Internet of Things (IoT) Application for Management in Automotive Parts Manufacturing

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Abstract*—Automotive parts manufacturing focuses on sustainable development manufacturing capabilities with future technology changes. Internet of Things (IoT) plays an important role in applying internet technology to machines and equipment in manufacturing processes for transformation towards Industry 4.0 as well as creating values added and higher competitive advantage for the sustainability of the industries. This research aims to study factors that influence decision-makers in selecting IoT applications for managing auto parts production and they consist of connectivity, telepresence, intelligence, security, and value including their fifteen sub-factors. In this research, The Fuzzy Analytic Network Process (FANP) is a Multiple Criteria Decision Making (MCDM) technique used to analyze, identify, and prioritize factors in selecting IoT applications for managing production processes. The questionnaire is designed based on the FANP technique to survey the importance of weight for each factor from executives of 88 auto parts manufacturers who authorize as the decision-makers for selecting IoT applications. The results have indicated that telepresence is the most important factor that will assist them in controlling production to guarantee that production capabilities meet the objective and connectivity is the second important factor that must ensure that IoT applications are compatible with their machinery and equipment can be controlled smoothly and precisely. Meanwhile, performance is the most important sub-factor and other sub-factors are ranked as functional orientation, data management, control, and compatibility respectively. Therefore, manufacturers can use this research as a criterion for selecting appropriate IoT applications for controlling their manufacturing for sustainable effectiveness.

Keywords*—*Internet of things; auto parts industry; FANP; MCDM; sustainable manufacturing

I. Introduction

The Internet of Things (IoT) is admitted as one of the most essential areas of future technology and is gaining various attention from several industries. IoT is considered a key driver for industries to transform industry 3.0 to industry 4.0 [1]. It is also crucial for integrating manufacturing processes for the fourth industrial revolution [2]. The gap between the physical and digital worlds can be bridged by synchronizing the flow of information with the physical flow for greater supply chain integration [3]. This is because IoTs devices play a crucial role in driving businesses to create superior connectivity and progressive operations to increase their agility [4]. It is an integration of interconnected sensing and communication technology that enables equipment, machines, sensors, robots, and automatic actuators [5]. IoT is determined into three groups: People to people, people to machine/things, Things/machine to things/machine, and Interacting through the internet [6]. The industrial internet of things is a concept based on the same principles as the IoT, but for connection machines in factories. The primary communication between machine-to-machine and automation based on the information exchanged between them [7]. Smart factory solutions are designed the enable sensors and connected edge devices to improve product quality and real-time factory operational efficiency. The potential to address the data captured and exchanged in real-time has multiplied [4]. Some devices are operating their functionality for progressive production, performance, and maintenance in the production [5] that can generate greater customer value through offered services. The efficacy can provide identifying, sensing, networking, and processing abilities for communicating with other devices and services through the internet.

Several organizations are searching for new technologies which can support their sustainable businesses [8] such as the Internet of Things (IoT), Big Data Analytics (BDA), Cloud Computing [5], and Blockchain (BC). Meanwhile, these new technologies can be used to support production and services in other sectors [9]. Besides, the mentioned technologies are currently applied in several industries for transforming towards Industry 4.0 which is a crucial industrial revolution in this century [10]. To improve supply chain structures and achieve sustainability, industry 4.0 becomes the most prominent solution in current manufacturing processes [11]. Therefore, industry 4.0 plays a critical role in bringing manufacturers to sustainable production [12]. Sustainable production covers important components such as production, process, and system which create value-added and sustainable growth for the business [13]. Therefore, this integration is a challenge for improving sustainable production in the future [14]. Moreover, Industry 4.0 also entails data exchange and autonomous systems, as well as manufacturing activities centered on the development of smart factories to respond to dynamic production [15]. Because the investment in IoT applications is expensive, decision-makers in selecting IoT applications in the auto parts production process confront a challenge in determining which relevant IoT apps should be chosen. Therefore, this study aims to answer this research question with the following objectives. 1) This research aims to study the influences of factors in selecting IoT applications in the auto parts industry, 2) the importance of each factor will be identified and prioritized, and 3) trends of decision-making for selecting IoT applications are studied for improving the management of the auto parts production. Thus, the first section of this article identifies factors that influence decision-making in selecting IoT applications by reviewing relevant literature. Subsequently, quantitative research is conducted by surveying decision-makers in the auto parts industry with a questionnaire developed based on the Fuzzy Analytical Network approach (FANP). The next section defines and formulas of FANP are introduced, and it can effectively identify and prioritize factors in selecting IoT applications for the auto parts production. Finally, the results of data analysis by FANP express and indicate important factors that influence decision-makers in selecting IoT applications for auto parts production.

II. Literature Review

A. Connectivity

Currently, the Internet is the interconnection hub of smart devices and can create an intelligent network throughout the value chain to machines, products, and systems [16]. This consequence is the connection and interaction between people and machines which leads to more interconnected production systems [17], the connection of physical devices and machines, and the integration of applications to the software or database [18]. The information was gathered through the IoTs to enhance the productivity of business processes [19]. Therefore, it is the industrial processes to connectivity technologies for monitoring the production activities, inventory management, sales management, and after-sales services. Compatibility is the connectivity and automation of collaboration activities [20]. and accessibility in entering the network while providing the general ability to generate data [6]. Data exchange is supported by different networks and data is gathered from networks connecting equipment, production line, and sensor network. Standardization is an important prerequisite in digitization. [21]. The connection of any object to the Internet could be one of the standardization challenges and the success of the development of interoperable. Standardization also enables the optimization between functionality, costs, and quality of applications and solutions. The key IoT infrastructures can help customers in industries to transform businesses and services successfully [22]. The combination of numerous sensors in wireless technologies can communicate with the Internet infrastructure and can collect information for different industrial applications. It is converting compatible data to interoperability between internet devices, appliances, and objects.

