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# Perspectives on Management Theory's Application in the Internet of Things Research.

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# Perspectives on Management Theory's Application in the Internet of Things Research.

## Abstract

The growing use of the Internet of Things (IoT) has provided businesses with a new opportunity. This study performed a systematic literature review and analyzed 179 peer-reviewed empirical studies using IoT technology to uncover prone theories in IoT implementation in business. The findings showed that Resource Dependence Theory, Game Theory, and Contingency Theory are the most extensively employed in research to understand better how businesses interact with their surrounding business environments. Furthermore, while Stakeholder Theory was employed in IoT research to understand how technology supports the improvement of the business environment, other theories such as Resource-Based View and Dynamic Capability theories have been used in prior studies to comprehend IoT capabilities. The theoretical and practical contributions are discussed.

**Keywords:** Internet of Things (IoT); IoT Application; IoT Property; IoT Technology Stack; Management Theory; Organizational Theory.

## 1. Introduction

Internet of Things (hereinafter IoT) is a global, dynamic, network-based infrastructure with self-regulating and interactive capabilities based on standard communication protocols (Atzori et al., 2010). In the IoT network, "objects" have identities, physical properties, and virtual personalities and use intelligent interfaces. By enabling objects to interact with each other, sharing information, and coordinating actions, IoT provides a wide range of solutions that can be used in businesses through a variety of applications (Al-Fuqaha, 2015). The interaction of perfectly interconnected objects in the network-based infrastructure results in the generation of massive quantities of data to support business decisions (Giusto et al., 2010; Gubbi et al., 2013).

As a vital disruptive technology, IoT has the potential to significantly impact businesses and economic systems (Atzori et al., 2010; Wortmann & Flüchter, 2015). Additionally, recognizing the potential of IoT for businesses has become critical for process management, strategy determination, and technology forecasting (Del Giudice, 2016). For example, by facilitating fast and accurate interactions among stakeholders, IoT enhances and accelerates business activities (Shrouf & Miragliotta, 2015), and enables businesses to track enterprise resources, production operations, and challenges in coordination with other business partners. In addition, data and information generated by IoT provide knowledge that can be used to monitor, make informed business decisions and regulate business processes (Akhtar et al., 2017; Shrouf & Miragliotta, 2015).

In recent years, research on IoT applications in business and the integration of emerging technologies has evolved (c.f. Li et al., 2015). However, most of the research on IoT has been exploratory in nature, or the emphasis has been given to the implementation of IoT to understand better the technology and its applications (e.g., Fatorachian et al., 2020; Graham et al., 2020), examining the phenomenon as an enabler technology, and leveraging IoT to create industry intelligence (Del Giudice, 2016). Furthermore, with the gradual evolution of IoT, more opportunities for the theoretical understanding of this technological phenomenon and its applications in business are emerging too (e.g., Atzori et al., 2010; Hognelid & Kalling, 2015).

In achieving the objectives stated above, management theories provide a theoretical ground to examine the growth and development of technology use in business (Sarkis et al., 2011). Delooff (1995) argued that in addition to more traditional areas of management, management theories should be used in business-related research. According to Glaser et al. (2009), theories, regardless of their area of application, are valuable lenses for evaluating the role of a technological phenomenon and their impacts on day-to-day business-related issues in the field of specialization. In addition, Gregor (2006) argued that theories based on systematically collected knowledge can be useful in understanding the function of socio-technical processes under investigation. Gassmann et al. (2016) also noted that management theories enrich business-related research by examining phenomena from new angles.

As such, by structuring the relationships between effective constructs (concepts), theory can provide a compelling argument for the whatness, whyness, and howness of different IoT functions in business and support the generation of new theoretical insights (Gregor, 2006). Therefore, it can be assumed that a sound theoretical understanding is required for the successful deployment of IoT in the real world. Van de Ven (1989, p. 486) argued that "*a good theory advances knowledge in a scientific discipline, guides research towards crucial questions, and enlightens the profession of management*". That is, good theories help to expand knowledge by providing logical reasons that justify the main constructs (what), their relationship (how), and their reason (why) (Miles, 2012).

To accelerate the theoretical maturity of a new research area, researchers often develop on the existing yet validated theories in the innovative application of emerging technologies to reach a group of middle-range theories (Colquitt & Zapata-Phelan, 2007). In other words, in line with the research objectives, researchers can offer adaptations or refinements to the existing theories to appropriately explain innovations, such as IoT technology (Hu et al., 2018).

In this research, we posit that building IoT applications in business necessitates sound managerial and organizational theoretical knowledge and understanding. We also argue that the application of management theories in studies will lead to various achievements such as (1) organizing thoughts and ideas, (2) developing and explaining relationships and interactions between individuals, groups, and entities, (3) improving expectations and predictions of individuals, groups, and organizations, and (4) achieving a better understanding of the world around us (Miles, 2012). For example, Hanafizadeh et al. (2021) have recently pointed to the significance of theories in studies of IoT technology in business and concluded that IoT technology paves the way for the realization of the assumptions of some theories. In the same vein, Hognelid and Kalling (2015) argued that the scientific contributions of applying management theories in IoT research would help practitioners and businesses make more informed decisions about how to use the technology.

To this end, this research focuses on the application of management and organizational theories to better understand how the IoT affects business and organization activities. In doing so, a systematic literature review will be conducted on the studies of the application of management theories in IoT technology to establish a relationship between (i) theoretical foundations, particularly ***assumptions*** of the theories, and (ii) ***properties*** of IoT technology (e.g., interaction, automation, and interoperability), which are used more frequently in the literature.

The relationship between theory and properties of the IoT refers to theories whose assumptions are realized or come closer to reality under the influence of the IoT properties. The properties in this research are defined as the IoT properties agreed upon by various researchers or/and referred to in several studies as properties of IoT technology. The establishment of such a relationship is important from two perspectives: (1) it helps to identify the properties of IoT technology in realizing the assumptions of theories, and (2) it enables more efficient use of prior findings in establishing the appropriateness of management theories in IoT application research. Therefore, we aim to identify management theories that can be used in IoT-related business research, theories whose assumptions are approached or realized under the influence of IoT technology and are therefore relevant to IoT-related business research. In this regard, the present research seeks to answer the following questions:

**RQ1:** *What are the IoT properties that the researchers have agreed on, as evidenced by their publications?*

**RQ2:** *Which management and organizational theories' assumptions are realized as a result of IoT technological properties?*

**RQ3:** *Which management and organizational theories are appropriate for conducting research on the application of IoT in business?*

The structure of this paper is as follows: after the introduction (Section 1), a brief literature review is presented (Section 2), then the theoretical background (Section 3) and the research methodology (Section 4) are presented. In the next section, the research findings and their analysis are examined (Section 5). Discussion of the findings (Section 6), and finally, the results, the limitations, and suggestions for future work are presented (Section 7).

## 2. Literature Review

In this section, we discuss previously published systematic review studies of IoT. For example, Al-Fuqaha et al. (2015), reviewed the technical details of IoT enabling technologies, their various protocols, and applications. Saheb et al. (2018) studied IoT big data analytics and its challenges with relational databases. These studies and others, such as (Ghosh et al., 2020) and (Sestino et al., 2020), have mostly targeted the technical and the practical aspects of IoT and have less focused on the application of management theories in IoT research. Some studies, such as Yang Lu et al. (2018), which thoroughly evaluated the role of IoT in various organizations and industries have paid little attention to theoretical concerns. Other studies, for example, Alkawsi et al. (2018), investigated the factors influencing the IoT adoption, and dissemination by reviewing and analyzing 32 articles. However, Fahmideh and Zowghi (2019) argued that systematic approaches are necessary for developing IoT platforms due to their dynamic, active, and heterogeneous nature and provided an evaluation framework for comparing the approaches proposed by researchers in the field of IoT technology based on reviewing 63 articles. In addition, Hognelid and Kalling (2015) studied the impact of IoT technology on the organizations and reported the interpretation of the results of the application of IoT to create value. The authors stated that the lack of literature on theoretical studies examining the use of IoT in organizations will lead to a misunderstanding of the strategic and investment consequences. The authors further asserted that there are limited contributions on the use of theory to describe the function of IoT in enterprises.

Compared with other review studies, it should be noted that this research takes a different approach to the use of management and organizational theories in IoT research, and focuses on the relationship between management theories and the properties of IoT technology. By doing so, we respond to Bohli et al. (2019), Whitmore et al. (2014), Shafique et al. (2020), and Brous et al. (2019), who stated that the impact of the application of IoT technology in business should be evaluated from the perspective of management and organizational theories.

## 3. Theoretical Background

### 3.1. IoT Technology Stack

From a technology perspective, the implementation of IoT requires using a combination of various hardware components based on the IoT architecture, software, and communication protocols (Wortmann et al., 2015). This is formed in three layers, i.e., (i) applications, (ii) hardware (things and devices), and (iii) connectivity (Andelfinger & Hänisch 2015). In a study by Porter and Heppelman (2014), the main technologies used in these three layers are described as "technology stack", which are based on a secure connection between cloud services, databases, analytic capabilities, and application platforms. Several researchers have used this conceptual framework because it provides an integrated view, and covers IoT technological requirements (e.g., Tesch, 2019; Wortmann et al., 2015). IoT technology stack framework consists of three layers: (1) IoT cloud (e.g., interaction and semantic technologies), (2) connectivity (e.g., distributed data storage and layered structure), and (3) thing/device (e.g., smart objects and heterogeneous devices), each layer having several components (Tesch, 2019). In addition, the IoT technology stack also has three aspects, which are software components responsible for providing service to different layers. These components are used to manage (1) authentication and security, (2) integration with business systems such as ERP or CRM, and (3) information exchange outside the organization. In this research, we use the technology stack to organize and classify the properties of IoT technology.

