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Politechnika Częstochowska

Wydział Zarządzania

AN APPROACH TO ASSESSING AND IMPROVING THE EFFECTIVENESS OF VISUAL INSPECTION PROCESSES FOR LARGE-SIZE PRODUCTS FROM THE FURNITURE INDUSTRY

15th International Scientific Conference WoodEMA 2022
„CRISIS MANAGEMENT AND SAFETY FORESIGHT IN FOREST-BASED SECTOR AND SMES OPERATING IN THE GLOBAL ENVIRONMENT”,
08th – 10th, June 2022

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INTRODUCTION

- **Visual inspection** is the method of looking for defects or imperfections using the naked eye and non-specialized inspection equipment.
- **Visual inspection** has its advantages and disadvantages...

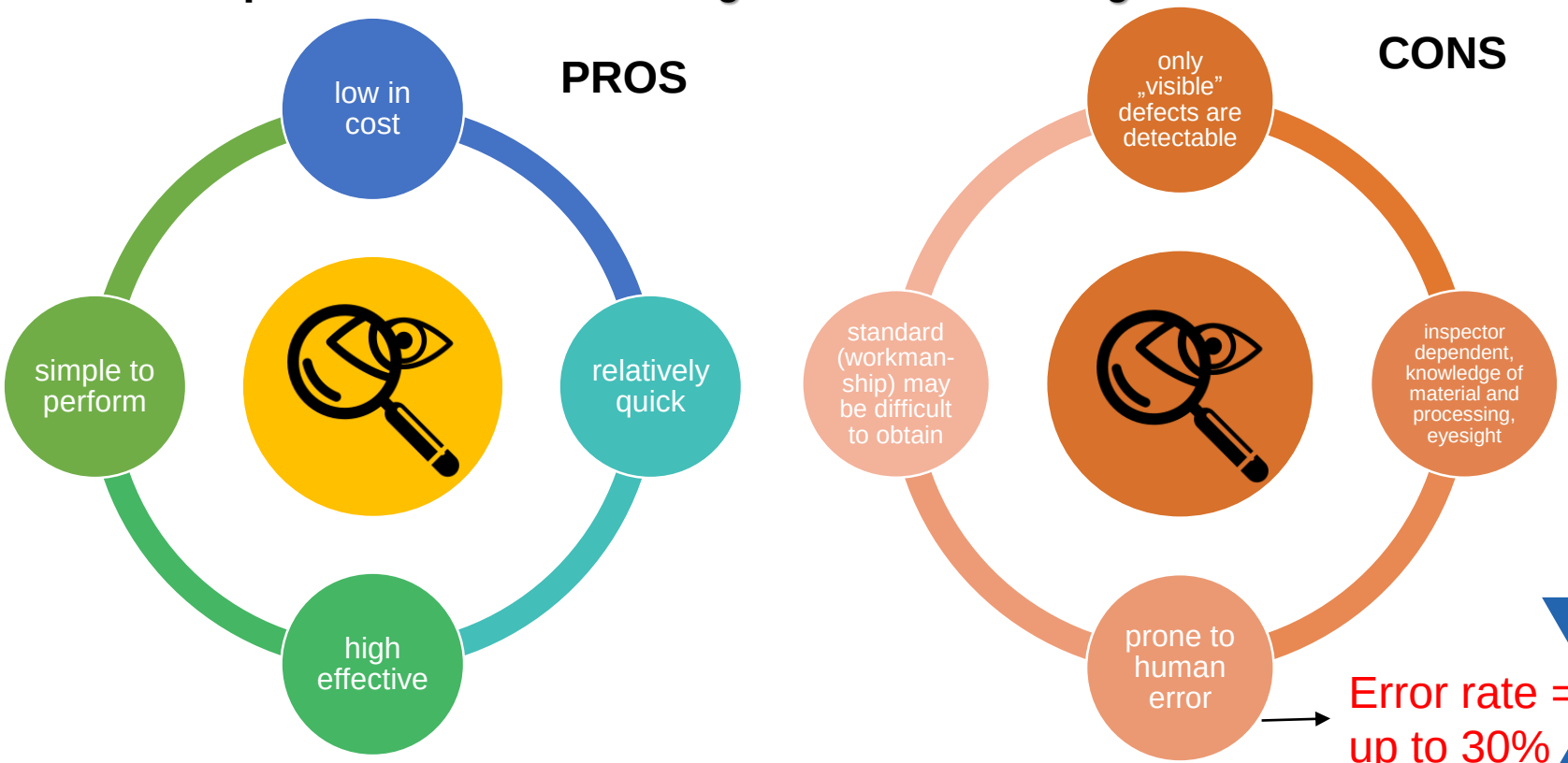


Fig. 1. The main benefits and limitations of visual inspection

INTRODUCTION

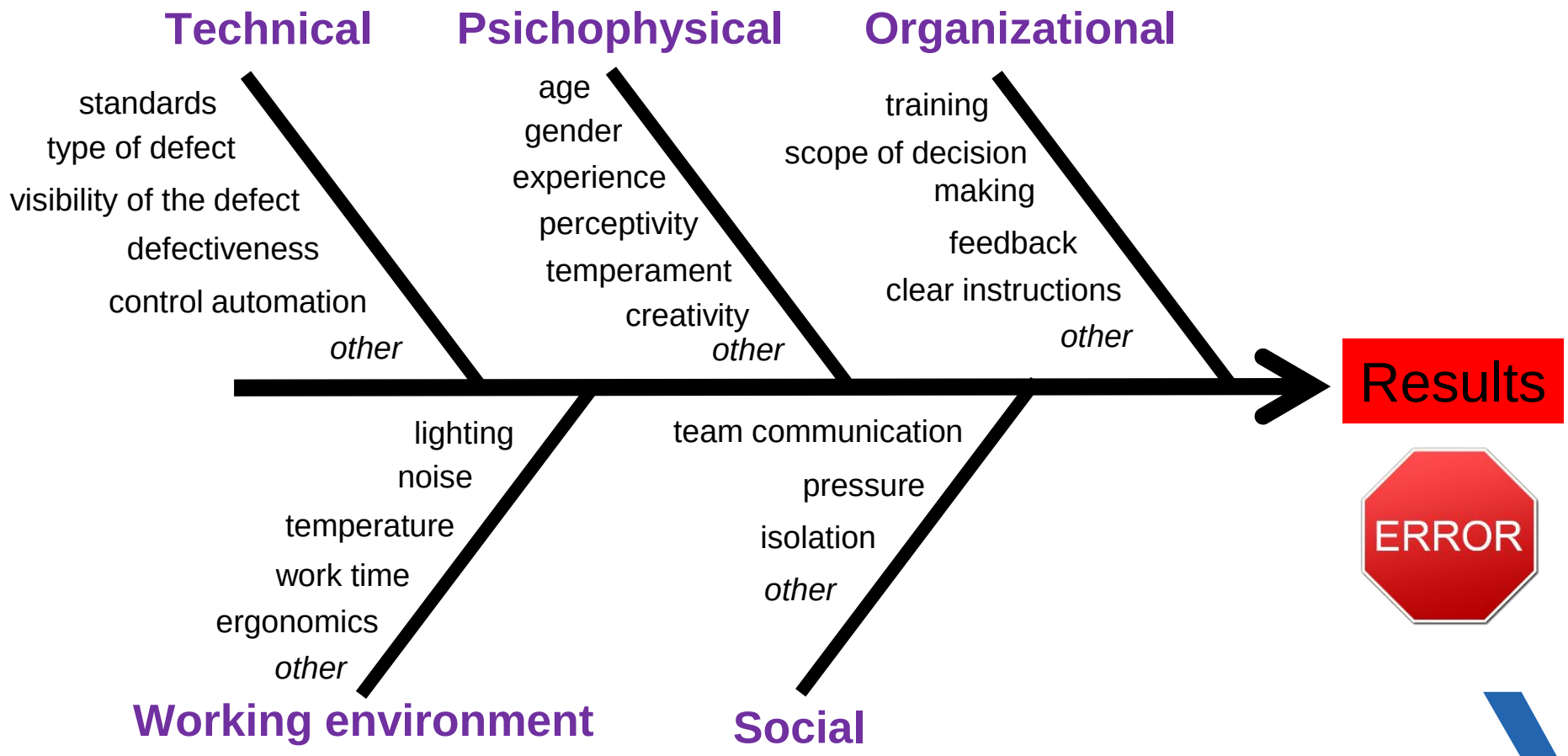


Fig. 2. Ishikawa diagram of factors influencing visual inspection results/errors

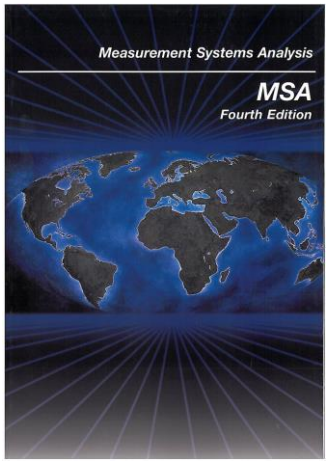
Source: own study based on Vogt A., Kujawińska A. 2013 *Analysis of the influence of selected factors on the effectiveness of visual inspection* (in Polish), *Inżynieria Maszyn*, R. 18, z. 1, pp. 40-50.

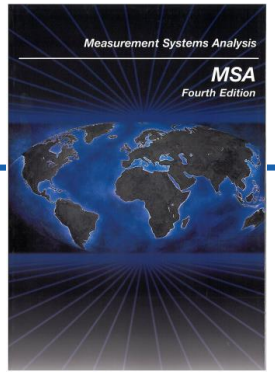
INTRODUCTION

- On the way to the improvement of the visual inspection process, **the measurement or study phase is very important**...