B. Telepresence

Telepresence can presentation where all employees can access their current operational status simultaneously, for convenient control and decision making by IoT applications. [21]. Thus, the services with the telepresence function would positively influence workers [23], and the performance of IoT devices in real-time from different locations at any time. Therefore, reliable telepresence helps consumers feel positive about their products and positive Internet experiences. The IoT System can improve management efficiency with more controllable and auditable management processes [24]. Synchronization of production systems between virtual and real systems depends on data from sensors and connected smart devices, and real-time data updates [25]. Connectivity automation of collaboration activities enables synchronization through IoT-enabled productivity [20]. It focuses on the synchronization of the production process in optimizing the production requirements [26]. Time and energy can be saved by using an internet device to synchronize things or products during the work process. IoT monitoring with dynamic system analysis and event processing integrates between device and business [20]. Communication between machines and connected machines provides information about the status of controlling or monitoring systems [27]. For example, the area of condition monitoring, predictive maintenance, estimating the remaining lifetime of the components, making decisions about urgent, short-term, and real-time actions [28]. Smart process monitoring is realized by connecting cloud computing and services the machine tools [29]. Internet of Things (IoT) dynamically controls and makes decisions, as well as the real-time monitoring and controlling of the manufacturing process [30]. The smart factory uses self-controlled machines and automated robots that have the module of adaptive intelligence to take necessary actions depending on pre-defined instructions [31]. It has an automatic device control system to continuously monitor performance in real-time anytime and anywhere. This data of smart factories will be available to humans or systems for the monitoring, prediction, and control of the production systems [32].

C. Intelligence

The intelligence of IoT is the capability to derive real-time data. The purpose of smart manufacturing into intelligence systems is to improve the positive production processes in all aspects [33]. Smart manufacturing information systems changed from digitization and networking to intelligence [34]. IoT applications must be embedded with intelligence to enhance devices that can monitor the environment, identify problems, communicate with each other, and potentially address problems without human assistance [35]. It more profoundly integrates manufacturing operations systems with communication, information, and intelligence technologies [36]. IoT devices are functional or personal assistants for organizations and are functions that control devices in real-time from different locations by connecting the internet devices of things to the employees [37]. Smart devices are focused on functional orientation, application, and analysis to be able to solve problems. The internet devices coordinate things, and function as personal assistants for the organization. Therefore, the service of this functional orientation will benefit employees. Challenges and applications of artificial intelligence are components of the concept of the Internet of Things. Relevant to Industry 4.0, it involves automation including artificial intelligence. The information system of smart manufacturing is based on the new technology of industrial artificial intelligence. Cloud Computing provides infrastructure, software, and platform as services [38]. Cloud computing and IoT are the main support technologies in Cloud manufacturing and can interact with each other in a cloud-based intelligent environment [39]. Therefore, cloud computing can continually access available data that requires manufacturing management applications and enables the effectiveness of processes.

D. Security

Security and privacy of sensitive data in Industrial IoT systems are necessary nowadays, and management trust is crucial for data security in IoT. [40]. Transparency, conflict of interests, data confidentiality, network security, and the safety of IoT devices are among the most important security and privacy problems. [41]. The security for industrial process measurement and control network and system security [42]. High-value industrial data can be harmed by a single click, potentially riskiness the entire process of industrial plants. Traceability and monitoring of systems are the results of real-time data management to prevent certain events or potential system failures [43]. As a result, higher-layer applications can avoid having to handle unneeded data and lower the danger of information privacy being compromised. Employees and businesses that share information between departments are protected by security, which encompasses information privacy, data management, and permission. [44]. It is the permission of employees and businesses when they communicate information, as well as a feature that allows an authorized user to search the database for specific information when needed. The ability to manage the information flow is known as data management. Information can be retrieved, integrated, and controlled using data management under the management service layer [43]. It is capable of handling large amounts of data and synchronizing operations in real-time.

E. Value

When connected devices can communicate with one another, the actual potential of the IoT for businesses may be completely realized. The connection of humans, parts, and systems creates self-guided, dynamic, real-time value-added interconnections across the value chain [45]. Several processes happen, and value is added to every process [46]. Improved product or service delivery, increased productivity, lower labor costs, lower energy usage, and a shorter build-to-order cycle are all examples of this benefit. There is also a need for Internet of Things integration in the operation of marketing activities, seasonal variations or market trends, and fluctuations in market demand or custom orders [28]. The benefits of the Internet of Things can be used to improve manufacturing processes and create new products. After receiving data from IoT devices, the organization can learn about some business concerns such as changes in client preferences or worker performance [34]. Similarly, The data, the convenience, and the ease with which it is collected and evaluated are the key drivers of this industrial revolution [47]. Using IoT devices or goods during the work process can help employees save time and energy [21]. [13]. It can also refer to services that help people manage their jobs more effectively and make quick judgments. The effectiveness of IoT enables stakeholders to make dynamic decisions based on real-time data [48]. It can manage the use of technology to fulfill company objectives [49]. The information could be utilized to assess different performance levels and provide statistical analysis reports. Data on machine tools will improve as a result of increased machine use, which can be used to improve overall performance [50].

