Silva, L.C.S., Ten Caten, C.S., Gaia, S. (2023). Tool for assessment of the green technology transfer structure in Brazilian public universities. *Administratie si Management Public*, 40, 156-170. DOI: https://doi.org/10.24818/amp/2023.40-10

Tool for assessment of the green technology transfer structure in Brazilian public universities

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Abstract: This article presents one analysis of the management of green technology transfer within the context of Brazilian public universities. The study aimed to evaluate the existing practices and identify areas for improvement in the dissemination and absorption of environmental technologies. The research methodology employs an applied and exploratory approach, combining quantitative and qualitative analyses. The study applied a tool specifically designed to assess and support technology managers in the green technology transfer process. This tool incorporates eleven dimensions, including People, Process, Budget, Relationship, Integrated Management, Research and Development (R&D) in Green Technologies, Intellectual Property, Valuation, Commercialization, Environment, and Society. To analyze the effectiveness of the developed tool, a diagnosis was carried out in the Brazilian scenario. The survey identified and evaluated 413 university-registered groups that are actively involved in green research. The collected data were analyzed using statistical techniques such as Pearson's linear correlation coefficients, multivariate analysis, and factor analysis. The findings highlight several gaps and challenges in the green technology transfer process. These gaps present opportunities for improvement and call for universities to develop strategic measures to address them. Collaborative efforts with Technology Transfer Offices (TTOs) and research groups within the institutions are also crucial in bridging these gaps. The study concludes by urging universities to adopt strategies that focus on reducing identified gaps and promoting sustainable collaboration between academia and industry in the field of green technology transfer. Overall, this research points to the current state of green technology transfer management in Brazilian public universities, providing valuable insights and recommendations for enhancing the process and driving sustainable innovation in the country.

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Keywords: technology transfer, green technology transfer, green innovation, public universities

JEL O, O3, O32, O33

DOI: https://doi.org/10.24818/amp/2023.40-10

Introduction

The planet has been going through constant technological transformations, and amid this process, climate changes directly affect the production system. According to the United Nations (UN), the world population reached 8 billion in 2022, and it is estimated to reach 9 billion in 2037. All this growth, linked to climate issues and the scarcity of resources already present in the world, has led the UN and other international organizations to discuss human nutrition, hunger, access to natural resources, sustainability, and the adoption of technology to combat current and future problems, among others.

UN actions, such as the creation and implementation of the 17 sustainable development goals of the 2030 Agenda, aim to eliminate extreme poverty and hunger, develop quality education for all, protect the planet, and promote peaceful and inclusive societies (UN, 2021). Additionally, annual actions taken by several nations through the Conference of the Parties (COP), created in 1995, have enabled the creation of major international treaties. Examples include the 1997 Kyoto Protocol, which aims to establish stricter guidelines for reducing greenhouse gas emissions, and the 2015 Paris Agreement, which aims to curb global warming.

The fact is that governments must rethink the way they interact with the ecosystem and industry and take more sustainable actions. In 2009, the national patent offices of Japan, Israel, South Korea, the United Kingdom, the United States of America, and Canada created pilot programs to accelerate the examination of patent applications for green technologies. These programs initially focused on specific areas such as alternative energies, transportation, energy conservation, waste management, and sustainable agriculture.

In Brazil, this program started in 2012 with the goal of reducing the time for patent examination by two years. Currently, the analysis and granting of patents in Brazil take an average of eleven years (National Institute of Industrial Property, 2021). One of the central reasons for this movement was to quickly identify and categorize technologies with an environmental appeal that can be analyzed and granted faster than other technologies through the patent system. By doing so, these technologies can replace current polluting technologies in the market.

Green technologies have assumed an important role in developing global sustainability and reducing CO_2 emissions. Recognizing the importance of developing these technologies in the fight against global climate change, several countries have emphasized the relevance of the patent granting procedure as a mechanism to stimulate green technologies within the country. Therefore, it is necessary to consider models for transferring these generated green technologies and to evaluate the internal and external transfer capabilities, especially those of public universities.

By evaluating the structure of green technology transfer using tools before the registration process of contractors, many gaps in this process can be reduced, providing a favorable scenario for making the best choices of mechanisms to transfer the negotiated green technology.