Fig. 3. PDSA cycle and DMAIC cycle as improvement cycles for any process

- Guidance *on the measurement/study phase* of attribute control systems (ex. visual inspection) in the Automotive Industry is provided in the Measurement System Analysis (MSA) handbook (AIAG, 2010).
- The Automotive Industry (AIAG) indicates to use the Kappa study to measure the level of effectiveness of a visual inspection system.





INTRODUCTION

What does the Kappa study look like in the original?

1. Select 3 appraisers (ex. quality controllers/operators).
2. Select about 50 real, physical samples, containing a specified number of conforming and non-conforming products (app. 50/50%).
3. Expert controller classify all samples (50) as OK and NOK to define a reference value (REF) for each product.
4. Individual controllers (3) classify all samples (50) as OK and NOK in 3 trials in a real control environment and in a given period of time.
5. The results are recorded and key attribute control system effectiveness measures are calculated, like *Effectiveness, False Alarm Rate, Miss Rate, Kappa Values*.
6. Taking decision on the acceptability of attribute control system.
7. Preparation of a report containing the interpretation of the obtained results, suggestions for improving the effectiveness of the attribute control system.

INTRODUCTION

Limitations in conducting the Kappa study in original version in companies from the furniture industry (in Poland - SMEs):

- difficulty in collecting in one place the required large physical sample of one type of product for the study (50) containing a certain number of good and bad products, in the case of large-size products from the furniture industry...
  - ✓ organizational difficulties: *space required for the study*, *time needed to collect special product samples for the study* (easy: large-series, mass production - Automotive Ind. vs harder: medium, small-series or unit production – SMEs in Furniture Ind.) -> *greater efforts and cost of the study*...

vs

...these could be a factors that discourage or even prevent Kappa study from being carried out in the furniture industry

RESULTS

- How can these limitations be dealt with and the Kappa study can be implemented in the furniture industry?

➢ the Kappa study can be carried out not on the basis of a physical sample of products, but on the basis of photos of products (compliant and non-compliant)...

the physical, real sample

photo of the sample

RESULTS

PQ-MSA
Power of quality

- Kappa study tool based on photos of product samples: PQ-MSA+ software from a Polish supplier - GRETOM Consulting

