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Evaluation Of Effectiveness And Acceptability Of Automated Testing System For Industrial Proximity Sensors: Technology Adoption

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Abstract- *This study examined the effectiveness and acceptability of an automated testing system specifically designed for industrial proximity sensors, focusing on accurately identifying PNP and NPN types. The system was developed to improve safety and efficiency in industrial automation by providing quick, user-friendly identification of sensor types, essential for correct load connection arrangements in automation systems. By applying a test voltage and monitoring current flow, the system identified PNP sensors, which allow current to flow from the positive supply to the load, and NPN sensors, which direct current from the load to the negative supply. The study evaluated the system's performance, serviceability, and aesthetics using the Technology Acceptance Model (TAM), which included perceived usefulness, ease of use, and actual usage. Rated highly effective and acceptable by mechatronics enthusiasts and instructors, with an effectiveness mean of 4.91 and acceptability mean of 4.86, the system demonstrated reliability in maintenance and as a valuable educational tool in automation.*

Keywords: Technology Adoption, Safety, Industrial Proximity Sensor, PNP and NPN

1. Introduction

A proximity sensor could identify objects nearby even when there was no physical touch (Zhang et al., 2022). The object being sensed was commonly referred to as the proximity sensor's target. Different objectives for proximity sensors required different sensors. For example, an inductive proximity sensor always required a metal target (Zangl et al., 2010); on the other hand, a photoelectric or capacitive proximity sensor could function with a plastic target (Zhang et al., 2022). In a PNP sensor, the PNP transistor operated in a manner that gave a positive output. When the sensor identified an object, the current flowed from the emitter to the base terminal, and the positive base voltage was activated in the system. This type of configuration was known as a sourcing configuration, where the sensor provided current to the load, such as a relay or controller (Mmldigi, 2024). Based on their output type, proximity sensors were divided into two primary categories: NPN and PNP (Fruett et al., 1999). An active LOW output was provided by NPN proximity sensors, which indicated that the sensor's output was connected to the ground when an object entered its detection range. ‘Sinking’ sensor was another name for this kind of sensor (Osadcuks et al., 2014). An active HIGH output was provided by PNP proximity sensors, and the sensor's output was linked to +24V when an object entered its detection range. This was recognized by the device as a logic HIGH signal when connected to a PLC input. The term "sourcing" was another name for PNP proximity sensors. Since proximity sensors had different electrical characteristics and output signals, there was no easy way to determine the type of sensor being used in an industrial setting (Osadcuks et al., 2014). A tool used to test the functionality of proximity sensors was called a proximity sensor tester. Capacitive touch sensors could be tested using some models of proximity sensor testers. In general, a proximity sensor tester was a useful tool for anyone who needed to confirm that proximity sensors in their machinery were operating correctly (Zangl et al., 2010). Several models of proximity sensor testers were already available in the market. Its operation mode could detect if the output signal of a sensor was NPN or PNP. The problem was that this tester was electronically made and difficult to repair (Naelga & Chavez, 2017). Thus, to address these problems, the researcher developed an Automated

Polarity Testing System for Industrial Proximity Sensor: Technology Adoption. This study aimed to develop an automated testing system for industrial proximity sensors that could accurately identify PNP and NPN types. The proposed testing system was designed to be user-friendly and able to quickly and accurately determine the type of sensor, which would help improve the efficiency and safety of industrial automation systems.

1.1 Objectives

This study aims to evaluate the effectiveness and acceptability of the developed automated testing system for industrial proximity sensors across several dimensions: performance, features, serviceability, and aesthetics (Chavez, 2023). Additionally, the level of acceptability of the system, as perceived by respondent groups, is assessed based on Technology Adoption Management criteria, including perceived usefulness, perceived ease of use, behavioral intention to use, and actual usage (Davis, 1989).

2. Methodology

A descriptive research method was used in this study, designed to observe and identify attributes of a specific phenomenon (Creswell, 2013). The study was conducted at Cebu Technological University – Main Campus in Cebu City, Philippines, targeting 25 instructors and 25 mechatronics enthusiasts. Instructors were those teaching at CTU-Main Campus, while mechatronics enthusiasts were individuals with a strong interest in the field. A researcher-made questionnaire, validated by three experts (one from industry, one from TESDA, and one from academia) (Chavez, 2022). This instrument assesses the acceptability and effectiveness of the Developed Automated Polarity Testing System for Industrial Proximity Sensors. The researcher obtained consent from the Campus Director's office to conduct the study.

