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# NOVEL POKA-YOKE APPROACHING TOWARD INDUSTRY-4.0: A LITERATURE REVIEW

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*Review Paper*

***Abstract:*** *Understanding quality in manufacturing starts with learning why errors happen and this could be improved by analysis with root causes related to human errors. Human reliability influenced by equipment design or working environment will come to concept of poka-yoke (mistake proofing), and various means to reduce mistakes that have been greatly improved recently with latest sophisticated technology. This article will discuss poka-yoke technology related to the Industry 4.0 (I4.0) or Smart Manufacturing concept. The method is to review research articles published within 2015-2020 with a keyword poka-yoke or mistake-proof or fault-proof and verify further whether their poka-yoke tools have implemented the I4.0 concept. The results obtained 50 selected articles, with 13 of them that already applied information technology, cloud computing, and augmented reality, which are considered as I4.0 tools. However, its application is not always satisfying concerning its suitability function, requirement of industries, culture, local regulation, and internal business concern, especially in terms of efficiency and cost.*

***Keywords***: *Poka-yoke, mistake-proof, fault-proof, industry 4.0.*

## 1. Introduction

There is a concept in quality management that prevents the human fault from occurring in production, which was introduced by Shigeo Shingo and named as poka-yoke (Malega, 2018). It deals with mistake-proof or error-proof as per original wording *yokeru* (avoid) and *poka* (mistakes) (Kurhade, 2015). The mistake can occur at any job at any type, e.g., misoperation, not performed as per protocol, using wrong tools, missing parts, having defects during assembling, using incorrect components, or inaccurate measurement (Kurhade, 2015).

Currently, we are facing Industry 4.0 or in short form as I4.0, and conventional industries will evolve to a smart and autonomous style (Ahmed et al., 2019), and it will introduce and develop new tools that reduce human error at an early step of

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product and process development (Lazarevic et al., 2019). It can be a communication strategy (Tezel & Aziz, 2017), or automation with a human touch (Romero et al., 2019) or software application to avoid mistyping (Hudori et al., 2017) or a smart decision tool (Ahmed et al., 2019) or a computerized testing tool (Bici et al., 2017) or using advanced technology like augmented reality to point out mistakes (Dario Antonelli & Astanin, 2015). Then, it comes to the question, how can poka-yoke and I4.0 supplement each other? And which I4.0 tools can support a poka-yoke method?

The precondition for this literature study is looking at various lean approaches including mistake-proofing methods. Indeed, there are many ideas of mistake-proofing methods with proper implementation according to their circumstances. However, there are insufficient published articles with this specific mistake-proof topic.

## 2. Research Methods

This literature review is the best method to study and analyze from basic theory, tools, experience, and lessons learned from either academic or practical exercise. According to Figure 1, this paper study starts with the initial collection as step number one of the total five steps. Collecting from various publishers, i.e. Science Direct, Research Gate, ProQuest Search, MDPI, Springer Open and Google Scholar within the year of 2015 until 2020. The keyword is "poka-yoke" or "mistake-proof" or "error-proof" or "fault-proof" for the industrial sector with the number of collected articles shown in Table 1.

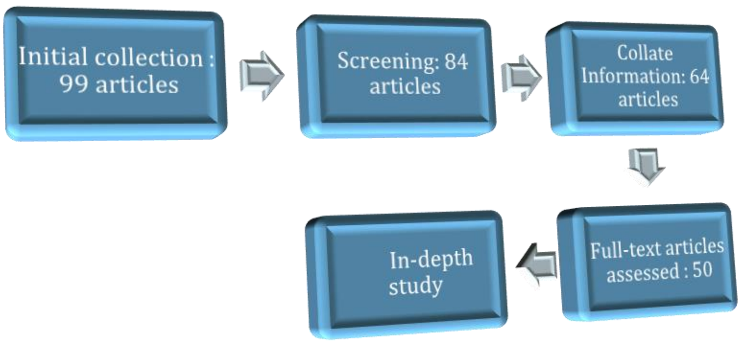


*Figure 1 Literature Study Framework*

*Table 1. Number of Articles at every stage*

| Stage | Article Qty |
|---|---|
| 1 | 99 |
| 2 | 84 |
| 3 | 64 |
| 4 | 50 |
| 5 | 50 |

- Stage 1. The initial collection, managed to collect 99 articles relevant to poka-yoke.

- Stage 2. Screening; omitted numbers of papers due to irrelevant research objects and kept 84 of them.
- Stage 3. Collate information, also removing the number of papers when digging information inside, only selected 64 related to industrial and manufacturing.
- Stage 4. Full-text article assessed, gained more knowledge and chosen 50 standing out.
- Stage 5. In-depth study for those remaining 50 articles.

