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# How IT Governance can assist IoT project implementation

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**Abstract:**
Internet of things (IoT) is considered a key technology for the Industry 4.0 revolution. Information Technology (IT) governance (ITG) is now an increasingly important tool for organizations to align their IT strategy and infrastructures with the organizations' business objectives. The most adopted ITG framework is COBIT, which defines seven enabler categories. These enablers aim to facilitate the implementation, identification, and management of IT. This research aims to determine, explore, and define which are the most suitable IT governance enablers to assist managers in IoT implementation. The study adopted the Design Science Research methodology, including two systematic literature reviews and a Delphi method to build the artefact. The artefact was demonstrated and evaluated in a real organization. The results indicate that data privacy, data protection, and data analysis are currently the most relevant enablers to consider in an IoT implementation because they increase the efficiency of the solution and enhance data credibility.

**Keywords:**
IT governance; IoT; enablers; COBIT; Design Science Research; Delphi method.

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## 1. Introduction

Information Technology (IT) is one of the pillars of our society, changing the way people relate to each other and how businesses communicate and interact among them [1]. IT has become an essential asset in operations and business growth; organizations are becoming completely dependent on it, which has led them to shift their attention to IT governance (ITG) [2][4].

ITG has been demanded by many organizations [5] to ensure that IT is aligned with business objectives [6] and creates value to the business [7]. Measuring IT performance and competitive advantages delivered by IT within the organization as well as align IT objectives with the overall business strategy are among the main goals of ITG [8]–[10]. Plus, ITG formalizes IT accountability to ensure more effectiveness and ethical management within the organization [11][7].

Grounded on the critical role of IT for business success, some ITG frameworks have been developed to guide and assist ITG implementation. One of the most known is COBIT [12], developed by the Information Technology Governance Institute of the Information Systems Audit and Control Association (ISACA) [13]. It defines COBIT as the framework for governing and managing IT in a holistic manner in all organizations [14]. Contributions of COBIT to organizations were studied before [15]. COBIT 2019 defines a set of enablers to support the implementation of an ITG system within an organizations' IT [14]. Enablers have the intention of allowing organizations to manage their complex interactions and facilitate successful outcomes [16]. ITG has been used to govern different kinds of technologies including emergent technologies applied in smart cities [17]–[19].

This is even more critical when an organization wants to adopt novel technologies to win competitive advantage. In turn, IoT was considered as the next wave of innovation by the industry leaders [12] and is becoming very popular in the context of the IT revolution that most are now facing [20]. According to a McKinsey report [21], there will be at least 30 million IoT devices connected and interacting by 2020. Given the ability to create better systems of knowledge-based decision systems [22], IoT is considered an important strategic technology trend that will shape business opportunities and competitive advantage [23]. However, it needs to be well integrated, managed, and governed to potentiate its benefits [24][25]. So far, no studies have been aimed at investigating ITG issues regarding IoT projects. Therefore, this research aims to investigate which are the main ITG enablers to help organizations implement IoT. Two systematic literature reviews (SLR) were performed to systematize ITG enabler definitions and define the former list of ITG enablers for IoT. Then, a Delphi study with three rounds was performed with 7 IoT experts. Lastly, the final list of ITG enablers was assessed in a very experienced organization regarding IoT projects.

## 2. Research Methodology

This research follows the design science research (DSR) methodology. It includes two SLRs and a Delphi method to find out a set of enablers that were afterwards validated via interviews to reach our artefact. In Figure 1 one may understand how all these techniques were applied and integrated. The motivation behind DSR is to improve the environment [26], implementing new and innovative artefacts [27] to solve identified organizational problems [28].

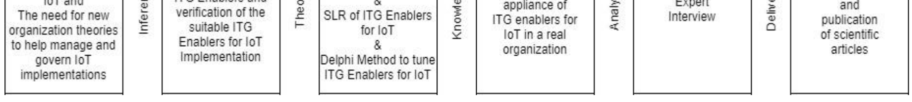


Fig. 1. DSR process model

The first and second phase of DSR are detailed in the Introduction. The remaining phases will be further explained in following sections. We performed two systematic literature reviews and a Delphi research to find out a set of enablers that were afterwards validated with interviews.

### 2.1 *Design and Development*

Grounded on the information presented in Figure 1 regarding the "Design and Development phase", Figure 2 conceptualizes how the several used methods relate to building the final artefact.

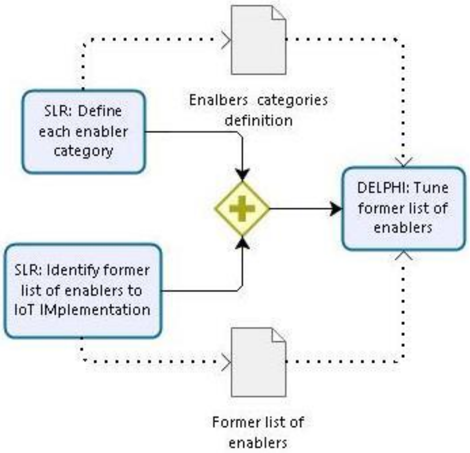


Fig. 2. Design and Development: How the methods relate to build the artefact

### 2.2 *Systematic Literature Review of IT Governance Enablers*

To perform this SLR the authors have followed guidelines proposed by Kitchenham [29]. Figure 3 delineates the methodology steps that were followed, which are further detailed in the next paragraphs.

