The Technology Executive Role: A Study of the Main Competencies and Capabilities of the CIO / CTO

A Systematic Review

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***Abstract*—Emerging trends in technology bring about a fundamental career change for professionals and, consequently, for companies and businesses. The digital transformation and the introduction of new technologies are exerting a huge impact on the role and responsibilities of the Technology Executive to support the organization's goals. This study proposes to examine the skills and responsibilities associated with the role of the Technology Executive, systematically reviewing the literature and comparing patterns in the analysis of the profiles and skills for this role. The result shows that the competences of the Technology Executive have undergone a significant change to incorporate skills in different areas, apart from the traditional technical area, which can be categorized into five main groups: Technologist, Strategist, Enabler, Innovator, and Financial.**

Keywords — IT; Executive; CIO; CTO; Competency; Capability; Systematic Review; As a Service.

I. INTRODUCTION

The pace of technological development has reached such high rates that even the great discoveries of a few years ago already face challenges from the more recent competing technologies, before even being able to establish themselves in a competitive market like the one we live in. Emerging technologies, named by Gartner, Inc. as Nexus of Forces [1] [2], or the convergence and mutual reinforcement of trends, like: social, mobile, data analytics, cloud computing, and the Internet of Things, just to name a few, leads us to a reflection about what the professional of the future's work will be like. It is not difficult to be surprised by the pace of change that these technologies are exacting in today's professionals and businesses, but, at the same time, we see that this is exactly the fast pace that paves the opportunity paths for the entire reinvention of complicated business models, established decades, perhaps centuries ago [3]. These business models are replaced not only by creativity, innovation, or entrepreneurial vision but also by the simple competent application of those new technologies, promoting real revolutions in certain markets.

In view of these new innovative technologies, we observe a common trend, the “service-based” business models [4]. Initially associated with specific types of cloud computing and Big Data, the name came to be used by different offer opportunities, in markets with heavy user-centric services, as their main competitive distinctiveness. This trend is defined by the new jargon of Everything as a Service (XaaS) [4]. It is this type of offer that serves as a catalyst for several business initiatives with a focus on the global offer of services, and with accelerated growth, as is the case of some successful startups. These new business models are by nature extremely dynamic and flexible and benefit from the fact that they are not tied to long-term contracts or large investments in infrastructure, as with traditional models.

While emerging technologies and service-based business models are facilitators of innovation and a gateway to an excess of opportunities, it is not uncommon to be presented with excellent ideas for new products or services, that never left the drawing board. The failure to achieve a market-ready solution can be due to a simple lack of knowledge of the current technology state that would support this new venture, or to the unfamiliarity with the market for the supply of raw materials, support solutions, and information. The absence of the Technology Executive's proper knowledge and planning often results in innovative services offers that cannot scale to global demand, even local demand but with increased volume, because the technological platform has not been updated at the same speed as required, or due to the absence of a link to the next step of development [5]. All of these factors could pose as roadblocks and will terminate a project prior to even being started. In this scenario, the technology executive plays a fundamental role in the success or failure of a new idea or business model. However, the qualifications necessary for a good performance of this professional include, but are not limited to, in-depth technical knowledge, relationship with the market, leadership, negotiation skills, interpersonal skills, and strategic foresight of the future. This causes the recruitment and hiring of a professional with this skillset difficult and costly for the company [6]. Within this context, we observe opportunities and challenges to the mapping of the competencies and role of a Technology Executive, when submitted to the opportunity to offer these competencies in an "as a service" model.

This work intends to expand the knowledge about the role and competencies of the Technology Executive, evaluate the work that has already been done on the definition of this role, and how the responsibilities associated with this profile are categorized, to support future work that

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would allow for the development of a software abstraction with the ability to mimic the role of a Chief Information Officer (CIO) / Chief Technology Officer (CTO), even if partly.