Digesting more the article contents, it has been listed out all articles based on the industrial type or place of research, poka-yoke type, and country of the researcher. Segregation based on poka-yoke type is mechanical, electronic, mechanical-electronic (mix), IT or system software, and the last is organizational, which is a focus on the development of protocol or procedure for the human-error problem. The summary of results based on the year of published papers is presented in Figure 2.

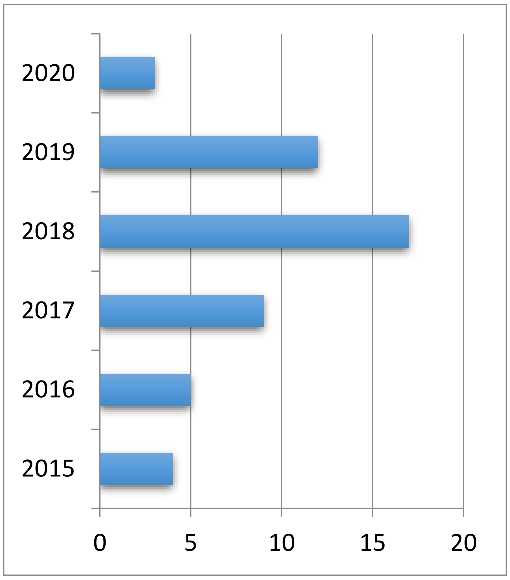


*Figure 2 Collected articles & papers based on the publishing year*

Analyzing the content from the final collected articles, there was a focus on a few aspects:

- Industrial type,
- Selected mistake-proof type (see Figure 3),
- Implementation,
- Enablers and inhibitors.

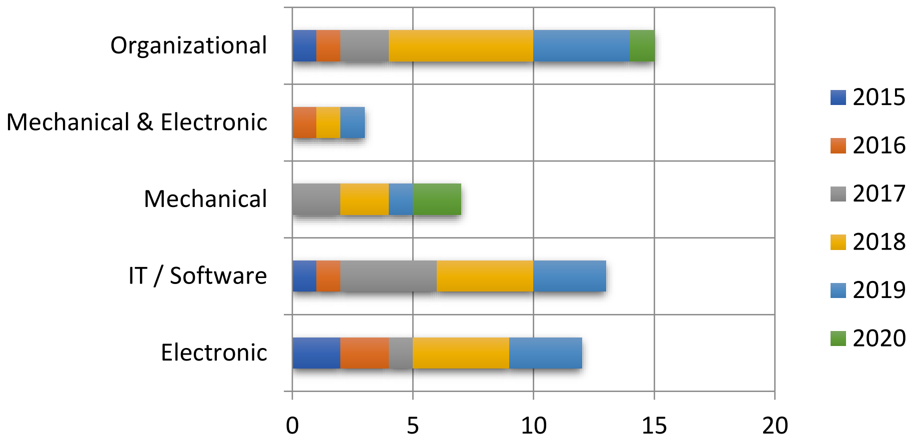


*Figure 3 Poka-yoke type*

Based on theory, the poka-yoke implementation started in the automobile industry (in the 1960s as part of Toyota Production System (TPS) in Japan), and furthermore it was adopted by textile, construction, electronics, woods, services, and other industries in various countries.

## 3. Results and Discussion

All articles and papers are elaborated in Table 2, including the country of author, research object and respective result. Surprisingly, the article published by the Japanese is none at this literature study and this concern can be reserved for future research.