2.1 Framework of the study

This study explores the effectiveness and acceptability of an automated testing system for industrial proximity sensors. At its core, the framework examines the Industrial Proximity Sensor technology, which is commonly used in industrial environments to detect the presence or distance of objects, contributing to automation and safety.

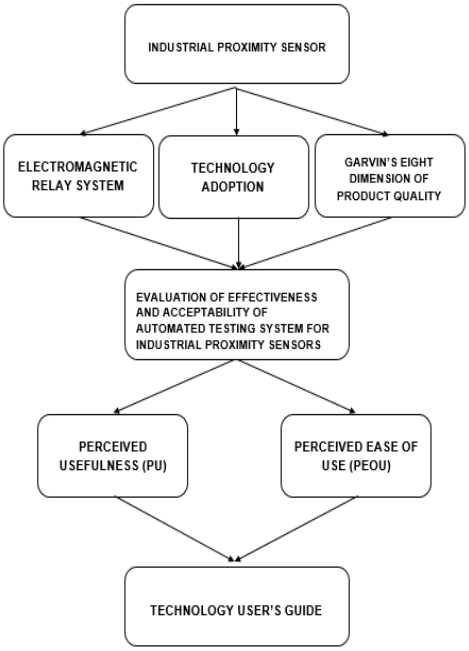

Figure 1: Framework of the study

The study examines the Electromagnetic Relay System, Technology Adoption, and Garvin's Eight Dimensions of Product Quality to evaluate an automated testing system for proximity sensors (Garvin, 1987). The relay system is essential for sensor operation or testing, while technology adoption focuses on factors influencing the system's acceptance in industry. Garvin's dimensions assess sensor quality, including performance and durability. Central to this study is assessing the system's effectiveness and acceptability, using constructs from the Technology Acceptance Model (TAM): Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). The study results in a Technology User's Guide to aid users in applying the system effectively, supported by Garvin's quality dimensions and Davis's TAM model.

3. Result and Discussion

3.1. Level of Effectiveness Based on the Functionality of the Developed Automated Polarity Testing System for Industrial Proximity Sensor

The effectiveness of the developed Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption as perceived by the chosen experts as to its Performance, Features, Serviceability, and Aesthetics (Davis, 1993).

Performance

The first to be determined in the survey was the performance of the prototype (Armstrong (2002). The most common performances observed during the utilization of the machine are identified. Furthermore, all these performances were carefully observed through repeated simulation and testing and validated through survey (Namoco, 2022). The first performance identified was "Can determine PNP type sensor," with a rated mean of 5. Second was "Can determine NPN type sensor" with a rated mean of 5. Third was "It has buzzer that will energize during detection," with a rated mean of 5. Lastly, "It has an indicator light that will energize during detection," with a rated mean of 5.

Table 1: Level of Effectiveness as to Performance

Performance	*Instructor*	*Mechatronics Enthusiast*	*Average Weighted Mean*	*VD*
Can determine PNP type sensor	5	5	5	HE
Can determine NPN type sensor	5	5	5	HE
It has a buzzer that will energize During detection	5	5	5	HE
It has an indicator light will energize during detection	5	5	5	HE
Total Average Weighted Mean			**5**	**HE**

Legend: *HE – Highly Effective; E – Effective; ME – Moderately Effective; LE – Less Effective; NE – Not Effective; VD – Verbal Description*

Table 1 also shows that the chosen respondents rated **highly effective,** which means that the Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption was considered capable of producing a result in terms of performance.