TABLE I. INTERNET OF THINGS (IOT) APPLICATION WITH REFERENCES

Factors	Reference
Connectivity	[7], [18], [19], [20], [21], [22], [65], [66]
Telepresence	[21], [23], [25], [27], [28], [29], [30], [32], [43]
Intelligence	[24], [33], [34], [35], [36], [39], [53], [71]
Security	[40], [41], [42], [43], [44], [52], [69]
Value	[13], [21], [28], [34], [45], [46], [48], [50]

F. Factors Influence IoT Applications

IoT devices have been recognized as useful in a variety of situations and environments [51]. Furthermore, IoT could connect disparate networks while also addressing security concerns [52]. It is a technology and innovation that focuses on motion and environmental detection [53]. Therefore, the main purpose of IoT was to provide a that could accept, store, and transmit data over the Internet within computer devices including sensors, desktops, laptops, smartphones, and other electronic devices, some applications related to the IoT had provided value for consumers [54]. Moreover, these devices could potentially link to the Internet and keep track of personal and user data. The devices would then evaluate the data and make sensible recommendations to the users. From the literature review, IoT applications with references as the Table I and factors have been derived and reviewed to determine the factors that influence IoT applications for auto parts production as connectivity, telepresence, intelligence, security, and value which are shown in Fig. 1.

III. MATERIALS AND METHODS

A. Data Collection

This study was based on the quantitative research principle by using the survey method for data collection. The population of auto parts manufacturers came from the automotive institute and the institute identified that there were 720 auto parts firms. Subsequently, the sample size for this research was 88 samples as Yamane's formula [55]. The research tool in this study was a questionnaire that was developed based on factors of connectivity, telepresence, intelligence, security, and value as the framework shown in Fig. 1.

After the questionnaire was developed completely, the research distributed the questionnaire to 88 respondents sampled by snowball method who were the decision-makers in implementing IoT in automotive part manufacturers. At the beginning of this survey, five experts the auto parts manufacturers, which had deployed IoT applications in the auto parts production, were identified and called in for asking their permission to answer the questionnaire.

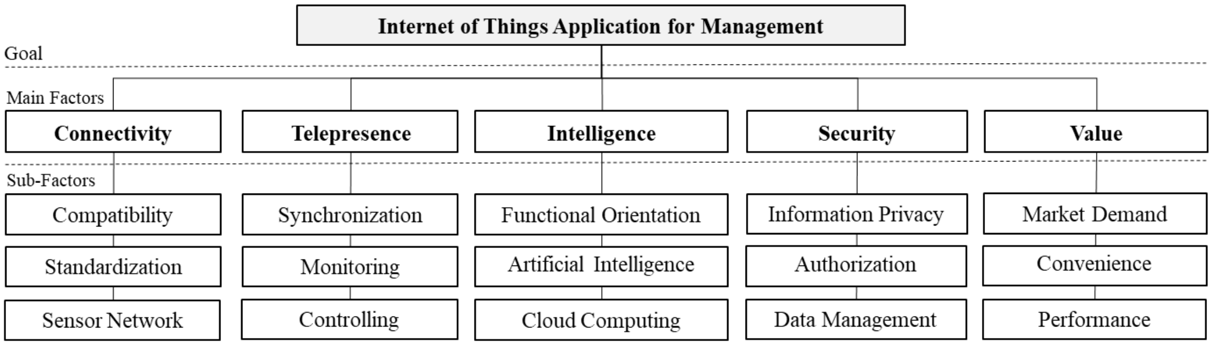

Fig. 1. Conceptual Framework of Internet of Things Application for Management.

B. Analytic Network Process

The analytic hierarchy process (AHP) is a well-known multiple criteria decision-making (MCDM) method that has been widely used in a variety of decision-making situations. The principle of AHP is to distinguish problems in a linear top-bottom format as a hierarchy. While the upper levels of the constructed hierarchy are independent of all lower levels, and the components in each level are likewise independent. However, some decision-making problems cannot be structured as a hierarchy, or some components have relations to other components in the structure. Thus, the analytic network process had been developed to address the mentioned problems of AHP and deal with dependencies between criteria and alternatives [57]. The components in the same level can be functionally dependent and the lower levels can reversely affect the upper level in each component. [58]. The advantages of ANP for considering dependencies between criteria and alternatives are listed as follows [59].

- The approach can deal with various, and complicated criteria.
- It supports decision-makers to build a decision-making model and to study relationships in the matrix form.
- It can evaluate both quantitative and qualitative criteria with the pairwise comparison technique to identify the importance of criteria.

Therefore, ANP is the appropriate MCDM approach than AHP for identifying and prioritizing factors that influence decision-makers in selecting IoT applications because the dependencies between each main factor and its sub-factors will be analyzed.

C. Fuzzy Analytic Network Process

1) Fuzzy set theory: To deal with situations involving uncertainty, imprecision, and vagueness, Zadeh (1965) created a fuzzy set theory. The capacity to represent ambiguous data is a major contribution of fuzzy set theory. [60]. The theory also permits mathematical operations and programming to be applied to the fuzzy domain. Generally, the fuzzy set is defined by a membership function, which represents the grade of any element x of X that has the partial membership to M. The value between zero and one determines the degree to which an element belongs to a set. So an element x belongs to $M, \mu_M(x) = 1$ and $\mu_M(x) = 0$ [56, 60, 61].