| Outlining Systematic Literature Review | | Conducting Systematic Literature Review | | Reporting the Reviews |
|---|---|---|---|---|
| **Identification of the need for a review**<br>• Despite identified, a detailed definition of ITG enablers is unknown | | **Applying filters and get final articles**<br>• 31 articles analyzed | | **Report the findings**<br>• Present the definition of the several enablers |
| **Objective of the review**<br>• Define each ITG enabler | → | **Perform Data extraction and analysis of the sample**<br>• Extraction information about enablers definition | → | |
| **Review Protocol**<br>• Search strings, filters, repositories, inclusion/exclusion criteria, quality criteria | | | | |

Fig. 3. ITG enablers SLR stages.

This SLR aimed to better understand the definition of each ITG enabler proposed by COBIT2019. These are Principles, Policies, and Frameworks; Processes; Culture, Ethics, and Behavior; Services, Infrastructure, and Applications; People, Skills, and Competencies; Organizational Structures; and Information.

The search for this review began on July 12th, 2018 and ended on October 15th, 2018 in the following databases: Google Scholar and Scopus. Data sources were systematically searched using carefully selected search terms or keywords that are presented in Table 1.

Table 1. ITG enablers SLR: Search string and keywords

| Search Category | Keywords |
|---|---|
| ITG | IT governance definition |
| ITG Enablers | IT governance principles, IT governance culture, IT governance ethics, IT governance information, IT governance people, Governance organizational structures, IT governance skills, IT governance competencies, IT governance applications, IT People |
| COBIT Enablers | COBIT processes, COBIT principles, COBIT framework. |

For example, the term ITG is included along with enablers, as they are very complementary to one another. The search was separated by categories (“ITG”, “ITG enablers”, “COBIT enablers”). Within these categories, several keywords were selected and combined using Boolean “AND”, e.g.: between IT governance “AND” principles. Table 2 presents the filtration stages and which filters were used.

The inclusion and exclusion (IE) criteria for this review were guided by the following criteria questions:

- **IE1:** Is the article context related to ITG?
- **IE2:** Is the article related to the research context?
- **IE3:** Do the findings of the article provide valuable insights to define one or more ITG enablers?

Table 2. ITG enablers SLR: Filtration stages

| Filtration Iterations | Description | Assessment criteria | Article Count |
|---|---|---|---|
| 1st filtration | Identification of the relevant studies from the selected databases. | Search Category and keywords using the filter “”. | 35559 |
| 2nd filtration | The studies were excluded based on their titles. | Title = Search terms. | 3327 |
| 3rd filtration | The studies were excluded based on their abstracts. | Keywords inside the abstract. | 359 |
| Final filtration | Obtain the most relevant articles. | Address the quality and criteria questions. | 31 |

It is important to point out that this review included only articles published in English with a year range between 1999 to 2018. Furthermore, quality criteria were applied. The authors have selected only articles ranked as Q1/Q2 (from Scimago) or A/B (from ERA) ranking. Overall, 31 articles were selected and analyzed. Following the concept-centric approach [30], Table 3 identifies the analyzed articles for each ITG enabler. Each enabler was then defined and its description used in the Delphi phase. For space limitations, the complete definition of each enabler is not presented.

Table 3. ITG enablers SLR: Final list and references

| ITG enablers | References | Total |
|---|---|---|
| Principles, Policies, and Frameworks | [12], [13], [31]–[43] | 14 |
| Processes | [32], [39], [40], [42], [44]–[47] | 8 |
| Culture, Ethics, and Behavior | [39], [42], [43], [46]–[50] | 8 |
| Services, Infrastructure, and Applications | [33], [36], [39], [51]–[53] | 7 |
| People, Skills, and Competencies | [39], [40], [50], [54]–[57] | 7 |
| Organizational Structures | [5], [39], [42], [46], [47] | 5 |
| Information | [39], [42], [50], [58] | 4 |

## 2.3 *Systematic Literature Review of IT Governance Enablers for IoT*

To perform this SLR the authors have followed guidelines proposed by Kitchenham [29]. Figure 4 presents the methodology steps that were adhered to and are further detailed in the next paragraphs.

