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A EFICIÊNCIA DO CAPITAL INTANGÍVEL EM EMPRESAS DE CONCESSÃO DE RODOVIAS BRASILEIRAS

THE EFFICIENCY OF INTANGIBLE CAPITAL IN BRAZILIAN HIGHWAY CONCESSION COMPANIES

[TRADUÇÃO INGLESA]

ELIZETE TARRAGO TRENTIN

CASCAVEL
2023

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[TRADUÇÃO INGLESA]

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Advisor: Professor Dra. Delci Grapegia Dal Vesco
Co-advisor: Professor Dr. Marcelo Roger Meneghatti.

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RESUMO

Tarrago Trentin, Elizete. (2023). A eficiência do capital intangível em empresas de concessão de rodovias brasileiras (Dissertação). Programa de Pós-Graduação em Administração (PPGA), Universidade Estadual do Oeste do Paraná – UNIOESTE, Cascavel, PR, Brasil.

Como parte estratégica para os negócios das empresas de concessão pública de rodovias, o reconhecimento da eficiência técnica do ativo intangível dos contratos de concessão, adquiridos externamente, adicionado aos índices dos componentes do modelo de agregação de valor do Capital Intelectual (VAICTM) ajustado, produzidos internamente, relativo aos interesses dos stakeholders, é usado como critério de análise da competitividade e o valor da empresa. Este trabalho tem a intenção de compreender o desenvolvimento eficaz do ativo intangível adquirido externamente, adicionado aos ativos intangíveis produzidos internamente, relacionados a eficiência do Lucro Líquido Operacional (LLO). A pesquisa tem como objetivo analisar os investimentos em ativo intangível adquirido externamente ou produzido internamente que afeta a eficiência da vantagem competitiva. Para realizar esta pesquisa, foram utilizadas informações financeiras dos relatórios anuais das demonstrações contábeis e do balanço patrimonial de 14 concessionárias listadas na BM&FBovespa, referente aos exercícios de 2019 a 2021. Para a análise, aplicou-se a técnica não paramétrica da Análise Envoltória dos Dados (DEA). Os resultados apontaram correlação negativa fraca entre os *inputs* das variáveis analisadas pela DEA, isso justifica as demandas excedentes nos *inputs* identificada pelo modelo que caracterizam a não eficiência de algumas variáveis. Para atender o bjetivo geral, o modelo apontou que os ativos intangíveis do Capital relacional, humano e estrutural, produzidos internamente, causam impacto no desempenho do Ativo Intangível dos contratos de concessão das empresas estudadas e afeta a eficiência na vantagem competitiva. Diante disso, o resultado eficiente na geraçao do lucro por investimentos eficaz em ativos intangíveis produzidos internamente e adquiridos externamente foi alcançado. Dessa forma, a empresa Anhanguera Bandeirante S.A, foi a unica empresa dentre as 14 analisadas a atingir a eficiência em todos os modelos DEA tanto ao *input* quanto ao *output*. Nesse sentido, observou-se que os fatores Capital Humano (CH) e Capital Estrutural (CE) foram determinantes na pesquisa na projeção de eficiência técnica, orientado ao *output* na maximização do resultado medido pelo Lucro Líquido Operacional (LLO). A pesquisa contribui para uma abordagem diferenciada na associação dos componentes de valor agregado do modelo VAIC™ ajustado com o montante de investimento em ativo intangível dos contratos de concessão do serviço público de rodovias. Ademais, contribui para ampliar a análise para além do capital humano, abrangendo os demais componentes de valor, a fim de considerar a eficiência dos diferentes tipos de insumos para os *input*s (Pesquisa e Desenvolvimento e Tecnologia da Informação) na criação de valor para o *output* (LLO).

Palavras-chave: Criação de Valor; Vantagem Competitiva; Índices de Desempenho.

ABSTRACT

Tarrago Trentin, Elizete. (2023). The efficiency of intangible capital in brazilian highway concession companies (Dissertation). Post-Graduate Program in Managemente (PPGA), State University of Western Paraná] UNIOESTE, Cascavel, PR, Brazil.

As a strategic part for the business of public highway concession companies, the recognition of the technical efficiency of the intangible assets of concession contracts (external intangibles), added to the indices of the components of the adjusted Intellectual Capital (VAIC^{TM}) value aggregation model (internal intangibles), relating to the interests of stakeholders, is used as a criterion for analyzing the competitiveness and value of the company. This work intends to understand the effective development of external intangible assets, added to internal intangible assets related to the efficiency of Net Operating Profit (LLO). The research aims to analyze investments in intangible assets acquired externally or produced internally that affect the efficiency of competitive advantage. To carry out this research, financial information was used from the annual reports of the financial statements and the balance sheet of 14 concessionaires listed on BM&FBovespa, referring to the years 2019 to 2021. For the analysis, the non-parametric technique of Data Envelopment Analysis was applied (DEA). The results showed a weak negative correlation between the *inputs* of the variables analyzed by the DEA, this justifies the excess demands on the *inputs* identified by the model that characterize the non-efficiency of some variables. To meet the general objective, the model pointed out that relational, human and structural capital (internal intangibles) have an impact on the performance of the Intangible Assets of concession contracts (external intangibles) of the companies studied and affects the efficiency of competitive advantage. Given this, the efficient result in generating profit through effective investments in internal and external intangible assets was achieved. Thus, the company Anhanguera Bandeirante S.A, was the only company among the 14 analyzed to achieve efficiency in all DEA models both at *input* and *output*. In this sense, it was observed that the factors Human Capital (HC) and Structural Capital (CE) were decisive in the research in projecting technical efficiency, oriented towards *output* in maximizing the result measured by Net Operating Profit (LLO). The research contributes to a differentiated approach in associating the added value components of the VAIC™ model adjusted with the amount of investment in intangible assets of public highway service concession contracts. Furthermore, it contributes to expanding the analysis beyond human capital, covering other value components, in order to consider the efficiency of different types of *inputs* (Research and Development and Information Technology) in creating value for the *output* (LLO).