2) Triangular fuzzy number: A triangular fuzzy number (TFN) is presented as (l, m, u), where $l \leq m \leq u$. The membership function $\mu_M(x)$ of TFN is obtained by Equation (1).

$$\mu_M(x) = \begin{cases} (x-l)/(m-l) & l \leq x \leq m \\ (u-x)/(u-m) & m \leq x \leq u \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

The membership functions of triangular fuzzy numbers are used for the pairwise comparison of decision variables from "Very bad" to "Excellent", and the middle preference values between them. The membership functions of TFNs, $M_i = (m_{i1}, m_{i2}, m_{i3})$, where $i = 1,2, \cdots, n$ and m_{i1}, m_{i2}, m_{i3} are the lower, middle, and upper values of the fuzzy number M_i, respectively [56, 61]. According to the concept of extent analysis, each object is taken and extent analysis for each goal g_i is performed, respectively. Therefore, the m extent analysis values for each object are obtained as the following signs [61]:

$$M_{g_i}^1, M_{g_i}^2, \cdots, M_{g_i}^m, \; i=1,2,\cdots,n \tag{2}$$

where $M_{g1}^j (j = 1, 2, \ldots, m)$ are presented in triangular fuzzy numbers.

3) Fuzzy analytic network process: Fuzzy analytic network process (Fuzzy ANP) is a multiple criteria decision-making (MCDM) approach that uses both interdependences of criteria and inner dependences of criteria with the pairwise comparison matrix. The steps of Chang's (1996) extent analysis can be given as follows [61, 62]. The value of fuzzy synthetic extent for the i^{th} object is defined as:

$$S_i = \sum_{j=1}^{m} M_{gi}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j\right]^{-1} \tag{3}$$

To obtain $\sum_{j=1}^{m} M_{gi}^j$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that:

$$\sum_{j=1}^{m} M_{gi}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \tag{4}$$

And to obtain $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j\right]^{-1}$, perform the fuzzy addition operation of $M_{g_i}^j (j = 1,2, \ldots, m)$ values such that:

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (5)$$

Then the inverse of the vector in eq. (5) is calculated as follows:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right) \quad (6)$$

The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as:

$$V(M_2 \geq M_1) = \sup[\min(\mu_{M_1}(x), \mu_{M_2}(y)] \quad (7)$$

and can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = \begin{cases} 1 & \text{if } m_2 \geq m_1, \\ 0 & \text{if } l_1 \geq u_2, \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{otherwise} \end{cases} \quad (8)$$

The degree of possibility for a convex fuzzy number is greater than k convex fuzzy numbers $M_i (i = 1,2, \dots, k)$ that can be defined by:

$$V(M \geq M_1, M_2, \dots, M_k) = \min V(M \geq M_i), \quad i = 1, 2, \dots, k \quad (9)$$

Assume that:

$$d(S_i) = \min V(S_i \geq S_k), \quad k = 1, 2, \dots, n; k \neq i \quad (10)$$

Then the weights vector is calculated by:

$$W' = (d(S_1), d(S_2), \dots, d(S_n))^T \quad (11)$$

And weight vectors are normalized as follows.

$$W = (d(A_1), d(A_2), \dots, d(A_n))^T \quad (12)$$

Where W is a real number, and $A_i = (i = 1, 2, \dots n)$ are n elements.

IV. RESULTS

This paper, Internet of Things application is divided into five categories consisting of Connectivity, Telepresence, Intelligence, Security and Value. Each category contains several IoT applications for management which are shown in Fig. 1. This study proposes the Internet of Things application for management related to the auto parts manufacturers in Thailand. This section can be divided into six steps to evaluate the industry. The first step is to determine the Internet of Things framework of main factors and sub-factors, which is performed using a questionnaire survey that uses the fuzzy ANP approach to calculate the weights of the factors and sub-factors. The application is based on the methods outlined in the preceding part and is explained step by step, along with the outcomes.

Step 1. Determine the fuzzy scale for the important weight of factors and sub-factors from a decision-maker with the responsibility for the Internet of Things application management in a company. Choose appropriate linguistic variables for the relative weight of the factors as defined by Table II [61,72] prepare a pair-wise comparison to each factor from expert opinion by using the linguistic scale.

Step 2. Conduct the questionnaire survey for exploring internet of things application for management in practices by collecting data from 88 respondents in auto parts companies.

Step 3. Calculate the consistency ratio (CR) by Equation (13).

$$CR = \frac{CI}{RI} \quad (13)$$

When $CI = \frac{(\lambda_{max} - n)}{(n-1)}$ and $\lambda_{max} = \sum_{i=1}^{n}\left[\sum_{j=1}^{n} a_{ij} W_j\right]$. The CR value should be lower than 0.1 which means the weights are determined by decision-makers have consistency. If the CR value is greater than 0.1, it expresses those weights determined to have no consistency. Therefore, the research should review the evaluation of main factors and sub-factors in the first step.

Step 4. Calculate the average fuzzy evaluation matrix from the questionnaire survey and the local weights of the main factors and sub-factors as shown in Tables III to VIII.

Step 5. Calculate the inner dependence weights and the dependencies among the factors that are considered the main factors as shown in Table IX.

Step 6. Calculate the global weights of sub-factors by multiplying the local weights of the sub-factors with the interdependent weights of main factors as shown in Table X.

From the results, the CR ratios of five main factors and fifteen sub-factors were lower than 0.1 which expressed weights determined by decision-makers of auto parts companies had consistency. In this study, the decision-makers made the pairwise comparison for main factors and sub-factors and they were analyzed by fuzzy ANP. The results indicated that telepresence was the most important factor with the interdependent weight at 22.9 percent. Next, connectivity was the second rank of the important factor with a weight of 20.5 percent. While value, security, and intelligence had interdependent weights at 19.7, 18.7, and 18.2 percent respectively.