Features

The second to be determined in the survey was the features of the prototype. Feature is another very important aspect of any product as this is the customer basis before purchasing any machine. The features identified are the most common functions utilized by the machine being developed (Pepito, 2023). The survey result and the statistical interpretation result are shown in Table 5. "It has light indicator during detection" with a rated mean of 5, "It can identify PNP sensor" with a rated mean of 4.98, "It can identify NPN sensor" with a rated mean of 5, "User-friendly testing system industrial proximity sensor" with a rated mean of 4.8, The device has an average weighted mean of 4.95. All these ratings on features have a common verbal description result of **"Highly Effective."**

Table 2: Level of Effectiveness as to Features

Features	*Instructor*	*Mechatronics Enthusiast*	*Average Weighted Mean*	*VD*
It has light indicator detection	5	5	5	HE
It can identify PNP sensor	5	4.96	4.98	HE
It can identify NPN sensor	5	5	5	HE
User-friendly testing system industrial proximity sensor	4.8	4.8	4.8	HE
Total Average Weighted Mean			**4.95**	**HE**

The Table also shows that the respondents rated it **highly effective:** this means that the Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption was considered to be practical to use in the field in terms of features.

Serviceability

Another feature of the machine that is being rated is the effectivity level of serviceability. The tabulated summary of survey results and statistical data analysis summary are shown in Table 3. "Easy to

maintain" has a weighted mean of 4.86, "Easy to replace components in circuit board" has a weighted mean of 4.8, "Easy to troubleshoot circuit design" has a weighted mean of 4.88, and "Availability of spare parts" has a weighted mean of 4.96. It appears that each of the identified serviceability factor has a common verbal description result in which it is labeled as highly effective.

Table 3: Level of Effectiveness as to Serviceability

Serviceability	*Instructor*	*Mechatronics Enthusiast*	*Average Weighted Mean*	*VD*
Easy to maintain	4.88	4.84	4.86	HE
Easy to replace components in circuit board	4.8	4.8	4.8	HE
Easy to troubleshoot circuit design	4.96	4.8	4.88	HE
Availability of spare-parts	5	4.92	4.96	HE
Total Average Weighted Mean			**4.87**	**HE**

Serviceability has an average weighted mean of 4.87. This means that the Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption was still considered to be easy to repair or to maintain by the users.

Aesthetics

The factor "A lightweight design for testing system industrial proximity sensor" has a weighted mean of 4.78, "A compact design for testing system industrial proximity sensor" has a weighted mean of 4.88, "A decent cable management for testing system industrial proximity sensor" has a weighted mean of 4.82 and "A LED indicator for testing system industrial proximity sensor" has a weighted mean of 4.9. Moreover, the identified aesthetics factor still has a common verbal description result of highly effective, and the average weighted mean is 4.85. This means that the Aesthetic factor of the Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption was commendable

Table 4: Level of Effectiveness as to Aesthetics

Aesthetics	*Instructor*	*Mechatronics Enthusiast*	*Average Weighted Mean*	*VD*
A lightweight design for testing system industrial proximity sensor.	4.64	4.92	4.78	HE
A compact design for testing system industrial proximity sensor.	4.84	4.92	4.88	HE
A decent cable management for testing system industrial proximity sensor.	4.8	4.84	4.82	HE
A LED indicator for testing system industrial proximity sensor.	4.84	4.96	4.9	HE
Total Average Weighted Mean			**4.85**	**HE**

Summary of the Effectiveness in the Development of the Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption

Shown in Table 5 is the summary of responses on the effectiveness of the development of the Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption.

Table 5: Overall Summary of Effectiveness

Criteria	*Instructor*	*Mechatronics Enthusiast*	*Average Weighted Mean*	*VD*
Performance	5	5	5	HE
Features	4.95	4.95	4.95	HE
Serviceability	4.84	4.91	4.87	HE
Aesthetics	4.91	4.78	4.85	HE
Total Average Weighted Mean	**4.92**	**4.91**	**4.91**	**HE**

It also included the summary of statistical analysis results in each criterion. The result was generated with the use of the mini-tab statistical software and was interpreted based on the condition of effectiveness criteria. The data shows that the overall average weighted mean of the machine, both from mechatronics enthusiast and the instructor is **4.91**, which falls under the verbal description of **"Highly Effective,"** and the standard deviation is 0.09604. Thus, the overall effectiveness decision of the machine as to performance, features, serviceability, and aesthetics was ready for deployment in the actual field in order to help maintenance technicians during troubleshooting or during preventive maintenance in manufacturing plant. Also, it can be used by the instructor in their respective classes to demonstrate the function of proximity sensor to their students.

3.2. Level of Acceptability of Automated Testing System for Industrial Proximity Sensor Based on Technology Acceptance Model

The acceptability of the developed Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption as to Perceived Usefulness, Perceived Ease of Use, Behavioral Intention to Use and Actual Usage.