Keywords: Value Creation; Competitive advantage; Performance Indexes.

LIST OF FIGURES

Figure 1: Potential identification of intangible assets 32
Figure 2: Elements of Intangible Assets 33
Figure 3: Categories of Intellectual Capital 35
Figure 4: University of West Ontario Model 36
Figure 5: Production System 42
Figure 6: Correspondence of mathematical models and the type of efficiency calculated. 47
Figure 7: Components of efficiency analysis 48
Figure 8: Theoretical model of the study 49
Figure 9: Structure of the VAIC^{TM} model 52
Figure 10: Phases of the empirical model 57
Figure 11: BCC DEA Model - Variables used in the research 60

FRAME LIST

Frame 1: Dissertation structure 25
Frame 2: Intangible Asset Identification Criteria 31
Frame 3: Core Competencies 32
Frame 4: Categories of Intangible Assets 35

LIST OF TABLES

Table 1: Research design 50
Table 2: Research Sample 51
Table 3: Financial Statement Data in R$1,000 52
Table 4: VAIC™ Earned Value 53
Table 5: Reformulated Earned Value of the Survey 53
Table 6: Pulic Efficiency Evaluators 53
Table 7: Reformulated Research Efficiency Evaluators 54
Table 8: Sample of the indicators of the value components of the reformulated VAIC 54
Table 9: Reformulated VAIC Sample Totals 55
Table 10: Calculation of Intangible Assets of concession contracts and Net Operating Profit 56
Table 11: Productive Efficiency of the CR Variable (CEE) 64
Table 12: Productive Efficiency of the HC Variable (HCE) 65
Table 13: Productive Efficiency of the EC Variable (SCE) 66
Table 14: Intangible Capital Dispersion (IC) Measures in R$ 66
Table 15: Measures of Dispersion of Operating Net Income in R$ 67
Table 16: Correlation measures between variables. 69
Table 17: Efficiency level, oriented to *inputs* 71
Table 18: Technical Efficiency and Scale Return *Input* Orientation 73
Table 19: Technical Efficiency and Scale Return Orientation to *output* 74
Table 20: *Output*-Oriented DMUS *Benchmarks* Targets – 2019 76
Table 21: Relative target of *output*-oriented *benchmark*s DMUS - 2019 77
Table 22: *Output*-Oriented DMUS *Benchmark*s Targets – 2020 77
Table 23: Relative target of *output*-oriented *benchmarks* DMUS - 2020 78
Table 24: Targets DMUS *benchmarks* oriented to *output* – 2021 78
Table 25: Relative target of *output*-oriented *benchmarks* DMUS - 2021 79
Table 26: Target and *output*-oriented gaps in the DEA model – Fiscal Year 2019 80
Table 27: Efficiency, targets and o*utput*-oriented gaps in the DEA model – Fiscal Year 2020 81
Table 28: Efficiency, targets and *output*-oriented gaps in the DEA model – Fiscal Year 2021 82
Table 29: Relative Efficiency BCC *Input*-Oriented Multipliers 83

CHART LIST

Chart 1: Input or output orientation model 43
Chart 2: (a) Theoretical efficiency frontier (not known); (b) Efficiency frontier estimated by the non-parametric method. 44
Chart 3: Variable Scale Returns 46
Chart 4: Dispersion and Distribution of Relational Capital 64
Chart 5: Dispersion and Distribution of Human Capital 65
Chart 6: Dispersion and Distribution of Structural Capital 66
Chart 7: Dispersion and Distribution of Intangible Capital (CI) 67
Chart 8: Dispersion and Distribution of Operating Net Income (LLO) 68
Chart 9: Efficiency level, oriented to inputs - BCC Model 72

LIST OF ACRONYMS

A	Amortization
ANTT	National Land Transport Agency
BC	Basis of conclusion
BCC	Bancker, Charnes e Cooper
CCR	Charnes, Cooper e Rhodes
CE	Capital employed
CEE	Efficiency Relational Capital
CF	Federal Constitution
CI	Capital Intangible
CND	National Privatization Council
CPC	Accounting Pronouncementes Committee
CR	Relational Capital
CRS	Constant Returns to Scale
CSN	Companhia Siderúrgica Nacional
CVM	Securities and Exchange Commission
CVRD	Companhia Vale do Rio Doce
D	Depreciation
DASP	Administrative Department of the Public Service
DEA	Data Envelopment Analysis
DMUS	Decision Making Units
DNER	National Department of Highways
DNIT	National Departmente of Transport Infrastructure
EPL	Logistics and Planning Company S.A.
EVA	Economic Value Added
HCE	Human Capital
IASB	International Accounting Standards Board
IDEs	Physical, financial and intangibel assets
IFRIC	International Financial Reporting Interpretatios Committee
IRB	Instituto de Resseguros do Brasil
IT	IT Technology

LLO	Operating Net Income
MCASP	Accounting Manual Applied to the Public Sector
PF	Fractional Programming
PIL	Logistics Investment Program
PL	Linear Programming
PPI	Investment Partnership Program
RADFI	Result before depreciation, financing and taxes
R & D	Research and Development
SCE	Structural Capital
SMAC	Society of Management Accounts of Canadá
VA	Value Added
VAIC™	Value Added Intelectual Coefficient
VRS	Variable Returns to Scale