For the importance of sub-factors, the results indicated that performance was the most important sub-factor that influenced the decision-makers with the global weight at 9.20 percent. The second rank was the functional orientation with a global weight of 8.80 percent, while data management, controlling, and compatibility had the global weights of 8.60, 8.30, and 8.28 percent respectively. For the least importance, the bottom five sub-factors had consisted of information privacy, cloud computing, authorization, artificial intelligence, and market demand with their global weights at 5.88, 5.41, 4.30, 3.91, and 2.84 percent respectively. Therefore, these sub-factors had less impact on the decision-maker during selection to apply IoT in their production management.

TABLE II. LINGUISTIC SCALE FOR RELATIVE WEIGHTS OF FACTORS

Risk Level	Triangular Fuzzy Scale	Triangular Fuzzy Reciprocal Scale
Just equal	(1, 1, 1)	(1, 1, 1)
Equally important	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly more important	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very strongly more important	(2, 5/2, 3)	(1/3, 2/5, 1/2)
More important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

TABLE III. LOCAL WEIGHT AND PAIR-WISE COMPARISON MATRIX OF "MAIN FACTORS"

Main Factors	Connectivity	Telepresence	Intelligence	Security	Value	Weights
Connectivity	1.000, 1.000, 1.000	0.876, 1.209, 1.563	0.996, 1.344, 1.731	1.086, 1.398, 1.742	0.665, 1.029, 1.537	0.206
Telepresence	0.789, 1.010, 1.389	1.000, 1.000, 1.000	1.054, 1.385, 1.811	1.069, 1.414, 1.786	1.044, 1.329, 1.744	0.234
Intelligence	0.770, 1.039, 1.408	0.667, 0.880, 1.185	1.000, 1.000, 1.000	0.688, 0.974, 1.311	0.869, 1.216, 1.593	0.179
Security	0.948, 1.224, 1.547	0.710, 0.894, 1.163	1.076, 1.415, 1.835	1.000, 1.000, 1.000	0.754, 1.098, 1.473	0.184
Value	0.759, 1.128, 1.773	0.722, 0.897, 1.138	0.759, 0.983, 1.324	0.923, 1.255, 1.864	1.000, 1.000, 1.000	0.198

TABLE IV. LOCAL WEIGHT AND PAIR-WISE COMPARISON MATRIX OF "CONNECTIVITY"

Sub-factors	Compatibility	Standardization	Sensor network	Weights
Compatibility	1.000, 1.000, 1.000	1.221, 1.624, 2.059	0.982, 1.269, 1.572	0.404
Standardization	0.633, 0.839, 1.112	1.000, 1.000, 1.000	0.760, 1.121, 1.623	0.287
Sensor network	0.781, 0.947, 1.195	0.723, 1.063, 1.574	1.000, 1.000, 1.000	0.309

TABLE V. LOCAL WEIGHT AND PAIR-WISE COMPARISON MATRIX OF "TELEPRESENCE"

Sub-factors	Synchronization	Monitoring	Controlling	Weights
Synchronization	1.000, 1.000, 1.000	0.828, 1.202, 1.638	0.828, 1.167, 1627	0.345
Monitoring	0.706, 1.004, 1.458	1.000, 1.000, 1.000	0.619, 0.835, 1.223	0.293
Controlling	0.782, 1.108, 1.515	0.985, 1.424, 1.879	1.000, 1.000, 1.000	0.363

TABLE VI. LOCAL WEIGHT AND PAIR-WISE COMPARISON MATRIX OF "INTELLIGENCE"

Sub-factors	Functional Orientation	Artificial Intelligence	Cloud Computing	Weights
Functional Orientation	1.000, 1.000, 1.000	1.367, 1.814, 2.364	1.133, 1.551, 2.011	0.486
Artificial Intelligence	0.507, 0.693, 0.938	1.000, 1.000, 1.000	0.679, 0.992, 1.441	0.215
Cloud Computing	0.567, 0.772, 1.061	0.887, 1.256, 1.739	1.000, 1.000, 1.000	0.298

TABLE VII. LOCAL WEIGHT AND PAIR-WISE COMPARISON MATRIX OF "SECURITY"

Sub-factors	Information Privacy	Authorization	Data Management	Weights
Information Privacy	1.000, 1.000, 1.000	0.952, 0.303, 1.761	0.652, 0.900, 1.239	0.314
Authorization	0.693, 0.954, 1.294	1.000, 1.000, 1.000	0.539, 0.706, 0.979	0.230
Data Management	1.131, 1.554, 2.059	1.287, 1.744, 2.212	1.000, 1.000, 1.000	0.456

TABLE VIII. LOCAL WEIGHT AND PAIR-WISE COMPARISON MATRIX OF "VALUE"

Sub-factors	Marketing demand	Convenience	Performance	Weights
Marketing Demand	1.000, 1.000, 1.000	0.578, 0.752, 1.023	0.557, 0.726, 0.970	0.144
Convenience	1.397, 1.839, 2.305	1.000, 1.000, 1.000	0.663, 0.853, 1.222	0.390
Performance	1.330, 1.773, 2.231	0.917, 1.304, 1.705	1.000, 1.000, 1.000	0.466