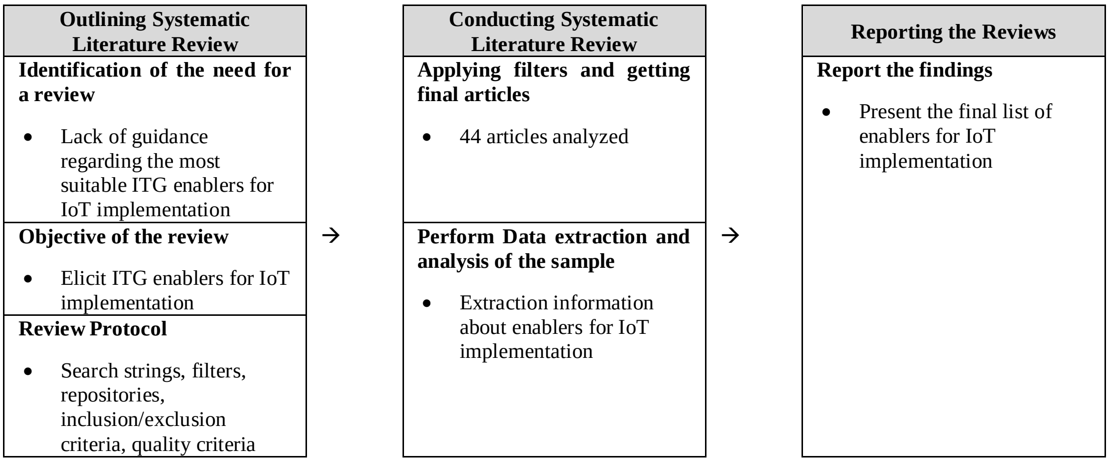


Fig. 4. ITG enablers for IoT implementation SLR stages.

The search for this review began on October 20th, 2018 and finished on December 23rd, 2018 in the following databases: Google Scholar, Taylor & Francis and Scopus. Google Scholar and Scopus are two brokers from which we captured nearly all the articles. During the second SLR we decided to further reinforce our review and chose to include Taylor DB. We could have chosen IEEE or ACM, but these DBs tend to be more technical; we believed that Taylor could be more productive to obtain proper articles. The data sources were systematically examined using carefully selected search terms or keywords (Table 4). Table 5 presents the filtration stages and which filters were used in this search.

Table 4. ITG enablers SLR for IoT: Search string and keywords

| Search Category | Keywords |
|---|---|
| IoT | IoT definition, IoT adoption |
| IoT Enablers | IoT principles, IoT adoption principles, IoT frameworks, IoT frameworks standards, IoT policies, IoT processes, IoT processes governance, IoT processes cobit, IoT organizational structures, IoT structures, IoT culture, IoT ethics, IoT behavior, IoT information, IoT services, IoT infrastructures, IoT applications governance, IoT people, IoT people roles, IoT people responsibilities, IoT skills, IoT competencies |

Table 5. ITG enablers SLR for IoT: Filtration stages

| Filtration Stages | Description | Assessment criteria | Count |
|---|---|---|---|
| 1st filtration | Identification of the relevant studies from the selected database | Search Category and keywords using the filter “” | 12315 |
| 2nd filtration | Exclude the studies based on their titles | Title = Search terms | 9965 |
| 3rd filtration | Exclude the studies based on their abstract | Keywords inside the abstract | 2347 |
| Final filtration | Obtain selected relevant articles | Address IE and QC | 44 |

The IE criteria used to tune this review were the following: “IE1: Is the article context related to ITG?”; “IE2: Is the article context related to IoT?”; “IE3: The description of the article is related to the research context?”; “IE4: Do the findings of the article provide valuable insights to define one or more ITG enablers?”.

Quality criteria were also applied. The authors have selected only articles from SJR Q1/Q2 classification, ranking ERA A/B, or ranking Qualis A1/A2/B1. In the end, 44 articles were selected and analyzed. Following the concept-centric approach [30], Table 6 lists the enablers for IoT implementation and respective references.

Table 6. ITG enablers SLR for IoT: Former list of ITG enablers for IoT implementation

| Enablers | ID | Recommendations | References from literature |
|---|---|---|---|
| Principles, Policies, and Frameworks | F1 | Promote interoperability via decentralization. | [70] |
| | F2 | Promote collaboration between organizations. | [71] |
| | F3 | Implementation of trust. | [72] |
| | F4 | Implementation of transparency. | [72] |
| | F5 | Implementation of data privacy and data protection. | [72] |
| | F6 | Implementation of accountability. | [72] |
| | F7 | Interiorization of risk management. | [73] |
| | F8 | Cooperation between organizations in building policies. | [74] |
| | F9 | Governance framework application. | [75] |
| | F10 | Strategic policies to promote innovation. | [74] |
| | F11 | Include users’ privacy issues in IoT policies. | [76] |
| | F12 | Operational principles are aligned with IoT procedures. | [74] |
| | F13 | Include cybersecurity and digital policies in IoT policies. | [77] |
| | F14 | Governance framework guides the management team in IoT implementation. | [72] |
| Processes | P1 | Strategy processes to coordinate IoT processes. | [78] |
| | P2 | Business processes to align the IoT process with business models. | [79] |
| | P3 | Governance processes to decompose and decentralize the business processes. | [79] |
| | P4 | Information processing towards business decisions. | [80] |
| | P5 | Implementing a sound data management process. | [81] |
| | P6 | Implementation of data analytics process. | [81] |
| | P7 | Implementing application management process to promote scalability. | [82] |
| | P8 | Implementing application monitoring process to guarantee business continuity. | [83] |
| | P9 | Implementation of application security management in development process. | [75] |
| Organizational Structures | O1 | Assignment of roles, responsibilities, and tasks in IoT. | [84] |
| Culture, Ethics, and Behavior | B1 | Spread social culture in IoT implementation. | [85] |
| | B2 | Organization’s culture aligns with identity, autonomy and trust protection of IoT users. | [82] |
| | B3 | Organizations implement his culture and values in IoT acceptance. | [85] |
| | B4 | Ethics integrates social behaviors, privacy, and integrity in IoT implementation. | [86] |
| | B5 | Implementation of awareness in people’s attitude and motivation. | [87] |
| Information | I1 | Information research techniques for IoT support. | [88] |
| Services, Infrastructures and Applications | S1 | IoT services promotes sustainability. | [89] |
| | S2 | IoT services are built on top of strong standards and protocols. | [90] |
| | S3 | IoT infrastructures it is aligned with continuity of investment. | [85] |
| | S4 | Ensure IoT services improve the organization’s efficiency by being aligned with business needs. | [90] |
| People, Skills, and Competencies | C1 | Integration of people in IoT. | [85] |
| | C2 | Socio-technical skills to promote automation. | [87] |
| | C3 | Implementation of strategic skills for goals guidance. | [91] |
| | C4 | Implementation of information skills for requirements analysis. | [91] |
| | C5 | Implementation of organization skills to improve decision making. | [91] |
| | C6 | Implementing people as an important role in IoT acceptance. | [85] |