The technology transfer (TT) process can be extremely important and a strategic approach for industries and universities to address sustainability and resource scarcity (Schlie et al., 1987; Seror, 1996; Sedaitis, 2000; Amessea & Cohendet, 2001; Clark & Oxman, 2001; Jayaraman et al., 2004; McAdam et al., 2005; Gotham et al., 2011; Khabiri et al., 2012).

The advanced industrialization process requires companies not only to know their potential and management structure but also to seek cooperative partnerships with universities and research institutes. This aims to develop innovation projects through technology transfer to operate in an increasingly effective and sustainable manner (Harmon et al., 1997; Di Benedetto et al., 2003; Awny, 2005; Gorschek et al., 2006; Coppola & Elliot, 2007; Warren et al., 2008; Fontana, 2011; Genet et al., 2012; Heinzl et al., 2013; Landry et al., 2013; Šanda & Křupka, 2018; Ammar & Profiroiu, 2020; Erwin et al., 2022).

Cooperation also allows companies to gain new academic knowledge and experience. Companies can keep up with the rapid changes of new technologies and integrate new products into their portfolios (Shi, 1995; Trott, 1995; Gupta, 1998; Stock & Tatikonda, 2000; Malik, 2002; Todo, 2003; Siegel et al., 2004; Sharma et al., 2006; Waroonkun et al., 2008; Philbin, 2008; Malik et al., 2011; Schoen et al., 2014).

Currently, there are innovation models in the literature such as Berreyre (1975), Schumpeter (1984), and the Oslo Manual (Organisation for Economic Co-operation and Development - OECD, 2005). There are also tools for evaluating the process of innovation management in organizations, such as the Innovation Radar (Sawhney et al., 2006) and the Octagon of Innovation (Scherer & Carlomagno, 2009). Models to enable technology transfer, such as the Bozeman model (2000), exist. However, there is only one tool for assessing technology transfer management, proposed by Silva et al. (2023), called the Green Technology Transfer Radar. Evaluating this process effectively will enable better optimization of available human, technological, financial, and environmental resources, ensuring sustainability in the innovation process.

Considering this, the objective of this research was to evaluate the management of green technology transfer in Brazilian universities and public institutes, as well as to diagnose the researched activities. The study aims to answer two questions: (i) How can the green technology transfer process be evaluated? and (ii) What is the scenario of green technology transfer in Brazil?

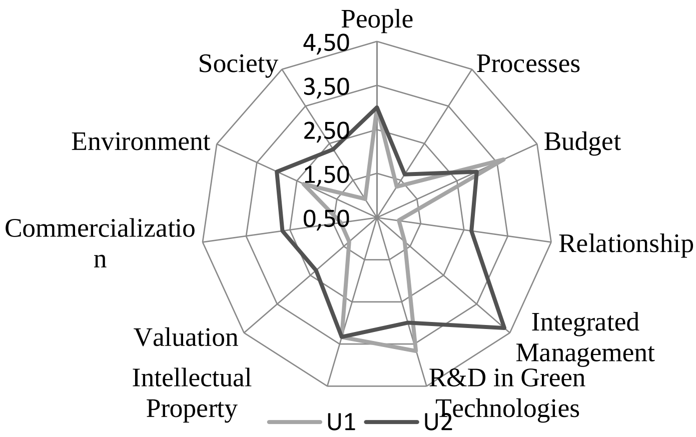
1. Green Technology Transfer

The Green Technology Transfer Radar tool was structured by Silva (2016) and Silva et al. (2023) with eleven dimensions: People, Processes, Budget, Relationships, Integrated Management, Research and Development in Green Technologies, Intellectual Property, Valuation, Commercialization, Environment, and Society. These dimensions present the main points to be managed in the green technology transfer process in the university-industry context. They cover aspects ranging from strategy to the process of transforming ideas into patenting, as well as monitoring the impacts generated by the transferred technology.