The rest of the paper is structured as follows. In Section II, we present basic concepts related to the role of the Technology Executive and how its relevance and responsibilities to business success grew in importance over time. Next, in Section III, we introduce the methodology along with the objectives, the description of the methods, processes, and the protocol used in the systematic review of this study. In Section IV, we will detail the results associated with the research. Then, in the following section, we will interpret the results from the previous one and how they relate to the research questions. Finally, we conclude the work in Section VI, where some conclusions and future works will be depicted.

II. THE TECHNOLOGY EXECUTIVE ROLE

The preliminary applications, associated with computers and information systems, had simplified scopes of objectives and well-defined expectations for both the Information Technology departments and their managers. They were required to collect, store, and process financial and accounting data [7]. However, the responsibilities of this role evolved. The changes began with the need for hardware and software integration activities, in the 1970s, and continued with the design and implementation of networked platforms, in the 1990s. These changes continued with the analysis, selection, and acquisition of new software and services, in the 2000s. During the last decade, it became expected that the IT department produced a direct link with the companies' business model and results. The historical evolution for the responsibilities of the Technology Executive could be measured, in the history of companies, by the maturity and growth of their business model, from the basic use of technology in everyday processes to the exploration of emerging technologies to create a differential competitive in their business objectives.

III. APPLIED PROTOCOL

Based on the guidelines for performing Systematic Literature Reviews in Software Engineering proposed by Kitchenham [8], this work introduces the following methodology: (1) search strategy, (2) automatic search and selection, (3) identification of inclusion and exclusion criteria, (4) critical evaluation, (5) data extraction and (6) synthesis. This methodology is presented next in the order indicated above.

The principal goal of this review is to "identify studies that allow assessing the adoption of the concept of Everything as a Service, in the offering of technical, behavioral and business skills, associated with a technology executive". This study applied the aforementioned guidelines to systematically review the published research databases, looking for answers to three research questions:

- RQ1 - What studies on defining the technology executive role have previously been conducted?
- RQ2 - What are the responsibilities of the technology executive role?
- RQ3 - How are the competencies associated with the role of the technology executive categorized?

To properly define the scope of the principal goal of this review and allow for better structuring of the research questions, this study used the Population, Intervention, Comparison, Outcome, and Context (PICOC) criteria [8] in formulating the search strings, as will be presented on the following step.

A. Search Strategies

The research strategy underwent some modifications and trials before the use of the Population, Intervention, Comparison, Outcome, and Context (PICOC) criteria, due to the broad scope of our study, to better define the structure of the research questions. It was decided not to limit the findings by Context criterion to allow a larger universe of responses.

- Population: The technology executive (CIO / CTO);
- Intervention: Utilization of an "as a service" model;
- Comparison: Companies with a technology executive;
- Outcomes: Reduced dependence on technical, business, or behavioral skills.

B. Automatic Search and Selection

This work prioritized the search for results in the format of preliminary, academic, and industrial studies, which presented evidence about the objective of this work (PICOC), on the indicated research data sources. Research-Articles, Journals, Magazines, and studies presented at conferences, were used. Due to time constraints and better adherence to the methodology, only two selected data sources were used for this study. The IEEE Xplore and the ACM Digital Library are highly recommended and were chosen due to their recognized scope, content, and relevance. Both are data sources frequently used in reviews with the indexed scientific literature.

TABLE I. BUILDING OF SEARCH STRINGS

PICOC Criterion	Search String
Population	(("chief information officer" OR cio) OR ("chief technology officer" OR cto)) AND (challenges OR opportunities OR role OR attribution OR qualification OR competencies OR task OR survey)
Intervention	((("chief information officer" OR cio) OR ("chief technology officer" OR cto)) OR ((corporate OR enterprise) AND (it OR ("information technology")))) AND ("as a service")
Comparison	(("technology executive" OR "cto" OR "cio") OR (("c-level" OR "c level") AND ("it" OR "technology"))) AND ("enterprise" OR "enterprises" OR "company" OR "companies")
Outcome	(("it" OR "information technology") AND "as a service") AND ("cost reduction" OR "increased performance" OR ("return" AND "investment"))
Context	Not used

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We chose to compose specific strings to match each Population, Intervention, Comparison, Outcome, and Context (PICOC) criteria. The detail of each criterion was used to form the basis for the building of each search string, as described in Table I.

