Evaluation of the main technology valuation methods applied to intellectual property

Avaliação dos principais métodos de avaliação da tecnologia aplicada à propriedade intelectual

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Abstract

The Technology Licensing Office (TLO) face several challenges, and one of them is related to the commercialization of technologies created by Scientific and Technological Institutions (STI), specifically regarding the valuation of technologies with market potential. This involves assigning a monetary value to the technologies to enable their negotiation for transfer to the productive sector. The objective of this study was to evaluate the main methods or valuation models of technology applied to intellectual property as a means of supporting the commercialization and technology transfer processes in TLOs. The research methodology used to conduct this study on valuation methods applicable to TLOs was a systematic literature review.

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review. As a result, a guide was developed, consisting of a few questions, which allows for a quick review to select, in a clear and objective manner, the most appropriate technology valuation method to be applied, taking into account the interests of the evaluator. In this way, the main technology valuation methods were identified, as well as the main advantages and disadvantages of each of the models addressed in this study.

**Keywords:** Intellectual Property. Technology Commercialization. Technology Valuation. Technology Licensing Office.

**Resumo**

O Escritório de Licenciamento de Tecnologia (TLO) enfrenta diversos desafios, e um deles está relacionado à comercialização de tecnologias criadas por Instituições Científicas e Tecnológicas (IST), especificamente no que diz respeito à avaliação de tecnologias com potencial de mercado. Isso envolve atribuir um valor monetário às tecnologias para permitir sua negociação para transferência ao setor produtivo. O objetivo deste estudo foi avaliar os principais métodos ou modelos de avaliação da tecnologia aplicada à propriedade intelectual como forma de apoiar os processos de comercialização e transferência de tecnologia nos TLOs. A metodologia de investigação utilizada para realizar este estudo sobre os métodos de avaliação aplicáveis aos TLO foi uma revisão sistemática da literatura. Consequentemente, foi elaborado um guia, composto por algumas questões, que permite uma revisão rápida para selecionar, de forma clara e objetiva, o método de avaliação tecnológica mais adequado a aplicar, tendo em conta os interesses do avaliador. Desta forma, foram identificados os principais métodos de avaliação de tecnologia, bem como as principais vantagens e desvantagens de cada um dos modelos abordados neste estudo.


**Introduction**

The relationship between companies and universities is a recurrently debated topic among researchers in the academic world since the mutual dependence between these sectors is noticeable (CLOSS; FERREIRA, 2012; BERNI, 2015; MATEI et al., 2020; SALA, 2020; GAZZETTA et al., 2020; BRIXNER et al., 2021). There is a consensus among scholars that the partnership between these two pillars of our society should be strengthened.
In this context, the Innovation Law of Brazil, Law No. 10,793/04 of December 2, 2004, amended by Law No. 13,243 of January 11, 2016, considered a regulatory landmark for innovation in Brazil (DIAZ, 2008; ANDRADE, 2016; SOARES et al., 2016), established the definitions of innovation, scientific and technological institutions, technology licensing office, and other concepts and definitions. The definitions that will be used in this work are exposed and presented in Table 1.

<table>
<thead>
<tr>
<th>Title</th>
<th>Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation</td>
<td>Introduction of novelty or improvement in the productive and social environment that results in new products, services, or processes;</td>
</tr>
<tr>
<td>Scientific and Technological Institutions (STI)</td>
<td>Agency or entity of the public administration with the institutional mission of conducting basic or applied research of a scientific or technological nature, or the development of new products, services, or processes;</td>
</tr>
<tr>
<td>Technology Licensing Office (TLO)</td>
<td>Structure established by one or more STI aimed at managing the institutional innovation policy</td>
</tr>
</tbody>
</table>

Table 1 - Concepts included in the Innovation Law of Brazil
Source: Adapted from Brazil (2004, 2016)

The Innovation Law of Brazil also decrees, among other obligations, that each Brazilian STI must have its TLO, either independently or in association with other STIs (BRAZIL, 2004, 2016). In the present, TLOs are already established in Brazilian STIs and have, as one of their main objectives, the management of intellectual property and the transfer of technologies created or developed by researchers from STIs to companies. (SILVA, 2013; ANDRADE, 2016; BUENO, TORKOMIAN, 2018; FERREIRA et al., 2020). Innovation has been gaining increasing importance in our society and is an indispensable element for companies (VITORELI; GOBBO JUNIOR, 2012; COSTA, 2013; CARVALHO; SUGANO; AGUIAR, 2015; ANDRADE ET AL., 2016B), but in Brazil, the university-company interaction is still in an embryonic stage, incapable of promoting the production of new technologies that would generate socio-economic development (TORKOMIAN, 2009; RAUEN, 2015; SILVA; NASCIMENTO, 2016; IATA, 2017; FOCHESATTO, 2020).