1) People: How is the support for the green technology transfer, its incentives, and knowledge diversity for the sustainable area?
2) Processes: How are the green technology transfer opportunities created, developed, and evaluated?
3) Budget: How are green technology transfer initiatives funded?
4) Relationship: How does the university use its stakeholders in the creation and improvement of sustainable ideas?
5) Integrated Management: How are activities and decisions in conducting projects involving green technologies planned and managed in laboratories, the TTOs, and academic boards?
6) Research and Development in Green Technologies: How are scientific projects researched and developed for green technologies?
7) Intellectual Property: How are the measures for the patenting process and registration of technology transfer contracts conducted?
8) Valuation: How are the tools and measures applied to the valuation of technologies before going to the market?
9) Commercialization: How are negotiations and commercialization of transferred technologies conducted?
10) Environment: How are the impacts of the environment resulting from the insertion of transferred green technologies measured and monitored?
11) Society: In what ways was the history of society studied and evaluated as well as its consumption pattern before the transfer of green technology? And how were the impacts of the use of technology measured and monitored in the lives of people in society?

The author created a questionnaire with 33 closed questions that compose the dimensions of the green technology transfer radar tool; 3 questions were distributed for each dimension. The tool has a Likert scale, with scores from 1 to 5, where 1 is never, 2 rarely, 3 occasionally, 4 frequently, and 5 very frequently, the higher the score presented in the question, the better the potential for green technology transfer in universities. The illustrative model of the toll can be seen in Figure 1.

Figure 1. Radar representation of green technology transfer



Source: Silva, 2016; Silva et al., 2023

2. Research methodology

The research is, by its nature, applied. From an objective standpoint, it is descriptive and exploratory. The approach used is both quantitative and qualitative. The research was conducted in three phases. The first phase involved exploring the literature on the dimensions of the tool.

In the second phase, the dimensions of the tool were developed, an operationalization/application model was created, and a questionnaire with 33 closed questions was prepared. Three questions were assigned to each dimension. To test the questionnaire's validation, it was initially sent to 8 Technology Transfer Office (TTO) managers and 20 researchers from Brazilian research groups/laboratories. After receiving feedback, corrections were made, and the final questionnaire was validated.

The third phase involved validating the green technology transfer tool by applying it to research groups/laboratories and the TTOs of their respective universities and/or research institutes. This was done to validate the instrument and diagnose their activities related to technology transfer.

The research groups/laboratories and universities were selected from the Directory of Research Groups in Brazil, which is maintained by the National Council for Scientific and Technological Development (CNPq). The directory serves as the main platform for registering research groups in the Brazilian government. Information was sought on activities directly related to the development of green technologies, with priority given to areas that are part of the green patents program of the National Institute of Industrial Property of Brazil.

These areas include Agriculture, Energy (Conservation and alternative energies), Waste Management, and Transportation. Among the 37,640 existing groups, 255 research groups/laboratories were identified in the CNPq directories. Table 1 shows the distribution of the groups according to their subarea of knowledge. The 413 groups consist of 2,338 researchers and 2,645 registered students. The areas of knowledge with the highest number of identified groups were Agriculture and Waste Management.

Table 1. Distribution of research groups in green areas in Brazil

Agriculture		**Waste management**		**Transport**		**Energy**	
Area	Nº	Area	Nº	Area	Nº	Area	Nº
Agricultural Sciences	82	Agricultural Sciences	23	Agricultural Sciences	0	Agricultural Sciences	2
Biological Sciences	3	Biological Sciences	6	Biological Sciences	0	Biological Sciences	0
Exact and Earth Sciences	7	Exact and Earth Sciences	13	Exact and Earth Sciences	1	Exact and Earth Sciences	5
Human Sciences	5	Human Sciences	0	Human Sciences	0	Human Sciences	1
Applied Social Sciences	4	Applied Social Sciences	2	Applied Social Sciences	1	Applied Social Sciences	2
Engineering	5	Engineering	60	Engineering	9	Engineering	24
Total groups:	**106**	**Total groups:**	**104**	**Total groups:**	**11**	**Total groups:**	**34**
Total Researchers	1.201	Total Researchers	796	Total Researchers	92	Total Researchers	249
Total Students	1.177	Total Students	1.150	Total Students	95	Total Students	223

Source: Silva, 2016

The tool's questionnaire was applied to the total population of 413 research groups/laboratories surveyed in the prospection and in their respective TTOs of universities and research institutes. The survey return rate was 55 universities.