Perceived Usefulness

The first to be determined in the survey as to the level of acceptability was the perceived usefulness of the prototype. The identified are the most common usefulness observed during the utilization of the machine. Furthermore, all this usefulness was carefully observed through repeated simulation and testing and validated through surveys.

Table 6: Acceptability as to Perceived Usefulness

Perceived Usefulness	*Instructor*	*Mechatronics Enthusiast*	*Average Weighted Mean*	*VD*
Using the Automated Testing System for Industrial Proximity Sensor would increase the efficiency in testing the voltage polarity output of a proximity sensor.	4.88	4.84	4.86	SA
The Automated Testing System for Industrial Proximity Sensor displays the correct voltage polarity the output of a proximity sensor. Can Determine NPN type sensor	4.96	4.72	4.84	SA
It is easier to check the voltage polarity output of proximity sensor using Automated Polarity Testing System for Industrial Proximity Sensor.	4.8	4.76	4.78	SA
The Automated Polarity Testing system for Industrial Proximity Sensor would be useful for testing the output voltage of proximity sensor.	4.92	4.84	4.88	SA

Total Average Weighted Mean	**4.84**	**SA**

Legend: SA – Strongly Agree; A – Agree; N – Neutral; D-Disagree; SD – Strongly Disagree; VD – Verbal Description

The data shows that the chosen respondents, both mechatronics enthusiasts and instructors, rated a weighted mean of 4.84, which falls under the verbal description of "**Strongly Agree,"** and this means that the Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption can help maintenance technician in troubleshooting machines.

Perceived Ease of Use

The second to be determined in the survey was the perceived ease of use of the prototype. It is a very important aspect of any product as this is the customer basis before purchasing any machine. The survey result and the statistical interpretation result are shown in Table 7.

Table 7: Acceptability as to Perceived Ease of Use

Perceived Ease of Use	*Instructor*	*Mechatronics Enthusiast*	*Average Weighted Mean*	*VD*
It is easy for me in operating the Automated Polarity Testing System for Industrial Proximity Sensor.	4.96	4.96	4.96	SA
It is easy for me to find the voltage polarity output in identifying PNP proximity sensor by using the Automated Testing System for Industrial Proximity Sensor.	5	4.92	4.96	SA
It is easy for me to find the voltage polarity output in identifying NPN proximity sensor by using the Automated Testing System for Industrial Proximity Sensor.	4.8	4.92	4.86	SA
he Automated Testing System for Industrial Proximity Sensor is easy to use (user-friendly).	4.88	4.88	4.88	SA
Total Average Weighted Mean			**4.92**	**SA**

The Table also shows that the device has an average weighted mean of 4.92. All these ratings on features have a common verbal description result of **Highly Acceptable;** this means that the Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption was easy to operate or to use, and it can help users to identify the polarity output of a proximity sensor.

Behavioral Intention to Use

Another aspect of the machine that is being rated is the acceptability level of behavioral intention to use. The tabulated summary of survey results and statistical data analysis summary are shown in Table 8.

Table 8: Acceptability as to Behavioral Intention to Use

Behavioral Intention to Use	*Instructor*	*Mechatronics Enthusiast*	*Average Weighted Mean*	*VD*

I have a clear conception of the functionality of the Automated Testing System for Industrial Proximity Sensor.	4.76	4.88	4.82	SA
I feel confident that the Automated Testing System for Industrial Proximity Sensor is reliable.	4.72	4.84	4.78	SA
I believe it is risk-free to use the Automated Testing System for Industrial Proximity Sensor.	5	4.68	4.84	SA
I feel confident that I can keep the Automated Testing System for Industrial Proximity Sensor under control.	4.84	4.8	4.82	SA
Total Average Weighted Mean			**4.82**	**SA**

Behavioral Intention to use has an average weighted mean of 4.82, the verbal description was strongly agreed. This means that the Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption was reliable in testing the polarity output of a proximity sensor and it can help users for a fast testing if the sensor is functional or not.

Actual Usage

The last aspect of the machine that is being rated is the acceptability level of Actual Usage. Based on the result the identified actual usage still has a common verbal description, which results in it being of highly acceptable, and the average weighted mean is 4.86. This means that the Actual Usage of the Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption is commendable and still considered to be **highly acceptable**. Further, it can give advantage to the user for easy troubleshooting and tracing of the polarity output of a proximity sensor.