There are many reasons that can be raised to justify the low relationship between Brazilian STIs and the productive sector. Among the difficulties, one can highlight a weak intellectual property management by many Brazilian TLOs (BARBOSA et al., 2018), the prioritization of time in research and development for the private sector, rather than
necessarily for universities (CARVALHO; SUGANO; AGUIAR, 2015) and low company participation in gross R&D&I expenditure (VERDE; MIRANDA, 2019) stemming from the lack of a conducive environment for private investment due to public policies (CRUZ, 2010; BARBOZA et al., 2017; FREIRE et al., 2017; NEGRI et al., 2018; SILVA, 2018, 2019), among other factors.

Regarding the management of intellectual property, TLOs face several challenges, one of which is related to the commercialization of technologies created by STIs, specifically this challenge pertains to the valuation of technologies with market potential (SILVA, 2013; LORENZONI, 2019; FOCHESATTO, 2020; FERREIRA; CARVALHO, 2021; MORAES et al., 2021), which involves assigning a monetary value to these technologies to facilitate their negotiation and transfer to the productive sector. This process aims to generate mutual benefits for the STIs, companies, and society as a whole, by enabling the technology created to become an innovation and ultimately contributing to socioeconomic development (TRES; FERRETI, 2015; OLIVEIRA, 2020).

Technology valuation involves the use of a set of tools to estimate the value of a technology, in this case, protected through intellectual property (SOUZA, 2009; ANDRADE, 2016). It is a poorly developed and understood technique in Brazilian TLOs (GUIMARÃES, 2013; SILVA 2013; FOCHESATTO, 2020) and the lack of diffusion of a clear and accepted method for technology valuation by TLOs managers in Brazilian STIs is generating significant difficulties in commercializing research in R&D&I (ANDRADE, 2016; FERREIRA et al., 2020). This justifies the conduct of this research.

In this context, this research aims to address the following question: what are the differences between the most common technology valuation methods and how can they be better applied by TLOs.

**Method**

The research method used for conducting this study on technology valuation methods applicable to TLOs was the systematic literature review (SLR). SLR is one of the most widely used and essential research methodologies, suitable for studies aimed at investigating the available scientific knowledge on a specific research field (GOMES; CAMINHA, 2013; OKOLI; DUARTE, 2019).

The SLR allowed the integration of studies conducted separately from various sources, thus aiding the dissemination of new knowledge important to the academic community.
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(SAMPAIO; MANCINI, 2007; THOMÉ, 2016; OKOLI; DUARTE, 2019). Through the integration of these studies, a novel line of thought was constructed, providing researchers with a fresh opportunity to acquire the desired knowledge (GOMES; CAMINHA, 2013). Moreover, it is a research method that requires strict and well-established criteria for its application, including proper identification, evaluation, and synthesis of the available literature (THOMÉ, 2016).

For this research, an eight-step guide proposed by Okoli and Duarte (2019) was used as the basis. The steps for conducting the literature review are outlined and presented in Figure 1.

Figure 1 – Guide for the development of systematic literature reviews
Source: Okoli and Duarte (2019)

The initial step in this literature review was to determine its research objective: "Why conduct a literature review on technology valuation methods?". Starting with this question, the study aims to identify efficient technology valuation methods for TLOs of Brazilian STIs. This objective is supported by prior research findings that highlight the lack of suitable tools for technology valuation in Brazilian TLOs, hindering the correct commercialization and technology transfer (GUIMARÃES, 2013; ANDRADE, 2016; FERREIRA et al., 2020).
Next, in the planning stage of the protocol and team training, several meetings were held with those responsible for this study to define the appropriate methodology for the purpose of this research. Thus, it was decided that conducting a systematic literature review on methods or models for the valuation of intellectual properties would be the most appropriate approach. After opting to use a SLR, it was deemed necessary to conduct studies to apply the methodology correctly. To achieve this objective, articles were selected for an in-depth reading, and a course on the subject was undertaken.

Afterwards, following the guide proposed by Okoli and Duarte (2019), a practical selection was applied to choose the researches that would be useful for the development of this study. Firstly, the databases to be used for searching articles related to technology valuation were defined, in this case, the Scopus and Google Scholar databases were chosen. Subsequently, the keywords in Portuguese and English that would be relevant for locating the most appropriate research for the objective of this study were selected. In Portuguese, the chosen keywords were: métodos de valoração; modelos de valoração; valoração de tecnologia; valoração de ativos intangíveis; valoração de patentes. In English, the following keywords were opted for: valuation methods; valuing technology; technologies valuation.