The sample was composed of the following equation (1): Where n = size of the population (255), $Z\alpha/^2$ = critical value that corresponds to the desired confidence level σ = population standard deviation of the variable, E = margin of error or maximum estimation error.

$$n = \frac{(Za/2.\sigma)^2}{E} \qquad (1)$$

After application, with a desired confidence level of 95%, a margin of error of 11,7%, and a sample size corresponding to 55 universities. The sample chosen is considered safe and with a good margin of error.

The objective of applying the questionnaire in the TTOs and in the research groups of the same institution was to trace a comparative scenario through the green technology transfer radar between the response of the university's technology transfer agent (TTO) responsible agent for the technology transfer of the university

(TTO) and the distinct research groups/laboratories that develop science, technology and innovation activities, these groups, in many contexts have no approach with the TTOs.

Due to some complex information related to the TTO functions, and the management activities in the research groups, the application of the questionnaire with the leaders, enabled more authenticity in the ability to analyze the information, referring to the real scenario. Thus, the managers were selected to answer the questionnaires. The questionnaire was applied electronically, using the Google Forms tool, in the period between 06/06/2022 to 20/10/2022.

To obtain a single average on each of the eleven dimensions of the green technology transfer radar tool, the scores given by the respondents on a Likert scale between 1 and 5 for each of the 3 questions were added up and divided by the total number of questions (3) to obtain the final average.

To analyze the information collected in the green technology transfer radar survey, Pearson's linear correlation coefficients between the dimensions were verified, then the multivariate statistical technique factor analysis, generating a smaller number of new latent variables, unobserved, which are calculated from the raw data. The factor extraction method considered was that of principal components, the factor rotation was performed using the orthogonal Varimax method, and Kaiser's criterion (eigenvalue above 1) that determined the number of factors to be used in this analysis.

In order to verify the existence of differences between the averages of the TTOs and the research groups, analysis of variance (ANOVA) was first carried out, Tukey's test was applied because it allowed for multiple comparisons between all averages taken two by two, considering a significance level of 5%, not rejecting the hypothesis of equality between the averages of the dimensions. The statistical analyses were developed with the support of Minitab software 16.0. When considering a significance level of 5%, we did not reject the hypothesis of equality between the average levels.

3. Research results and discussions

This topic presents the results of the green technology transfer radar validation with universities and research institutes in Brazil. It was obtained 55 responses from universities, 35 responses from the research groups, and 20 from the TTOs. The names of the groups and universities are identified by letters and numbers to ensure the confidentiality of the respondent's identification.

The survey with the managers of the TTOs and research groups/ laboratories made it possible to observe more effectively the functioning of environments with respect to the structure of universities and research institutions concerning the green technology transfer process. Figures 3 to 5 present a scenario of the green technology transfer structure of the research groups/laboratories in the areas of Waste Management, Agriculture, Energy, and Transportation. Acronyms have been assigned to the group names to simplify the statistical analysis. Figures 6 to 7 present scenarios of TTOs of the education/research institutions, where the interferences between the dimensions of the green technology transfer radar tool can be observed.

