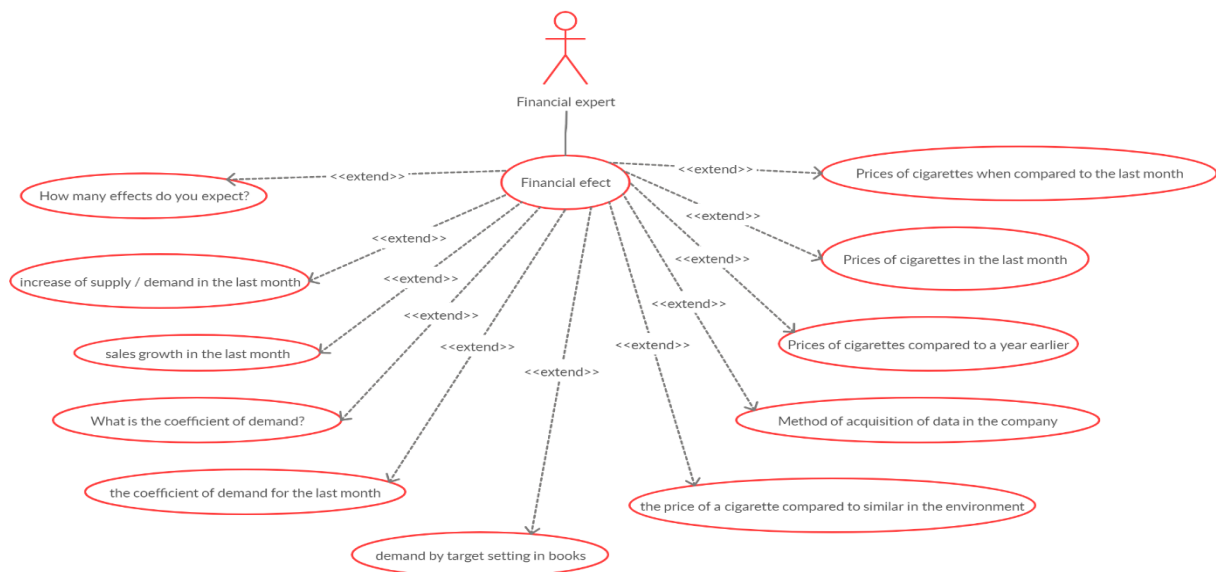
**Figure 4.** Use Case model of financial factors

    Figure 5 shows the use case model of marketing factors. Expert marketers' response to the set of issues related to marketing. By placing the weight on the responses obtained marketing incentive benefits cigarette production.
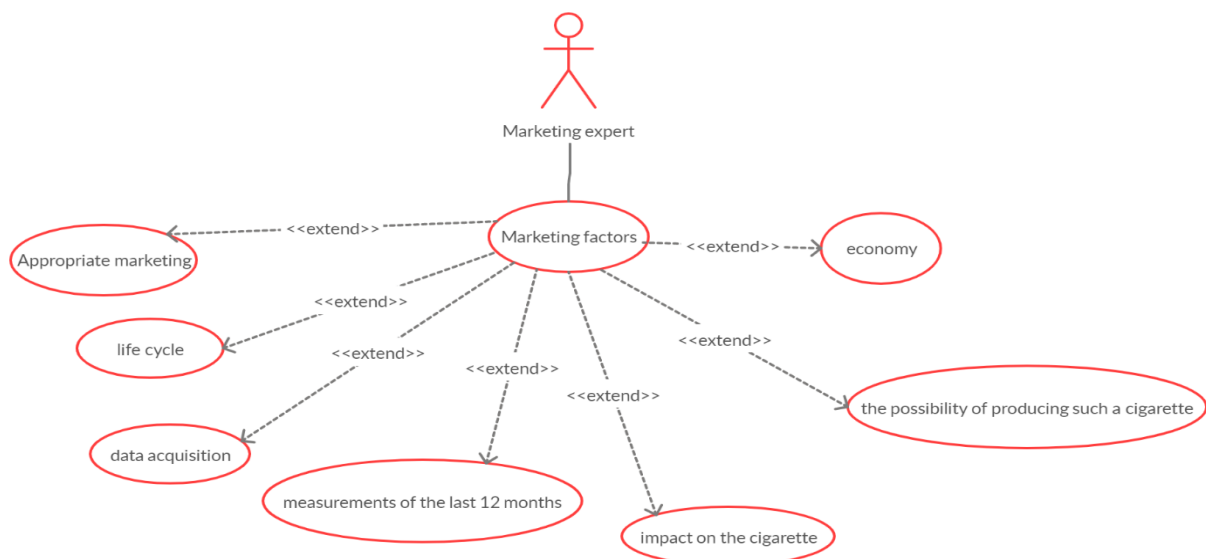
Figure 5. Use Case model of the marketing benefits coefficient production