Thus, after these definitions, the fourth stage of the review was conducted, carrying out the literature search for the studies endorsed by the previous selection. In the search process, preference was given to publications from the last 10 years, with an even stronger preference for those published within the last 5 years. This approach ensured that the review focused on the most recent and relevant research in the field of technology valuation. Thus, after this rigorous selection process, a total of 87 articles were identified.

Next, data from the studies were extracted systematically and qualitatively. Thus, a preference was given to predominantly qualitative research, while quantitative studies were given less priority. The reason for this preference is the better alignment of qualitative research with the accomplishment of the objective of this review.

In the sixth stage of the review, a qualitative evaluation of studies for the elimination of articles with insufficient quality was conducted. In general, articles that did not address at least one form of technology valuation were excluded. Subsequently, the studies were synthesized, combining the extracted facts about valuation methods in a qualitative manner.

Finally, in the eighth and last stage of the review, this research was written following the standards of scientific article writing, as well as taking due care to ensure that other researchers can reproduce the findings.
Literature Review

The concept of intellectual property refers to the idea of protecting human creations, whether they are artistic, industrial, or scientific, with the purpose of preserving the rights of inventors or owners to obtain recognition and reward. (BARBOSA, 2003; BRANCO et al., 2011; LEMOS, 2011; GOMES, 2020).

Regarding the management of intellectual property, one of the models proposed in the literature to be applied in TLOs of STIs is the model proposed by Andrade (2016). The model proposed by the author is displayed and presented in Figure 2.

In this model, first and foremost, it is important to emphasize that the STIs are solely responsible for promoting research and its development. Once a research project is deemed completed by the STI, the first stage begins: technology admission. During the technology admission process, the TLO can either search for ongoing research within the STI or receive direct submissions from them. Once a research project is selected, an analysis is conducted to assess its potential for commercialization. If it is found that there is insufficient potential for commercialization, the research project is returned from the TLO to the STI to continue its development and achieve commercial viability. The second stage is technology protection. During this stage, the selected research project undergoes formatting, application, and
monitoring of the protection process. Once the protection process is completed, the third stage, commercialization, begins. In this stage, the TLO, together with the intellectual property holders, are responsible for offering, negotiating, formalizing, and managing the contract to successfully conclude the technology transfer process (ANDRADE, 2016; ANDRADE ET AL., 2016A; ANDRADE ET AL., 2016C; ANDRADE ET AL. 2017).

In this research, emphasis is given to an essential procedure, which is carried out in the subprocess of negotiating technology: its proper valuation. Valuation refers to the act of determining a monetary value for an asset with the intention of commercializing it, but without aiming to precisely predict the asset's value. Instead, considering the risks and uncertainties of the market, the goal is to provide an expected value for the asset (SOUZA, 2009). Valuating an asset serves as a valuable tool when negotiating technology, (SOUZA, 2016; CABRERA; ARELLANO, 2018; LEITE et al., 2018; QUINTELLA, 2019) and this valuation process should be conducted based on a technically and market-driven analysis, consistently updated, in order to achieve the best outcomes (ANDRADE, 2016; ANDRADE ET AL., 2016C).

Many are the existing technology valuation methods aimed at promoting the transfer of intellectual property (ROMAN et al., 2013; CABRERA; ARELLANO, 2018; FERREIRA, 2019). This large number of models brings about more difficulties for the task to be effectively carried out by the TLO, as it becomes an obstacle to the diffusion of methods, a consensus among scholars, duly efficient for the Brazilian scenario (DAMODARAN, 2007; CARVALHO, 2019). In this context, the use of an incorrect valuation model can hinder the stages of negotiation and commercialization of the technology (SILVA, 2013).

Below, in Table 2, the main technology valuation methods found in the literature are exposed and presented, classified based on their complexity.

<table>
<thead>
<tr>
<th>Valuation method</th>
<th>Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% Rule</td>
<td>Low</td>
</tr>
<tr>
<td>Reproduction Cost</td>
<td></td>
</tr>
<tr>
<td>Replacement Cost</td>
<td></td>
</tr>
<tr>
<td>Market Comparables</td>
<td></td>
</tr>
<tr>
<td>Industry Standards</td>
<td></td>
</tr>
<tr>
<td>Pita Method</td>
<td></td>
</tr>
<tr>
<td>Discounted Cash Flow (DCF)</td>
<td></td>
</tr>
<tr>
<td>Gompertz Curve Adaptation</td>
<td></td>
</tr>
<tr>
<td>Real Options Theory (ROT)</td>
<td>High</td>
</tr>
</tbody>
</table>