Figure 2 – Research Waste Management Groups

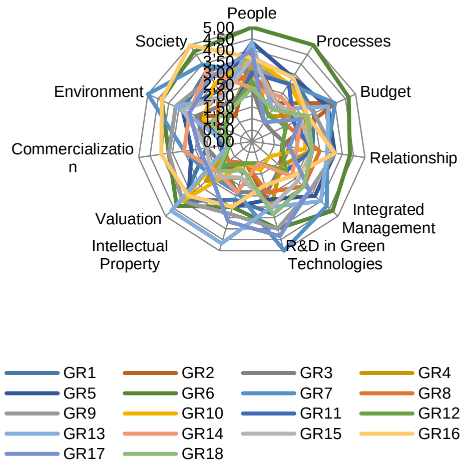


Figure 3 – Research Agriculture Groups

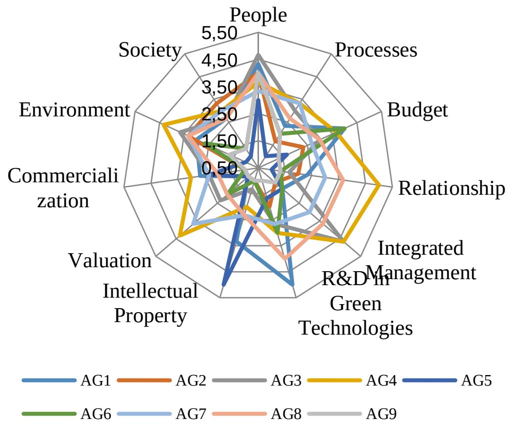


Figure 4 – Research Energy Groups

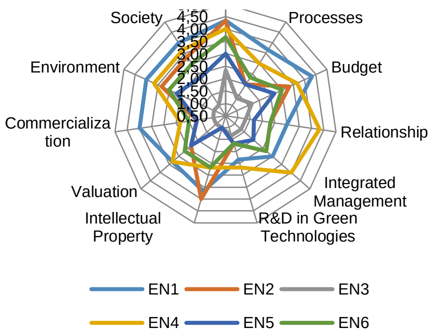


Figure 5 – Research Transport Groups

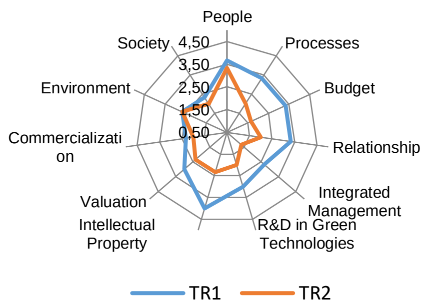


Figure 6 – Research TTO´s RGTT

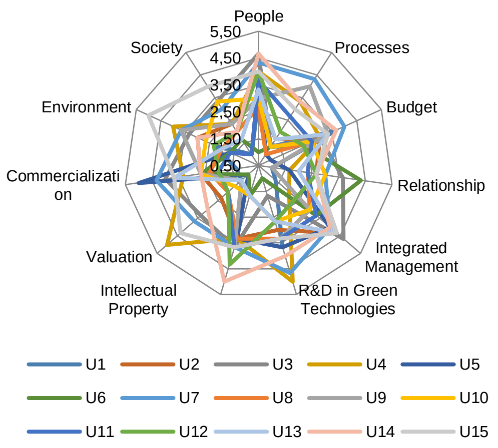
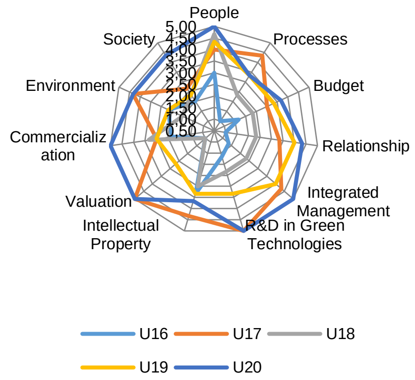


Figure 7 – Research TTO´s RGTT



Source: Authors' contribution

The ideal result would be that averages of the 11 dimensions of the TTOs and research groups would be equal to 5, making the transfer of green technologies efficient, however, as can be seen in the graphs above, one notices a constant oscillation of the averages However, the GR6 group had a lower oscillation of the averages among the groups, and the overall average of the dimensions was 4.30, among the TTOs the (U8) was the one that presented a better performance with an overall average of the dimensions of 4.40.
In Pearson's correlation coefficient table, there is a strong correlation between the dimensions, with only 8 of the 55 correlations found being less than 0.30.
The highest correlation coefficients, considering the coefficients above 0.60 are presented in Table 2.

Table 2. Highest correlation coefficients.