*Table 2 Mapping Poka-Yoke Implementation from 50 articles*

| No | Paper Identity | Country of Author | Research object | Result |
|---|---|---|---|---|
| 1 | (Dahivale & Lokhande, 2020) | India | Rejection from reverse logistics and scrap | After implementation of poka-yoke, rejection and scrap rates are significantly reduced to 'zero'. |
| 2 | (Solaimani & Sedighi, 2020) | Netherland | Lean implement-ation including Poka Yoke in Construction | Carry out and sustain the lean in construction and poka-yoke is part of them, particularly for safety. |
| 3 | (Selvam & Loganathan, 2019) | India | Design & fabric-ation of hydraulic conduit connector | Improvement on quick releasing coupling. Part of assembly is made noticeable. Eventually, it raises a confidence level of the operator's. |
| 4 | (Muharam & Latif, 2019) | Indonesia | Vibration signal for machine monitoring | Poka yoke device can observe machine condition, such as bearing abnormal alarm. Furthermore, this system is also being used to see machinery and equipment condition. |
| 5 | (Romero et al., 2019) | Italy | Jidoka/Automation with human touch | Advised for step-by-step fully-automated operation deployment to let workers gain knowledge and change working culture towards semi-automated or fully automated operation, through development of stages and adopting Jidoka Systems, instead of immediate applying a fully automated solution. |
| 6 | (Rösiö et al., 2019) | Sweden | Assessment manu-facturing system and Poka Yoke as part of diagnosable criteria | Develop assessment model to measure ability for modification and change variation of product and volume. |
| 7 | (Putri & Handayani, 2019) | Indonesia | Craft bag product quality (for cement powder) | Improvement with 3 poka yoke methods, i.e. warning, control & shutdown. |
| 8 | (Hoellthaler et al., 2019) | Germany | Digitalization to support Poka-Yoke for a lean production system | Digital manner for tools and methods is indeed achievable, eventually reduces waste of time, cost and quality. |
| 9 | (Attia et al., 2019) | Egypt | Poka yoke in clothes printing machines | A mechanical poka yoke prototype is manufactured for diminishing problems. |
| 10 | (D. Antonelli & Stadnicka, 2019) | Italy | Identify potential mistakes either by human or robot. | Define proper mistake proofing (poka yoke) methods in an HRC (Human-Robot Collaboration) assembly work cell. The best solution is to standardize the part and uniform the dimension. |
| 11 | (Saputra et al., 2019) | Indonesia | Molding machine of plastic industry | Improvement is achieved gaining a value of 1.65 of SPC through poka-yoke implementation. |
| 12 | (Rubio-romero & Pardo, 2019) | Spain | Perform an analysis of lean, fault-proof and preventive activity in construction | "Personal-Protective-Equipment" or PPE is considered poka-yoke, and also warning sign with RFID and reflective railings. |
| 13 | (Ahmed et al., 2019) | Australia | SVPD in design, process and inspection | Disseminate a smart system based on experimental expertise to support product development design, product planning that is able to enhance manufacturing process. |

| | | | | |
|---|---|---|---|---|
| 14 | (Qeshmy et al., 2019) | Sweden | Aim to identify human error fact-ors in an assembly line using Augmented Reality for Smart Factory. | Augmented-Reality is not suitable if the aim is identification of human failure. The AR is not fully developed for the moment. |
| 15 | (Bajjou & Chafi, 2018) | Morocco | Survey in Moroccan con-struction industry | 61 % of the respondents are familiar with lean construction practices, and 68% are not familiar with Poka-yoke. |
| 16 | (Satolo et al., 2018) | Brazil | To rank the tools of the lean | Poka yoke is rank 11 among lean tools like VSM, six-sigma, 5S, kaizen, etc. |
| 17 | (S. Kumar et al., 2018) | India | SME with continuous improvement | Achieving by Lean-Kaizen approaching. However, found weakness in motivation of employees to eliminate wastes. |
| 18 | (Gavriluţă et al., 2018) | Romania | Laboratory system for modern manu-facturing | Develop a laboratory situation and environment for a sophisticated industrial method, including a simulating flow of process and lean. |
| 19 | (Soni & Yadav, 2018) | India | Review on produc-tivity improvement by poka yoke implementation | Application of poka yoke on a liner cutting machine to prevent possibility of liner mouth misalignment and increase the productivity. |
| 20 | (Vinayagasundaram, R. Velmurugan, 2018) | India | Pick-to-light at compressor manufacturing | Implement poka yoke approaching for a zero-defect in an assembly line; pickers or operators are prompted by lights (hence the name pick-to-light). |
| 21 | (Dawood et al., 2018) | Saudi Arabia | Lean tools in a soft drink company, Poka-yoke for variable missing operations, under fill, over fill, break ages. | Identify non-value adding activities, thereby enhancing productivity.<br>Step 1: Detect the abnormality-(Andon),<br>Step-2: Stop the equipment or line by Poka-yoke,<br>Step-3: Fix and correct the immediate condition by Poka-yoke,<br>Step 4: Verify causes and install a counter measure Poka-yoke. |
| 22 | (Lilja, 2018) | Sweden | Tetrapak packaging machine | Using three sub-functions (Physical, signaling and control) in the solution as all these functions seek to improve the environment around the assembler. |
| 23 | (Malega, 2018) | Slovak | Business process and system in a general review | Poka yoke represents an excellent method for eliminating human errors in production process. |
| 24 | (Prayogi et al., 2018) | Indonesia | Smart-key assembly in car manufacturing | Design two poka-yoke devices along with sensors that are integrated to the whole assembly system. |
| 25 | (Sundaramali et al., 2018) | India | Avoiding unneces-sary assembly of defective compo-nents and marking them | The whole inspection from the beginning has involved Poka Yoke. |
| 26 | (Pötters et al., 2018) | Germany | Shop floor process simulation for several methods including poka-yoke | Identification of how to get optimal quality involves optimization experts in the company. This initial identification approach is carried out before the actual test is conducted. |
| 27 | (Ardi et al., 2018) | Indonesia | Process of mounting actuator bracket | The design with Poka yoke overcomes the occurrence of bolt damage when installing the bracket. |