Table 2 - Main valuation methods existing in the literature
Source: The Authors

Revista Gestão e Secretariado (GeSec), São Paulo, SP, v. 14, n. 10, 2023, p. 18864-18888.
The 25% Rule is a method for valuing low-complexity technologies. This rule establishes that 75% of the gains generated by the technology should be allocated to the licensee, and the remaining 25% of the profits are for the licensor of the intellectual property (FERREIRA, 2019). As it is a straightforward tool, using this method simplifies the process of patent valuation. However, it is a consensus among researchers that, even though it assists in licensing negotiations, limiting a percentage value is arbitrary (FOCHESATTO, 2020).

The valuation method known as Reproduction Cost is based solely on the expenses incurred by the STI to replicate the technology that will be commercialized (SANTOS; SANTIAGO, 2008; GUIMARÃES, 2013; ROMAN et al., 2013). Examples of resources that must be considered to calculate the Reproduction Cost include the hours dedicated by developers, patent maintenance, equipment depreciation, materials used, energy expenditure, etc. It is important to highlight that, for the correct application of this method, proper monitoring of expenditure values during the development of the technology to be valued must have occurred (SANTOS; SANTIAGO, 2008; PAIVA; SHIKI, 2017). Using this method allows for a view of the minimum resources allocated to the development of the asset, but on the other hand, it does not take into account the benefits that the technology may bring to the acquirer (PITKETHLY, 1997; PITA, 2010; SOUZA, 2016; FERREIRA et al., 2020). Therefore, when opting for the use of this method, the objective is only to recover the invested capital (ROMAN et al., 2013; FOCHESATTO, 2020).

Just like the previous method described, the method known as Replacement Cost proposes the valuation of a particular technology based on the expense incurred to produce it, but now the technology cost is calculated from the buyer's perspective. In this scenario, the price of the technology is determined based on the amount that the acquirer would spend to internally conceive something with the same or similar functionality (ROMAN et al., 2013). It is a consensus among researchers that the main advantage of both the Replacement Cost method and the Reproduction Cost method is their simplicity. When applied in combination with other forms of valuation, these methods have their proper usefulness, with calculating the expenses of conceiving a technology being a good starting point to arrive at the value of an asset (GUIMARÃES, 2013; FERREIRA et al., 2020). However, on the other hand, due to being highly limited valuation models, they are not commonly used.

Market Comparables valuation is performed through comparisons with recent transactions of similar assets, assuming that the technologies have similar market performance (PITA, 2010; SOUZA, 2016; PAIVA; SHIKI, 2017). This method has several limitations, but it is still useful. In its favor, it offers the practicality of application (PAIVA; SHIKI, 2017;
FOCHESATTO, 2020), and provides an idea of the values that the market accepts for the technology being valued (ACHLEITNER et al., 2009). The method does not take into account the risks and potential of the technology and requires a large volume of information to be effectively usable (PITA, 2010; GUIMARÃES, 2013). And since most technology transactions are conducted confidentially, only a few pieces of information are made available in an accessible way (PITA, 2010; ROMAN et al., 2013). In addition, when the valuation is carried out for a radical innovation, it will be difficult to find a similar technology that has been commercialized in the market for comparison purposes (ROMAN et al., 2013; PAIVA; SHIKI, 2017; FOCHESATTO, 2020). And even if a similar technology is located, conducting a comparison may result in an undervaluation of the asset (SOUZA, 2009).

Another way to value a technology with a market-based approach is by using standardized royalty rates applied to the revenue generated by the private sector from the sales of products utilizing the negotiated technology. In other words, the acquirer will make the payment for the technology transfer only after the asset is being commercialized, with a percentage of the sales being allocated to the previous owners of the intellectual property (PARR, 1995, 1997; MORAES et al., 2021). One of the most commonly used royalty standards comes from Russell Parr book (2007): Royalty Rates for Licensing Intellectual Property (GUIMARÃES, 2013). The Table 3 presents standardized royalty rates for different industrial sectors derived from Parr (2007), calculated based on the median of the rates charged in various analyzed licensing agreements.