These search strings were applied separately in each of the research databases, and later consolidated into a single reference file in the BibTeX format. The total number of results was 4,236. The initial results are shown in the Table II below, separated by data source and construction criteria for each search string.

TABLE II. INITIAL SEARCH RESULTS

PICOC Criterion	IEEE Xplore	ACM DL
Population	364	1476
Intervention	433	425
Comparison	194	902
Outcome	63	409
Context	Not used	Not used

The initial result, after consolidation, was assessed to exclude duplicated items. Next, the partial result was submitted to the inclusion and exclusion criteria presented in the next step of this study.

C. Identification of Inclusion and Exclusion Criteria

In this work, we admitted only studies related to the role of the Chief Information Officer (CIO) / Chief Technology Officer (CTO) as a technology executive. Results that did not highlight in their title any of the criteria for constructing the search terms were discarded. This review narrowed the studies examined to those published between 2017 and June 2020, as it is related to a more recent research area.

The studies that fit one or more of these following criteria were also excluded:

- Not written in the English language;
- Related to topics with similar acronyms, but different meanings from the desired;
- Call for works, prefaces, conference annals, handouts, summaries, panels, interviews, and news reports.

We will now describe the application of the inclusion and exclusion criteria presented above in the search and initial selection of research papers. This step started with an individual search per string, described in the previous stage, in each of the research sources. Each search result, associated with one PICOC criterion in one data source, was stored in a file in the BibTeX format. The result files were then concatenated and grouped by PICOC criteria, and then merged into a single result file to be imported into the Zotero software [9] for duplicates exclusion.

A total of 1,418 duplicate items were eliminated from the initial results after the consolidation. This activity produced 2,848 unique items that were submitted to the Inclusion and Exclusion Criteria.

Then, a list was generated with the results, in Comma-Separated Values (CSV) format, for importing into the Google spreadsheet tool (Google Sheets). Only articles of the types Conference Papers and Journal Articles were selected, using the Google Sheets filter tool and the "Item Type" column.

Additionally, it was established that the cut-off date required for consideration in this study would be works produced within the last 3 years at the most. We decided to consider only the results published from 2017 onwards as this study relates to new concepts and recent research areas. The Google Sheets filter tool was used again, and we selected all results with a value equal to, or greater than, 2017 in the column "Publication Year". This resulted in another 1,980 items excluded. After limiting the types of publications and applying the time cut-off criteria described above, the number of unique items was brought down to 869.

In the next step, we filtered the titles of the remaining articles to exclude items that do not highlight the relationship with the main purpose of this review or the alignment with any of the research questions. To do this, we used the Google Sheets filter function, with the syntax described below, to select articles using multiple criteria:

```
=FILTER('Sampaio-DPES_SLR'!A2:CI,
regexmatch('Sampaio-DPES_SLR'!E2:E ,
"CIO|CTO|Chief Information Officer|Chief
Technology Officer|Information Technology|as a
Service|Role|Technology Management|IT
Governance|Best Practices"))
```

A total of 238 works remained after this last step. We analyzed the title for each of these articles to determine its adherence to this systematic review. Several works that were not related to the main theme or research questions, but that met some of the terms used in the filter of the previous step were eliminated, as we can see from the details below.

Some works related to physics, performance analysis in software development, human resources, and deployment of cloud services, were included in the result due to the use of terms such as “role”, “software as a service”, “executive”, and the acronyms CIO / CTO. In such cases, papers whose titles did not comply with the scope of the review were eliminated. The works whose titles left uncertainties about their adherence to the main theme were also listed for review in the next step. At the end of this step, 193 entries were excluded, leaving 45 items for further analysis.