https://pq-msa.pl/

RESULTS

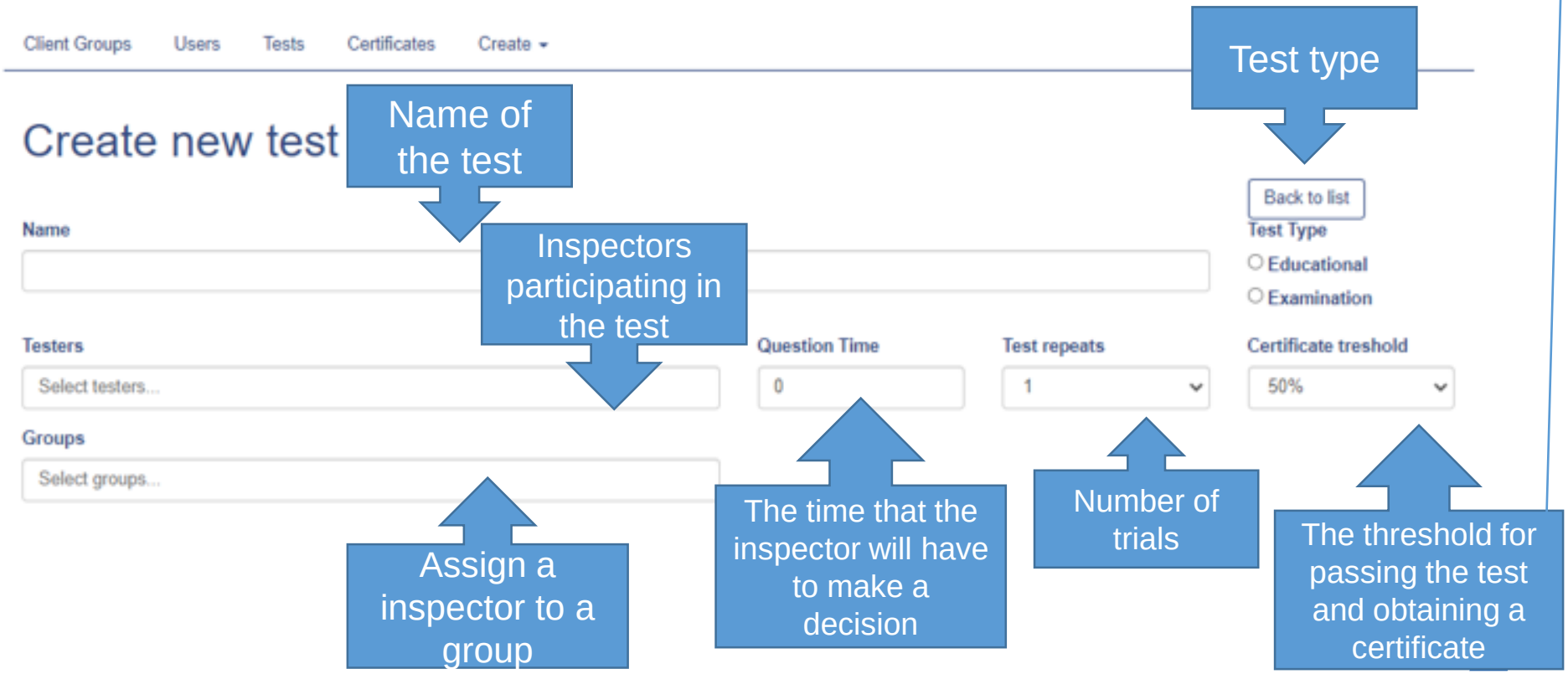
Basic functionality of PQ-MSA+:

- PQ-MSA+ application is available online from any device (*computer, smartphone, tablet*) that supports the browser (excluding Microsoft Internet Explorer) and has access to the Internet.
- In order to gain access to PQ-MSA+, simply log in to the website www.pqmsa.pl.
- The application can be used in international teams thanks to the possibility of choosing up to 4 languages (Polish, English, German and Chinese).
- 2 levels of access to the program: level 1 - controller, level 2 - admin.

RESULTS

Creation and course of the analysis:

- **Create a test**

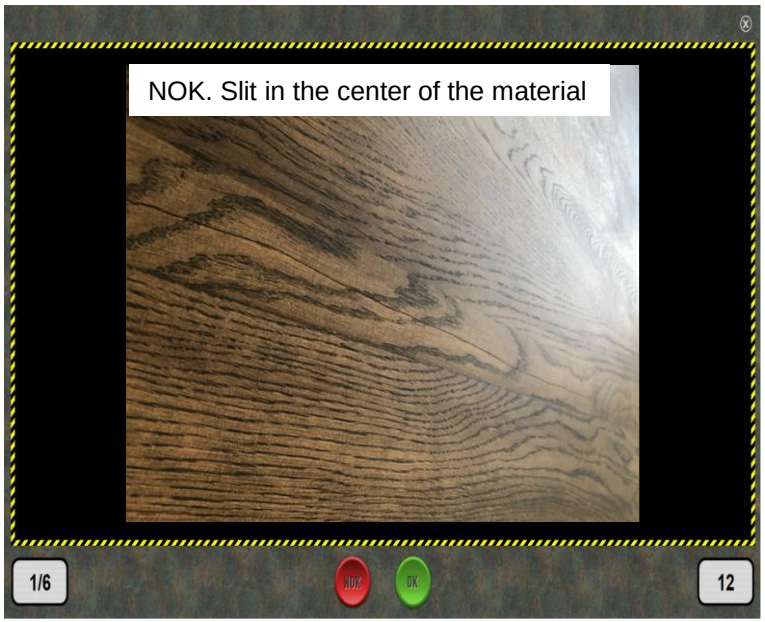


RESULTS

Creation and course of the analysis:

Test type

- **Create a test**



Educational test

[possibility to view all questions with correct answers and their explanations without time limit. The test is available any number of Times]

Examination test

[real Kappa study. The controllers must classify the product shown in the photo as OK or NOK (compliant or non-compliant) within a specified time]

RESULTS

Creation and course of the analysis:

- **Create a test**

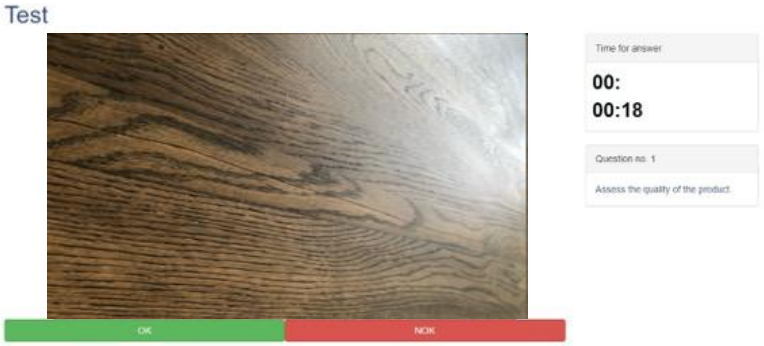
#	ID	Image	Question	Answer	Description
1	15613		**EN**: Rate product quality	NOK	**EN**: NOK. Longitudinal crack
2	15614		**EN**: Rate product quality	NOK	**EN**: NOK. Longitudinal crack
3	15615		**EN**: Rate product quality	NOK	**EN**: NOK. White stain on the material

RESULTS

Creation and course of the analysis:

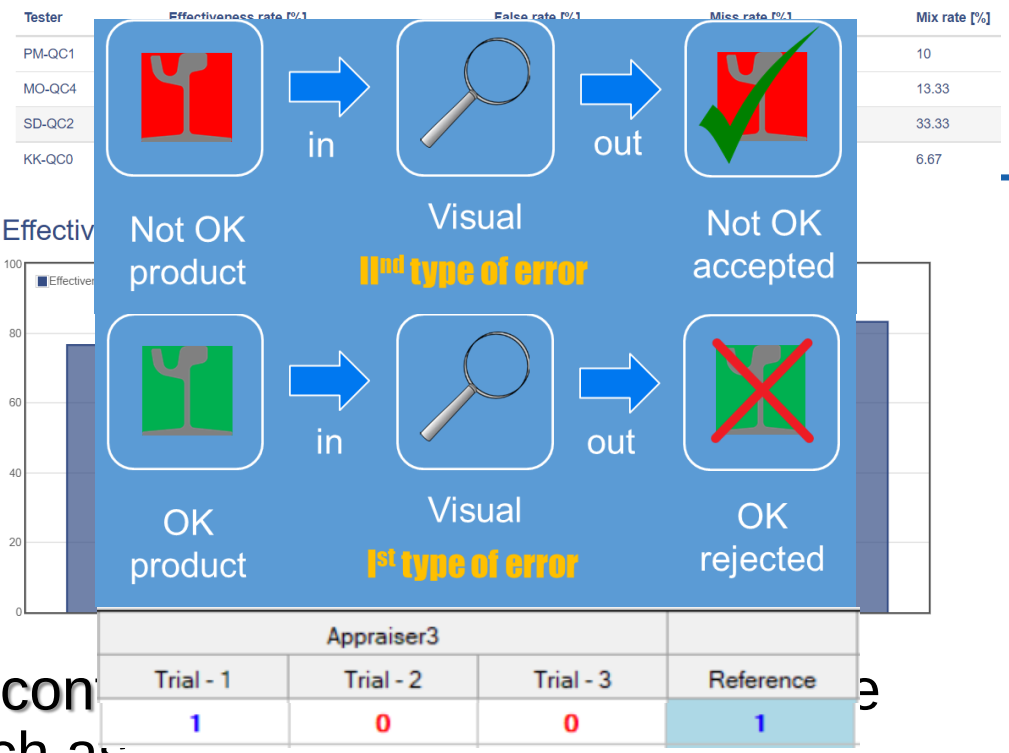
➢ The course of the analysis

- The photos are displayed **in random order** while the test is running. The inspector only has to decide **whether the product shown is good or defective.**



- After completing the test, the controller can **check incorrect answers** with an additional description.
- If he obtains the agreed test result, he will additionally be able to print a **certificate.**

Decision for the control system	Effective-ness [%]	Miss Rate [%]	False Alarm Rate [%]
Acceptance	≥ 90	≤ 2	≤ 5
On the verge of acceptance - the need for improvement	> 80 - < 90	> 2 - ≤ 5	> 5 - ≤ 10
Unacceptable - necessity for improvement	< 80	> 5	> 10



Extensive statistics

- Statistics divided into con… …e can find indicators such as:
  - Effectiveness (share of correct/consistent answers, controller repeatability).
  - Miss rate (share of non-compliant products assessed by the controllers as compliant, type II errors -> higher cost).
  - False alarm rate (share of compliant products assessed as defective by the controllers; type I errors).
  - Mix rate (number of inconsistent assessments – the controller once assessed the product as compliant and once as non-compliant).

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Cummulative

Tester	Kappa
PM-QC1	0.64
MO-QC4	0.31
SD-QC2	0.21
KK-QC0	0.73

1,00	Perfect agreement
	Very good agreement
0,75	Good agreement
0,74	Moderate agreement
0,40	Weak agreement
0,39	Very weak agreement
0,00	Lack of agreement

SD-QC2	KK-QC0
0.24	0.69
0.44	0.38
-	0.24
0.24	-

- Individual statistics – in which there are answers of individual controllers with highlighted incorrect answers.
- Statistics for the product – statistics illustrating the test results from the product side. They allow, among others to judge which photos caused the controllers the most problems.
- KAPPA – statistics enabling the assessment of compliance of the assessment between individual controllers, as well as between the controller and the reference value (expert).

The collected statistics can be analysed with a division into created groups (e.g. *controllers from various shifts, departments or suppliers*).

RESULTS

Table 1. Kappa study versions possible to be performed with the use of the PQ-MSA+ program for products of the furniture industry

Division Criteria (Relating to Single Kappa Study)	Version of the Kappa Study
1. Depending on the specific type of components / finished products assessed	a) one specific type (e.g. furniture boards), b) different types (e.g. furniture boards, wardrobes, chests of drawers, couches, etc.).
2. Depending on the origin of components/ finished products/photos assessed	a) from internal control processes/from one supplier/from one company branch, b) from customer complaints (the most often photos!!!)/from different suppliers/ from different company branches, c) mixed set.
3. Depending on the location and intensity of non-conformity in the photos of components / finished products which determining the possibility of detecting non-compliance by raters / quality controllers	a) case of high-intensity non-conformity/known & popular non-conformity location – easy to detect, b) case of moderate-intensity non-conformity/rather typical non-conformity location – quite easy/quite hard to detect, c) case of low-intensity non-conformity/unknown & unusual non-conformity location – hard to detect. d) mixed set (the best option)
4. Depending on the number of raters/quality controllers	a) 3, b) more than 3.
5. Depending on the origin of the raters/quality controllers	a) from the QC department/one shift/from one supplier/from one company branch, b) operators at workstations/different shifts/from different suppliers/from different company branches, c) mixed set.