TABLE IX. INNER DEPENDENCE WEIGHT OF THE FACTORS

Factors	Connectivity	Telepresence	Intelligence	Security	Value
Connectivity	1.000	0.255	0.254	0.258	0.264
Telepresence	0.310	1.000	0.286	0.278	0.294
Intelligence	0.223	0.240	1.000	0.228	0.205
Security	0.237	0.247	0.208	1.000	0.237
Value	0.231	0.259	0.252	0.236	1.000

TABLE X. TOTAL WEIGHT OF MAIN FACTORS AND SUB-FACTORS

Factors	Interdependent weights	Ranking	Sub-factors	Local weights	Ranking	Global weights	Ranking
Connectivity	0.205	2	Compatibility Standardization Sensor network	0.404 0.287 0.309	1 3 2	0.083 0.059 0.063	5 10 9
Telepresence	0.229	1	Synchronization Monitoring Controlling	0.345 0.293 0.363	2 3 1	0.079 0.067 0.083	6 8 4
Intelligence	0.182	5	Functional Orientation Artificial Intelligence Cloud Computing	0.486 0.215 0.298	1 3 2	0.088 0.039 0.054	2 14 12
Security	0.187	4	Information Privacy Authorization Data Management	0.314 0.230 0.456	2 3 1	0.059 0.043 0.086	11 13 3
Value	0.197	3	Market Demand Convenience Performance	0.144 0.390 0.466	3 2 1	0.028 0.077 0.092	15 7 1

V. DISCUSSION

Results from this study have indicated that the importance level of each variable is different by the factor of telepresence is the most important because there is telepresence for considering proposed data in working units that are connected to IoT for tracking operations in the production process. The data should be presented in real-time to executives and employees to track circumstances in production more conveniently. Moreover, it has impacted the controlling, decision-making, and planning that is done more efficiently. The second factor is connectivity which is important for integrating the production process of auto parts to control processes connected. Furthermore, the connectivity is for processing and exchanging data with suppliers, production process, and warehouse management following Just-In-Time production for more flexibility and accuracy. For the performance factor, it can be connected to IoT which is important in controlling and tracking operations more quickly. The accuracy of data enhances forecasting and decision-making, as well as the ability to improve working units throughout the supply chain, following specified plans. The function orientation is a crucial part that must control flows of produced auto parts continuously throughout the process and lay down guidelines with relevant departments both inside and outside the organization. Besides, data that is connected to IoT can improve function orientation more efficiently. Finally, data management is for managing big data from IoT through a data center that relates to internal and external networks that enhance efficient operations in the production process of auto parts. However, the results can be discussed in detail for each factor as follows.

A. Telepresence

The telepresence can consolidate and analyze data for presenting reports from several perspectives as requirements and scopes of each department such as the productivity report of each production line versus production plan or failure reports. The reports are for relevant departments can receive information and prepare for any case from the defined plan delayed. It can be summarized and proposed to executives as management dashboards on important issues for industrial management based on changing circumstances or needs. It can also be used as information for each department to have a picture of their performance or service levels of others to improve their processes more efficiently [63], such as presenting information in the production process, auto parts approval data for delivery, notifying customers, or forecasting stock more precisely. Therefore, the presentation of data enables all relevant segments to evaluate and track actual production reports against targets in real-time.

1) Controlling: Operating processes following targets or defined plans is necessary to ensure continuity and accuracy in the production of auto parts for stable working throughout production operations, enabling dynamic control, and situational assessment for data analysis in decision-making more quickly and anywhere [30, 64]. Besides, controlling through several Programmable Logic Control (PLC) systems can deal with machines that have complex functions in the production line of various auto parts to ensure that operations are in line with the production plan. Therefore, it expresses that the automated control of the production system supports operations through the working steps, controlling robots to comply with requirements is for operating continuous production, such as plating and painting robots that are controlled to work relative to the movement of parts on production belts, or robots at the packing belts which must be controlled to operate accurately and precisely as the determined functions to meet the customer orders. Additionally, robots are controlled to welt joints of auto parts as specified standards as well as control interaction or transmission environments between devices.

2) Synchronization: The auto parts manufacturing process is for connecting data to work consistently throughout the supply chain, such as ordering, controlling, or transmitting data without any interruption in the working process. Therefore, all units must precisely synchronize data into the central operating system for a holistic view of all productions. As a result, management is more convenient and faster [25, 26]. Process synchronization can create balance in production lines and units because the production of auto parts includes the main production line for assembly parts and the second production line for assembly sub-parts as well as parts from suppliers that are a part of the production.

3) Monitoring: The manufacturing process of auto parts is crucial due to the large number of components and suppliers in the supply chain. It can dynamically monitor and perform real-time analysis efficiently [20]. Therefore, applying the internet of things is to continuously monitor operations of each unit on the production line, such as monitoring the assembly process to track operations as planned, monitoring the operating systems for avoiding potential risks and system failures, or doing preventative maintenance for machines, etc.

B. Connectivity

Connectivity is a crucial integration in the production of auto parts for control of various stages to detect machines and equipment for the exchange of data in analytical processing [65]. Particularly, the auto parts industry produces parts with a Just-In-Time production system to meet the needs of the production line in terms of quantity, time, and quality. Therefore, data connections with suppliers have real-time access to various information, and coordination with suppliers is streamlined and accurate [66]. Enable efficient operation, such as planning production requirements and delivering raw material parts in due course, managing raw materials in warehouses to be alerted reducing raw material shortages, and reliability of the delivery of raw material parts, etc.