## 3. Delphi Method

The Delphi method has been a popular tool in information systems research [59]. It aims to obtain the most reliable information from a group of experts [60] via a series of questionnaires with feedback-controlled opinion [61] to reach a reliable consensus amongst them [59]. The five-point Likert-type scale is the preferred tool, with the cut-off point set within score three and four [62]–[65]. In this research the cut-off is 3.5. Previously used in ITG domain [66] the Delphi method was then adopted by the authors to reach consensus regarding the final list of ITG enablers for IoT implementation.

Eleven experts were invited to participate in this research with a 37 percent drop off rate (7 experts accepted). The Delphi method was divided into three rounds. By the end of the third round none of the participants quit the study. According to literature, the tendency is reducing the number of participants in each new round [67]–[69]. Another point that is important to highlight is that this Delphi study took more than 45 days, as also recommended in literature [60]. Table 7 details all the rounds of the Delphi. The first round was used to validate the initial list of recommendations extracted from the literature using a degree of concordance between 1 and 5, and to increase the list with new recommendations provided by the participants. The second round was used to determine the level of efficiency from each recommendation on each ITG enabler in IoT, identifying a top 10 most important recommendations for an IoT implementation. The third round was used to increase the consensus of concordance and efficiency within the group about the recommendations. Table 6 lists the enablers for IoT implementation and respective references.

Table 7. Delphi: List of rounds

| Phase | Date | | Input | Output | Participants | |
|---|---|---|---|---|---|---|
| | Begin | End | | | Invited | accepted |
| Round 1 | 01/02/2019 | 28/02/2019 | ITG definitions<br>ITG Enablers for IoT | New List of recommendations and their definition | 11 | 7 |
| Round 2 | 19/03/2019 | 06/04/2019 | List recommendations from round 1 | Top 10 recommendations and efficiency level on each recommendation. | 7 | 7 |
| Round 3 | 12/04/2019 | 06/05/2019 | List of recommendations from round 2 | Consensus in the efficiency level and top 10 recommendations | 7 | 7 |

### *3.1 First Round*

During the analysis of the first round, an exclusion criterion was created to factor out the weakest recommendations on the initial list. The exclusion criteria used was: any recommendation is excluded if the average rate of the recommendation is equal or below 3.5. After the first round, the confirmatory phase led to the exclusion of eight recommendations (red bars in Figure 5) from the initial list (F8, F11, F14, P3, B1, I1, C3, and C5). In addition, two recommendations were merged (F5 and F11) since according to participants they represent the same objective. The authors have created graphs for each ITG enabler for IoT.

Moreover, by exploring the qualitative information collected from the interviewees, the authors were able to add nine new recommendations. Table 8 presents these new recommendations which are: F6; F11; P3; P10; O2; I1; S5; S6; C3. It must be noted that the new recommendations (when possible) took the IDs of the removed ones.