| | | | | |
|---|---|---|---|---|
| 28 | (Kurdve et al., 2018) | Sweden | Prototype for building wood modules with poka-yoke | The eco-strategy can be used, but need more consideration to optimize the product life, optimize product function, and minimize environmental waste in the specification and concept phase. Chosen material can be finalized during prototyping. |
| 29 | (Kurdve, 2018) | Sweden | Assembly-line work instruction in digital manner with fault-proof safety & quality | Poka-yoke, standardized work instruction and using ready-assembly materials became solutions at Husmuttern (wood-ware factory) although there is digital support available, but it does not fit with workers' skills at wood-ware company. |
| 30 | (Schaede et al., 2018) | Germany | Decision tree of CNC program with product parameters | CNC is programmed for automatic with a limited parameter. Decision tree is used to determine the best procedure. Example implementation was presented, proving beneficial of automated CNC program. |
| 31 | (M. Kumar et al., 2018) | India | Adding real time production data as poka-yoke system | PLCs are equipped with servers for real-time fabrication data to ensure 100% inspection is carried out and sent to management. This is a poka-yoke method, so that operators cannot take a short-cut in production. |
| 32 | (Erdogan et al., 2017) | USA | Measure kaizen effectiveness in the wood industry | Provide the latest views on the use of Kaizen and other improvement opportunities while staying focused on quality, safety, fault-proof and waste. |
| 33 | (Lemahieu et al., 2017) | USA | Lean in education | Highlighted lean in educational environment and delivering more efficient education and training. |
| 34 | (Tezel & Aziz, 2017) | UK | Visual-management (VM) system in England construction project | Identify beneficial of Visual-management system for a transportation construction project. Potential of poka-yoke system for quality inspection and worker safety. |
| 35 | (B. Kumar & Kumar, 2017) | India | Poka yoke on needle roller bearing | Poka yoke implementation has decreased a missing needle and obtained maximum efficient bearing. |
| 36 | (Che-Ani MN. et al., 2017) | Malaysia | Quality in process production | Quality has improved and ensured economic benefit by poka-yoke. |
| 37 | (Ardi & Abdurrahman, 2017) | Indonesia | Oxygen sensor machine functiona-lity | Increase efficiency check of oxygen sensor machine by poka yoke system. Rating errors reduced by 0.14% and MOR hit 90% target. |
| 38 | (Hudori et al., 2017) | Indonesia | Pallet package information at shipping dept | Poka yoke implementation for pallet package information. |
| 39 | (Rojo Abollado et al., 2017) | UK | Optimize business process and change the information systems to support evolving of the business. | Overview of benefits that the implementation of digital workflow is doable in an aerospace company, along with detailed challenges of both digital workflows and human factor risks. |
| 40 | (Bici et al., 2017) | Italy | Computer-aided-tolerancing-and-inspection | Automatic measurement through specific algorithms is useful in guaranteeing measurement results involving many samples. |
| 41 | (Isnain & Karningsih, 2016) | Indonesia | Car body parts manufacturing | Implement Poka Yoke sensors at a press machine and finish wrapping. |
| 42 | (Alghozali et al., 2016) | Malaysia | Vending machine product quality | Quality improvement in vending machine services by adopting the poka-yoke approach, adding date-based alarm warnings. |

| | | | | |
|---|---|---|---|---|
| 43 | (Thareja, 2016) | India | Real life or common use exemplars | By citing various tools for correction, error proofing (poka yoke) of the processes is done. |
| 44 | (Fauzan et al., 2016) | Indonesia | Printing processing with minimizing waste defect | Improvement suggestions were made as well as a poka yoke system as an effort to minimize waste defect. |
| 45 | (D. Antonelli & Stadnicka, 2016) | Italy | Mistake-proof solution by Fuzzy logic for: 1. Welding spot 2. Kitting process 3. Roller bearing seals | Propose a package to get the most suitable solution by using fuzzy-logic on KPI criteria. |
| 46 | (Tak & Wagh, 2015) | India | Poka-yoke on punching machine | Problems can be managed by poka-yoke. |
| 47 | (Singh & Singh, 2015) | India | Continuous improvement of North India manufacturing | Significantly increased OEE reached 3.01%. |
| 48 | (Shrigadi et al. 2015) | India | Using a sensor on a particular place, then it can prevent mixing of different casting on a process line. | If there is an incorrect casting, the sensor gives an alarm and the conveyor stops, so the operator changes the wrong one. |
| 49 | (Dario Antonelli & Astanin, 2015) | Italy | Augmented-Reality (AR) to improve welding quality | Using AR devices displayed welding point data. |
| 50 | (Lazarevic et al., 2019) | Serbia | Literature review of Poka Yoke, 211 manuscripts with 50 examples | Poka-yoke's new approach is to recognize existing gaps and describe using experience in the field. |