### 3.2. Elements of a Theory

Theories are useful tools and help to achieve research goals in a field of study by (1) organizing thoughts and ideas, (2) creating and explaining interrelationships among entities, (3) improving predictions and expectations, and (4) better understanding of the world (Hambrick, 2007). Miles (2012) and Corley and Gioia (2011), define theory as a set of structures and their interrelationships that illuminate why and how a phenomenon occurs. Good theories involve four main elements: (1) what, (2) how, (3) why, and (4) who, where and when (Whetten, 1989). In a theory, *what* refers to the main constructs of the theory. *How* describes the relationships among the constructs. In general, it can be said that what and how elements form the domain or subject of the theory. *Why* helps to explain the underpinnings of the constructs and their proposed relationships. In other words, a crucial component for the whyness of a theory is the assumptions that make all the constructs of the theory meaningful along with each other (Miles, 2012).

More precisely, a theory can be considered as a system of constructs or variables in which the constructs or variables are related through propositions or hypotheses. Although not observable directly or indirectly, constructs may be defined in terms of observable variables or indices (Kaplan, 1964, p. 55). A variable is defined as an observable entity that accepts two or more values (Schwab, 1980). Thus, a construct is the subjective configuration of an objective phenomenon, while a variable is regarded as an operational configuration of a construct (Bacharach, 1989). At the abstract level, propositions express the relationships among constructs, and at the level closer to reality, hypotheses (derived from the propositions) specify the relationships among variables. In other words, hypotheses are objective and operational propositions of these abstract relationships, and therefore the reflections of constructs in hypotheses are constructed as specific variables. The whole system is limited by the theory's assumptions (Bacharach, 1989). Therefore, it is important to understand the difference between assumption and variable in the application of theory in research. For example, in technology acceptance model (TAM) theory, the two variables, perceived ease of use and perceived usefulness, are the behavioral determinants of using a technology (Davis et al., 1989). The theory's assumption is that users can use a particular technology based on individual cost-benefit considerations (Röcker, 2010).

Finally, the theory should express its boundary conditions/assumptions in the sense of *whom* the theory applies to, *when* it applies, and *where* it applies (Sandberg & Alvesson, 2021). Dubin (1969) argued that every theory's assumptions cannot be realized in all circumstances and are dependent on a number of factors and constraints. One of the effective factors in creating the conditions for realizing a theory's assumptions is technology (Silva et al., 2020). The application of technology leads to the emergence of capabilities and properties in the organization, which were not previously possible (Akhtar et al., 2017). Access to real-time information, the development of operational insights, and the creation of unique opportunities for the organization make it possible to answer *when* and *how* questions of a management theory (Cheng and Lu, 2021). The opportunities created by applying technology will change the boundaries and limitations defined for a theory, including space, time, and value (Miles, 2012). Weber (1947) believes that the value-based nature of assumptions cannot be removed from theory when applied. In other words, to use a theory while paying attention to its assumptions, it is necessary to examine the conditions for its realization (Bacharach, 1989). The concept of realizing the assumptions of a theory by technology is directly related to the positive or negative effects that technology properties have on the assumptions of theories. Of course, the conditions for realizing assumptions vary depending on their positive or negative nature. This difference is well seen in the criticisms of the transaction cost economics (Williamson, 1975, 1981), due to its negative assumption about human behavior (or the opportunism assumption). In contrast, Zipkin (2012) considered trust as an opposing assumption that negates opportunism. Thus, it seems that the concept of realizing the assumptions of transaction cost economics by technology is directly related to the positive or negative effects that the properties of technology respectively have on trust or opportunism.

Nevertheless, from the perspective of transaction cost economics, answering whether an organization's investment in the IoT is profitable is related to the negative effect of IoT technology on the opportunism assumption of that theory (or its positive effect on trust). In this case, if the IoT can have a detrimental effect on their opportunistic behaviors by exposing members' actions, implementing this technology in the organization will be effective. Therefore, the theory assumption has been realized under the influence of IoT or has come closer to reality. In another example, regarding the resource heterogeneity assumption from a resource-based view, Barney (1991), argue that combining the IoT with other strategic resources of an organization can increase the heterogeneity of its resources over competitors. In this regard, the IoT will then leads to a competitive advantage, and consequently, realizing the resource heterogeneity assumption.

It should be noted that the authors acknowledge that management and organizational studies have, nevertheless, used theories from other disciplines, such as psychology and the social sciences. Therefore, by the term “management and organizational theory”, we refer to all theories that have been used in management and organizational research.

### *3.3. Types of Theories*

There has been several attempts to present the concept of classifying theories based on structural properties. In information systems (IS) research, Iivari (1983) classified theoretical levels into conceptual, descriptive, and prescriptive. Moreover, Minckley et al.’s (1986) research provided another classification of theories, categorizing theories into three types: descriptive, explanatory, and predictive (Minckley et al., 1986). Furthermore, Markus and Robey (1988) classified theories in terms of structure, nature, logical structure, and level of analysis. Finally, Cushing (1990) pointed to the separate stages of scientific research that include a description of facts, empirical generalizations, and theory.

Although several researchers have defined and categorized different types of theories, Gregor (2006) provided one of the most successful and widely accepted classifications in IS research community. Gregor categorized the goals of a theory into four groups: (i) analysis and description, (ii) explanation, (iii) prediction, and (iv) prescription. The first group describes the phenomena under study and analyzes the relationships between structures, the degree of generalizability of structures, their relationships and boundaries, and observations. The second group explains how, why, and when an event occurs based on causal perspectives and reasoning methods. Such explanations are usually intended to enhance the understanding of phenomena or providing a richer insight. The third group expresses preconditions and determines the probability of future events. Finally, the fourth group provides a description of a method or structure or both to create an artifact in a way that, in practice, provides a kind of prediction in that field (Gregor, 2006). In a further attempt, based on four groups of theories identified above, Gregor (2006) presented five types of theories used in IS research. The major addition to this new classification is the fifth category, “Explanation and prediction (EP)”, which offers explicit prescriptions such as methods and techniques. This classification of theories will be used to analyze the literature and report the findings in the present study.

## 4. Research Methodology

In this research, a systematic literature review (SLR) was conducted. The SLR attempts to understand the problem and is commonly not used to find solutions (Kupiainen et al., 2015). The processes of planning review, searching articles, selecting articles, extracting data from the articles, data analysis, and synthesizing are the main steps of SLR research (Massaro et al., 2016). Figure 1 shows the integrated literature review steps used in this research.

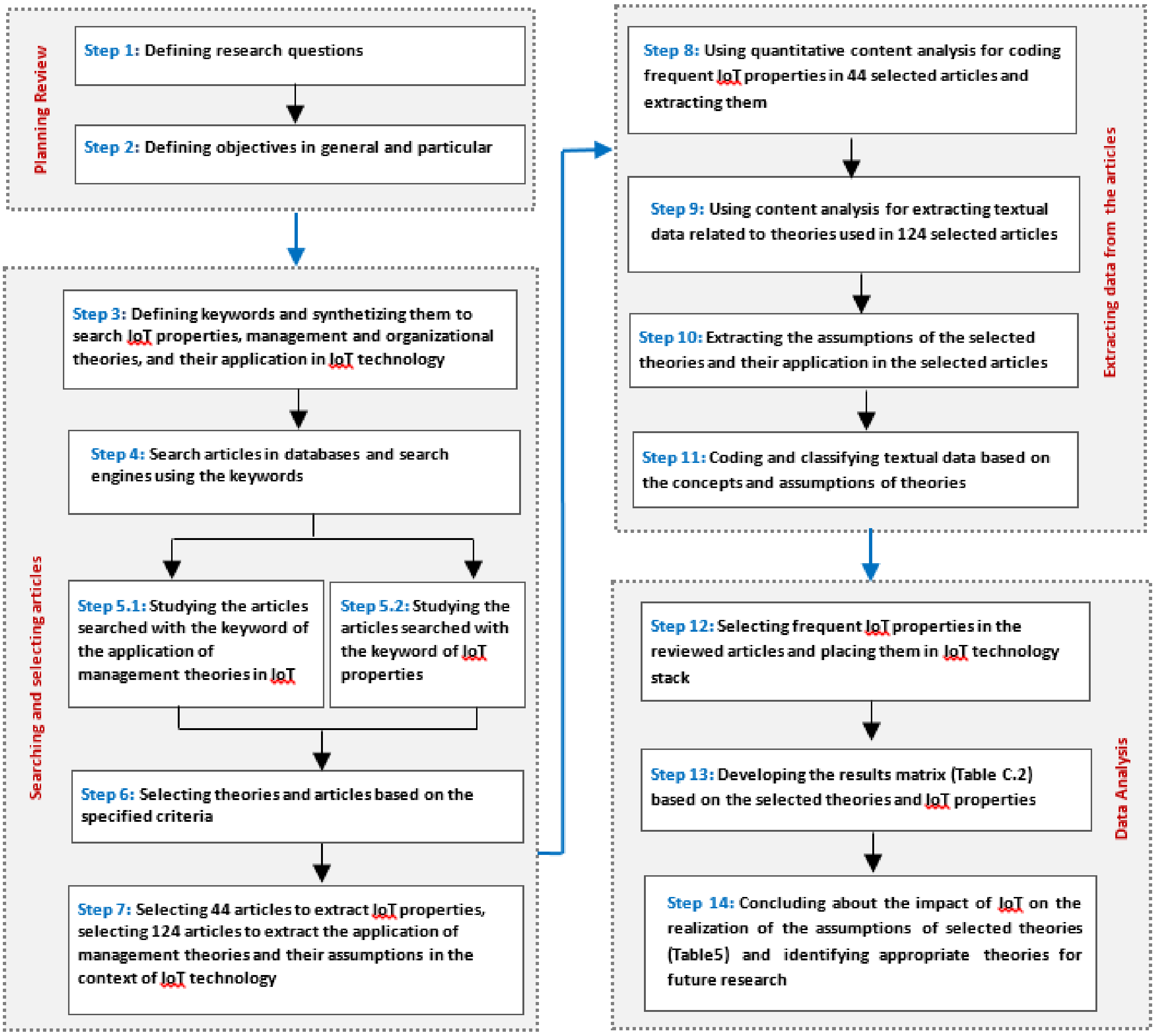


**Figure 1.** The Steps of SLR.

### *4.1. Planning Review*

As stated, the primary purpose of this study is to identify management and organizational theories, which are more frequently used or deem appropriate to conduct research on the application of IoT technology in business. In this research, the appropriateness of a theory is defined as meeting the following criteria.