1) Compatibility: The Auto parts manufacturing process is for centralizing data of operational statuses quickly and up to date. Particularly, several parts produced from different suppliers need to be linked with the same platform [6], for example, linking customer production data to assemble a vehicle that lets suppliers know what materials to produce or order during what period. In a part of compatibility for quality inspection data of vehicle chassis parts, when it is compared to the customer-specified standards, assembling auto parts that must match the production plan according to the specified model. In case of the product does not meet standards, it will inform details of errors for revisions, etc.

2) Sensor network: Linking sensors to computer systems in the same network is to communicate with each other inside and outside the organization [22,67]. This method enables data transfer, controlling and tracking working statuses, or detecting errors that occur in the production process, such as errors from machines in the manufacture of auto parts or detecting parts that do not meet the standard or track statuses in the logistic process effectively. Besides, the sensor network can build trust by connecting external sensor networks to auto parts suppliers for coordination through the enterprise resource planning system (ERP) that allows data from suppliers to be centralized into the data center such as production planning, quality management of parts, purchasing and delivery statuses, disbursement of raw materials, etc. The logistic management in the transportation of auto parts that are linked to the sensor network can control and trace the services by connecting to the Global Positioning System (GPS). Furthermore, it can check the driver's status and physical condition for safety and efficiency purposes.

3) Standardization: Standards for auto parts manufacturers must build confidence throughout the supply chain process [21]. Effective control under the same standards, such as standardized performance of parts, is created and delivered to both inside and outside involved units through the correct digital system as designed. It can be connected to various measurements to detect non-compliant auto parts, such as checking the coating standard of all standard vehicle parts in terms of thickness and shades. It must be precise checking because the color is very close, or the traceability process of auto parts (vehicles have a wide range of different models and parts, there must be standards for tracking the production process and sources), etc.

C. Value

Creating value in the auto parts manufacturing industry can create value-added through tracking, recording, and data processing. Exchange of information and display insights that enable more accurate and faster decision making by enabling organizations to dynamically recognize the device connection that can communicate [45] such as linking data from suppliers, production, logistic system, and services. It supports the ability of data analysis throughout the production process or can operate automated systems that are linked to production plans in the production process of auto parts. Therefore, costs have been reduced from removing wastes in the production and increasing value-added in operations. Moreover, decision-making and strategies can be appropriately operated from the quality data.

1) Performance: The basic need of the auto parts industry to operate. Using an appropriate production factor and reducing waste in the working process can be done. IoT is a tool that can support operations work more accurately and quickly as well as reduce waste of time and errors [50, 68]. Moreover, tracking devices and connecting data can help to produce quality auto parts that meet the customer's needs, data from IoT can evaluate performances in departments for improving their performances consistently.

2) Convenience: The access insights that are analyzed and processed, can be used in operating the quality production because IoT can create convenience in terms of data collection from resources [47, 65]. It can facilitate operators or executives in working such as convenience in tracking real-time performances of different product lines at the same time, convenience in tracking the shipment of auto parts from suppliers, and convenience in trust-building to the customers by enabling tracking of production information and services.

3) Market demand: The application in marketing helps auto parts manufacturers to get the correct data on customer needs [28, 34]. The auto parts can be adjusted to meet the customer's needs as well as quality standards or other requirements that the customers accept. Change circumstances and market volatility through devices and data networks can exchange the data with customers in perspectives such as quality issues, customer complaints about quality issues, and production plans changing. It occurs from the data exchange in the same operating system including determining the delivery cycle to meet the just-in-time system or anticipating new products developed.

D. Security

Information security plays a crucial role which restricting access to only relevant data to prevent espionage from unauthorized persons [40, 69]. The auto parts industry because data in business operations must be kept confidentially for the highest benefit of the organization, particularly the auto parts industry has a large network of people involved. Therefore, permissions of data access and data management require a security system to prevent data leakage from employee or system errors such as production data, logistics data, customer service data, etc.

1) Data management: The auto parts industry where data collection is dynamically changing. Center data management must have the capability to deal with big data, filter standard data, and manage data more efficiently [70]. Therefore, it is necessary to have an efficient storage system for managing data formats, data display, and managing data as the operation characteristic to prevent failures of the system that may occur from various specifications or productions from different suppliers. Besides, failures can be occurred by capability data of different production lines, data of the automated system, or robots that need data characteristics in terms of the readable language by robots.

2) Information privacy: Information privacy is a challenge in the development and services of IoT solutions that require strict compliance with standards of data privacy, access statuses of using devices in production, encrypting, and controlling data under the security policy [43]. including reducing the risk of disclosure because the industry has more trade secrets such as production technology, product details, and features as well as developing new products in the future. The considered information privacy management is the controlling of connecting between devices in both internal and external organizations. Preventive management that maintains the confidentiality of process data in the supply chain access the secured cloud system in connecting production data.

3) Authorization: Data access in levels of departments is an important part that must be operated consistently with information privacy to avoid obstacles to access to information excluded the permission for practitioners to access self-information. In the industry, the cross-function team can work with other employees from other departments in terms of developing new products that should have the team from R&D, marketing, production, or suppliers. Therefore, people in the team should be able to access information about each other. Therefore, assigning permissions to temporarily grant access to the necessary information of other entities but there must be a controller of authority to access only specified data for preventing data security that may impact the total production of auto parts such as standard parameters in the quality inspection or accessibility of trade secrets. The importance of accessing sensitive information can prevent problems or adverse events in the organization.