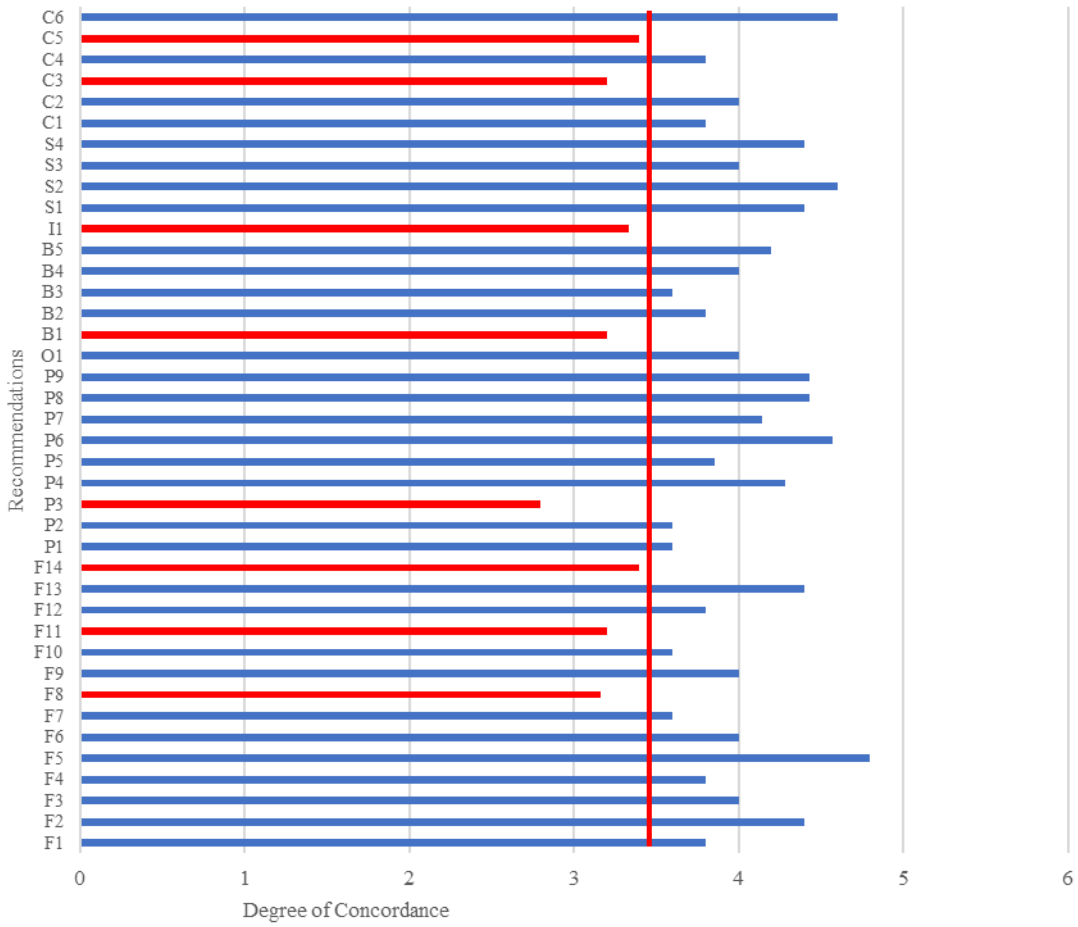


Fig. 5. List of excluded recommendation

Table 8. Delphi – first round: Final list of ITG enablers for IoT implementation

| ID | Recommendations |
|---|---|
| F1 | Promote interoperability via decentralization |
| F2 | Promote collaboration between organizations |
| F3 | Implementation of trust |
| F4 | Implementation of transparency |
| F5 | Implementation of data privacy and data protection |
| F6 | **IoT agile principles** |
| F7 | Interiorization of risk management |
| F8 | Governance Framework Application |
| F9 | Strategic policies to promote innovation |
| F10 | End-to-End security principles |
| F11 | **Data audit principle** |
| F12 | Operation Principles are aligned with IoT procedures |
| F13 | Include Cybersecurity and digital policies in IoT policies |
| P1 | Strategy processes to coordinate IoT processes |
| P2 | Business processes to align IoT processes with business models |
| P3 | **Problem identification processes** |
| P4 | Information processing towards business decisions |

| ID | Recommendations |
|---|---|
| P5 | Implementing a sound data management process |
| P6 | Implementation of data analytics processes |
| P7 | Implementing application management process to promote scalability |
| P8 | Implementing application monitoring process to guarantee business continuity |
| P9 | Implementation of application security management in development process |
| P10 | **Digitalization processes** |
| O1 | Assignment of roles, responsibilities, and tasks in IoT |
| O2 | **Implementation of accountability** |
| O3 | Responsabilization assignment matrix |
| B1 | Organization's culture aligns with identity, autonomy and trust protection of IoT users |
| B2 | The organization implements his culture and values in IoT acceptance |
| B3 | Ethics integrates social behaviours, privacy, and integrity in IoT implementation |
| B4 | Implementation of awareness in people's attitude and motivation |
| I1 | **Data exchange between organizations** |
| S1 | IoT services promote sustainability |
| S2 | IoT services are built on top of strong standards and protocols |
| S3 | IoT infrastructures it is aligned with continuity of investment |
| S4 | Ensure IoT services improve the organization's efficiency by being aligned with business needs |
| S5 | **Predictive technologies to support decision makers** |
| S6 | **Service delivery management to improve scalability** |
| C1 | Integration of people in IoT |
| C2 | Socio-technical skills to promote automation |
| C3 | **User experience to improve effectiveness** |
| C4 | Implementation of information skills for requirements analysis |
| C5 | Implementing people as an important role in IoT acceptance |

The next section presents the second round of Delphi.

### *3.2 Second Round*

The second round was sent on March 19th to the participants with a two weeks deadline to fulfil the questionnaire. This round aimed to get a rate in terms of efficiency of each ITG enabler recommendation validated in the first round, using a score between one (not efficient) and five (very efficient). In addition, the participants were invited to point out from the list of recommendation which ones they believed to be the top 10 for an IoT implementation. After gathering all the answers, ranking points were used to define each position. First choice gets 10 ranking points and the 10th gets 1 ranking point. Table 9 presents the overall top 10 recommendations.