- The theories which are most frequently used in the literature to address a particular property of the IoT. As such, the theories, which are used more frequently than other theories by researchers to describe one or more properties of IoT technology, were named as the *selected theories*.
- Theories whose assumptions are realized or come closer to reality under the influence of the properties of the IoT.

### *4.2. Search Strategy and Inclusion Criteria*

Table 1 shows the search terms and their combinations specified to extract the relevant studies. We searched for journal articles, conference proceedings, books, and book chapters.

**Table 1.** Keywords Combination.

| Searches | Combination of keywords |
|---|---|
| Route 1 | (("IoT") OR ("Internet of Things")) AND (("IoT properties") OR ("IoT attributes") OR ("IoT layer")) AND (PUBYEAR > 2010) |
| Route 2 | (TITLE-ABS-KEY ("Internet of Things") OR TITLE-ABS-KEY ("IoT") OR TITLE-ABS-KEY ("4 industry ")) AND (TITLE-ABS-KEY ("theory") OR TITLE-ABS-KEY ("organizational theory") OR TITLE-ABS-KEY ("management theory") OR TITLE-ABS-KEY ("perspective ") OR TITLE-ABS-KEY ("view ") OR TITLE-ABS-KEY ("conceptual")) AND (TITLE-ABS-KEY ("organization") OR TITLE-ABS-KEY ("firm") OR TITLE-ABS-KEY ("company") OR TITLE-ABS-KEY ("agency ") OR TITLE-ABS-KEY ("shop") OR TITLE-ABS-KEY ("market") OR TITLE-ABS-KEY ("business") OR TITLE-ABS-KEY ("Service")) AND (LIMIT-TO (SUBJAREA,"BUSI")) |

The database search consisted of two parallel routes, as shown in Figure 2. Route 1 was intended to identify prior studies in reporting the IoT properties, and searched for studies focusing on IoT-based research, and at this stage, Scopus, Web of Science, Google Scholar, Science Direct database, and ResearchGate social network were used to select publications from 2010 to the first quarter of 2022. Route 2 was used to identify studies on the application of IoT technology in businesses and searched for studies addressing research related to the management and organizational theories in IoT research to describe the application of technology in the firm. Route 2 selected publications from 2013 to the first quarter of 2022 and only the Scopus search engine was used because of the possibility of providing better coverage of the latest literature. This coverage is 70% higher than Web of Science (WoS) (Brzezinski, 2015).

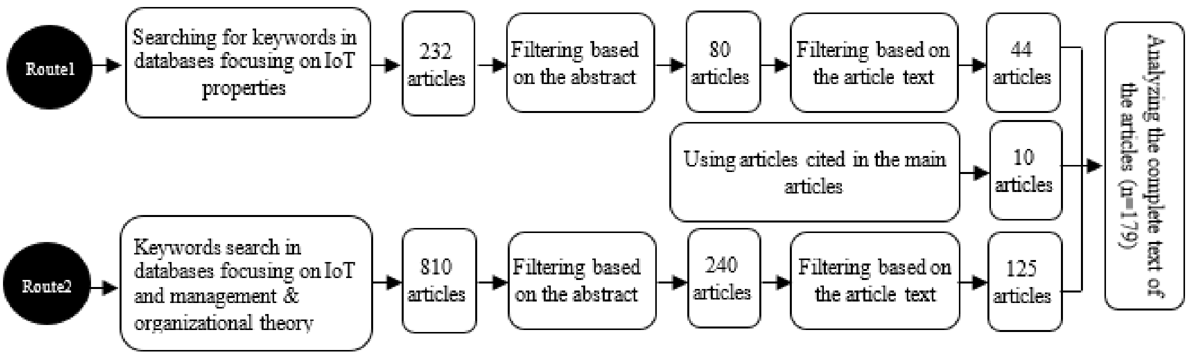


**Figure 2.** The articles search process.

After reviewing the title, abstract, and keywords, studies were selected based on their match with the search terms specified in Table 1, and whose research focus or question(s) were related to IoT and addressed the relationships between management and organizational theories and IoT properties. In addition, the consequences of employing IoT technology in business were considered when selecting the studies. These consequences are dependent on the performance of one or a combination of IoT technology properties that set it apart from other new IT technologies. Because of the unique properties of this technology, a favorable ground is provided for the assumptions of some theories to be one step closer to realization.

As a result, in <u>*Route 1*</u>, 232 studies were selected, and after reviewing the abstracts and removing the duplicate entries, the full text of 80 studies was downloaded and read by the authors. Based on their relevance and match with the inclusion criteria, 44 studies remained for further analysis. In <u>*Route 2*</u>, 810 studies were initially retrieved, and after reviewing the abstract and checking for possible duplications, 240 studies remained. Furthermore, we excluded 115 studies after screening the content for their appropriateness. Then, the authors read the full text of the 125 studies, and 69 theories were extracted. In addition to the main database searches, ten more studies cited by the selected studies were added to the list. This practice is referred to as adding records identified through other sources (secondary sources). All in all, we retained 179 studies for the analysis. The number of selected studies and their types are presented separately in Table 2.

**Table 2.** The sources and types of searched studies.

| Document type | # | Total | Time period | Sources | # | Search route |
|---|---|---|---|---|---|---|
| Article | 30 | | | Scopus | 32 | |
| Review | 10 | | | WoS | 5 | |
| Conference Paper | 3 | 44 | 2010-2022$Q_1$ | Science Direct | 3 | **IoT properties** |
| Book | 1 | | | Research Gate | 2 | |
| Book Chapter | - | | | Google Scholar | 2 | |
| Article | 75 | | | | | |
| Review | 42 | | | | | |
| Book/ Book Chapter | 1 | 125 | 2010-2022Q1 | Scopus | 125 | **Management and organizational theories on the application of IoT in business** |
| Conference Paper | 6 | | | | | |
| Lecture Notes | 1 | | | | | |
| Article | 3 | 10 | - | Scopus | 8 | **Secondary source articles** |
| Book | 7 | | | WoS | 2 | |

### *4.3. Extracting Data and Analysis Procedure*

After selecting the studies, the quantitative content analysis method was employed to extract the theories and properties that were more frequently used in the selected studies. Content analysis is a procedure for collecting and organizing information in a standard format that allows the researcher to analyze the properties of a text and describe its content objectively, systematically, and quantitatively (Chelimsky, 1989; Croucher & Cronn-Mills, 2014). To answer the 1st RQ, after identifying the IoT properties, 19 properties with the highest frequency of occurrence in the selected studies were chosen for further analysis. To answer the 2nd RQ, the assumptions related to theories and their application in IoT research were extracted and coded. For coding, the text of the studies was read. Then, the sections explaining the properties of IoT technology and theoretical assumptions were separated, and the meaningful expressions indicating the effectiveness of IoT technology properties in realizing theoretical assumptions were obtained. After encoding the data, they were separated based on the properties of IoT technology in the layers/aspects of the IoT technology stack. Mendeley software version (1.19.8) was used to search related sections in studies. To answer the 3rd RQ, after reviewing the coded content, the results matrix (Table B.1 in Appendix B) was developed based on the properties of IoT technology and the selected theories.

## 5. Research Findings

As noted earlier, the analysis of the relationship between IoT properties and assumptions of management and organizational theories was the aim of the current study. The relationships were established using the outcomes of reviewed studies that link one or more theories to IoT properties in business research. Section 5.1 explains the processes of selecting the IoT technology properties. Section 5.2 describes the procedures of the theory selections, their assumptions, and their implications in applying IoT to business. Such implications are shaped considering the properties of IoT technology and its impact on the business. This effect can be interpreted with the help of the theory(s). The research sources used in this section are classified and presented separately according to the theories and by assigning a research ID to each source in Appendix C.