Transfer dimensions		Correlation Coefficient
Integrated management	Relationship	0,64
Valuation	Processes	0,65
Commercialization	Integrated management	0,62
Environment	Processes	0,65
Environment	Budget	0,62
Environment	Valuation	0,71
Society	Environment	0,79

Source: Authors' contribution

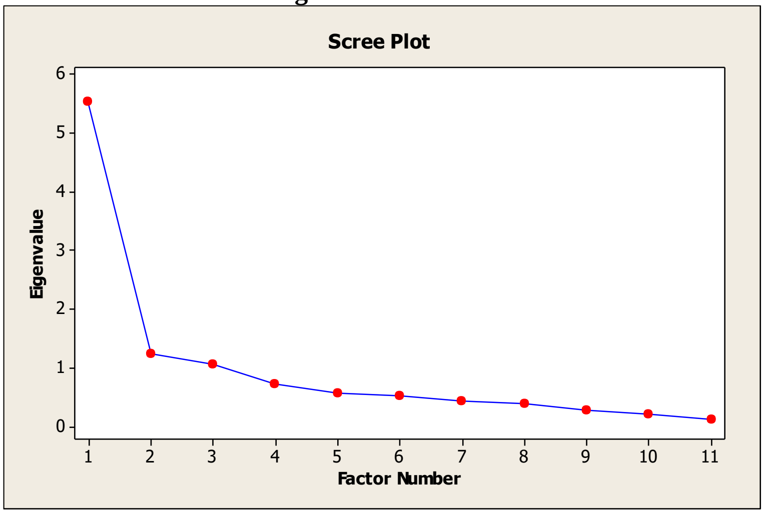
The number of factors to be extracted (Table 3). The Kaiser criterion suggests that three factors should be extracted: the first presents an eigenvalue of 5.52, carrying about 50% of the variance. The second factor presents an eigenvalue of 1.24, carrying about 11% of the variance. The third eigenvalue of 1.04 carries about 10% of the variance. Together, these three factors explain 71% of the variance of the original variables. Figure 8 illustrates the dispersion of the components in the Scree test.

Table 3. Eigenvalues and variance

Variables	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
People	0,64	0,19	-0,42	-0,22	0,43	-0,34	-0,03	-0,19	-0,07	0,00	0,03
Processes	0,76	-0,22	-0,23	-0,01	0,02	0,07	0,51	0,16	-0,01	0,16	-0,02
Budget	0,73	-0,04	-0,40	0,30	-0,01	-0,09	-0,18	0,38	0,07	-0,17	-0,03
Relationship	0,68	-0,33	0,39	0,29	0,27	0,13	-0,07	0,02	-0,29	-0,01	0,10
Integrated Management	0,73	0,13	0,41	0,34	0,12	-0,17	-0,05	-0,09	0,28	0,16	-0,07
R&D in Green Technologies	0,64	0,46	-0,22	0,32	-0,36	0,01	0,01	-0,24	-0,21	0,03	-0,05
Intellectual Property	0,49	0,69	0,08	-0,26	0,14	0,35	-0,13	0,21	-0,02	0,11	-0,01
Valuation	0,80	-0,19	-0,10	-0,07	0,09	0,40	0,05	-0,26	0,15	-0,21	-0,06
Commercialization	0,66	0,31	0,49	-0,21	-0,14	-0,23	0,23	0,07	-0,01	-0,24	0,04
Environment	0,86	-0,19	-0,11	-0,17	-0,29	0,00	-0,15	-0,05	0,13	0,10	0,22
Society	0,73	-0,42	0,15	-0,37	-0,17	-0,10	-0,21	0,03	-0,12	0,08	-0,18
Eigenvalues	5,52	1,24	1,04	0,71	0,56	0,51	0,43	0,39	0,27	0,21	0,11
% Var	50,00	11,00	10,0	7,00	5,00	5,00	4,00	4,00	2,00	2,00	0,00

Source: Authors' contribution

Figure 8. Scree Plot



Source: Authors' contribution

Table 4 presents the values of three factors without and with orthogonal Varimax rotation.