E. Intelligence

Intelligence is directly involved in the production of auto parts that uses IoT to interact between machine and machine, or machine and human to understand patterns or behaviors of wise operations. Furthermore, It can adjust production systems of auto parts to digital systems to increase their intelligence [24]. Ssuch as intelligence in evaluation and analysis for the volume of produced auto parts in each production line and using data to measure performances as planned against the past data as well as forecasting its trend. Intelligence in simultaneous controlling complex machines and equipment in the main and second production lines is for the operations can be traced and controlled more efficiently.

1) Functional orientation: The auto parts production that can be applied to use IoT for providing information that is beneficial to operators can work accurately and make decisions efficiently. Furthermore, functional orientation for tracking auto parts from suppliers or customers can be connected to logistics processes for continuous monitoring [65]. This emphasizes the exact time of delivery according to the specified cycle [24]. The functional orientation has been used to align works and be an assistant for the organization in multi-tasks such as connecting ERPs in the supply chain, determining collaborative networks clearly, and set-up clear process flows. Besides, automated data recording with RFID can check the status of auto parts from suppliers and the production more effectively that expresses production data and quality of raw material for planning.

2) Cloud computing: The auto parts industry is a service that provides an external IT infrastructure for connecting software and platforms that can process big data from IoT to respond to intelligent processing that can access data anytime and anywhere. This can respond to the needs of customers and related parties more comprehensively [34,71]. Internal and external organizations under collaboration have a data center to access data conveniently such as the production report of auto parts through the organization’s web browser and software and all data will be simultaneously kept on the service provider’s server. Therefore, the user can access the system all time the most services are the type of web applications to support data-driven. When there is sufficient data for creating innovation in the manufacturing process of auto parts.

3) Artificial intelligence: Artificial Intelligence (AI) is a cutting-edge technology that has changed the way of working for the auto parts industry and has been involved with IoT directly. AI also helps to increase customer satisfaction by analyzing big data from the customer relationship management (CRM) system that supports continuous production and creates value-added for the organization [34, 71]. It supports the industry to operate with complex matters more quickly such as quality inspection of auto parts by running a simulation of used auto parts in a real situation instead of real inspections that spends more time and resources than the simulation. Besides, it can propose the best alternative to the operators to consider and make decisions more precisely such as selecting the best route for transportation purposes or predicting possible incidents that may occur in the production line in advance. Moreover, AI can be developed into an intelligent operating system that can interact with humans, intelligent production that can predict or notify any incident in the production, and planning and inspection for auto parts to be stocked and utilize spaces in the warehouse more effectively. With another application, raw materials in the process can be scanned to trigger the automated reimbursement system to feed raw materials into the production line continuously and support the non-stop production. Therefore, the production data can be transferred to other departments such as planning, purchasing, production, and marketing departments to know the statuses in production at the same time and use the data to plan future operations more precisely.

VI. Conclusion

In this research, five factors have been identified that influence the auto parts industry for applying Internet of Things (IoT) technology to integrate production management with connectivity, telepresence, intelligence, security, and value respectively. The study has revealed that telepresence is the most important factor for decision-makers of auto parts manufacturers in selecting IoT applications for managing production. While the importance of connectivity, value, security, and intelligence are prioritized in descending order respectively. For the importance of sub-factors, the top five ranks have consisted of performance, functional orientation, data management, controlling, and compatibility respectively which influence the auto parts manufacturers to decide for applying IoT. Meanwhile, information privacy, cloud computing, authorization, artificial intelligence, and market demand have less influence on decision-makers for selecting IoT to apply to their auto parts production. To the results of this study, auto parts manufacturers can make use of factors and sub-factors as selection criteria for procuring internet devices or relevant equipment to IoT to improve their production management as well as the firm's performances in terms of financial and production benefits.

In implications for management, this research benefits executive (Decision-makers) in auto parts manufacturers who are seeking IoT applications to improve production capabilities to increase value-added and competitive advantages. The first criteria that they need to consider when selecting IoT applications are telepresence. Telepresence will assist them in controlling production lines to guarantee that production capabilities meet the objective, and all data from each unit in the production lines should be integrated for daily performance monitoring and early detection of any events that could stop production. Connectivity is the second criterion that needs to consider for selecting IoT applications. Decision-makers must ensure that IoT applications are compatible with their machinery and equipment so that they can be controlled smoothly and precisely, and they are also connected to the existing computer network. Moreover, considered IoT applications should have a standard that is both trustworthy and market acceptance. Next, the values that decision-makers should consider, are to improve performance in production, be convenient to use, and be desired by end-users. Therefore, if consumers can perceive the value and benefits of IoT applications, they will be more likely to accept them, and their obstacles to using them will be greatly lowered. Security is the next criterion to consider in the selection of IoT applications. To avoid the risk of data disclosure or leaking, IoT applications should have an efficient data storage system to manage sent data from devices, as well as a data privacy standard. Besides, data access should be set with authorization to avoid unauthorized access to personal information or commercial secrets. Finally, intelligence is considered the least important criteria for selecting IoT applications because most auto parts manufacturers in use manpower in production. Moreover, the industry still needs skilled manpower for producing high-quality auto parts. Intelligence may be necessary for the firms that are looking for cost reduction and automated processes. These firms want to expand their capacity and productivity to supply auto parts for large automotive firms with increased demand.

The auto parts manufacturers who have fully implemented and used IoT applications in their manufacturing lines are limited to very large enterprises, which is a limitation of this study. Therefore, small and medium-sized auto parts manufacturers may choose to integrate some IoT applications in their production as a way to save money. For future research, these factors in this study will be used as the selection criteria to evaluate and select appropriate IoT applications for managing auto parts production.

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