<table>
<thead>
<tr>
<th>Industry sector</th>
<th>Licenses analyzed</th>
<th>Minimum royalty</th>
<th>Maximum royalty</th>
<th>Median royalty rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>32</td>
<td>0.3%</td>
<td>7.0%</td>
<td>2.8%</td>
</tr>
<tr>
<td>Automotive</td>
<td>35</td>
<td>1.0%</td>
<td>15.0%</td>
<td>4.0%</td>
</tr>
<tr>
<td>Consumer goods</td>
<td>90</td>
<td>0.0%</td>
<td>17.0%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Computers</td>
<td>68</td>
<td>0.2%</td>
<td>15.0%</td>
<td>4.0%</td>
</tr>
<tr>
<td>Electronics</td>
<td>132</td>
<td>0.5%</td>
<td>15.0%</td>
<td>4.0%</td>
</tr>
<tr>
<td>Energy and entertainment</td>
<td>86</td>
<td>0.5%</td>
<td>20.0%</td>
<td>5.0%</td>
</tr>
<tr>
<td>Pharmaceuticals and biotechnology</td>
<td>328</td>
<td>0.1%</td>
<td>40.0%</td>
<td>5.1%</td>
</tr>
<tr>
<td>Internet</td>
<td>47</td>
<td>0.3%</td>
<td>40.0%</td>
<td>7.5%</td>
</tr>
<tr>
<td>Machinery and tools</td>
<td>84</td>
<td>0.5%</td>
<td>25.0%</td>
<td>4.5%</td>
</tr>
<tr>
<td>Media and entertainment</td>
<td>19</td>
<td>2.0%</td>
<td>50.0%</td>
<td>8.0%</td>
</tr>
<tr>
<td>Healthcare products</td>
<td>280</td>
<td>0.1%</td>
<td>77.0%</td>
<td>4.8%</td>
</tr>
<tr>
<td>Chemical</td>
<td>72</td>
<td>0.5%</td>
<td>25.0%</td>
<td>3.6%</td>
</tr>
<tr>
<td>Semiconductors</td>
<td>78</td>
<td>0.0%</td>
<td>30.0%</td>
<td>3.2%</td>
</tr>
<tr>
<td>Softwares</td>
<td>119</td>
<td>0.0%</td>
<td>70.0%</td>
<td>6.8%</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>63</td>
<td>0.4%</td>
<td>25.0%</td>
<td>4.7%</td>
</tr>
<tr>
<td>Total</td>
<td>1533</td>
<td>0.0%</td>
<td>77.0%</td>
<td>4.5%</td>
</tr>
</tbody>
</table>

Table 3 – Royalty rates charged for different industry sectors
Source: Parr (2007)
In this sense, industry standards are the benchmarks for royalty rates by market sectors (FOCHESATTO, 2020). This method proves to be an interesting alternative for cases where the technology is still in its early stages, as it avoids undervaluation or overvaluation of the asset, resulting in fairer values for both sides of the negotiation (MORAES et al., 2021).

An alternative to traditional technology valuation models is the method developed by Pita (2010). The author devised a valuation model for a petrochemical company, and with the dissemination of the research, other scholars have shown interest in the method and have been verifying its effectiveness in Brazilian TLOs, such as Paiva and Shiki (2017). In this method, the value of the technology is calculated based on a set of patent characteristics, aiming to address, among other issues, the lack of speed in delivering results compared to traditional methods.

Pita (2010) presents the following equation to represent the calculation of the technology value:

\[ V_{i,t} = C_{total} \cdot (P_{margin} + P_{volume} + P_{investment} + P_{legal}) \cdot (1 - d \cdot t) \]

Where:

- \( V_{i,t} \) = patent value of patent i in year t;
- \( C_{total} \) = total maintenance cost of patents in all countries (expenses incurred for patent filings and renewals);
- \( P_{margin} \) = award for the contribution margin criterion;
- \( P_{volume} \) = award for the volume criterion;
- \( P_{investment} \) = award for the criterion of investment in production assets;
- \( P_{legal} \) = additional award for granting in countries;
- \( d \) = depreciation rate (the author set it at 5% per annum);
- \( t \) = technology utilization time.

In relation to the calculation of awards (P), the author created a mechanism that allows measuring the economic impact of the asset, based on the Technological Readiness Level of the Patent (TRL) (MORAES et al., 2021). For the additional award for granting in countries, a value of +5 points is added for each country where the patent is granted. For other awards, Pita (2010) developed a table with the scores that should be determined according to the impact and TRL. Below, Table 4 presents the awards mechanism developed by Pita (2010):

<table>
<thead>
<tr>
<th>TRL</th>
<th>Impact on contribution margin</th>
<th>Impact on volume</th>
<th>Impact on investment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>6</td>
<td>9</td>
</tr>
</tbody>
</table>
Pita (2010) divides the economic impact of the new technology into three distinct scenarios: low, moderate, and high. The author suggests comparing the impact of the patent with that of the closest substitute to choose the scenario in which the asset is inserted. This criterion can be applied both for the impact on the contribution margin and for the impact on investment. As for the impact on volume, the criterion is more objective as it is based on the volume of products benefiting from the new asset.