RESULTS

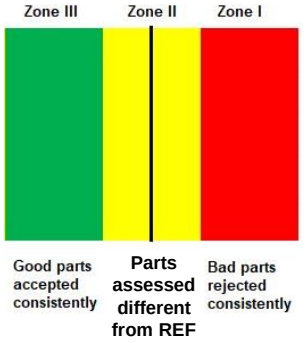
Level 1
– easy –
visible, easy to discernible scratches

Level 2
– medium –
rather a discernible scratch

Level 3
– hard –
hardly discernible small scratch

Fig. 4. Different levels of non-conformities intensity on the product photo determining the different difficulty of their detection

- **How good our controllers are at detecting small / hard to notice non-conformities?**
- **How observant/ precise are they when assessing?**



	Appraiser1			Appraiser2			Appraiser3				
Parts/Trial	Trial - 1	Trial - 2	Trial - 3	Trial - 1	Trial - 2	Trial - 3	Trial - 1	Trial - 2	Trial - 3	Reference	Code
6	1	1	0	1	1	0	1	0	0	1	x
7	1	1	1	1	1	1	1	0	1	1	x

RESULTS

Level 1
– easy –
big non-conformity in the center

Level 2
– medium –
small non-conformity in the right center

Level 3
– hard –
small non-conformity in the upper left corner

Fig. 5. Different levels of non-conformities location on the product photo determining the different difficulty of their detection

- **How good our controllers are at detecting non-conformities appearing in different location?**
- **How observant/ precise are they when assessing?**

RESULTS

Pros

- no need to use real products - especially useful for large, heavy products (A, B),
- less effort (time, cost) of preparation and carrying out of the Kappa study (A, B),
- built-in indicators which comply with the international standards (MSA) (B),
- 24h access to the multilingual tests (B),
- supports cooperation between plants and suppliers (A, B),
- lessons learned from wrong and inconsistent controllers' decisions and the possibility of standardization (A, B),
- training option and increasing controllers' knowledge (A, B).

Cons

- photos will never reflect the real "quality" of a physical product sample (A, B),
- the photo itself & the non-conformities parameters on the photo determine the possibility of detecting non-conformities cases during the test (A, B),
- it is difficult for the study to take place in a place where the visual inspection process is actually used (A, B) -> only approximate conditions of true Kappa studies (A, B),
- no possibility of zooming in on the photo, changing its angle, seeing the photo from different perspectives (B),
- no possibility of explaining the decisions made by the controllers (B).

Fig. 6. Summary of the pros and cons of Kappa studies based on product photos (A) and with the use of the PQ-MSA+ software (B)

RESULTS

- Good-quality „flat lay” photos (with good resolution, exposure parameters, no reflections). Standardized photo size
- Verification of photos is necessary before admission to tests. Validation of photos by conducting pre-test for series of products photos by an expert controller before the right test
- The different intensity of the non-conformity and its location should be shown in the photo (to obtain more information on the effectiveness of controllers in detecting non-conformities)
- Review by the Kappa study supervisor of errors (errors of type I and II) and inconsistent controllers' decisions with the controllers themselves after the Kappa test
- Possibility to zoom the photo if necessary, reverse the photo by any angle, change the viewing angle of the photo (*proposed additional functions in the PQ-MSA+ software*)
- Possibility of justifying the decision made (during classifying the product as non-conforming, i.e. NOK) by the quality controller by adding a comment (*proposed additional functions in the PQ-MSA+ software*)

Fig. 7. Factors contributing to increasing the reliability of Kappa studies based on product photos and with the use of PQ-MSA+ software

CONCLUSION

→ photos based Kappa study and its tool - PQ-MSA+ program may be the best option to conduct the Kappa test in the furniture industry for large-size products

→ increasing the reliability of Kappa study using the products photos requires appropriate preparation of product photos samples

→ there is a wider range of possibilities to use product photos to improve the effectiveness of visual inspection system (*training goals, standardization goals, lessons learned case studies, benchamarking*)

→ periodic quality controllers training and examination with the use of product photos and the PQ-MSA+ program can be crucial to ensure visual inspection method be effective in the furniture industry

→ the preparation and implementation of the Kappa study using products photos and the PQ-MSA+ program (*despite this solution imperfections*) in the furniture industry can be a valuable lesson, the conclusions of which will contribute to improving the effectiveness of the visual inspection system

CONCLUSION

https://pq-msa.pl/

https://pq-fmea.pl/

Thanks to GRETOM Consulting, the PQ-MSA+ and PQ-FMEA software are used by free license during didactic classes at the Faculty of Management of the Czestochowa University of Technology