After that, as shown in Figure 6 manufacturing expert answers questions related to the manufacturability of the required product. Questions have their weight and form the basis of the budget coefficient facilities for manufacturing such products.
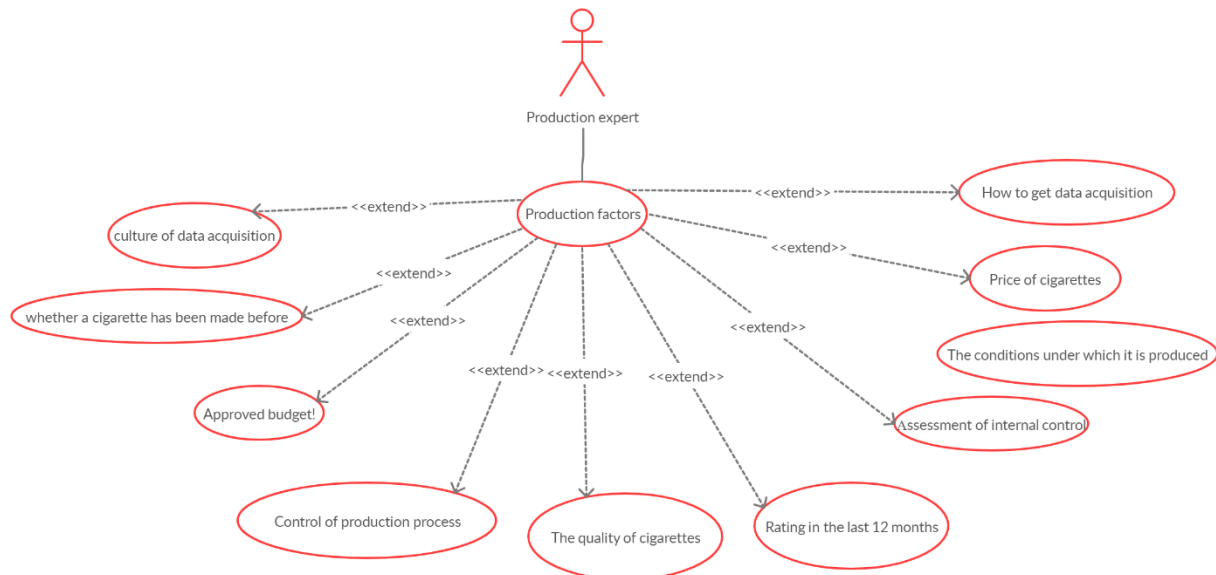
Figure 6. Use Case model coefficient manufacturability

The main characteristics of the product which are **analyzed** are:
- Weight cigarettes declared as SUPER LIGHT, LIGHT, CLASSIC
- The quality of tobacco (moisture content of roots)
- Quality of paper
- Glue for tobacco
- The filter sticks

The main parameter, i.e., the one that most affects the quality of the product is damp tobacco. It affects:
- the weight of the cigarette
- the productivities of cigarettes (CUG)
- the overall coefficient of convenient use of the cigarette

Based on this, work on the measurement of moisture in tobacco daily in the course of a year. In various periods of time affect different causes that invest in tobacco be larger or smaller.

4. Analysis of results for moisture over time

After the analysis table, we obtain copies diagram percentage malfunction in the function of measuring the date Figure 7 where we can observe that after measuring and analyzing the percentage of defect samples to obtain samples malfunction ranges from -15% to + 20%.

If further grouped into stage sets, where each set assign a name: positive big, positive middle, positive small, almost without fail, negative small, negative big, negative mean and introduce rules making the correct input, and based on the knowledge base, we can affect the return on the system, reducing and increasing the entry of tobacco through the trim drives on the machine, keeping it in an appropriate weight for this type of cigarettes.

To receive a rating by giving a series of errors, the cause of the error and error detection. All errors that are entered must have corrective measures to be taken to correct the error. If an error does not exist in the knowledge base must be entered, as well as the rules and corrective measures.