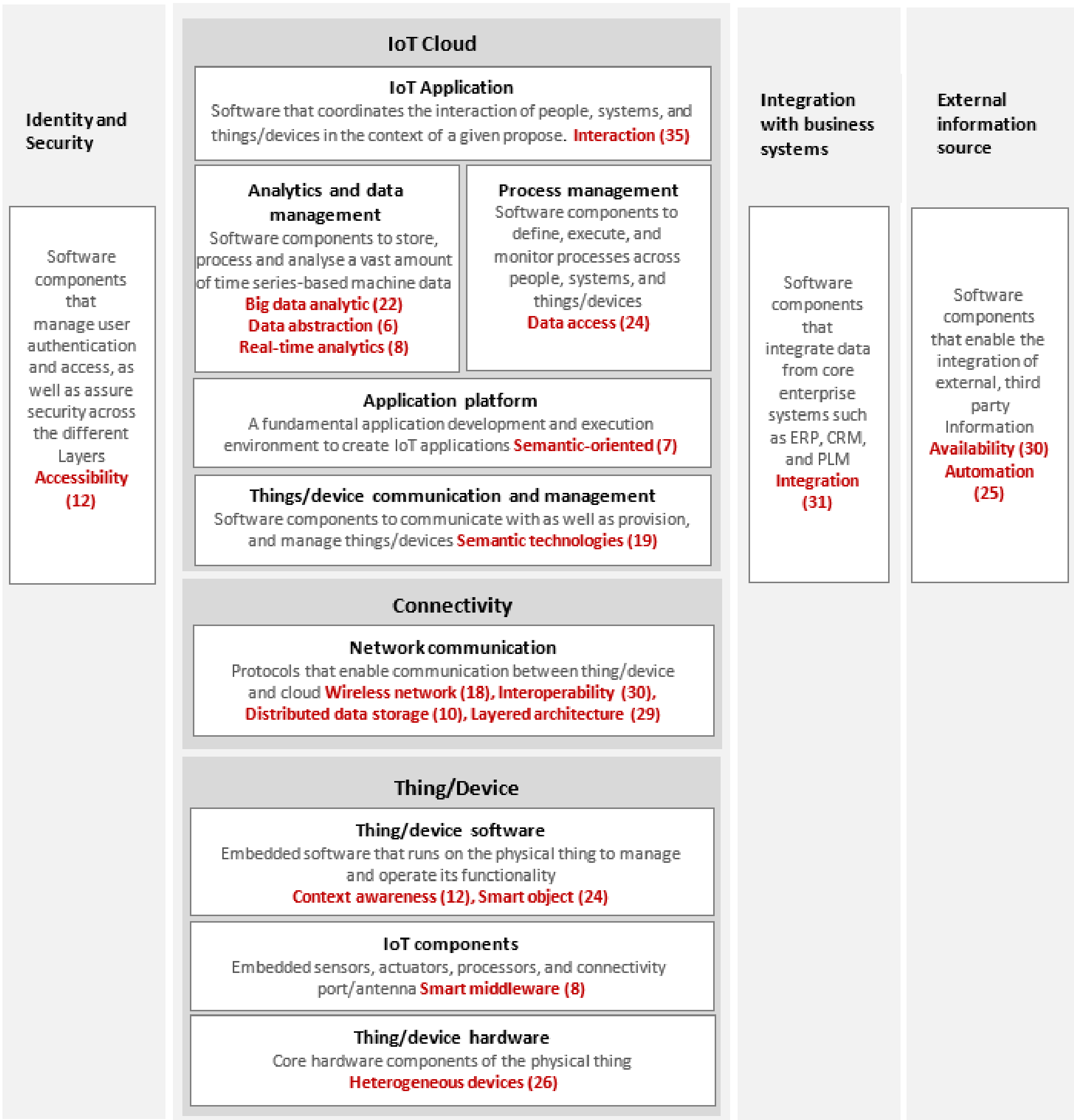


**Figure 3.** Frequent properties of IoT technology based on the layers of IoT technology Stack (Porter & Heppelmann, 2014) and their frequency in research.

### *5.1. The Properties of IoT Technology*

The selected studies were reviewed to extract the properties of IoT technology with higher frequency. The IoT properties are those *features* (characteristics) agreed upon by various researchers and/or referred to in several studies as properties of IoT technology. Then words and phrases related to IoT properties were extracted and coded accordingly. Based on 44 selected studies on IoT technology, 23 frequent properties were initially extracted through the first route. However, four properties, namely, (i) process-awareness, (ii) activity-awareness, (iii) policy-awareness, and (iv) unambiguous data, were removed from the IoT property list and further investigation due to their low frequency usage, making 19 IoT properties in total (see Figure 3).

These properties are distributed based on the nature and functional relationship with the concepts of layers and aspects of the IoT technology stack as discussed in Section 3.1 and are presented in Table B.1 in Appendix B. The properties of IoT technology in the *IoT cloud layer* (the first layer) comprise five components: (i) IoT application, (ii) analytics and data management, (iii) process management, (iv) application platform, and (v) things/device communication and management. Of these main five components, the properties of interaction, big data analytics, data abstraction, real-time analytics, data access, semantic-oriented, and semantic technologies have a conceptual relationship with the IoT cloud layer (see Figure 3). Four properties of wireless network, interoperability, distributed data storage, and layered architecture, are related to the function of the *connectivity layer* (the second layer). As per properties of IoT technology in the *thing/device layer* (the third layer), which is comprised of three components (i) thing/device software, (ii) IoT component, and (iii) thing/device hardware, the properties of context awareness, smart object, and smart middleware from the first and second components, and heterogeneous devices from the third component of this layer were identified. The accessibility, integration, availability, and automation properties are compatible with the function of the three aspects of the IoT technology framework. Figure 3 shows the properties associated with each layer/aspect and their frequency in the articles. These properties will be used to analyze the relationship between theory and IoT technology in the following sections.

### *5.2. Selected Theories*

As mentioned, content analysis was used to analyze the 125 studies selected through the second route (see Table A.1 of Appendix A). In total, 69 theories were identified and coded. In the next step, the repetition of theories in each study or, in other words, their frequency was counted. To do so, Shannon's entropy method was used to weigh the theories and select theories with high repetition (Chen, 2020). The entropy weight indicates the relative significance of the coefficient of each theory compared to other selected theories. The significance of the coefficients of the theories was calculated based on the weight obtained from their frequency (Table A.2 Appendix). The greater the difference between the frequency of theories in a column, the lower the entropy of the elements in that column and the greater the entropy weight, which indicates the importance of the theory. According to Tables A.2 to A.4 of Appendix A, the article-theory matrix was formed, and the significance of coefficients of the theories was calculated based on the weight obtained from their frequency of application. After calculating the significance of coefficients, the Scree test was used to demonstrate the theories with the highest significance coefficient (Cattell, 1966; Hanafizadeh et al., 2009). This test allows for the screening of theories with the lowest/highest coefficient of significance. In this test, the significance of coefficients of the theories was first plotted in a line graph. Then, from the point where the slope of the graph changed ($\lambda_j$[1] $\succ 1$), the theories with the highest coefficient of significance were selected. Figure 4 shows how the Scree test was performed and presents the results (for more details, see Table A.4 in Appendix A). In total, 8 out of 69 theories, which had higher frequencies, were selected for further investigation.

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[1] Importance coefficient of each theory (see Appendix A, Shannon Entropy Equations)

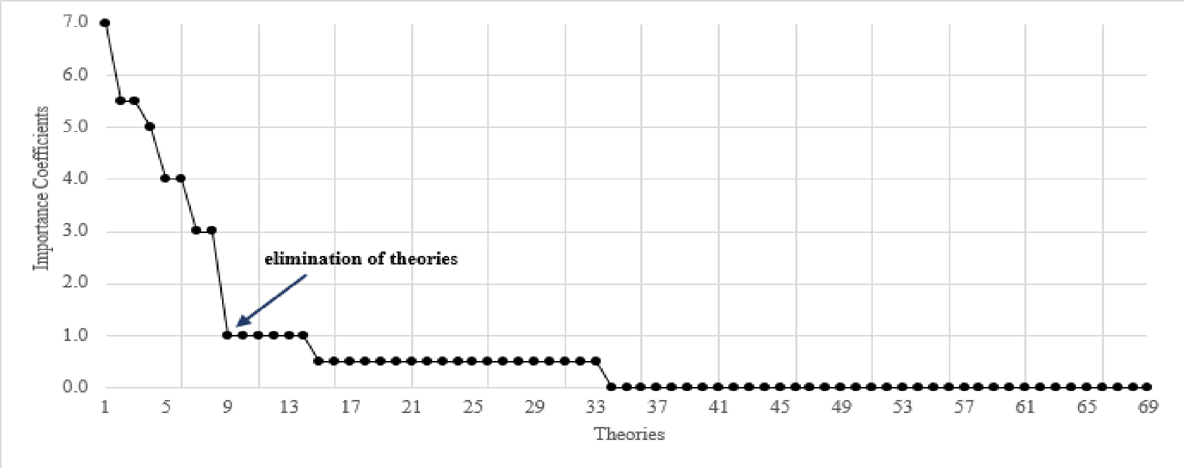


**Figure 4:** Selection of management theories with Scree Test

The eight most frequently used theories in research on the application of IoT in business are presented in Table 3. Although the authors are aware of the potential limitations of such an assumption, we; nevertheless, considered the frequency of use to detect the most important theories in the analysis. Moreover, to elaborate on these theories, we employed Gregor's (2006) classification of theories in IS research (e.g., analysis and description, explanation, prediction, explanation and prediction (EP), and design and action). We used the first letter of each theory to assign research IDs. The following abbreviations will be used when a theory is referred to in selected studies: C = contingency theory; D = diffusion of innovations theory; P = dynamic capability; G = game theory; I = institutional theory; B = resource-based view of the firm; R = resource dependency theory; and S = stakeholder theory. These references are classified in 8 groups based on the names of the theories in Table C.1 (Appendix C). These references involve two categories: (1) sources used for explaining the theory and its constructs, and (2) sources that studied the theory and the application of IoT in business.

**Table 3.** The studies with a focus on theories and IoT.

| Theory | General categories | Level of analysis | Source Type | | | | Study's ID |
|---|---|---|---|---|---|---|---|
| | | | J | B/BC | CP | LN | |
| Contingency theory | Organizational theories | Individual, Firm | 8 | 2 | - | - | [C1], [C2], [C3], [C4], [C5], [C6], [C7], [C8], [C9], [C10] |
| Diffusion of innovations theory | Sociology | Group, Firm, Industry, Society | 13 | 1 | 1 | 1 | [D1], [D2], [D3], [D4], [D5], [D6], [D7], [D8], [D9], [D10], [D11],[D12], [D13], [D14], [D15], [D16] |
| Dynamic capabilities | Resource-based theories | Capability, Firm | 12 | - | 1 | - | [P1], [P2], [P3], [P4], [P5], [P6], [P7], [P8], [P9], [P10], [P11], [P12], [P13], |
| Game theory | Rational/ strategic choice theories | Group, Individual, Firm, Industry | 11 | 3 | - | - | [G1], [G2], [G3], [G4], [G5], [G6], [G7], [G8], [G9], [G10], [G11],[G12], [G13], [G14] |
| Institutional theory | Behavioral theories | Group, Firm, Industry | 11 | 1 | - | - | [I1], [I2], [I3], [I4], [I5], [I6], [I7], [I8], [I9], [I10], [I11], [I12] |
| Resource-based view of the firm | Resource-based theories | Firm | 12 | 1 | - | - | [B1], [B2], [B3], [B4], [B5], [B6], [B7], [B8], [B9], [B10], [B11], [B12], [B13] |
| Resource dependency theory | Resource-based theories | Firm | 9 | 2 | - | - | [R1], [R2], [R3], [R4], [R5], [R6], [R7], [R8], [R9], [R10] ,[R11] |
| Stakeholder theory | Organizational theories | Firm | 11 | 1 | - | - | [S1], [S2], [S3], [S4], [S5], [S6], [S7], [S8], [S9], [S10], [S11], [S12] |

Note: J = Journal; B/BC = Book/Book chapter; CP = Conference paper; LN= Lecture Notes

A summary explaining the introduction, assumption(s), and key aspects of the eight selected theories in this research is presented in Table 4.