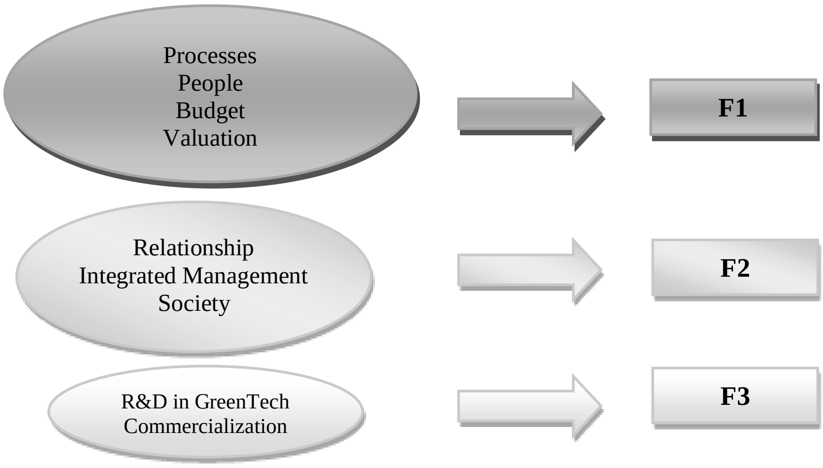
Table 4. Factor matrix without and with rotation (Varimax).

Non-rotated Matrix				Matrix rotated (Varimax)		
Transfer Dimensions	**F1**	**F2**	**F3**	**F1**	**F2**	**F3**
People	0,64	0,19	-0,42	0,72	0,07	0,3
Processes	0,76	-0,22	-0,23	0,69	0,46	0,06
Budget	0,73	-0,04	-0,4	0,78	0,25	0,15
Relationship	0,68	-0,33	0,39	0,17	0,83	0,12
Integrated Management	0,73	0,13	0,41	0,16	0,63	0,55
R&D in green technologies	0,64	0,46	-0,22	0,56	0,04	0,59
Intellectual Property	0,49	0,69	0,08	0,22	0	0,82
Valuation	0,80	-0,19	-0,1	0,61	0,55	0,14
Commercialization	0,66	0,31	0,49	0,04	0,54	0,69
Environment	0,86	-0,19	-0,11	0,65	0,58	0,17
Society	0,73	-0,42	0,15	0,39	0,76	0,00

Source: Authors' contribution

It can be seen that without the rotation there is a concentration of dimensions in factor (F1), whereas only intellectual property is found in factor two (F2). With the application of Varimax rotation a better distribution occurred. Figure 9 better represents the grouping of the dimensions of the data used in this research.

Figure 9. Rotated Dimensions



Source: Authors' contribution

The results of the test for comparison of means between the research groups, show the results of the test of the means of the TTOs, where with a confidence level of 95%.
The averages of the budget dimension among the different research groups are significantly different, whereas in the environment dimension, the AG5 group has an average equal to 1.00 and EN3 an average equal to 1.00 where they differ from the other groups, as well as GR6 that has an average equal to 5.00.
Among the TTOs, the averages of the dimensions of budget and intellectual property dimensions are significantly different.

4. Conclusions

The purpose of this research was reached since the green technology transfer radar tool was applied with the purpose of creating a mechanism through the eleven dimensions to evaluate this structure of green technology transfer within the scope of universities and institutions of science and technology in Brazil.
The statistical analysis applied allowed us to verify the characteristics of the TTOs and research groups regarding the dimensions adopted in the tool. The averages of the dimensions are small in some groups and TTOs, indicating that actions must be taken to improve their dimensions, again reinforcing that technology transfer becomes efficient if the dimensions are close to 5.
In the scope of interaction experience, the strengthening of the green technology transfer structure goes through the training of qualified labor to act in strategic sectors, and incentives to direct research carried out at universities, institutes, and industries towards priority areas for the country's development.
The researched universities must analyze the aspects and critical points raised and develop a green technology transfer model process, having the TTO as the facilitating agent in this process and integrating it into the green technology transfer model created the stage of evaluation of the transfer structure between the agents involved in this process. And, previously evaluating this transfer structure through tools, before the negotiation and approval process of the contracted parties, may reduce gaps in this process and will enable a favorable scenario for the best choices of mechanisms to transfer the negotiated green technology transfer
However, the universities must develop strategies to reduce the gaps mentioned in the application of the green technology transfer radar tool, in addition to promoting joint action with the TTOs and research groups within their institutions.

Conflict of Interest Statement

The authors declare no conflict of interest.

Acknowledgment

This research received a specific grant from a funding agency in the public, agency: CAPES Higher Education Improvement Coordination.

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