The Molins Mark 9 machine enables reliable, high-quality cigarette production at 5,000 ppm speeds. Programmable logic controllers (PLCs) are controlled through a new operating system. The

speed is 5000 cigarettes per minute for 70 mm length of the cigarette, the length of the tobacco path is 350 meters per minute.
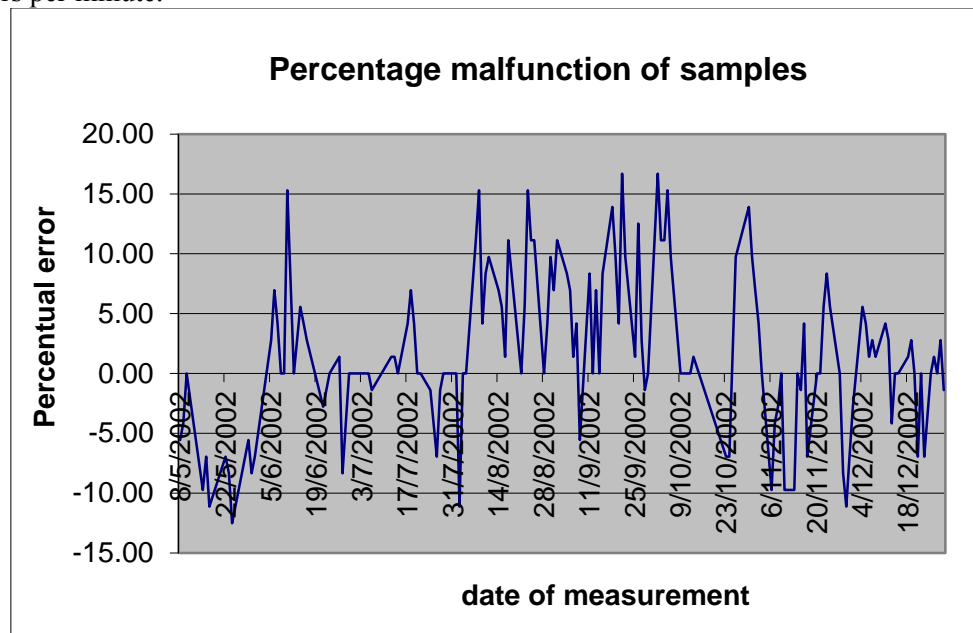
Figure 7. The percent failure of the sample's cigarettes in the function of date of measurement

Inputs can be divided into:

positive great	>15%	
positive Medium	>10%	<15%
positive Small	>5%	<10%
Almost without fail	around zero	
negative Small	>-5%	
negative Central	>- 10%	<5%
negative Large	>-15%	

Fuzzy data set consisting of pre-defined data output set [2], [7], [8]
reduce tobacco
Do not touch anything
Increase tobacco
rules
If the humidity is positive great and if caused the positive big mistake then Reduce tobacco!
If the humidity is around zero do not change anything.

5. Conclusion

Domain knowledge entered into the knowledge base allows adaptability of the system. The system based on various inputs, pre-set parameters (cost, quality) seeks to adapt the production system in order to achieve the maximum effects of the production system. The developed system meets all EU recommendations for such a product and adaptable to the conditions of the target country in which it creates such a product and the desired level of quality. [9]

Explicitly stated, production by introducing automation is becoming increasingly**,** easier to operate and more complex to monitor. For example, the production of cigarettes in tobacco factory Banja Luka implemented the expert system developed in this paper, based on the input parameters, which are almost always variable decides what will be action taken to output a finished product (which in this case cigarettes), be the context of the required standards.

The system manages the quality in real-time and thereby correct the output size and operates a machine for the manufacture of cigarettes. On the input parameters in this way can be influenced before manufacturing starts the developed system of any adjustments on the basis of measurements performed during machine operation, concluding that come with such materials can achieve a certain output and the process stops only when he needed a new rule or new facts on the input parameters. In addition, the paper introduced a coefficient facilities cigarette as a parameter to support quality management. On the basis of this ratio can be concluded as much quality that is suitable from the incoming raw materials can get and what is the need for such quality. [9-11]

This also allows correction of certain input parameters that, if necessary, improve the quality. It was obvious multiple benefits of this approach. The production system has many times fewer interruptions than in the case of establishing the quality of the end of the production cycle. The system has the characteristics of learning (getting smarter by entering new rules and facts). Fuzzy logic and its implementation made it possible to follow the trends of certain parameters and to group them although not precisely defined and do not always have the same value. Each system and this require an assessment at the end. [12-14]

The fight for quality in all areas of life requires constant monitoring of the same. No human auditors, medals quality standards are not sufficient to maintain at all times the required level of product quality.

We require Fuzzy adaptive predictive expert systems for industrial process control process to be able to keep it under constant control. This may not be the production of cigarettes, but the production of drinking water or other products. Even if the product is awarded the highest score, only one error can cause a bad product or a product which endangers human health. This is a based role for INDUSTRY 4.0 [15]

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