**Table 4.** A summary of the information related to the selected theories.

| Theory | Type of theory | Introducing the theory | Key Aspects of the theory | Assumptions of the theory |
|---|---|---|---|---|
| **Contingency theory** | Explanation & Prediction | Contingency theory focuses on the uncertainty of the environment of organizations. According to this theory, organizations must adapt to environmental conditions; because such conditions can affect their characteristics (such as strategies and organizational structure) [C9]. | There are several ways to develop a plan for an organization. The optimal method of managing an organization and its situation depends on various internal and external factors. | The efficiency of an organization increases, when the environment and organization are compatible [C9]. |
| **Diffusion of innovations theory** | Explanation | The DoI theory points to understanding the process of adopting new technologies and explains why and how the new ideas and technologies are expanded [D16]. | Four stages are defined for the diffusion of innovation: invention, diffusion through the social system, time, and its consequences. | There are five key properties in the innovation process [D16] that have a positive effect on the adoption of innovation [D3]. |
| **Theory of dynamic capabilities** | Explanation | The Theory of Dynamic capabilities refers to the firm's ability to integrate, construct, and reconfigure internal and external competencies in changing environments. Capabilities are a combination of resources that organizations can use to achieve specific goals [P12, P13]. | The value of dynamic capabilities lies in the ability to manage resources for value creation strategies. These capabilities evolve through known learning mechanisms. | 1-Dynamic capabilities are organizational and strategic processes that are the source of value creation [P12].<br>2-The resources and capabilities of the organization should be adapted, renewed, and re-evaluated with changing environmental conditions [P10]. |
| **Game theory** | Explanation | This theory uses mathematical and analytical methods to predict, explain, and prescribe what players (economic agents) with different levels of rationality do in different situations [G13]. | The Game Theory uses a mathematical method for explaining natural competitive phenomena [G13]. | 1-The costs and benefits of a strategic decision in the game depend on the behavior of the parties [G13].<br>2-Actors who participate in a game are rational and try to get the maximum result [G13]. |
| **Institutional theory** | Explanation & Prediction | This theory considers the processes that create the structures and are considered a credible guide for social behaviors [I11]. | The behavior of firms is limited to heterogeneous processes such as imitation, norm, and coercion. | Individuals in society are satisfied with the institutionalization of affairs and adapt themselves to external norms [I11] |
| **Resource-based view of the firm (RBV)** | Explanation | This theory refers to the main sources of an enterprise. Organizational resources and capabilities in enterprises are different and differentiate their performance and competitive advantage [B13]. Resources and capabilities are key components of RBV. | Organizational resources and capabilities differentiate performance and competitive advantage. Valuable, unique, and inimitable resources can lead to the competitive advantage of enterprises. | 1-The main focus of the theory is on internal resources.<br>2-The main resources of the firm consist of tangible and intangible assets.<br>3-Organizational resources must be valuable, scarce, inimitable, and irreplaceable [B13]. |
| **Resource dependence theory (RDT)** | Explanation | This theory describes inter-organizational links as a set of power relations based on the exchanged resources [R11]. | Organizations are dependent on resources and activities outside the organization and are affected using resources. The ability of the firm to collect, change and provide useful services or products with higher speed can improve the organization's performance. | 1-Organizations are a set of internal and external coalitions.<br>2-The environment contains scarce and valuable resources that are essential for the survival of the organization.<br>3-Organizations have two goals: to obtain resources that minimize their dependence on other organizations; and resources that maximize the dependence of other organizations on them. |
| **Stakeholder theory** | Explanation | This theory argues that any legitimate person or group that participates in the activities of a firm does so to gain benefits [S12]. | The activities of the firm should create value for all stakeholders who are affected by the activities of the business. Each stakeholder should benefit from the actions taken in the business. Each stakeholder must strive for the long-term survival of the company. It is necessary to develop specific criteria for membership in the stakeholder team. | 1-Every firm needs to identify its internal and external stakeholders [S11].<br>2-The firm needs to gather more information about stakeholders to meet their expectations [S9]. |

*5.2.1. Contingency Theory (CT)*

According to CT, organizations are open systems that constantly interact with their environment and adapt to environmental pressures [C2, C10]. Study by [C4] shows that the application of IoT technology in business information management can solve the problems arising from organizational change and incompatibility with the environment by using contingency thinking. The use of IoT in intelligent business management paves the way for the innovation and development of businesses and improves the whole system's efficiency [C8]. In addition, [C5] mentioned increasing competitiveness and facilitating business model innovation as the outcomes of IoT application. Some studies show that the use of IoT in business has provided the context for adapting the structure and decisions of the business to its internal and external environments [C7]. As a result of evaluating environmental data, an enterprise may provide more appropriate decision-making conditions while closely monitoring and responding to changing environmental conditions [C1], allowing it to alter the production capacity of new products to meet market demands [C5].

In addition, CT can be used to study the success of IoT applications in the enterprise. For example, [C4] examined the successful application of IoT in an educational institution. The author identified properties such as interaction, wireless network, and interoperability of IoT technology, leading to new capabilities for learning and decision-making in the education process. The results of the application of IoT technology in education, including process facilitation, a better adaptation of the organizational structure to the environment, and the impacts on educational policies, were also discussed in [C4]. In another study, [C2] used CT to determine the success of IoT implementation in the enterprise and introduced four effective contingency variables: (1) type of corporation, (2) organization size, (3) levels of IoT maturity, and (4) organization's experience in using sensing devices. Training staff, supporting the use of tailored smart tools, and conducting accurate and frequent reviews of smart tool performance were highlighted as essential strategies to improve contingency and boost the effectiveness of the IoT applications in the organization [C2].

In the studies reviewed, CT was used to explain the IoT phenomenon in the form of logical reasoning. This theory is also used to study environmental interactions and receive feedback. The two applications, namely, *describing the impact of technology application in the organization* and *predicting the consequences of its application*, according to the types of theories mentioned by Gregor (2006), indicate the characteristics of the fourth type of theory, namely explanation and prediction (EP).

*5.2.2. Diffusion of Innovations Theory (DoI)*

The DoI theory helps to understand the process of innovation adoption [D16]. DoI has been widely used as a basic theory in IoT innovation adoption studies. For example, [D5] used DoI theory to investigate the effects of the development and application of IoT innovations in various fields. The authors pointed to the key challenges faced by the development of innovation and the need to understand the decision-making conditions of the users when adopting new technology. This study showed that trust, cost, perceived value, privacy, and security are common concerns that arise in different areas of IoT applications. Other scholars also found perceived benefits, perceived costs, external pressure [D4], compatibility, perceived usefulness, and perceived ease of use [D12] to be important determinants of IoT innovation adoption, while technology trust [D14] and trialability [D12] were found to be indirectly related to the IoT adoption through perceived benefits. In another study, several barriers such as low readiness infrastructure, poor data management, lack of IoT experts, lack of IoT regulatory guidelines, data protection rules for service receivers, and lack of a consistent reimbursement model for IoT development in the service sector were mentioned [D6].

In the reviewed studies, the DoI theory was used to describe *how IoT innovation is adopted and why there are challenges in its application*. This theory tries *to understand the phenomenon of IoT* and *the consequences of its application in various fields* and therefore is consistent with the second type of theories in Gregor's (2006) research, namely explaining theories.

### *5.2.3. Dynamic Capabilities Theory (DCT)*

Dynamic capabilities are the capacity of an enterprise to integrate, create and renovate internal and external capabilities when interacting with changing environments [P2, P12]. The application of IoT in business will lead to collecting information from the environment resulting in the rapid exchange of vital and instantaneous information with the stakeholders [P3]. The outcome is making proper decisions based on the knowledge that plays an essential role in creating dynamic data and information processing capability [P6].

[P11] asserted that the dynamism of capabilities can be the key driver of innovation and a determinant in an organization's macro decisions. Data storage capability and high processing speed allow the business to make real-time decisions at a higher speed. They also facilitate the continuity of data analysis trends to interact with the environment [P1, P10].

The logic of DCT theory is applied to comprehend IoT technology as a capability that can provide businesses with a competitive edge in extremely dynamic and uncertain circumstances. For example, [P9] pointed to the application of IoT in business as a determinant of operational agility and building organizational capability. [P10] mentioned that the concepts of RBV and DCT theories are used for the successful application and implementation of IoT [P10]. [P7], through the lens of DCT, investigated the smart city and explained the concept of an urban organization with dynamic capabilities based on sense, seize, align, and transform functions. Although IoT technology can directly impact the organization's improved performance, it may not be adequate to maximize operational benefits. Organizations often need human capabilities to process data and share information. These capabilities, together with IoT, can provide managers with better opportunities to achieve operational benefits [P9].

In the reviewed studies, DCT has been used to *describe the organizational capabilitie*s after implementing the IoT. This theory explains *how and why an enterprise's capabilities change*. However, in none of the reviewed studies, this theory has been used to describe and predict the status of the organization's capabilities in the future, and therefore it is consistent with the second type of theories in Gregor's (2006) research, namely Explaining theories.

### *5.2.4. Game Theory (GT)*

Game theory utilizes mathematical and analytical techniques to explain natural competitive phenomena [G3, G7, G13]. A sustainable strategy is achieved based on the interaction with the environment and using context-awareness employing IoT technology in business [G10]. Research shows that the IoT can provide different service levels to suppliers and buyers using data collected from enterprises [G6]. The two issues of position selection and service quality are evaluated when providing services.

Reviewing the studies shows the connection between GT and the application of IoT technology. For example, [G10] described the evolutionary GT and the impact of IoT technology. In this type of GT, evolution and natural selection replace the actors' rationality, and IoT technology uses RFID[2] to help supply chain stakeholders to analyze environmental information and achieve a sustainable strategy [G10]. [G9] used this theory to examine how information sharing and security investment strategies are performed. This doubles the need for information security, and as shown by [G9], a centralized decision-making solution using IoT data is the optimal solution. This study shows that as the size of the corporate communication network increases, the cost of investing in information security will also increase [G9].

Overall, the GT describes *how and why people make decisions in specific situations*. This theory also refers to *the rationality of the actors and their effort to achieve maximum outcomes* and helps to *understand the interrelationships* of actors. Regarding theory types of Gregor's (2006) research, it is an explaining theory.