SUMMARY

1 INTRODUCTION 15

1.1 RESEARCH PROBLEM 18

1.2 OBJECTIVES 21

1.2.1 General 21

1.2.2 Specific 21

1.3 JUSTIFICATIVE AND CONTRIBUTION OF TECHNICAL PRODUCTION 21

1.4 DISSERTATION STRUCTURE 24

2 THEORETICAL REFERENCE 26

2.1 PUBLIC COMPANIES AND THE CONCESSION PROGRAM 26

2.1.1 Incorporation of Public Companies in Brazil 27

2.1.2 Highway concession program 28

2.2 INTANGIBLE ASSETS 30

2.2.1 Elements of Intangible Assets 32

2.2.2 Value creation, efficiency and competitive advantage 37

2.3 EFFICIENCY METERS 38

2.3.1 Value Added Intellectual Coefficient – VAIC™ 39

2.3.2 Data Envelopment Analysis 41

3 METHOD AND LEGAL RESEARCH TECHNIQUES 50

3.1 RESEARCH DESIGN 50

3.2 DATA COLLECTION PROCEDURES 51

3.3 DATA ANALYSIS PROCEDURES 56

3.4 VARIABLE CONSIDERATIONS 61

3.5 LIMITATIONS OF RESEARCH METHODS AND TECHNIQUES 62

4 ANALYSIS AND DISCUSSION OF RESULTS 63

4.1 STATISTICAL VALIDATION OF BCC MODEL VARIABLES 63
4.2 TECHNICAL AND PRODUCTIVE EFFICIENCY LEVELS 70
4.3 TECHNICAL EFFICIENCY AND SCALE RETURN 72
4.4 TARGET PROJECTION OF DMUS BENCHMARKS 75
4.5 THE EFFICIENCY OF INTANGIBLE CAPITAL IN BRAZILIAN HIGHWAY CONCESSION COMPANIES 80
5 FINAL CONSIDERATIONS 87
REFERENCES 90

1 INTRODUCTION

The search for competitive advantage and market value, in the offer of quality products and services by private entities (Yang, Jaafar, Mamun, Salameh & Nawi, 2022), reflects on financial performance and greater market share (Cahyono *et al*. 2023). The participation of these companies in bids and contracts for the provision of public service of highways, under the concession or permission regime, is one of the forms most used by governments for infrastructure services.

Public-private partnerships aim to meet the state's needs for infrastructure improvements in order to reduce transportation costs and stimulate economic growth (Fernandes, Lima & Teixeira, 2022). This requires that the industry seek to recognize its intangible assets in achieving efficiency (Zhe; Hong-Hong & Yu-Lian, 2014).

The public concession service dates from the seventeenth century. It emerged in France and sparked discussions about its nature (Souto, 1997). Considering that, there are currents that describe the concession as a unilateral act, in which State sovereignty confers on the private the execution of the public service (Bacelar, 2009).

In Brazil, the Federal Constitution attributes, in article 175, the provision of public services to the Government, under the regime of a concession or permission agreement by a private public entity, provided by Law No. 8987 of February 13, 1995. This is because these entities build or renovate an infrastructure to be used in the provision of public services, with the right to operate and manage it for a period.

The new Bidding and Contracts Law No. 14,133 of April 1, 2021 has subsidiary application to Law No. 8987/1997 about public service concession and permission contracts. In its article 5, it establishes the principles of efficiency, equality and competitiveness, set forth in Decree Law No. 4,657, of September 4, 1942 (Law of Introduction to the Rules of Brazilian Law).

With growing competitiveness and the amount of information, there was a concern of public concession companies with the management of intangible assets and their accounting (Moura, Fank & Varela, 2012). In this sense, the *International Financial Reporting Interpretations Committee* (IFRIC) emerged, which edited standard No. 12 (IFRIC 12), presenting the interpretation of the *International Accounting Standards Board* (IASB), the accounting standards for intangible assets of concession contracts by public companies.

The right of the concessionaires over the infrastructure, the recognition and measurement of the contract value and the accounting treatment after the financial asset and intangible asset is recommended by the Accounting Pronouncements Committee (ICPC 01 of 2011). Thus, the accounting of the gains earned by the concessionaire can only be recognized as a financial asset if the contract is unconditional and enforceable by law.

The recognition of gains as an intangible asset is subject to the use of the service by users and the granting of authorization to charge for the public service. In this way, in the recognition of intangible assets, there is a requirement for a definition that is recognized as a probable enjoyment of the future economic benefits generated in favor of the entity, so that its cost can be reliably measurable (*International Accounting Standards Board*, IAS 38 of Intangible Assets, 2022).

Therefore, it is noteworthy that the initial investment to acquire the right to exploit the concession contract is characterized as an intangible asset acquired externally and public concession companies face challenges in the management of these assets acquired by right of use. In this sense, it is essential that there is a clear definition of the probability of future economic benefits in favor of the entity.

On the other hand, internally produced intangible assets play an important role in the survival of companies (Reina, Ensslin, Gallone, & Reina, 2009). Consequently, intellectual capital is an element that manifests itself in people with the sum of their skills in the organizational context; they are intangible resources that will produce internal assets of high value for companies (Ensslin & Ensslin, 2008).

The forms of intellectual capital can arise from hidden values developed internally under three basic forms: human, structural and relational capital (Edvinsson & Malone, 1998). In addition, hidden intangible assets are a source of sustainable advantages in a competitive environment (Hoss, Rojo & Grapeggia, 2010).