Table 9. Delphi – Round 2: Top 10 recommendations

| Top10 | ID | Recommendations | Ranking Points |
|---|---|---|---|
| 1 | F5 | Implementation of data privacy and data protection. | 49 |
| 2 | P5 | Implementing a sound data management process. | 36 |
| 3 | P6 | Implementation of data analytics processes. | 33 |
| 4 | S2 | IoT services are built on top of strong standards and protocols. | 31 |
| 5 | F10 | End-to-End security principles. | 18 |
| 6 | F8 | Governance framework application | 17 |
| 7 | P2 | Business processes to align IoT processes with business models. | 16 |
| 8 | F2 | Promote collaboration between organizations. | 14 |
| 9 | C2 | Socio-technical skills to promote automation. | 14 |
| 10 | O1 | Assignment of roles, responsibilities and tasks in IoT. | 13 |

### *3.3 Third Round*

In the third round, participants were asked to review their answers from round two according to the group's average. The objective of this round was to deliver more consensual results in terms of ITG enablers efficiency and in the top 10 recommendations. Comparison between round two and three is detailed in Figure 6.

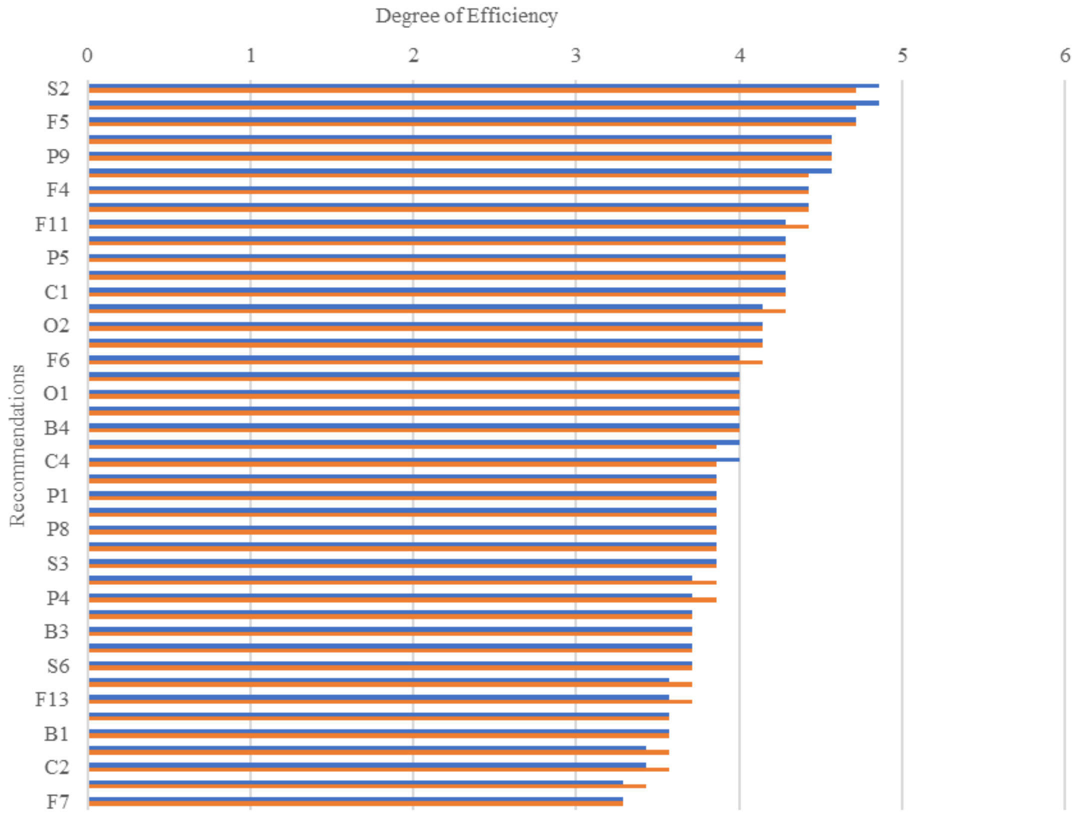


Fig. 6. Delphi – Round 3: Comparison between efficiency scores (Round 2 – Orange; Round 3 – Blue)

Table 10 presents the ten most important recommendations by the participants involved in the Delphi research.

Table 10. Delphi – Round 3: Tuned top 10 recommendations

| **Top 10** | **ID** | **Recommendation** | **Ranking Points Round 2** | **Ranking Points Round 3** | **Delta** | **Position** |
|---|---|---|---|---|---|---|
| 1 | F5 | Implementation of data privacy and data protection | 49 | 59 | +10 | --- |
| 2 | S2 | IoT services are built on top of strong standards and protocols | 31 | 45 | +14 | ↑+2 |
| 3 | P5 | Implementing a sound data management process | 36 | 42 | +6 | ↓-1 |
| 4 | P6 | Implementation of data analytics processes | 33 | 40 | +7 | ↓-1 |
| 5 | F10 | End-to-End security principles | 18 | 30 | +12 | --- |
| 6 | F8 | Governance Framework Application | 17 | 27 | +10 | --- |
| 7 | O1 | Assignment of roles, responsibilities, and tasks in IoT | 13 | 18 | +5 | ↑+3 |
| 8 | P2 | Business processes to align IoT processes with business models | 16 | 17 | +1 | ↓-1 |
| 9 | F2 | Promote collaboration between organizations | 14 | 10 | -4 | --- |
| 10 | O2 | Implementation of accountability | 10 | 10 | 0 | New |

The next section presents the demonstration and evaluation.