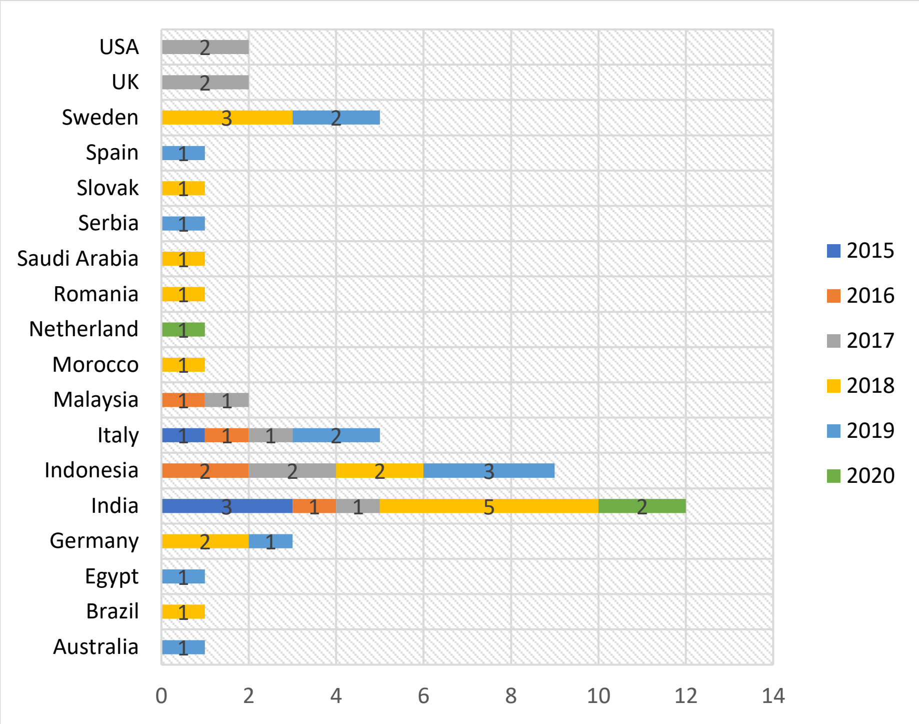


*Figure 4 Country of author*

### 3.1. Brief Results Based on Country

Around a quarter of the collected articles are published by authors from India as seen in Figure 4. There are also authors from many European nations as well as Asia followed by the US, Australia, and Africa. This representation of authors' countries shows that a poka-yoke idea is spread all over the nations, see Table 2 that maps all articles and Figure 4.

### 3.2. Review on Poka-yoke Type

Various articles & researchers on mapping all articles of Table 2 are divided based-on five poka-yoke types as shown in Table 3.

*Table 3. Poka-yoke type in respective articles*

| Poka-yoke type | Article Author | Sum |
|---|---|---|
| Electronic | (Muharam & Latif, 2019), (Putri & Handayani, 2019), (Saputra et al., 2019), (Vinayagasundaram, R. Velmurugan, 2018), (Dawood et al., 2018), (Prayogi et al., 2018), (Ardi et al., 2018; Ardi & Abdurrahman, 2017), (Isnain & Karningsih, 2016), (Alghozali et al., 2016), (Tak & Wagh, 2015), (Shrigadi et al., 2015). | 12 |
| Mechanical | (Dahivale & Lokhande, 2020), (Selvam & Loganathan, 2019), (Attia et al., 2019), (Soni & Yadav, 2018), (Sundaramali et al., 2018), (B. Kumar & Kumar, 2017), | 7 |

| | | |
|---|---|---|
| | (Che-Ani MN. et al., 2017) | |
| Mix Mech-Elect | (Rubio-Romero & Pardo, 2019), (Lilja, 2018), (Fauzan et al., 2016) | 3 |
| IT / Software | (Hoellthaler et al., 2019), (Ahmed et al., 2019), (Qeshmy et al., 2019), (Pötters et al., 2018), (Kurdve et al., 2018), (Schaede et al., 2018), (M. Kumar et al., 2018), (Tezel & Aziz, 2017), (Hudori et al., 2017), (Rojo Abollado et al., 2017), (Bici et al., 2017), (D. Antonelli & Stadnicka, 2016), (Dario Antonelli & Astanin, 2015) | 13 |
| Organizational | (Solaimani & Sedighi, 2020), (Romero et al., 2019), (Rösiö et al., 2019), (D. Antonelli & Stadnicka, 2019), (Bajjou & Chafi, 2018), (Satolo et al., 2018), (S. Kumar et al., 2018), (Gavriluţă et al., 2018), (Malega, 2018), (Kurdve, 2018), (Erdogan et al., 2017), (Lemahieu et al., 2017), (Thareja, 2016), (Singh & Singh, 2015), (Lazarevic et al., 2019) | 15 |

Organizational, as a category, includes methods, protocols, procedures, or an IT / Software concept which is a recent advanced tool, i.e. a device connected to the server database, remote control access, control system, and another computerized approaching. The Electronics type, for instance, includes sensors, lights, electronic signs. Mechanical includes stoppers, railing fences, bolts/nuts, etc. Mix Electronic and Mechanical is sensors that are connected to mechanical actions.