As a factor of differentiation and innovation capacity, intangible assets, especially those produced internally, play a strategic role in competitiveness. These assets are the main boosters of a company's value (Rojo, Sousa & Trento, 2012).

By measuring intangible assets as a source of sustainable advantage and added value for companies, it becomes possible to negotiate with financiers and investors. Thus, investing resources in these assets results in subsequent gains, evidencing the creation of value to the organization, considered as the main driver of growth and competitiveness (Hoss, et al, 2010).).

The intangible asset, when used to determine the value of the company, may exceed the book value. However, it emerges as a driving force in the development of a company's equity (Hoss *et al*., 2010).

By recognizing the efficiency level of the production system related to its employees, the company may reverse a situation of inefficiency. Thus, the sum of a company's knowledge and intellectual resources tends to constitute valuable intangible assets (Edvinsson & Malone, 1998).

According to the aforementioned authors, an enterprise based on the efficiency of intellectual capital depends on the competence of its workers, the attributes and instruments they use, as well as the efficient use of structural and relational capital. Aligned with this, the Net Operating Profit is noteworthy, a relevant factor in decision making.

Considering this context, techniques for analyzing productive efficiency, both parametric and non-parametric, can serve as a basis for stakeholders. From this, it is essential to carry out an analysis of the effectiveness of the efficiency of internally produced and externally acquired intangible assets related to net operating income in Decision Making Units - DMUS (Mariano, 2007).

In turn, the coefficients of the factors of intellectual capital (relational, human and structural), internally produced intangible assets, in line with the amount of intangible assets acquired externally from the concession contracts, can direct stakeholders to understand the decision-making phenomenon for investments in intangible assets. Thus, it is possible to clarify the performance of these investments when compared to the operating net income of Brazilian public service highway companies.

Given the above, this research aims to analyze the investments in intangible assets acquired externally and those produced internally, depending on the resources used in the parameters of efficient and effective productivity. In this way, it is possible to contribute with a differentiated approach in the association of the value-adding components of the VAIC™ model (internally produced intangibles), with the amount of intangible assets of the public highway service concession contracts (acquired externally), comparing them to the operating net income, in generating efficiency and competitive advantage.

1.1 RESEARCH PROBLEM

Considering that the bidding for public service concession and permission contracts in Brazil must comply with the principles of efficiency, equality, competitiveness, among others, especially the principle of judgment by objective criteria, listed in article 14 of Law No. 8.987, of 1995 (Law on Public Service Concession and Permission Contracts), and article 5 of Law No. 14.133, of 2021 (Law on Bids and Administrative Contracts), companies that have concession or permission contracts and also market their shares on the stock exchange, when presenting their intangible assets duly accounted for, comply with such principles.

Due to the current accounting context in Brazil, which is undergoing numerous transformations, the IFRIC, an auxiliary body of the IASB, issued the interpretation of International Accounting Standards IFRIC 12, in November 2006, to assist in the accounting of transactions in the sphere of public concession contracts (Cruz *et al.,* 2009). From this perspective, the technical interpretation of concession contracts given by the *Accounting Pronouncements Committee* in 2011 aims at converging the accounting standards with international standards related to IFRIC 12.

Guidelines from ICPC 01 to concessionaires on how to account for these contracts indicate to the concessionaire providing construction or improvement services, remunerated by users of public services, received or receivable, that it can be recognized as an intangible asset. Therefore, these changes reflect in the financial statements of these companies.

The Brazilian Securities and Exchange Commission (CVM), when consolidating the technical guidelines of the CPC, by CVM Resolution No. 132, of June 3, 2022, in items 24 to 27, referring to the concession agreements on the infrastructure, in the construction phase, explained that BC 62 of IFRIC 12 equivalent to ICPC 01 concluded that the operator's asset, when performing the contractual construction obligations, represents its accumulated right to be paid for the supply or provision of construction services and should be classified as a financial asset. Therefore, in the same ICPC 01 and BC 68, it was concluded that the operator's assets should be classified as intangible assets given that the performance of the contract becomes a right to charge users of the public service granted.

However, the CVM considers that, during the construction phase (execution of the contractual obligation), it is impracticable to identify the financial asset or intangible asset from the portion of the construction revenue, thus concluding that it will only be possible to distinguish them, after the completion of the work, in which the economic useful life is determined for the purpose of amortizing the cost of the asset. That being so, it is acceptable

that the value of the construction revenue, during the construction phase, be fully considered as an intangible asset, only after it is deemed feasible to allocate the portion corresponding to the financial asset of the indemnity, in which this fact must be disclosed.

In accounting for the long-term concession agreement, the resolution determines the accounting recognition of the grant right arising from the bidding process. Thus, the concessionaire undertakes to deliver economic resources in exchange for the right to exploit the contracted object within the foreseen period (CVM, 2022).

In this context, when the consideration is in currency, the value of the intangible asset will be measured at its cost in the grant right, at the time of signing the concession agreement. And, when the counterpart is offered in improvement construction services, different measurement conditions are pointed out (CVM, 2022).

Improvement construction services, which represent a potential in generating additional revenue, must be carried out through an execution contract, aiming to recover the investment (CVM, 2022). Therefore, the recognition of the right to explore and the obligation to build are carried as construction services are provided (CVM, 2022).

In construction services that do not symbolize the generation of additional revenue in an execution contract, the resolution determines that a provision be constituted with the estimated value of revenue from the term of possession, corresponding to the beginning of exploration and the end of the concession. In addition, it will have, as a counterpart, the expense of the period (CVM, 2022). From this context, in the execution of the construction service, the resolution indicates that the excess amount of the amount of accrued revenue must be recognized as an intangible asset or financial asset, depending on the circumstances. Thus, the obligation emerges when signing the contract with the grant's obtaining and the estimated value of the obligation's part to be paid (CVM, 2022).