### *5.2.5. Institutional Theory (IT)*

This theory explains the reasons and the ways external pressures are exerted on the organization and how the organization is affected by external forces, which might impact its operations [I3, I12]. The results of [I6] indicate the positive effect of urban institutions on the individuals' desire to build IoT-based devices. However, it is difficult to gain legitimacy for IoT-based innovations, especially in emerging economies where societies are seldom interested in supporting entrepreneurs for whom they do not have any record. Thus, social culture can restrict entrepreneurial orientation [I2]. In addition, the complexity and resources required to develop IoT in an institutional environment can be the biggest obstacle in emerging economies [I6]. Weak environments will have a negative impact on the development of IoT-based businesses; thus, the use of IoT will face more limitations [I6]. The context-awareness property of IoT technology can be effective in its adoption, though [I6]. As stated by [I2], the application of IoT in business will provide the ground for competition with other enterprises and facilitate business model innovation.

Institutional theory can also help understand which pressures (normative, mimetic, and coercive) have the greatest impact on the dissemination and development of the application of IoT technology in various fields [I5].

In sum, institutional theory has been used to *understand the factors affecting the adoption of innovation*, and its application has led to the *creation of insights on the importance of institutional environments*. In addition, this theory has been used to *explain and predict the impact of environmental factors*. Therefore, according to the types of theories mentioned in Gregor's (2006) research, this indicates the characteristics of the fourth type of theory, namely explanation and prediction (EP).

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[2] Radio-Frequency Identification

### 5.2.6. *Resource-Based View of the Firm (RBV)*

The RBV theory explains that organizational resources and capabilities vary across firms, differentiating firms' performance and competitive advantage [B13]. A study by [B5] showed that the use of IoT in an enterprise will change key resources, activities, partners, and the cost structure. In this case, IoT-based solutions can become the main source of competitive advantage [B6]. Moreover, [B8] stated that applying IoT-based solutions increases efficiency in customer-supplier relationships and supports the firm's position among other competitors.

Several strategic capabilities of the firm were identified in the literature, such as business model development [B4, B8], building scalable solution platforms [B6], IoT value selling [B8], and IoT value delivery [B11], business intelligence and measurement [B3]. These key capabilities enable manufacturers to create and develop value creation solutions through IoT.

The application of IoT technology will bring strategic capabilities to the enterprise. Given the role of information as a major source of competitive advantage, the assumption of RBV theory about value-creating organizational resources and their conditions is realized.

[B10] discussed IoT-based businesses and the way to protect strategic resources such as information using RBV theory. In addition, the study [B3] explained the strategic factors of business model innovation for IoT-based solutions and its results from the perspective of RBV theory [B3]. [B11] used RBV theory to answer how technologies such as IoT affect the development of software systems.

In the reviewed studies, RBV theory has been used to *understand the importance of information-based resources* in organizations and *to explain the role of strategic resources* derived from the application of IoT technology in the enterprise. RBV theory deals with *why and how valuable resources affect the organization's performance*, and in this regard, it can be said that according to Gregor's (2006) research, it is an explanation theory.

### 5.2.7. *Resource Dependence Theory (RDT)*

The RDT describes a firm as an open system dependent on environmental probabilities [R11]. According to this theory, a firm needs partners with resources due to a lack of capability or resources [R7, R10]. The relationship between stakeholders through IoT with a focus on manufactured products creates a connection among consumers, manufacturers, and intermediaries [R4]. As a result, the constant interaction of stakeholders leads to the formation of business networks [R4]. Hence, manufacturers can get more details about the use of the products, the product's performance in different scenarios, or present value propositions to customers [R4].

Insights are created using the IoT and the interaction among the supply chain members, as such insights may lead to the development of new business models based on information sharing [R5]. Consequently, information sharing may result in better management of the risks associated with new business models. The data collected by IoT can also be used to identify product application patterns, improve processes, and enhance productivity [R4]. The IoT technology enables access to data for decision-making by creating a network of resources [R4]. With the help of IoT and through the interaction of things, more knowledge of the environment and context awareness is achieved. This knowledge increases the enterprise's decision-making power, resulting in an increase in profitable opportunities and a decrease in the threats to a firm.

Studies that have used RDT theory, and its application in IoT-related research have mainly focused on the supply chain management. For example, [R3] examined the dependency of resources from the perspective of RDT theory in a multi-tier supply chain. Moreover, [R4] pointed to the conceptualization of product-use data as a vital resource of the IoT-based network with the help of RDT theory, and highlighted the actors' reliance on one another for profit opportunities.

In the reviewed studies, RDT theory has been used to *explain how dependency on resources such as data affects the enterprise's performance*. RDT refers to the *outcomes of resource dependency* and *explains its relationship to the organization's success*. According to Gregor's (2006) research, this theory can be identified as an explanation theory.

*5.2.8. Stakeholders Theory (ST)*

this theory explains how internal and external stakeholders influence the firm and why stakeholders exert pressure to reduce negative impacts and increase positive ones [S11-12]. The IoT makes it possible to interact with stakeholders effectively, identify needs intelligently, position, monitor instantly, and manage transparently [S10].

[S7] shows that every business is like a system where all stakeholders must participate in growing the business. To succeed in business, it is necessary to have a proper understanding of how to create value by making strategic decisions about stakeholder relationships in the value creation process [S3, S6]. Studies conducted by [S2] and [S8] show that the application of IoT in the firm provides opportunities to enhance customer loyalty and participation in value creation. The application of IoT in selecting enterprise suppliers can be based on system data and their comparison [S5].

From a ST perspective, by assessing and forecasting the impact of enterprise decisions on its stakeholders, IoT can provide a feasible option for enterprises to meet stakeholders' expectations better. For example, [S4] used the theory to explain how firms interact with suppliers on IoT-based platforms. Moreover, [S10] discussed the role of IoT and its impact on the green chain. These researchers also pointed to the role of ST in understanding enterprise development and its relationship with stakeholders. One of the results of IoT application in the green supply chain was transparent monitoring and management. [S6] used the theory to develop an IoT-based coordination system. They proposed three types of drivers based on ST to achieve a secure and sustainable system in service delivery: (1) interested stakeholders, their needs or demands, (2) the role of each stakeholder or its influence on others, and (3) practices (3PLs support) or technologies (IoT) used by stakeholders. In [S2], this theory was used to explain the challenges of applying innovations, especially IoT technology, in the health industry.

In the reviewed studies, ST has been used to *explain the application of IoT technology to stakeholder relations* in different industries. The use of this theory to explain *how stakeholders are affected using the IoT technology* and the *interaction between the organization and stakeholders* using IoT technology shows the appropriateness of this theory to explain the *whyness and howness* of the phenomena. Thus, according to Gregor's (2006) research, stakeholder theory is an explaining theory.

## 6. Discussion

In this study, management and organizational theories used in research related to the application of IoT in business were identified and thoroughly discussed. Moreover, the IoT properties were extracted from the literature, see Table B.1 in Appendix B, and were organized in the IoT technology stack framework for better understanding and order. In this framework, three layers of IoT cloud, connectivity and thing/device, and three aspects, including identity and security, external information source, and integration with business systems, were used to examine the application of IoT technology (Porter & Heppelmann, 2014). The retrieved IoT properties were then identified and counted based on the sum of the tasks of each layer/aspect, as shown in Figure 4. The results showed that the interaction with (35 cases) and the data abstraction with (6 cases) were the most and the least used properties (see Table B.1 in Appendix B). Moreover, based on the IoT technology stack, the highest frequency of the properties of the IoT technology was the IoT cloud layer (with 18 cases), and the lowest one was the integration with business systems (with 1 case), see Table C.2 (Appendix C). Furthermore, the performance of each layer of the IoT technology stack framework and its impact on business were analyzed based on the assumptions of management and organizational theories and IoT properties. Theories with a higher frequency of use in IoT research were chosen (8 in total). A summary explaining the introduction, assumption(s), and key aspects of the eight identified theories in this research is presented in Table 4.

The theory of dynamic capabilities was the most frequently used with nine IoT properties, including big data analytics, data abstraction, real-time analytics, data access, interaction, distributed data storage, smart middleware, smart object, and accessibility. The institutional theory was the least frequently used with one IoT property, that is, the interaction.

### *6.1. Relationship between IoT Properties and Management and Organizational Theories*

Reviewing studies dealing with the application of theories and their assumptions in IoT technology in business revealed that the properties of IoT technology enable the realization of several assumptions of the management or organizational theories. Also, the frequent use of the properties and a theory for study strengthens the relationship between specific IoT properties and the theory. In other words, the relationship between theory and IoT properties results from attributing specific IoT properties to the realization of high-frequency theory assumptions. Table C.2 (Appendix C) presents the relationship between IoT technology properties and selected theories based on the IoT technology stack framework.

The findings of revealed that in the IoT cloud layer, and its components, management and organizational theories have had the highest use in studies. In this layer, the interaction property of the *IoT application component* has made it possible to realize the assumptions of all eight theories selected. In the *Analytics and data management component*, the big data analytic property has prepared the ground for realizing the assumptions of RBV and DCT theories by changing the resources, activities, the cost structure of an enterprise [B5], developing competitive advantage [B6], and dynamic capabilities [P7]. Besides, the two properties, data abstraction and real-time analytics, have contributed to realizing the assumptions of RDT, RBV, and DCT theories through agile enterprise internal and external operations [P9], developing solutions based on the key capabilities [B6], and proper and rapid identification of the stakeholders' needs. In the *Process management component*, through the data access property of IoT technology, the development of the strategic capabilities of the enterprise, and platform-based solutions, the assumptions of RBV and DCT theories have come closer to reality. In the *Application platform component*, the semantic-oriented property of the IoT technology has created a novel capacity for internal resources by developing information-based resources [B10] and has led to the realization of the assumptions of RBV theory. In the *Things/device communication and management component*, employing the semantic technologies property contributes to realizing the assumptions of DoI theory for identifying the degree of progress in the adoption of technology [D15].

In the second layer of the IoT technology framework and in the *Network communication component*, the better adaptation of the organizational structure to the environment [C4], proper interaction with producers to identify new needs, and being informed of the customers' views about the products [D11] could be achieved through wireless network and interoperability properties, and the assumptions of DoI, CT and RDT theories are realized. Also, through the distributed data storage property and creating operational agility [P9], the assumptions of RDT and DCT theories have approached reality.