There are many different tools for respective purposes. However, the poka-yoke techniques have various names and they can be overlapped with each other. Particular tools may have different implementation proposed by various researchers or different industries. Many of these tools are used in conjunction with each other like visual control (andon) (Dawood et al., 2018) and automation with a human touch (jidoka) (Romero et al., 2019) as a poka-yoke tool.

Results in Table 3 show that 15 articles are categorized as organizational because they did not specify actual implementation of the tool. Furthermore, they are part of lean improvement strategy instead of poka-yoke alone. Others are elaborated more in the next section based on the industry type and local or particular region condition.

### 3.3. Review on Industrial Type

The empirical study of poka-yoke approaching is grouped into several categories. This includes common industries as the specified or not specific industries mentioned in the article. There is also Service and Education under one group, and so on, as shown in Figure 5. Most of the research took place in the automotive industry, about 20% of the collected articles, then the machinery industry 16%. SME is only 2% while there are plenty of articles nowadays about small and medium enterprise industries, but very few about poka-yoke.

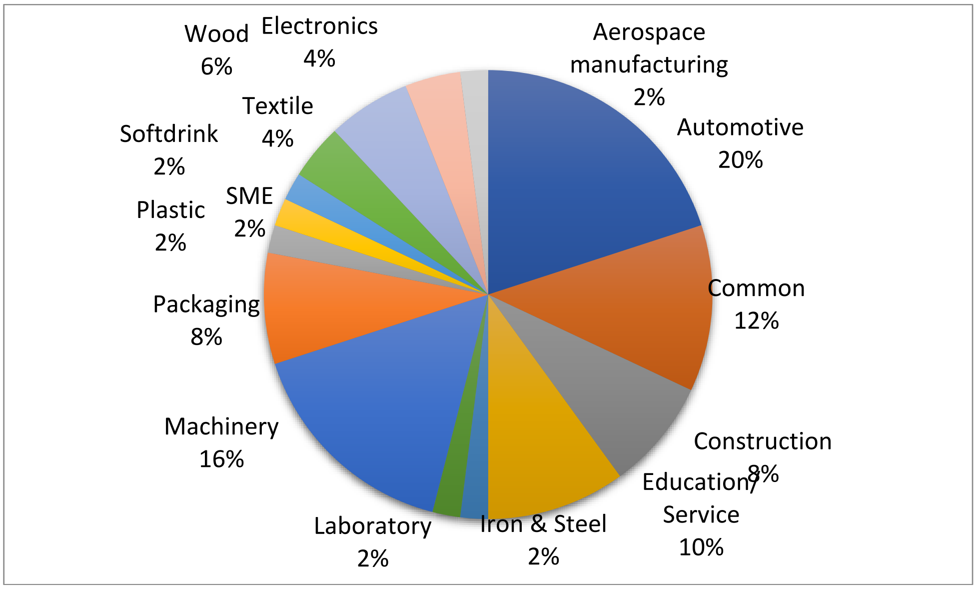


*Figure 5 Industry type*

*Table 4. Poka-Yoke type versus Researcher's Country*

| Country | Electronic | IT / Software | Mechanical | Mech & Elect. | Organiza tional | Total |
|---|---|---|---|---|---|---|
| Australia | | 1 | | | | 1 |
| Brazil | | | | | 1 | 1 |
| Egypt | | | 1 | | | 1 |
| Germany | | 3 | | | | 3 |
| India | 3 | 1 | 5 | | 3 | 12 |
| Indonesia | 7 | 1 | | 1 | | 9 |
| Italy | | 3 | | | 2 | 5 |
| Malaysia | 1 | | 1 | | | 2 |
| Morocco | | | | | 1 | 1 |
| Netherland | | | | | 1 | 1 |
| Romania | | | | | 1 | 1 |
| KSA | 1 | | | | | 1 |
| Serbia | | | | | 1 | 1 |
| Slovak | | | | | 1 | 1 |
| Spain | | | | 1 | | 1 |
| Sweden | | 2 | | 1 | 2 | 5 |
| UK | | 2 | | | | 2 |
| USA | | | | | 2 | 2 |
| Grand Total | 12 | 13 | 7 | 3 | 15 | 50 |

As per history that a poka-yoke tool was started in the automotive industry, it is not surprising that poka-yoke articles are mostly released from automotive industries with 20% out of 50 articles, see Figure 5. It comes with various poka-yoke types, such as electronic sensors (Prayogi et al., 2018), a photo-electric detector (Ardi & Abdurrahman, 2017), a proximity sensor & push button (Ardi et al., 2018), a sensor on a pressing machine (Isnain & Karningsih, 2016), a metal clip interlock (Tak & Wagh, 2015), and a sensor for casting (Shrigadi et al., 2015). Also, mechanical poka-yoke like different part dimensions & color code (Che-Ani MN. et al., 2017), IT poka-yoke with computer visualization (Qeshmy et al., 2019), and organizational poka-yoke with developing model (Rösiö et al., 2019) and introducing volume flexibility, product flexibility and process flexibility (Singh & Singh, 2015).