The resolution also determines that the recognition of the grant right, as an intangible asset for construction services, be provided at the beginning of the contract's term, at present value, based on the forecast of the construction revenue. In this context, changes in the estimated fair value of construction, which do not originate from monetary variation and interest, need to be adjusted to the value of intangible assets (CVM, 2022).

It was found, in the empirical analysis of 522 companies listed on BM&FBOVESPA by Mantovani & Santos (2014), that highway concessionaires presented the highest values of intangible assets. These assets presented 93.59% in relation to total assets. For these authors, this significant representation of intangible assets may have been reached by the large number of contractual concession rights acquired by these companies.

This finding is aligned with the study by Moura, Fank & Varela (2012), who analyzed the intangible assets of companies in the electricity sector in 2008 and found that 64.29% of companies in this sector had concession contracts in their intangible assets. These contracts can last for decades; the fees charged for the services provided are accounted for as external intangible assets, with a relevant impact on the equity of these companies.

Similar to the above, the intangible asset produced internally by intellectual capital, through human, structural and relational capital, is responsible for incorporating intelligence into the enterprise. For this reason, these assets must be managed with responsibility by the company (Araújo & Gilberto, 2020).

The impact on the organizations' performance, generated by the intangible assets produced internally by intellectual capital, can result, to the company, in an increase in customers, quality and profitability. In addition, it may also present several ways of production or processes, thus changing the culture of the organization (Araújo & Gilberto, 2020).

However, by considering internally produced and externally acquired intangible assets in evaluating return on capital, you can contribute to the outcome and success of an enterprise. Thus, these assets are considered as a source of sustainable competitive advantage for companies (Hoss et al., 2010).

From this context, there is a need to explore new forms of evaluation to analyze the productive efficiency of intangible assets produced internally and those acquired externally from concession companies, as a benefit to stakeholders. Consequently, in line with Iazzolino and Migliano (2014), an analysis of the indicators of the components of the adjusted VAIC™ intellectual capital, derived from the added value of PULIC (2000), linked to other value components that consider the efficiency of various types of *inputs*, may contribute to the creation of value of all other *inputs* in the production process.

Based on this assumption, the following research question was elaborated: what are the investments in Intangible Assets acquired externally or produced internally that affects efficiency in competitive advantage? From this question, the research objectives are developed.

1.2 OBJECTIVES

In order to answer the research question, the general objective and the specific objectives were elaborated, which serve as guides for the investigative, theoretical and empirical process of this study.

1.2.1 General

The general objective of the research is to analyze investments in externally acquired and internally produced intangible assets, which affects efficiency in competitive advantage.

1.2.2 Specific

The specific objectives that are presented are:

a) Analyzing the effective technical efficiency of the intangible assets of the DMU concession agreements, added to the productive efficiency indicators of the components of the value addition model (VAIC^{TM}), adjusted in the Data Envelopment Analysis (DEA);
b) Analyzing the scale efficiency of constant returns at the levels of total efficiency and technical efficiency, when CCR is equal to the *input*-oriented BCC regarding the *output* of intangible assets produced internally and acquired externally;
c) Presenting a goal projection to maximize the efficiency level of the non-efficient DMUS of its *benchmarks*, through the Return of Scale Variables of the DEA method.

1.3 JUSTIFICATIVE AND CONTRIBUTION OF TECHNICAL PRODUCTION

Growth, economic development and efficiency are part of the study's scope of Management Science. In this context, efficiency indicators, statistical techniques and scientific methods can clarify the effective efficiency of intangible assets of contracts in highway concession companies and investments in items of the components of intellectual capital; in addition, they show their influence on competitiveness and performance with the application of VAIC^{TM} adjusted methods and DEA.

As a starting point, the study by Iazzolino & Migliano (2014), carried out in 2,596 companies from six different economic sectors, was reviewed; thus, they presented a linear correlation analysis in the existence of a relationship between VAIC and EVA's concept.

The authors found that EVA and VAIC do not have significant correlations. They found that VAIC focuses on Intellectual Capital Efficiency (ICE), in a way that measures added value from the point of view of stakeholders. Thus, to satisfy stakeholders, they identified that it is necessary to create Value Added (VA) to pay staff salaries (Human Capital - HC) and gross operating profit (Structural Capital - SC = VA – HC/VA); the higher the VA created, the greater the probability of meeting the expectation of employees (HC) and shareholders (SC) (Iazzolino & Migliano, 2014).

The authors consider analysis beyond human capital, which covers other components of value. In this context, it is possible to consider the efficiency of different types of *input*s as a contribution to the creation of value of all *inputs* in the production process (Iazzolino & Migliano, 2014).

The research developed by Vogt, Degenhart and Rodrigues Junior (2018), carried out in 46 Brazilian companies from 2013 to 2015, with the application of the DEA, showed the use of statistical techniques and results obtained through secondary data. Thus, it analyzed the investor's preference model, using Data Envelopment Analysis.

The authors identified the efficiency of companies in relation to risk and return in the stock market, as well as the investor's preference model, further showing significant differences in efficiency levels between the companies studied (Vogt *et al*. 2018).

In the research by Souza Junior (2019), the relationship between governance and economic efficiency in Brazilian agricultural cooperatives was analyzed in a sample of 35 cooperatives for 2017. Therefore, the author used the *output*-oriented DEA method in the BCC model; in addition, he considered the indexes resulting from the EVA and support from the Friedman Test and the Sperman Correlation.