In the things/devices layer and in the *Things/device software component*, the properties of context-awareness and smart object enable the realization of the assumptions of the following theories: CT, through supervision and interaction with the environment [C1], DoI, by examining the outcomes of innovation development [D5], DCT, through dynamic capabilities of intelligent objects [P7], RBV, by changing the key resources [B10], RDT, by developing business networks [R4], and ST, through interaction opportunities and value creation [S8]. In addition, in the *IoT components*, and through the smart middleware property, opportunities are provided for continuing the data analysis process to interact with the environment [P1] and among the stakeholders [C7, S1]. This contributes to the realization of the assumptions of DoI, DCT, and ST theories. Besides, in the *Thing/device hardware component*, the heterogenous devices property provides for the realization of the assumptions of RDT theory by making the interaction among devices possible. Moreover, examining the IoT properties in the three aspects (identity and security, external information source, and integration with business systems) of the IoT technology stack framework model showed the lack of research on IoT properties in these aspects (see Table C.2). The accessibility, integration, availability, and automation properties of IoT make it possible to realize the assumptions of resource dependency theory and game theory.

### *6.2. Theoretical Implications*

According to our systematic literature review, IoT researchers have become increasingly interested in the application of management and organizational theories. While numerous studies have dealt with the identification of the practical capacity of these theories in business, few studies have considered the application of several theories in one study. While studies such as [C6, D10, I6, R4] have examined the application of a theory in IoT research, some studies such as [P10, S10] have examined two theories and their impact on IoT research.

In addition, to the best of our knowledge, no previous research has investigated the relationship between management and organizational theories and the application of IoT in business. Thus, the present study contributes to the literature by providing threefold theoretical implications: (1) management and organizational theories can provide valuable sources of theoretical foundations for future IoT research, (2) the results of this review show that there are theories with the potential to be used in IoT technology research, which have been neglected so far, and (3) based on the results provided in Table C.2, each layer/aspect of the IoT technology stack framework has its own collection of IoT technology properties. Table 5 presents the dominant IoT properties, theories, and their types in the form of theories suggested for conducting research on the function of each layer/aspect. Dominant properties are IoT technology properties that occur more frequently in IoT research not related to business and research on theories to explore the application of IoT in business.

**Table 5.** Suggested theories for research and their types per layer(s)/aspect(s) in IoT technology Stack framework.

| | Layers | | | |
|---|---|---|---|---|
| Layer/aspect | IoT Cloud | Connectivity | Thing/device | Aspects |
| Dominant IoT property | Interaction | Interoperability | Context awareness | Accessibility |
| Suggested theories for research | -Theory of dynamic capabilities<br>-Resource-based view | -Contingency theory<br>-Resource dependence theory | Stakeholder theory | Game theory |
| Type of suggested theories | Explanation | -Explanation & prediction<br>- Explanation | Explanation | Explanation |

Note: The aspects include identity & security, external information sources, and integration with business systems

According to the classification of theory types by Gregor (2006) and based on Table 5, the theories, which had the highest frequency in research in the *thing/device* and *IoT cloud* layers belong to the explanation (E) type of theories. A review of studies that specifically address the application of the theories of DC, RBV, ST, and IoT show that 35 studies, in particular [P1, P5, P9-10, B5-6, B8, S8], have used management and organizational theories to answer questions on why and how to use IoT in business. In addition, management theories in these studies answer the research questions about the relationship between IoT application and dynamic data to increase business knowledge and agility, explore the challenges and limitations of IoT application on a larger scale, expand firm activities, and improve product and service quality. Also, a review of 27 studies, in particular [R2, C1-6], in addition to explaining the impact of IoT on organizational structure and inter-organizational interaction, indicated that studies that have addressed the use of IoT in business from the perspective of resource dependence and contingency theories, predict the role of IoT in increasing firm productivity and business innovation. Reviewing studies related to the application of game theory in IoT research, especially studies [G6, G9-10], reveal that researchers, while addressing the issue of business information sharing and its profitability for the firm and the environment, use the concepts of game theory to explain potential risks of information sharing such as information leaks, issues related to security breaches and internal firm constraints.

### *6.3. Practical Implications*

The practical insights provided in this review research offer a comprehensive understanding of the phenomenon for business managers and decision-makers in the firm. This research addresses the strategic capabilities, which can be achieved by applying IoT technology in businesses (firms), understanding the management and organizational theories, their types, and the way they interact with the properties of IoT technology. Applying management theories also provide managers with a better opportunity to understand the use of the IoT in business. The most important consequences of applying IoT in a firm are the increased interaction between business and its environment [C7], knowledge sharing and facilitating communication between devices and stakeholders [S8], external and internal operations agility [P9], market situation analysis [G6], more proper identification of new needs for manufacturers [R4, R1], and effective interaction with stakeholders [S8].

Table 6 shows the application of IoT in business from the perspective of management and organizational theories. The results point to the realization of the assumptions of theories with the help of IoT technology in business. For example, the assumption of the game theory refers to the actors' rationality. One of the applications of game theory in IoT-based studies in the organization is automating decision-making. For example, fog computing, disaster management, and smart building control. Automated decision-making requires dynamic systems in which information constantly changes with changes in the processed environmental data. System dynamics and up-to-date information will lead to a more rational decision. Another practical contribution of this review paper is the insights, which indicate that the integration property of IoT technology has brought the assumption of actors' rationality and the impact of their decision on costs and benefits closer to realization. Furthermore, the DoI theory elaborates on the impact of technology and its successful establishment in the enterprise. Technology adoption analysis requires a proper understanding of the environment by collecting relevant data from the environment, and IoT technology can help in this regard.

Moreover, the results show that dynamic capabilities can be used to address the enterprise's abilities in integrating, creating, and rebuilding internal and external capabilities in interaction with the environment. With dynamic capabilities, the organization's abilities lead to achieving new and innovative forms of competitive advantage due to the dependence on the path and market positions. Effective resource management is also realized by increasing the awareness of environmental changes and with the help of IoT technology. Moreover, the assumption of contingency theory refers to increasing the firm's efficiency in case there is compatibility between the organizational structure and the dynamic environment. The results also show that the institutional theory assumes the institutionalizing activities and business adoption with external norms. Obtaining legitimacy for different innovations that result from a proper understanding of society can lead to the adoption of innovation.

**Table 6.** Analysis of the IoT application in business from the perspective of management theories.

| Theory | Realization of the assumptions of theory using | The relationship between the theory and IoT properties | The results of using IoT in business to respond to the assumptions of management theories |
|---|---|---|---|
| **Contingency theory** | Using IoT creates compatibility between the organization and the external environment, increasing the enterprise's efficiency. | **context awareness**[C1]<br>**Integration**[C5]<br>**Interaction** [C4, C6]<br>**Interoperability** [C4]<br>**wireless network** [C4] | Increasing compatibility between firm and environment [C1, C6].<br>Increasing environmental interactions and enabling accurate monitoring and compliance with environmental conditions [C4].<br>Enhancing enterprise competitiveness and facilitating innovation [C7].<br>Knowledge sharing and facilitating communication between devices and stakeholders [C7].<br>Adaptation of production capacity to the required conditions [C7]. |

| | | | |
|---|---|---|---|
| **Diffusion of innovations theory** | Depending on how the characteristics of innovation are understood, the rate of innovation adoption can be decreased or increased [D3]<br>DoI theory is useful for identifying the degree of advances in technology adoption in IoT [D5]. | **Context awareness** [D5]<br>**Interaction**[D5]<br>**Interoperability** [D8, D5]<br>**Semantic technologies** [D15]<br>**Smart middleware** [D8] | The importance of DoI for identifying the degree of progress in technology adoption [D15, D5].<br>The importance of IoT and understanding the interaction between context and technology [D5].<br>Using DoI to evaluate the impact of products based on intelligent technology, services, and processes [D8]. |
| **Theory of dynamic capabilities** | If IS resources do not directly lead the business to a competitive advantage, they can help the business to compete in the unstable environment by developing, adding, merging, and releasing key resources over time. Through the use of IoT, businesses transmit vital and instant information to their partners [P6]. | **Accessibility** [P10]<br>**Big data analytics** [P7]<br>**Data abstraction** [P7]<br>**Data access** [P5]<br>**Distributed data storage** [P9]<br>**Interaction** [P7]<br>**Real-time analytics** [P9]<br>**Smart middleware** [P1] | Gathering information from the environment using IoT and developing operational knowledge and insights from connecting things [P6].<br>Raising awareness of business networks using the insights created [P6].<br>Making the right decisions based on the knowledge taken [P6].<br>Internal and external operational agility with the help of capabilities created through the use of IoT [P9].<br>Business prosperity and survival due to capabilities created through the use of IoT [P9].<br>Facilitating communication, especially data and knowledge exchange between institutions [P1, P10].<br>Enabling rapid response to events and business agility [P3]. |
| **Game theory** | Using game theory, market analysis is performed with the entry of new firms, customers and suppliers based on data collected through IoT [G6]. | **Accessibility** [G8]<br>**Automation** [G4, G10]<br>**Availability** [G6]<br>**Integration** [G4]<br>**Interaction** [G10]<br>**Layer architecture** [G4] | Achieving a sustainable strategy in the game using IoT-derived interaction and context-awareness [G10].<br>Creating different service levels in firms (for stakeholders) using data collected by IoT [G6].<br>Analyzing the market situation with the entry of new firms, customers and suppliers based on data collected through IoT [G6].<br>Selecting the position and quality in service delivery using data aggregated by IoT [G6].<br>The enterprise’s use of reliable connections to IoT-recorded information to better collaborate with other partners [G8,G9]. |
| **Institutional theory** | Given the complexity and resources required for IoT development, the institutional environment can be the biggest barrier or incentive in emerging economies [I2]. | **Interaction** [I2] | The influence of urban institutions on people’s desire to build IoT-based devices [I2].<br>The negative impact of weak environments on the formation of IoT-based businesses [I6].<br>The positive role of IoT in managing the performance of small enterprises<br>Application of institutional theory in the adoption of IoT by firms. |
| **Resource-based view of the firm** | 1-IoT-based solutions can become a major source of competitive advantage [B6].<br>2-The firm’s strategic capabilities enable manufacturers to create and develop value creation solutions through the IoT [B3-4, B7-8].<br>3-The use of IoT technology will bring strategic capability for the enterprise [B6]. | **Big data analytics** [B5, B6]<br>**Context awareness** [B10]<br>**Data access** [B8]<br>**Interaction** [B10]<br>**Real-time analytics** [B5, B6, B8]<br>**Semantic-oriented** [B10] | Increasing the efficiency of customer-supplier relationships and supporting the firm’s position among other competitors through the use of IoT in business [B8].<br>Development of IoT-based solutions using key capabilities to create value [B5-6, B8].<br>The application of IoT in solution-providing businesses increases efficiency in customer-supplier relationships and supports the company's position among other competitors [B8]. |
| **Resource dependence theory** | 1-Using the IoT interactivity property allows stakeholder interaction [R4].<br>2-The environment contains scarce and valuable resources that are essential for the survival of the organization. The use of IoT provides communication and interaction between the firm and the environment [R5].<br>3-IoT technology enables access to data for decision making by creating a network of resources [R4]. | **Accessibility** [R4]<br>**Context awareness**[R4]<br>**Distributed data storage** [R4]<br>**Heterogeneous devices** [R2]<br>**Interaction** [R2,R4]<br>**Interoperability** [R2]<br>**Real-time analytics** [R4]<br>**wireless network** [R2] | Enabling products to interact with each other, communication among product users, manufacturers and intermediaries using IoT [R4].<br>Ability to identify new needs by gathering more detailed information for manufacturers [R1, R4].<br>Creating insights from interactions among users, products, manufacturers, intermediaries and other members of the supply chain [R2].<br>Development of new business models for manufacturers using the insights obtained from interaction [R5].<br>Creating a network of resources with the help of IoT to provide access to data for decision making and increasing efficiency [R4].<br>Providing a network-based shared resource and creating stakeholder dependency with the goal of gaining profitable opportunities [R5]. |
| **Stakeholder theory** | 1-Each firm needs to identify its internal and external stakeholders affected by the decisions [S10]. The use of IoT can provide intelligent identification, instant positioning and monitoring, and transparent management [S10].<br>2-In an IoT-based platform, the set of stakeholders can change over time. Different stakeholders can simultaneously have the potential to create value or damage the value created, depending on their capabilities and expectations [S6]. | **Interaction**[S2-3, S6]<br>**Smart object** [S1, S8]<br>**Smart middleware**[S1] | Intelligent identification, positioning, instant monitoring, and transparent management using IoT [S10].<br>Creating opportunities to enhance customer loyalty to the business after employing IoT and creating added value [S2].<br>Customizing products by learning more about the business owner’s priorities and behavior using IoT technology[S4].<br>Selecting suppliers based on data from the use of IoT [S5].<br>Effective interaction with stakeholders using IoT [S8]. |