In relation to the TRL, Paiva and Shiki (2017) simplified Pita’s method (2010) in their studies by excluding the last three TRL levels. Based on this, the authors developed a framework that aids in determining the level at which the technology is situated. Below, Table 5 displays and presents the established criteria for choosing the TRL, as developed by Paiva and Shiki (2017):

<table>
<thead>
<tr>
<th>TRL</th>
<th>Criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Basic principles observed: When technology is formulated solely based on studies, technical drawings, etc.</td>
</tr>
<tr>
<td>Level 2</td>
<td>Defined application: The technology has a specific branch directed but without testing.</td>
</tr>
<tr>
<td>Level 3</td>
<td>Initial laboratory phase: The technology was tested in a laboratory to validate the concept of the technology.</td>
</tr>
<tr>
<td>Level 4</td>
<td>Final laboratory phase: The technology was fully tested in the laboratory, integrating all its components.</td>
</tr>
<tr>
<td>Level 5</td>
<td>Prototype testing: When the technology has a prototype, even on a very reduced scale.</td>
</tr>
<tr>
<td>Level 6</td>
<td>Pilot unit testing: The technology was tested in a pilot unit.</td>
</tr>
</tbody>
</table>

In this context, excluding the last three rows from the award mechanisms table developed by Pita (2010), Paiva and Shiki (2017) named the model used in their studies as the "modified Pita method". The authors succeeded in their studies, which aimed to facilitate the valuation of a specific technology in a Brazilian TLO, thus demonstrating the theoretical efficiency of the Pita method, even when using the model in a simplified form.

A widely spread asset valuation method in the literature and currently the most utilized one is the discounted cash flow (DCF) (SANTOS; SANTIAGO, 2008; SOUZA, 2009; ROMAN et al., 2013; SOUZA, 2016; RIBEIRO, et al., 2018; MORAES et al., 2021). The main reason for scholars to choose this model is that, unlike most of the valuation methods
mentioned before, the DCF takes into account the risks associated with the acquisition of the technology, as well as the potential gains that the asset purchase may generate for the acquirer. The DCF calculation is based on the investments, revenues, and expenses during the technology's commercialization period (AZEVEDO; GUIMARÃES, 2013). Thus, the value of the asset is determined by discounting the risks of potential future gains (SOUSA, 2009; CLASSEN et al., 2017). The following equation illustrates the calculation:

\[
\text{Value of the technology} = \sum_{i=1}^{i=n} \frac{FC_i}{(1 + r)^i}
\]

Where:

- \(n\) = technology's useful life;
- \(FC_i\) = expected cash flow in period \(i\);
- \(r\) = discount rate that reflects the risks inherent to the evaluated technology.

The calculation of DCF is based on the main premise that the value of money varies over time (GALDI; TEIXEIRA; LOPES, 2008; FOCHESATTO, 2020). Thus, assuming the framework shown above as a basis, in DCF, the value of the technology is given by the summation of the present values of future cash flows, discounted by a rate to bring them to the present value. Although DCF is the most commonly used valuation method, it does have some limitations. The model is composed of static components, which can hinder valuation when the expected cash flow in the period is uncertain (SANTOS; SANTIAGO, 2008; SOUZA, 2016; GARCIA; FELDHAUS, 2018; CASTORENA; JARAMILLO, 2018). Additionally, risks are embedded in only one discount rate, and choosing the appropriate rate is usually a challenging task (GUIMARÃES, 2013; TEODORO, 2015; SOUZA, 2016; ISHII, 2017; PAIVA; SHIKI, 2017). Therefore, applying the DCF method is more advisable in situations with a lower number of uncertainties (MORAES et al., 2021).

Searching in the literature for new models for technology valuation that provide speed in obtaining results, but at the same time, are more complex than the previously mentioned ones, the method of Gompertz curve adaptation, presented by Azevedo and Guimarães (2013), was found. This valuation method proposes a study on the potential gains that the company may have after acquiring the technology, assuming technical success is mandatory. One of the differentiators of the model is the diversity of variables that compose the method and the
studies are formulated in three distinct scenarios, described as pessimistic, expected, and optimistic. The variables proposed by the authors are:

- **Net revenue (in millions):** the expected annual net revenue of the company with the purchase of the new technology;
- **Technology share (%):** the share of the annual net revenue expected to come from the new technology;
- **Annual growth rate (%):** estimates the growth curve of the technology's share in the company's net revenue;
- **Discount rate (%):** the discount on the price of the new technology based on the company's capital risk after the purchase;
- **Time to reach maximum share (years):** the estimated time for the new technology to start retracting its impact on the company's revenue;
- **Annual retraction rate (%):** the annual retraction of the new technology after reaching its peak;
- **Probability of scenarios (%):** the possibility of the occurrences of each of the three scenarios: pessimistic, expected, and optimistic. The authors use 50% for the expected scenario and 25% for both the pessimistic and optimistic scenarios;
- **Factor K:** directly influenced by the estimate of the time it takes for the new technology to reach maximum share in the company's revenue;
- **Factor B:** directly influenced by the estimate of the time it takes for the new technology to mature;
- **Revenue share limit (%):** the maximum estimated share that the new technology can have in the company's revenue. The authors use the same values as the 'technology share' variable in their studies;
- **Time to market (years):** the time for the new technology to be introduced in the company's products/services;
- **Royalties rate (%):** the amount to be paid by the company to the researchers conditioned to the effective participation of the new technology in the company's revenue.

In summary, this valuation would serve as significant support for the STIs to negotiate their technologies with companies and would facilitate, for example, the determination of the royalty rate. However, as it is a relatively recent model, Azevedo and Guimarães (2013) emphasize that the method of Gompertz curve adaptation still lacks further applications in TLOs to demonstrate its theoretical efficiency.
The real options theory (ROT) is a valuation method that can be considered an expanded version of DCF. ROT is a more complex valuation model as it takes into account managerial flexibility (GUIMARÃES, 2013; PAIVA; SHIKI, 2017; FERREIRA, 2019), allowing managers to better assess assets in light of the uncertainties present in the market (ROMAN et al., 2013). Fochesatto (2020) in his studies, presents the following equation that exemplifies the present value generated through the use of ROT, in a simplified manner:

\[
\text{Value of the technology} = \text{NPV}(DCF) + \text{NPV(flexibility)}
\]

Where:

\[
\text{NPV}(DCF) = \text{present value of the technology calculated by the DCF method;}
\]
\[
\text{NPV(flexibility)} = \text{present value of the cash flow of the options embedded in the project.}
\]

In this sense, real options add to the project manager the possibility of buying or selling a technology within a specified maximum period, based on how the value of this asset is fluctuating in the market (SOUZA, 2009). However, this method has limitations when it comes to obtaining data on the variation of the asset's value, and its own complexity is already a limiting factor (PITA, 2010; GUIMARÃES, 2013; WANG, 2016). Thus, often, the ROT method is overlooked when valuing a technology, as both TLOs and companies require agility and dynamism in their negotiations, advantages that real options do not provide (PITA, 2010; PAIVA; SHIKI, 2017).

Analysis of the Literature Review

This chapter presents the results of the analysis of the literature review, consolidating the main issues related to the differences between the most common technology valuation methods and indicating how they can be better applied by TLOs.

Thus, at this stage of the research, the decision was made to create a table that presents the reasons that can lead a researcher to prefer or choose each of the methods. Table 6 presents the main advantages and disadvantages of the technology valuation methods covered in this study, consolidating the findings from the literature review.
<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% Rule</td>
<td>1. Simple application;</td>
<td>1. Inflexible;</td>
</tr>
<tr>
<td></td>
<td>2. Does not require knowledge about the technology to use it;</td>
<td>2. Does not weigh the risks;</td>
</tr>
<tr>
<td></td>
<td>3. Valuation occurs instantly.</td>
<td>3. Does not consider the potential of the technology.</td>
</tr>
<tr>
<td>Reproduction Cost</td>
<td>1. Simple application;</td>
<td>1. Does not weigh the risks;</td>
</tr>
<tr>
<td></td>
<td>2. Requires few data to be used;</td>
<td>2. Does not consider the potential of the technology;</td>
</tr>
<tr>
<td></td>
<td>3. Valuation occurs rapidly;</td>
<td>3. If the goal is to obtain a more comprehensive valuation, it requires combining with another method.</td>
</tr>
<tr>
<td></td>
<td>4. Provides a broad view of the costs involved in the production of the new technology.</td>
<td></td>
</tr>
<tr>
<td>Replacement Cost</td>
<td>1. Useful when combined with another valuation method.</td>
<td>1. Does not weigh the risks;</td>
</tr>
<tr>
<td></td>
<td>2. Does not consider the potential of the technology;</td>
<td>2. Does not consider the potential of the technology;</td>
</tr>
<tr>
<td></td>
<td>3. As it requires taking the buyer’s perspective, there may be obstacles in obtaining the necessary information for the application of the method.</td>
<td></td>
</tr>
<tr>
<td>Market Comparables</td>
<td>1. Simple application;</td>
<td>1. Does not weigh the risks;</td>
</tr>
<tr>
<td></td>
<td>2. Provides a great idea of the market values.</td>
<td>2. Does not consider the potential of the technology;</td>
</tr>
<tr>
<td></td>
<td>3. Due to the need for information from already commercialized technologies, there may be obstacles in obtaining the data;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. If the technology is a radical innovation, the application of the method is not possible.</td>
<td></td>
</tr>
<tr>
<td>Industry Standards</td>
<td>1. Simple application;</td>
<td>1. The main study conducted on the method was published by Parr in 2007, meaning that the industrial standards defined by the author may be outdated;</td>
</tr>
<tr>
<td></td>
<td>2. Provides a great idea of the market values;</td>
<td>2. It becomes necessary to disclose the royalties paid by the acquirer, information that would likely be kept confidential by the company.</td>
</tr>
<tr>
<td></td>
<td>3. Prevents overvaluation or undervaluation of early-stage assets.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 6 – Main advantages and disadvantages of technology valuation methods.
Source: The Authors