The product of economic efficiency was evaluated by Souza Junior (2019), through the indicator of Economic Value Added in three models. The study obtained several efficiency results in relation to governance and economic efficiency in cooperatives. There was a relationship, when evaluated from an economic and social perspective, considering the direct and indirect benefits associated with cooperative members.

Given the above, the justification for this research, as an approach to a new focus on competitive advantage, through the financial performance of public highway concession companies, is to verify the effective technical efficiency of the intangible assets of the

concession contracts, added to the efficiency indexes of the productive factors of the adjusted value added intellectual capital (VAIC^{TM}), related to operating net income, through Data Envelopment Analysis (DEA).

The efficiency product may influence the competitive advantage of the concessionaires evaluated by the DEA method in the set of *inputs* by the indicators of the measures of intellectual capital, represented by 3 (three) independent factors applied to the VAIC model, from the Income Statement and Value Added (VA), in which: Factor 1 (one) Relational Capital Efficiency (CEE) represents the VA divided by the Capital Employed (CE); Factor number two (2) Human Capital Efficiency (HCE), represented by the VA, divided by investments in human capital (HC); Factor 3 (three), Structural Capital (SCE), designated by the VA-HC (SC), divided by the VA.

Likewise, the fourth *input* of the *input* set, called Intangible Capital, is the result of the intangible assets of the concession agreement recorded in the balance sheet of the concessionaires. Thus, as an action of the effectiveness of the numerical result of the *inputs* in the production of *outputs*, represented by the Operating Net Income for the year of the DMUs, it may serve as an indicator in the evaluation of the financial performance of these companies.

In order to determine the financial health of a company for a period of time, financial performance measures the result of a company's policies and operations in monetary terms, further evidencing the company's financial situation (Gomes, Ensslin, Sousa, Caddah Neto & Nascimento, 2021). To these authors, the results of this disclosure determine the value of the utility and efficiency of the benefits enjoyed by the interested parties.

In this context, as a practical contribution of this research, the efficiency evaluation indicators of DMUS and the efficiency-forming variables and their *benchmarks* are presented, as well as goals that can help the performance of these companies from the point of view of stakeholders.

Considering the indication of Iazzolino and Migliano (2014) to expand the analysis of the VA, from the need to measure the creation of value for the Net Operating Profit, emerges the importance of studies directed to the analysis of technical efficiency results through economic and financial indicators.

Based on the above and the contribution of the research mentioned above, the research can contribute both to stakeholders interested in the efficiency and performance of these companies and to managers and majority shareholders of highway concession companies.

For stakeholders, it can provide insights to regulatory and government agencies about the efficiency and performance of highway concession companies, helping to control efficiency

for regulatory and government purposes; for investors, it can help to map the efficiency of companies and, thus, assist the decision-making of investments or acquisitions of securities of these companies; for the community and users, it contributes by considering intellectual capital impacting the quality of services provided, in the service.

Finally, the research contributes to assist the managers of highway public service concession companies in the strategic Management of Intellectual Capital in relation to companies in the sector. Therefore, to be able to identify their *benchmarking* and recognize the components of intellectual capital with possible deficiencies.

1.4 DISSERTATION STRUCTURE

This work is structured in four chapters, besides the introduction, literature review, research methods and techniques, analysis and discussion of the results and, finally, the conclusion. In the literature review, studies related to the creation of public companies in Brazil and highway concession programs are addressed, as well as the role of the State in the regulation and concession of public services to the private sector, in order to supervise the concession contracts for the operation of federal road infrastructure in the country. Therefore, it aims to increase the State's capacity to intervene in society and in the economic market, through administrative and financial means, linked to the constitutional principle of efficiency in the training of personnel and management information of its intangible capital. The intangible asset plays an important role in the business economic scenario; it is a driver for the growth of wealth and economy of entities, represented by the elements of intellectual capital in the creation of value and competitive advantage, through efficiency indicators and statistical methods, which have emerged in the economic field as a metric to measure the efficiency of financial capital in the profitability of assets. In the research methodology, the research design and the analysis procedures employed are described. The fourth part presents the analysis and discussion of the results, in which the characterization of the variables in the DEA BCC model, the levels of technical and productive efficiency, efficiency and scale return and the projection of the target of the DMUS *benchmarks* are discussed. The structure of the dissertation is shown in Frame 1.

<table>
<tr><td colspan="2">2 THEORETICAL REFERENCE
2.1 PUBLIC COMPANIES AND THE CONCESSION PROGRAM
2.1.1 Incorporation of Public Companies in Brazil
2.1.2 Highway Concession Program
2.2 INTANGIBLE ASSETS
2.2.1 Elements of Intangible Assets
2.2.2 Value Creation, Efficiency and Competitive Advantage
2.3 EFFICIENCY METERS
2.3.1 Value Added Intellectual Coefficient – VAIC™
2.3.2 Data Envelopment Analysis (DEA)
3. RESEARCH METHODS AND TECHNIQUES
4. RESULTS ANALYSIS AND DISCUSSION</td></tr>
<tr><td>Input-oriented DEA CCR model
$MAX = \sum_{i=1}^{m} u_i \cdot y_{i0}$
Subject to:
$\sum_{j=1}^{n} v_j \cdot x_{j0} = 1$
$\sum_{i=1}^{m} u_i . yik - \sum_{j=1}^{n} v_j \cdot x_{jk} \leq 0, with\ k = 1,2 \ldots . z$
Input-oriented DEA BCC model:
$MAX\ PO = \sum_{i=1}^{m} ui \cdot yio + u$
Subject to:
$\sum_{j=1}^{n} v_j \cdot x_{j0} = 1$
$\sum_{i=1}^{m} u_i \cdot y_{jK+u} - \sum_{j=1}^{n} v_j \cdot x_{Jk} \leq 0, with\ \ k\ 1,2 \ldots . z$</td><td>SCALE RETURN:
Scale Efficiency =
$\frac{Total\ Efficiency\ (CCR)}{Technical\ Efficiency\ (BCC)}$</td></tr>
<tr><td colspan="2">5. FINAL CONSIDERATIONS</td></tr>
</table>

Frame 1: Dissertation structure
Source: the author (2023)

Sequentially, the theoretical foundations that support the discussions presented and contribute to the final synthesis are shown.