Poka-yoke approaching in service & education articles are mostly started from conceptual until implementation, i.e. developing lean laboratory (Gavriluță et al., 2018), systematic poka yoke implementation (Lazarevic et al., 2019), lean for education (Lemahieu et al., 2017), shop floor simulation (Pötters et al., 2018), and warning sign of vending service (Alghozali et al., 2016). Besides the automotive industry as originator, this poka-yoke is also suitable to be applied in the education and service area.

Looking at the construction sector, poka-yoke is implemented to cope with safety issues as PPE (Personal Protective Equipment) (Solaimani & Sedighi, 2020) including a warning sign, reflective railing & RFID tag (Rubio-Romero & Pardo, 2019) and utilize information technologies (IT) in inspection and safety (Tezel & Aziz, 2017). However, there is irony from survey results in the construction sector where most of the respondents are not familiar with a poka-yoke method, about 68% out of 330 valid responses, even though the personal protective equipment (PPE) is a poka-yoke tool in safety (Bajjou & Chafi, 2018).

### 3.4. Review on Research Place and Country

In general, the relationship between mistake-proofing implementation and organization culture is bond to one another (Satolo et al., 2018). Different countries have different cultures, different labor capabilities, local industry policy, education, etc. That is the reason the mistake-proof tools vary significantly among the nations since they are developed based on the appropriate and specific approaching of respective local requirements, see Fig. 3 and Table 5.

There is a factory in India that has poka-yoke approaching of engraved marking on scrap & disposal just to prevent someone sell the rejected ones to the black market (Sundaramali et al., 2018). For sure, this will not be happening in a developed country like the UK or Australia. On the other hand, there is a poka-yoke idea in a European factory to recognize a welding spot by using augmented reality (Dario Antonelli & Astanin, 2015), which is for another country. This idea is costly and too much in terms of saving cost of optimization.

Regardless of industry type or country, the poka-yoke tool is generally part of lean manufacturing to optimize and eliminate waste. The lean will make organizations more efficient and effective, especially related to quality, reliability, flexibility, innovation and cost and ultimately achieving organizational goals (Satolo et al., 2018).

Facing the challenging circumstance during the Covid-19 outbreak, and raising concern about medical equipment industries, it can be an exciting future research concerning lean manufacturing as well as poka-yoke approaching.

### 3.5. Novel Poka-yoke with I4.0 Approaching

Poka-yoke helps operators to avoid mistakes. Regardless of what kind of technology is being used, the goal is to detect and eliminate abnormal conditions that lead to the prevention of product defects. This can be a sort of sequence forced on the execution process and which stops when there is an error. Also, the same is done for I4.0 implementation.

Sophisticated technology at the moment, like auto-identification system that can ensure correct identification and digitalized product-ID, allows to retrieve components and identify incorrect ones (Mayr et al., 2018). It can be artificial intelligence (Mayr et al., 2018) that can automatically be adjusted to ensure optimal product quality. There are also augmented reality head-mounted displays to improve quality inspection (D. Antonelli & Stadnicka, 2016; Dario Antonelli & Astanin, 2015; Qeshmy et al., 2019), and RFID-readers can be used for the safety barrier of contractor workers (Rubio-Romero & Pardo, 2019).

As a result of reviewing relevant literature, a simple matrix is shown in Table 5 below figuring out I4.0 methods that can be utilized or support the novel poka-yoke approaching.

*Table 5. Possible I4.0 tools versus Poka-Yoke (Mayr et al., 2018)*

| Industry 4.0 Tools | Poka yoke |
|---|---|
| Human-computer interaction | √ |
| Virtual representation (e.g. VR, AR) | √ |
| Auto Identification | √ |
| Digital object memory | √ |
| Cloud | √ |
| Real-time | √ |
| Big data | √ |
| Artificial Intelligent | √ |

Accordingly, several articles particularly relevant with the idea of I4.0 tools are collected and summarized in Table 6 below. Mostly, those are categorized under the IT/Software poka-yoke type (see Table 3). There are usages of information technology for pallet information spreadsheet that can avoid mistyping during data entry (Hudori et al., 2017), Computer Aided Tolerancing & Inspection (CAT&I) to improve inspection (Bici et al., 2017), implementation of digital workflow in aerospace manufacturing that removes many human errors (Rojo Abollado et al., 2017) and digitalization in making a prototype of building wood modules (Kurdve et al., 2018).