All abstracts of the remaining works from the previous stage were evaluated. We were able to perceive that they ranged greatly in content. Similar to the previous step, some works were eliminated because they did not have the desired adherence to the main object of this study. It was necessary to manually retrieve the summary field of some articles because they did not present this information as a result of the search and initial selection. Also included for later analysis were the articles in which the analysis of adherence with the scope of this work proved to be imprecise or left doubts. The reading of the abstract resulted in the exclusion of another 29 articles, leaving 16 for thorough critical analysis and data extraction.

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Table III below shows the exclusion numbers for each step in this part of the study.

TABLE III. NUMBER OF STUDIES FILTERED IN EACH STEP OF THE SELECTION PROCESS

Selection process step	Number of articles selected
Data source search (after deduplication)	2848
Inclusion, exclusion, and time cut-off criteria	869
Title examination	45
Abstract analysis	16

D. Critical Evaluation

The studies that reached this critical evaluation step were submitted to a complete analysis. The studies were then analyzed in full, not just titles or abstracts. Six papers were discarded at the end of this stage since they did not exhibit adherence to the theme of the review nor answered any aspect of the leading questions. This resulted in a final set of 10 papers.

The final studies analyzed went on to the data extraction and synthesis stage, and the results obtained will be presented in the following section.

IV. RESULTS

This study identified 10 primary studies [7][10]-[18] dealing with a wide range of research topics and exploration models for each different situation.

According to [13], it is possible to categorize the skills of the Technology Executive into four main groups, namely, Strategist, Innovator, Enabler, and Technologist. We were able to find agreement in the primary studies with all four above mentioned groups, including other groups of less expressiveness, such as Leadership, Processes, and Business. The Financial group also yield several references, similar in number to the main groups indicated above. Studies that did not fit into any of these groups were classified as General. These last groups of categories are valid because they register the tendency to be constituted in sub-categories or to facilitate the comprehension of the responsibilities associated with the Technology Executive, evaluated later in this work.

A. Quantitative Analysis

The proposed research process resulted in 10 primary studies, written by 34 authors, linked to 15 institutions, based in 10 different countries, spread over four continents, and were published between the years of 2017 and 2020. The combined keyword number from the studies assessed by this paper yield a total of 49 distinct entries.

In what concerns the country of origin, there was no highlight to be made. Chile, Indonesia, and China appear with a somewhat higher result than the others (all with two publications each). The remaining countries had one publication only. Despite the small general amount of publications found on the role of the Technology Executive and the responsibilities associated with that role, we note that the geographical distribution, which covers most continents, illustrates the global interest in this subject.

The most common keywords used in the studies, by order of frequency were CIO (4), CTO (3), IT Executive (2), Role (3), Chief Information Officer (2), Technology (2), Technology Management (2). All other items were cited only once. The first 4 keywords, namely: CIO, CTO, IT Executive, and Role, indicate precisely the research object sought by this work.

V. DISCUSSION

First and foremost, it was possible to identify that the responsibilities associated with this role are constantly changing, which reflects in the need to constantly reconstruct the definition and attributions of that role. Secondly, we observed in many of the works, the statement that the fashion in which the profile for the Technology Executive is categorized is influenced by the type of exposure that the company has to Technology. The focus and performance of the executives vary, according to the company's orientation and exposure concerning technology, as well as its definition as a strategic asset or as an infrastructure base for operational efficiency. This comes to show that this research field is very extensive and that requires a continuous effort to contribute to its development.

The analysis also pointed to a shortage of supply capable of playing this role, associated with the need for specific training to accommodate the demand for Technology Executives. This is because there is still a misalignment between the expected performance of these Executives, by companies (demand), and the type of professional profile available to exercise this role (offer).