The RDT theory describes an enterprise as an open system dependent upon environmental probabilities. The use of IoT helps to connect consumers, producers, and intermediaries. The interaction of supply chain members creates and shapes insight that can pave the way for developing new business models based on information sharing. Finally, the stakeholder theory deals with the impact of an enterprise's good or service provision on internal and external stakeholders. In addition, the application of IoT technology leads to the formation of a new set of relationships among stakeholders. Therefore, the opportunities to enhance customer loyalty and participation in creating added value will increase with the help of IoT technology. As Table 6 indicates, the realization of the assumptions of other theories are made possible by the enterprises through (i) increasing IS-based resources, (ii) providing data and the possibility for processing it for better analysis of the firm's condition for interactions with stakeholders, (iii) reducing environmental complexity, (iv) creating competitive advantages based on new information resources, and (v) developing new value creation strategies. Figure 5 shows the implications of IoT application in the firm and the theories that explain or predict these implications.

## 7. Conclusion

In this review study, the rationale of theories and their assumptions to conduct research on IoT applications in business were assessed using 179 peer-reviewed studies published between 2000 to the first quarter of 2022. The application of IoT technology in business presents businesses with numerous complexities and ambiguities. While, on the one hand, it may lead to the gradual evolution of technology, on the other, it may emphasize the need to use management and organizational theories in business. In addition, using theories whose assumptions are one step closer to realization due to the properties of IoT technology can be effective in studying the components of the IoT-based business model (Hanafizadeh et al., 2021). This research provides a comprehensive review of literature on IoT applications from the perspective of management and organizational theories. The findings presented here can help researchers to identify and apply relevant theories of IoT applications in the business context. They also help managers reduce uncertainties in the development process when using applications of IoT technology in the business.

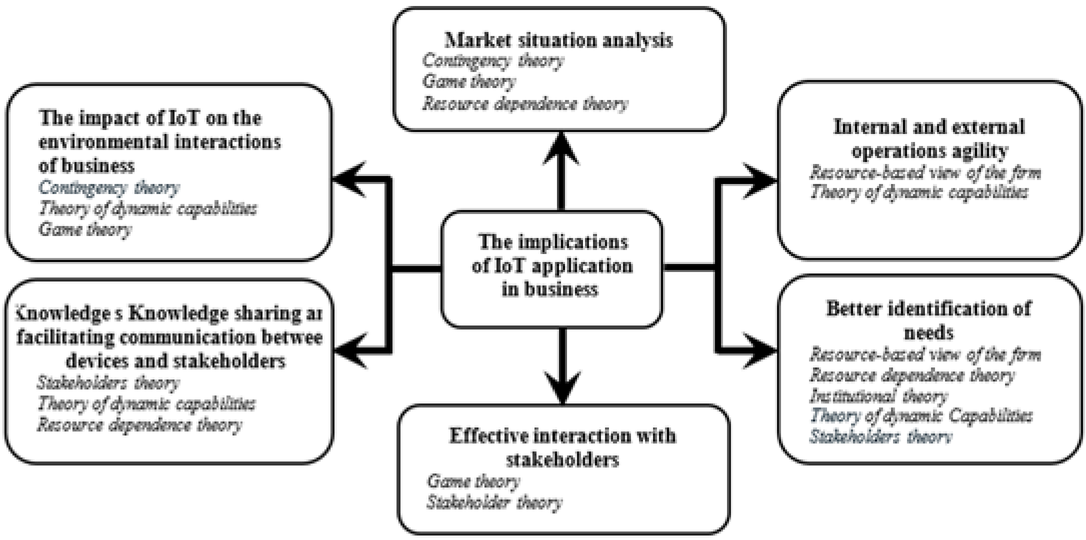


**Figure5.** The implications of IoT application in business based on responding to the assumptions of management theories

In addition, we found that due to the importance of IoT technology, empirical studies of the application of IoT in firms are evolving. For this purpose, sufficient knowledge of the technology is necessary, and management theories can significantly contribute to providing theoretical insights. In addition, the review of the literature shows that the realization of the theories' assumptions in the context of IoT technology can pave the way for recognizing the capacity of the technology and make it possible to explain and predict the outcomes of IoT applications in business. This helps the researcher gain more knowledge of the applicability of theories in analyzing, explaining, and predicting the functions of IoT in the organizations and use the related theories depending on their area of study by investigating these results. The three key contributions of this study can be summarized as follows:

1. Based on the studies on the improvement of resources and tools required for a business for IoT application, it was found that many prior studies have focused on new technologies and the facilities needed by the business to develop and apply IoT [P1, P7, P10, B10]. The concepts studied in this group are most relevant to the *IoT cloud layer* of the IoT technology stack framework. As Table 5 indicates, the dominant property of IoT technology in this layer is interaction, and two theories of dynamic capabilities and resource-based view, are proposed for research in this field.

2. Based on the studies related to the interaction of business and dynamic environment, it was found that research examining the impact of IoT technology applications in business and in the context of the enterprise environment falls into this category [R2, C1, C6, G6]. According to the IoT technology stack framework, the concepts of the *connectivity layer*, and the IoT properties in this layer can be used in future research. As presented in Table 5, the results show that interoperability is the dominating property of IoT technology in this layer. The proposed theories are resource dependence theory and contingency theory. The external information source also addresses the issue of business interaction and integration with the environment. According to Table 5, the dominant property of the technology in aspects is accessibility and the proposed theory is the game theory.

3. Based on the studies on IoT application and improvement of the business environment, it was found that the concepts studied in business research and IoT-based applications have the highest degree of relationship with the *thing/device layer* of the technology stack of the IoT framework (see, e.g., https://crokepark.ie) [S8]. Based on Table 5, in this layer, the dominant property is context awareness, and stakeholder theory is proposed for research in this field.

### *7.1. Limitations and Suggestions for Future Research*

This study has some limitations, and the most important one is the approach used to select the IoT technology properties and theories based on their frequency of use. However, the authors' assumption in this study is based on the principle that the higher frequency of use of a phenomenon corresponds to the higher agreement among researchers. Moreover, due to the limited space, we only explored the eight most important theories from the list of theories examined. Other theories such as organizational information processing theory, affordance theory, coevolution theory, optimization decision theory, transaction cost theory, behavioral reasoning theory, social theory, accountability theory, and network theory can be examined in more depth in future research on the application of IoT in various fields.

The second limitation is the approach used to select theories using the SCOPUS. Due to the use of this search engine, not all IoT application research in business may have been retrieved and reviewed. The third limitation is related to the properties of IoT technology, which have been addressed within the IoT technology stack framework and the role of each layer/aspect. The tasks of each layer/aspect within the IoT technology stack may have limited some results in examining the properties of IoT technology and realizing the assumptions of management and organizational theories (Table C.2). As an example, we can mention the integration property. This property is not considered in its general sense. Based on its definition in the aspect of "integration with business systems", only those applications are considered in the text of the articles that refer to integration with practical business systems. Finally, the dissimilarity of some of the definitions of IoT technology can be mentioned. The IoT-related literature includes a diverse set of perspectives and concepts that are not necessarily fixed. Despite this limitation, to classify the IoT properties, we used the IoT technology stack framework provided by Tesch (2019), Wortmann et al. (2015), and Porter et al. (2014), which has the highest recognition and citation rate in Scopus as a reference and framework for IoT technology.

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## Appendices