The Table 6 provides a summary of the asset valuation methods addressed in this study, but choosing one of them can still be a challenging task due to the numerous advantages and disadvantages they present.

Thus, a guide was developed, consolidating the literature review analysis, consisting of a few questions that allow for a quick read, making it clear and objective to choose the most appropriate technology valuation method to be applied, considering the interests of the valuation performer. The guide takes into account all the valuation models addressed in this research and is presented in Figure 3.
The first question to be answered in the guide to initiate the process of choosing an asset valuation method is whether the researcher wants to take into consideration the potentiality of the technology at the time of valuation. This is a very important question because potentiality is a variable that can have a significant influence on the final value of a technology's negotiation between an STI and a company.

Normally, when the potentiality of the technology is disregarded, the researcher is looking for a valuation model that is simpler to apply. Based on this choice, according to the guide, the researcher needs to answer whether they want a valuation based on royalties or not. If they do, the next question is whether they are interested in using market royalty references. If the answer to this question is yes, the guide recommends the use of the industrial standards method, and if not, the option presented would be the 25% rule method.

If the researcher does not want to consider the potentiality of the technology and also does not wish to apply a valuation model based on royalties, the guide presents another path where the researcher needs to answer whether they want to conduct a valuation based on the development costs of the asset. If they do not want to, the guide recommends the market comparables method. If they do want to, it is necessary to determine whether the party...
acquiring the technology is willing to fully reimburse the costs incurred in its development. If yes, the guide recommends using the reproduction cost method, and if not, the advisable method is the replacement cost.

Returning to the beginning of the guide, if the researcher has answered that they want to consider the potentiality of the asset, the next question is whether there is a preference for a more agile valuation model. If the answer is negative, the guide recommends using the real options theory method.

If the researcher wants to consider the potentiality of the technology and also prefers a more agile valuation model, they need to answer whether they are willing to use non-traditional valuation methods. If the researcher is not willing to opt for this type of model, the recommended approach is to perform the valuation of the asset using the discounted cash flow method. However, if there is a willingness to explore non-traditional methods, there is one last question where the researcher needs to answer whether they prefer a simple application valuation method. If yes, the guide recommends the Pita method, and if not, the suggested approach is to use the Gompertz curve adaptation method.

Final Considerations

Searching in the literature for asset valuation models, one can find various types: from easily applicable but overly simplistic, such as the reproduction cost method; to highly accurate but requiring challenging data acquisition, like the market comparables method; and finally, widely accepted among scholars but with significant complexity in application, such as the real options theory method. Through this investigation, it was observed that TLOs face significant challenges in making this choice, primarily due to the multitude of variables inherent in each of these models.

Thus, this study aimed to overcome this barrier by providing techniques that can assist technology managers in TLOs in choosing among the main methods found in the literature. The primary technology valuation models were identified and evaluated concerning their applicability to intellectual property valuation in TLOs. Table 6 provides a brief summary of each of the main valuation methods, presenting their key advantages and disadvantages as addressed in this study. On the other hand, Figure 3 serves as a decision-making guide among valuation methods, designed to expedite the process of selecting the most appropriate model for application. Therefore, these tools can be valuable resources when conducting asset valuation in TLOs of Brazilian STIs.
For the continuation of this research or future work, it is recommended to apply each of the models to a single technology or more to identify the variation in results found in each method. Additionally, it is suggested to develop a computational tool that facilitates and expedites the application of these methods.

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Evaluation of the main technology valuation methods applied to intellectual property


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