2 THEORETICAL REFERENCE

This chapter deals with the theoretical framework of the intangible assets of concession contracts and the value-adding components of the intellectual capital of highway companies. To portray Public Companies in Brazil, the Concession Programs that present the grantor responsible for regulating the activities of highway infrastructure exploration in the country were used as a focus. Likewise, the inspection of efficiency in the execution of federal highway concession contracts and in the professional training of employees was considered, demonstrated in the work carried out by these companies in the projects, which must be returned to the federal government at the end of the contract.

The second section of this chapter presents the Intangible Asset and its elements, essential in the accounting disclosure of a company. The asset acts as a driver for the development and wealth of an enterprise, creating value, efficiency and competitive advantage, related to costs and benefits.

The third and last section of this chapter is dedicated to expose the efficiency meters in asset profitability through the VAIC™ method, in order to add value to the classes of human capital, structural capital and relational capital. In addition, it evidences the Data Envelopment Analysis (DEA), as a non-parametric statistical technique in the evaluation of economic efficiency, productive of the Intangible Assets of the concession contracts, added to the productive efficiency of the components of the value aggregation model of the Intellectual Capital of VAIC^{TM} in Brazilian public service companies, as a support in the interpretation and analysis of the results acquired in the empirical research.

2.1 PUBLIC COMPANIES AND THE CONCESSION PROGRAM

Public companies are entities governed by private law and are part of the Public Administration, recognized and authorized by the State through concessions and managed by the private sector (Souto, 1997). For instance, Banco do Brasil was the first mixed-capital company in the Brazilian territory, having its foundation originated from a charter deliberated by the Prince Regent, on October 12, 1808 (Souto, 1997).

2.1.1 Incorporation of Public Companies in Brazil

The creation of public companies in Brazil dates from the twentieth century, from the perspective of the State in adopting a business infrastructure, formed by several companies, such as: Instituto de Resseguros do Brasil (IRB) from 1939; Companhia Siderúrgica Nacional (CSN) from 1941; Companhia Vale do Rio Doce (CVRD) from 1943 and Companhia Hidrelétrica do São Francisco from 1945 (Souto, 1997).

This period also served for the generation of state-owned companies, providing spaces in which private companies were not interested or had insufficient capital for their conception. Therefore, the growth of the State and its intervention in the economy was represented by the advent of the State of Social Welfare (Leite, 2007).

In order to guarantee social rights, the Welfare-Social State assumed the role of promoting economic growth and international competitiveness, thus evidencing the character of the State as a *res publica* (Pereira, 1997, p.9). In this context, the intervention of the State in the economy was related as means for development (Leite, 2007).

The government of Getúlio Vargas demarcated the implementation of the Interventionist State. With the increase in state interventions in the economy, in 1938, the Administrative Department of the Public Service (DASP) was created; this body employed state-of-the-art administrative technology and professionalized the public service, according to the degree of merit (Martins, 1997).

In 1970, the growth of state-owned enterprises and capital investments contributed to the country's economic development. Consequently, inexpressive increases in public spending emerged, leading to discussions on the interventionist validity of the State in the economy (Leite, 2007).

However, in the 1970s, there were several fiscal crises that discredited the ability to maintain a welfare state, resuming the implementation of the most widespread liberal ideas. The understanding became that the state was intervening too much in the economy. Therefore, a new regulation of the market would be necessary to remove the power of the State (Pereira, 1998, p. 28).

The redemocratization of Brazil in the 1980s was the reflection created by the external debt crisis in the fiscal deterioration in Latin America, with the transfer of the flow of international capital. Because of this, state-owned companies practiced tariff adjustments below inflation in the execution of public policies, acquiring, for themselves, relevant liabilities (Giambiagi & Além, 1999; Leite, 2007).

Given the context, there was an increase in transfers of federal tax resources, in order to meet the operational needs of these companies (Giambiagi & Além, 1999). In response to these mismatches in public accounts, the privatization process was pointed out as a solution. It was judged that the resources obtained in privatizations could be useful for reducing public debt (Leite, 2007).

Based on the structural reforms resulting from the privatization of the economy, it was believed that Brazil could make room for a new phase of development. In this sense, the country would be aligned with the rhetoric of the Washington consensus, which involves privatizations, opening the economy, fiscal adjustment, combating inflation and adopting pro-market policies (Giambiagi, *et al*., 1999).

The Master Plan for the Reform of the State Apparatus of 1995 presented a proposal to redefine the role of the State, which was no longer directly responsible for economic and social development through the production of goods and services, to strengthen itself as a promoter and regulator of this development. In this sense, the State ceased to be the executor, exercising the role of regulator.

From this context, Decree No. 95.886, of March 29, 1988, prepared in the Sarney government, created the Federal Privatization Program, which covered the regulation and concession of public services to the private sector in the country (Giambiagi & Além, 1999).

2.1.2 Highway concession program

In Brazil, the responsibility for regulating the activities of operation of the federal toll road infrastructure and supervising the execution of federal highway concession contracts delivered to the private sector is granted to the National Land Transport Agency (ANTT). Given that, non-pedestrianized highways are part of the National Department of Transport Infrastructure (DNIT). In this sense, state toll roads or not are the responsibility of the states.