## 4. Demonstration and Evaluation

An experienced IoT organization was assessed in order to validate if the proposed recommendations were used in their IoT projects and if they resulted in a positive impact. The interviewee has more than 20 years of experience in the field and the targeted organization has dozens of ongoing IoT projects. However, for confidentiality reasons we are not able to provide information on the organization nor the name of the interviewee.

We asked for the interviewee's opinion regarding the most important and efficient recommendations obtained (Figure 6) and if the top 10 recommendations were useful in an IoT project. Regarding the full set of mechanisms, qualitative information is provided in Table 11. The researchers made an effort to collect more qualitative information about the top 10 mechanisms, but others were also discussed. On the top 10 mechanisms, the interviewee argued that "…all recommendations mentioned in the top 10 recommendations are useful in an IoT project to bring more effectiveness of the solution and to meet the requirements requested by the customer during the implementation. However, I must say that we did not feel the need to implement B2 since we do not feel that acceptance depends on meeting the culture and values in this organization". This remark is due to the fact that this organization has a strong involvement in IoT projects, and the workers are aligned with that mindset. However, in less experienced organizations this recommendation may be important to consider. In Table 11, you can see the detailed comments of the interviewee for each recommendation.

Table 11. Evaluation - interview: Comments per recommendations

| ID | Recommendation | Comments |
|---|---|---|
| Q1 | Implementation of data privacy and data protection (F5) | "This recommendation is essential to exist during an IoT implementation and after the implementation and our organization implements from the begin of the implementation until the end solution." |
| Q2 | Implementation of data privacy and data protection (F5) | "There is a constant worry and care to have this during an implementation." |
| Q3 | IoT services are built on top of strong standards and protocols (S2) | "In our IoT implementations we normally use protocols in the levels of encryption, access and in data formatting and some example of protocols are AES, LoRa, IPSec, SSH, SHA and REST protocol." |
| Q4 | Implementing people as an important role in IoT acceptance (C5) | "People are essential during the implementation and after the solution is implemented. In addition, it is important to consider that people and processes must be adaptive based on the solution, therefore we tried to include the stakeholders during the implementation process to leverage the acceptance." |
| Q5 | Implementing a sound data management process (P5) and Implementation of data analytics processes (P6) | "Yes we use these recommendations and we put more emphasis into data identification and data validation, because there is uncertainty in data obtained by the solution, so there must be several ways to test the data and to validate the data using data harmonization." |
| Q6 | Promote collaboration between organizations (F2) | "If an organization has the idea to be alone in the IoT sector will not be successful. So, a partnership is essential during an IoT implementation. The interaction was made at the same level between organizations (IoT and data levels)." |
| Q7 | Governance Framework Application (F8) | "Our organization didn't use any governance framework during an IoT implementation, therefore this recommendation in my perspective is not useful." |
| Q8 | Business processes to align IoT processes with business models (P2) | "Yes, we tried to implement this recommendation, but the trend for the future is the opposite, because if the organization only focus to align the IoT processes to the business models will lose scalability in IoT where in the long term will not bring many benefits in terms of business to the organization." |
| Q9 | Assignment of roles, responsibilities, and tasks in IoT (O1) | "Normally the people already have their roles in the organization, we only make the adaption of processes, and people only change tasks and not functions." |

| ID | Recommendation | Comments |
|---|---|---|
| Q10 | F5, P9, O2, B2, I1, S2, C5 | "The organization in the IoT implementation use all of the recommendations to bring more efficiency into the solution and we put more focus in the S2 recommendation "IoT services are built on top of strong standards and protocols". In addition, the organization focused on the use of open standards in their IoT solutions." |
| Q11 | End-to-End security principles (F10) | "The organization implements it through all IoT projects. Actually, we turned it native using IPv6." |
| Q12 | Implementation of accountability (O2) | "The organization tries to implement this recommendation but there is a flaw in the assignment of responsibilities which makes the IoT implementation less efficient, due to a lack of responsibility level in the new tasks of the people." |
| Q13 | Implementation of application security management in development process (P9) | "The organization do not apply this recommendation in particular, because the solution already has security tools that applied security management process." |
| Q14 | The organization implements his culture and values in IoT acceptance (B2) | "Any implementation of values and culture was not made in the IoT solution because the acceptance does not depend on meeting the culture and values but instead depends on the effectiveness of the solution, therefore we do not implement this recommendation." |
| Q15 | Data exchange between organizations (I1) | "We use this recommendation, but this exchange of information did not increase efficiency, instead increase the credibility, due to the validation of data to support the decision makers to getting the right decisions for the business. Also, increased the speed of acceptance and the priority level of IoT. This exchange of information between organizations brings always new ideas, new solutions." |

## 5. Research Synthesis and Findings

At the end of this research, some literature statements were reinforced, and others elicited and added as novel insights to the body of knowledge. The following paragraphs intend to connect the main findings of this research and the literature of the area.