A. RQ1 – Assessment

We observed that most of the studies opted for the survey based on interviews (7 studies) when evaluating what types of studies have already been conducted to define the role of the Technology Executive. Some works opted for the use of forms or questionnaires, to qualify the moment of the interview, or in the selection of the interviewee (4 studies). The Literature Review was also used to qualify the interview step (3 studies). Other methods were used, to select the target audience and to analyze the profile characteristics, to define the role of the Technology Executive, and to answer this research question, but which were mentioned only once.

By grouping the types of automation used to select candidates for the interview and to effectively collect data for analysis, we found that most studies opted for some manual method of assessing requirements and profile characteristics. Another smaller group opted to use automated data selection and extraction techniques, with a highlight on the use of Natural Language Processing (NLP) [15] and on the analysis of public data sources in Social Networks [13].

To answer this research question, each work could contribute with more than one type of study, therefore, the total number of types of studies is not relevant when compared with the number of primary papers. Out of all primary papers selected for the final analysis, a single one

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failed to identify an acceptable answer to this research question.

B. RQ2 - Assessment

Only half of the studies analyzed indicated some type of formalization concerning the definition of responsibilities for the role of the Technology Executive. We understand that the interest in this area of study has taken a more accelerated pace over the past few years, when the attributions of this role were no longer restricted to the issues of the companies' operational infrastructure, and started to have an impact on strategic business objectives [7][13].

The concern with the alignment between the responsibilities of the Technology Executive and the strategic performance of companies, without neglecting traditional structuring, operational and support activities, became clear among the answers found. It was also possible to identify the growth in requirements for soft skills and negotiation, indicating that the main target audience for this role is increasingly closer to the top-level executives (C-Suite), and to the external client for the businesses.

> *"The Chief Technology Officer (CTO) is responsible for linking technology with strategy, market issues, and top management guidelines; it is also responsible for promoting innovation and facilitating the intersection among research, development, technology innovation, and leadership vision."* [18]

C. RQ3 – Assessment

An important highlight that arises as a result of this research is the finding, in the role of the Technology Executive, of many requirements commonly associated with the Business Executive. It is traditional to find technology profiles that play the role of the main executive; however, we find several positions occupied by professionals with first training in business [17].

This work found 43 different terms for category grouping of the Technology Executive profile. From these, the Technologist and the Strategist profiles (both with 7 citations each) stood out. The first profile can be traced back to the first moments of technology development. It is the technical role best known for its alignment with operational and structuring responsibilities. However, the latter describes a profile further aligned with the strategic business objectives, the Strategist profile. The other noticeable categories found in this work are gradually located between the first two described above. As they have a more technical or business tendency, they are the Innovator, Financial, and Enabler (each with 4 citations each). The last terms worth mentioning are Processes and Leadership (with 2 citations each), and 12 other categories that had only one citation each.

VI. CONCLUSION

According to the result of this literature review, the skills of the Technology Executive can be divided into five main groups, namely, Technologist, Strategist, Enabler, Financial, and Innovator. The purpose of this review was to identify previous studies on the role of the Technology Executive, which would allow us to categorize their main responsibilities and competencies. In the search phase, 2848 studies were found, of which 10 were classified as primary studies after applying the exclusion criteria.

Some limitations should be noted in the present study. First, the potential bias due to the design of the methodology using a single researcher only, with the task of deciding the selection criteria and analyzing the quality of the works by himself. Second, the absence of data sources outside the academic environment, such as social networks and specialized market research companies (Garter Inc. or McKinsey & Company as examples). The main focus of this work was to find patterns in how to assess the competencies and skills associated with the role of the Technology Executive to offer an overview of the current state of the art.

In future works, we intend to perform studies including other data sources, and the mapping of the specific duties of each profile from the Technologist to the Strategist can be outlined to support a proposal to develop a software abstraction of the most operational skills of the Technology Executive.

This work intended to provide an introductory overview of the difficulty related to mapping roles, competencies, and activities associated with the Technology Executive. The development of this research in future works will include and further explore other research databases to display these facts and points more palpably.

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