Table 9: Acceptability as to Actual Usage

Actual Usage	*Instructor*	*Mechatronics Enthusiast*	*Average Weighted Mean*	*VD*
I am capable of using the Automated Testing System for Industrial Proximity Sensor.	5	4.92	4.96	SA
I have fun using the Automated Testing System for Industrial Proximity Sensor.	5	4.84	4.92	SA
Using the Automated Testing System for Industrial Proximity Sensor	4.76	4.88	4.82	SA

gives me an advantage over those who don't.				
Using the Automated Testing System for Industrial Proximity Sensor is a good idea.	4.64	4.84	4.74	SA
Total Average Weighted Mean			**4.86**	**SA**

Summary of the Acceptability in the Development of the Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption

Shown in Table 10 is the summary of responses on the acceptability in the development of the Automated Polarity Testing System for Industrial Proximity Sensor: Technology Adoption. It also included the summary of statistical analysis result in each criterion. The result was generated with the use of the mini-tab statistical software and was interpreted based on the condition of acceptability criteria.

Table 10: Overall Summary of Acceptability

Criteria	*Instructor*	*Mechatronics Enthusiast*	*Average Weighted Mean*	*VD*
Perceived Usefulness	4.79	4.89	4.84	SA
Perceived Ease of Use	4.92	4.91	4.92	SA
Behavioral Intention to Use	4.8	4.83	4.82	SA
Actual Usage	4.87	4.85	4.86	SA
Overall mean	4.85	4.88	**4.86**	**SA**

The data shows that the overall average weighted mean of the machine, both from mechatronics enthusiast and the instructor, is **4.86**, which falls under the verbal description of **"Highly Acceptable,"** and the standard Deviation is 0.09813. Thus, the overall acceptability decision of the machine as to perceived usefulness, perceived ease of use, behavioral intention to use, and actual usage was commendable. It can help users for reliable troubleshooting of the machine in terms of testing the polarity output of a proximity sensor, and also it can be used as instructional material for the instructor to their students.

4. Findings

The prototype can determine the polarity output of a proximity sensor with a weighted mean of 5 or equivalent to 100%. The respondents consist of 25 instructors and 25 mechatronic enthusiasts. Another aspect of the prototype is the features in which 99% of the respondents notify that the prototype was effective in determining the polarity output of a proximity sensor. In terms of serviceability, 97.4% indicate that the prototype is easy to maintain, the components in the circuit board were easy to replace, and 98.6% apprise that there are many available spare parts of the prototype. 98.2% of the respondents said that the prototype was capable producing results, and that it is practical to use in the actual field of automation to help the user determine precisely the polarity output of a proximity sensor.

As to the level of acceptability of the prototype based on the technology acceptance model instructor rated 4.88 or equivalent to 97.6%, and the mechatronics enthusiast rated 4.845 or 96.9%. 96.6% notified that using the developed polarity tester would increase the efficiency in testing the voltage output of a proximity sensor. 95.6% apprise that it is easier to check the voltage polarity of a proximity sensor. A clear conception of the functionality of the Automated Polarity Testing System for Industrial Proximity Sensor was rated 96.4%. The user will be confident of using the device because of its compact design. 96.8% believe that the prototype is risk-free from any electrocution for the reason that the device has a low voltage input. Using the Automated Polarity Testing System for Industrial Proximity Sensor was an advantage to those who don't.

5. Conclusion

Based on the data from the study, the developed Automated Polarity Testing System for Industrial Proximity Sensors is both highly effective and highly acceptable. The system received high ratings across

all evaluated dimensions: performance, features, serviceability, and aesthetics, with an overall effectiveness rating of 4.91. The results indicate the system reliably distinguishes PNP and NPN sensor types, offering essential functionalities such as light indicators and ease of use.

In terms of acceptability, the system was perceived as highly useful and user-friendly, with a total acceptability mean of 4.86. It received positive feedback from both instructors and mechatronics enthusiasts regarding perceived ease of use, behavioral intention, and actual usage, demonstrating its reliability for troubleshooting and teaching purposes. This suggests the system could enhance maintenance efficiency and serve as an effective instructional tool in automation fields.

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