Organizations do not implement IoT for matters of marketing or image. The IoT adoption, like any other technology, should be a strategic decision [92] grounded on business needs and aligned with business objectives [93]. Therefore, new business processes must be designed or a redesign of current ones is required to incorporate IoT technology in an organizations' business (P2).

A business process is usually defined as a set of activities that together perform a business objective [94]. With the inclusion of IoT technology in business processes new activities will be added; therefore, new roles and responsibilities must be defined (O1) so that accountability can be established (O2) and absence of responsibility in IT failures is avoided [84].

IoT systems collect and manipulate huge amounts of data [95] and privacy must be assured as well as protected from threats (F5). The exponential growth of data in IoT systems and the need to be controlled calls for a solid Data Management process (P5) which is seen in literature as a core process for IoT success [96]. Plus, since IoT projects are complex [97] and data security seems to be a critical issue, end-to-end security principles (F10) must be evangelized. One way to ensure security is by adopting one or more of the many standards and protocols (S2) that already exist [98].

Information is currently one of the key assets of organizations [99] and Information systems have an important role in producing reliable information from raw data [46] so that managers can make decisions accordingly [92]. IoT systems are no exception; thus, the implementation of capable analytics processes (P6) are imperative to create reliable information and knowledge from all the collected data.

Many IoT projects require the involvement of other organizations [71]. This increases the potential risks of the project and therefore special attention should be paid to the efficient collaboration of the respective organizations (F2).

Nowadays, organizations are not able to compete or even survive without a strong IT function [99]. With the increasing importance of IT in organizations' success, enterprise governance of IT became critical to ensure business/IT alignment [100]. Thus, the implementation of an ITG framework (F8) is advised and well seen by the experts.

## 6. Conclusions, limitations and future research

At the beginning of this investigation the purpose was to identify a list of the main ITG enablers for IoT implementation, thus helping managers improve IoT project results with better governance. At the end, the main conclusions of this investigation are presented. The enabler "processes, principles, frameworks and policies" appears to be the most investigated in literature. This makes sense since many researchers have focused their research on evolving and extending ITG frameworks in different organizational contexts. The application of ITG frameworks in IoT is not an exception. Nevertheless, few studies exist clearly exploring how ITG may help IoT implementation projects. Both enabler categories "people, skills and competencies" and "information" are the less explored ones in literature

According to the practitioners, the less relevant ITG enabler categories are "Culture, Ethics, and Behaviour" and "Information". Such conclusion is grounded on the absence of recommendations of those enablers on the defined top 10, and according to the rate of efficiency the maximum score in the group's average was four in the Delphi results. However, the authors believe that the scarce enablers in the "information" category may have influenced this conclusion. On the contrary, "Principles, Policies and Frameworks" (4 of the top 10) and "Processes" (3 out of 10 in top 10) are seen as the most relevant enabler categories for IoT projects. All the enablers about data seem to be essential in IoT. Three of the first four enablers in the top 10 are Data-oriented. Implementation of roles and responsibilities are seen as an important step since the beginning of an IoT implementation. People still have an active role in IoT projects, thus managers should increase efforts in IoT acceptance by people. The "Process" category has a high correlation with "Principles, Policies, and Frameworks", given the focus in data and how organizations will manipulate that which is obtained by IoT systems. Such correlation is essential since the processes of data management and data analytics are critical to extracting information from data, and the implementation of data privacy and data protection is necessary to assure data integrity and trustful information. It is important to assign roles and responsibilities to the people involved in an IoT project, convincing them that it is necessary to adapt their tasks into the IoT implementation as well as to adapt the current processes of the organization to increase the efficiency of the implementation. When more than one organization is involved in the IoT project, the focus on the level of data must be reinforced since multiple organizations may need to access and use data to retrieve valuable information and knowledge necessary for their business. In addition, organizations working in silos may not succeed in the long term, because the collaboration between organizations may increase the success rate of an IoT implementation.

Last but not least, people seem to be a considerable barrier to increase the acceptance of IoT, and it is suggested (C5) to involve people from the beginning. Therefore, they can understand that these abnormal patterns always bring new ideas and new solutions into their business. The results indicate that data privacy, data protection, and data analysis are currently the most relevant enablers to consider in an IoT implementation because they increase the efficiency of the solution and data credibility.

This investigation has some limitations as well. The lack of studies relating to ITG enablers with IoT forced the authors to perform a more interpretive analysis of most studies. Moreover, some experts did not accept our invitation to participate in the Delphi study, reducing the possible number of contributions. The study has limitations regarding the type of organization given that it was carried out in the banking industry of a particular country, Portugal. Future research should go deeper in exploring the ITG enablers for IoT implementation in different kinds of organizations taking into account contingency factors such as regional differences, size of the organization, country, type of control, public or private, amongst others. An exploratory study upon each ITG enabler/mechanism can lead to a strengthening of the findings concerning this topic. Finally, we would recommend a quantitative study to be more precise in generalizing the order of importance in each ITG enabler for IoT implementation. We are currently working in the implementation of part of these mechanisms in an organization.

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