Less satisfactory results occur when the I4.0 technology itself is not sufficiently mature or not suitable with the chosen industry, for instance, the augmented reality for welding spot inspection (Dario Antonelli & Astanin, 2015) and for managing errors caused by the human on the assembly line of automotive industry (Qeshmy et al., 2019). It can enhance the quality of manufacture; however, it needs further study for the overall process and cost constraint.

Cloud computing is introduced for an electronic industry with real-time production data working as a poka-yoke, so there is no chance to bypass the system (M. Kumar et al., 2018).

*Table 6 Novel Poka-Yoke with I4.0 Approaching*

| Researcher | Brief Description |
|---|---|
| (Hoellthaler et al., 2019), Germany | Digitalization of various methods and tools (including Poka-Yoke) will look forward as Industry 4.0 concepts. |
| (Ahmed et al., 2019), Australia | SVPD (Smart Virtual Product Development) enhances quality and time as I4.0 concepts, Poka-yoke is one of the enablers. |
| (Qeshmy et al., 2019), Sweden | Design Augmented Reality and Artificial Intelligent to present any error occur and avoid wrong choices. |
| (Pötters et al., 2018), Germany | Develop a model with shop floor simulation. This includes 5S, Poka Yoke, etc. |
| (Kurdve et al., 2018), Sweden | Develop a system prototype for eco-friendly building modules including fault-proofing (poka-yoke). |
| (Schaede et al., 2018), Germany | New integrated CNC (Computer Numeric Control) presented a promising human-error-free solution. |
| (M. Kumar et al., 2018), India | Cloud computerization for manufacture, particularly SME in India. Poka-yoke is used for 100% inspection. |
| (Tezel & Aziz, 2017), UK | The IT usage replaces conventional systems in the construction sector including a poka-yoke system for inspection and worker safety. |
| (Hudori et al., 2017), Indonesia | Poka-yoke method is implemented in software application: 1) Avoid errors or mistyping during data entry, 2) Warning, 3) The same template as earlier design that the operator has been familiar with to reduce misunderstanding, 4) Time saving, no manual entry. |
| (Rojo Abollado et al., 2017), UK | Digital workflow systems eliminate human errors, and save time. This system can overcome the actions that are late or negate other tasks. |
| (Bici et al., 2017), Italy | CAT&I (Computer Aided Tolerancing & Inspection) very useful in following:<br>• Avoiding errors of measurement points.<br>• Shape deviation analysis relevant, e.g. plastic shrinkage. |
| (D. Antonelli & Stadnicka, 2016), Italy | Propose a Poka-Yoke system to assist industrial problem solving by applying fuzzy logic.<br>The mistake is detected during a production process of<br>1. Welding spot<br>2. Kitting process<br>3. Roller bearing seals. |
| (Dario Antonelli & Astanin, 2015), Italy | Sophisticated tool (Augmented-reality) is applied to improve quality by error-free. |

Introducing I4.0 technologies for novel poka-yoke tools depends on several factors, i.e. usability, selective data, end-user acceptance, ethical, regional requirements, and cost. The novel poka-yoke tools should be well-considered as part of improvements.

The presented novel poka-yoke in Table 6 is not a single tool for cost reduction. This should be part of lean manufacturing, which is a more complex solution. If I4.0 facility is implemented as "nice-to-have" solutions, it can be ended with unsatisfactory results.

Based on reviewed articles, most of them try to develop a tool in conjunction with others to enhance results. Strategically, every concept can be aligned with lean. And actually there are a lot of ways for improvement like Condition-based monitoring that are integrated with a Maintenance database system, remote visual management, cloud computing, etc. (Mayr et al., 2018)

Based on organizational practices, lean tools that can be adopted successfully in a common industry are: standardization, control, training / learning, team-based organization, employee empowerment, adaptability, reward system, belief, commitment, communication, work methods, etc. (Lazarevic et al., 2019).

## 4. Conclusion

Implementation of I4.0 concept as a novel poka-yoke tool is an encouraged part of lean strategy. As for I4.0 perspective, everything is digital; business models, production systems, machines, operators, products and services. However, this must consider many factors, i.e. respective regional condition, social aspect, regulation and internal organization requirement with regard to business process and cost-effectiveness and the most important is its functionality that appropriates with a respective industry. Otherwise, it will undoubtedly end in dissatisfaction. There is a rule of thumb that the industry needs to measure their efforts of poka-yoke implementation as performance measurement. Organizations need to conduct the right measures and then make encouragements if there is a wrong direction of chosen approaching. However, that information is hard to get, and only specific articles provide measurement values. For future research, production effectivity metrics need to be developed to justify the performance value before poka-yoke approaching against post-implementation.

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