The transfer of the highway to the private sector for a certain time is when the concession of highways occurs; the government is the one that defines how the private sector will work. Therefore, the State supervises the work of the concessionaire, maintaining authority over the project.

At the end of the term of the contract, the concessionaire will have to return the assets to the government, maintaining the improvements made. In this context, the concessionaire's counterpart is the collection of the toll for the use of users of public roads.

The amount received by these companies serves to cover the expenses of construction, maintenance, conservation and general operation of the highway. As a result, the population receives the benefits invested by the private sector due to the concession contracts and the government continues to own the public assets (ANTT, 2020).

The Federal Highway Concessions Program began with the creation of Ministerial Ordinance No. 10/1993. The first stage of highway concessions by the private sector in Brazil began in 1994; during this period, exploration was granted for the construction of the Rio Niterói Bridge. Around 1995, four more stretches of federal highways were granted.

With the creation of Law No. 9,277, in May 1996 (called the Law of Delegations), there was a possibility for States, Municipalities and the Federal District to request the assignment of stretches of federal highways, in order to include them in their Highway Concession Programs. Thus, with the emergence of the Law of Delegations, in 1998, the concession of the road lot of BR-116/392/RS by the Government of the State of Rio Grande do Sul occurred. Subsequently, in 2000, this concession was subrogated to the Federal Government.

The government faced difficulties in the 2000 fiscal year to implement state programs. In this context, the National Council for Privatization (CND), through Resolution No. 8, of April 5, 2000, requested the revision of the Federal Highway Delegation Program dealt with in Law No. 9.277/96, authorizing the Ministry of Transport to adopt measures necessary for the unification of the road concession policy.

In 2001, the National Land Transport Agency (ANTT) was created, designated by Law No. 10.233, assigning to the Agency the responsibility for the activities of exploration of the federal road infrastructure. Thus, in 2005, ANTT took over to carry out necessary studies for the bidding for federal highway concessions, which, until then, had been carried out by the Ministry of Transport.

The 2nd stage of the concessions was marked by the holding of auctions with 7 lots of federal highways in 2007. In the first auction, held in 2009, in the Northeast region, the concessionaire Via Bahia won the section BR-116/324/BA and BA-526/528.

The 3rd Stage took place, within the Logistics Investment Program (PIL), in 2013, in which it was inaugurated with the concession of 2 road sections. In 2014, contracts were signed for 5 new concessions on highways that pass through 6 Brazilian states, thus expanding the number of grants made in the scope of the 3rd Stage.

In 2015, after the end of the concession contract for the Rio Niterói Bridge, signed in 1994 by the National Department of Highways - DNER, ANTT promoted a new concession auction for the Bridge for a period of 30 years. Therefore, in 2016, it was the turn of the

Investment Partnership Program (PPI), created by Law No. 13.334, of 2016; its purpose was to expand and strengthen the interaction between the State and the private sector through the execution of partnership contracts and other privatization measures, created for the Program, together with ANTT and Logistics and Planning Company S.A. (EPL), with the mission of executing the planned activities.

Law No. 13,448, published on June 5, 2017, established guidelines for the extension and re-bidding of partnership contracts in the Investment Partnership Program (PPI), specifically qualified for this purpose. Therefore, the inauguration of the 4th Stage of road concessions in 2018, together with the auction of the concession of the Rodovia de Integração do Sul (sections of highways BR-101/290/386/448/RS), included important advances in the regulatory model.

In order to offer new instruments so that the contracts are more rigorous, but, at the same time, sufficiently dynamic to meet the changes that occur over the 30 years of concession, in 2019, two (2) more contracts were signed with ViaSul concessionaires (BR-101/290/386/448/RS highways) and with Ecovias do Cerrado (BR-364/365/GO/MG) (ANTT, 2020).

The resumption of budget balance, in the containment of the public deficit, forces the State to rethink the quality of spending, implementing changes in its performance model, in the presumption of efficiency and effectiveness in the state's economy. In this way, the Master Plan for State Reform (1995) emerged with the objective of increasing its capacity to intervene in society and the economic market by administrative and financial means, thus replacing the bureaucratic management model with a management model linked to the constitutional principle of efficiency (art.37. CF). This through training of personnel and management information to identify, recognize and measure an intangible asset of the concession contracts.

2.2 INTANGIBLE ASSETS

As an important role in the business economic scenario, intangible assets play a preponderant factor for the sustainability and competitive advantage of companies (Villalonga, 2004). These assets appear as elements without physical property, they have added value and can be marketed by a company because they are identified and measured through standards, legislation and technical pronouncements (Mantovani & Santos, 2014).

In the Equity Accounting Procedures of the Public Sector Accounting Manual (MCASP, 2022), Intangible Assets are non-monetary assets, without physical substance, identifiable,

controlled by the entity and generator of future economic benefits or potential services. In this sense, it has the identification criterion, presented in Frame 2.

It is separable from the entity and can be sold, transferred, licensed, rented or exchanged, individually or together with a related contract, asset or liability regardless of the intention of use by the entity;	It results out of contractual rights or other legal rights, whether or not such rights are transferable or separable from the entity or other rights and obligations.

Frame 2: Intangible Asset Identification Criteria
Source: MCASP (2023)

In the identification of acquisition costs attributed to intangible assets by financial accounting, there was a greater difference, in the case of Williams' goodwill; Stanga and Holder (1989), presented by Hoss, Rojo and Grapeggia (2010), which can be seen in Figure 1.

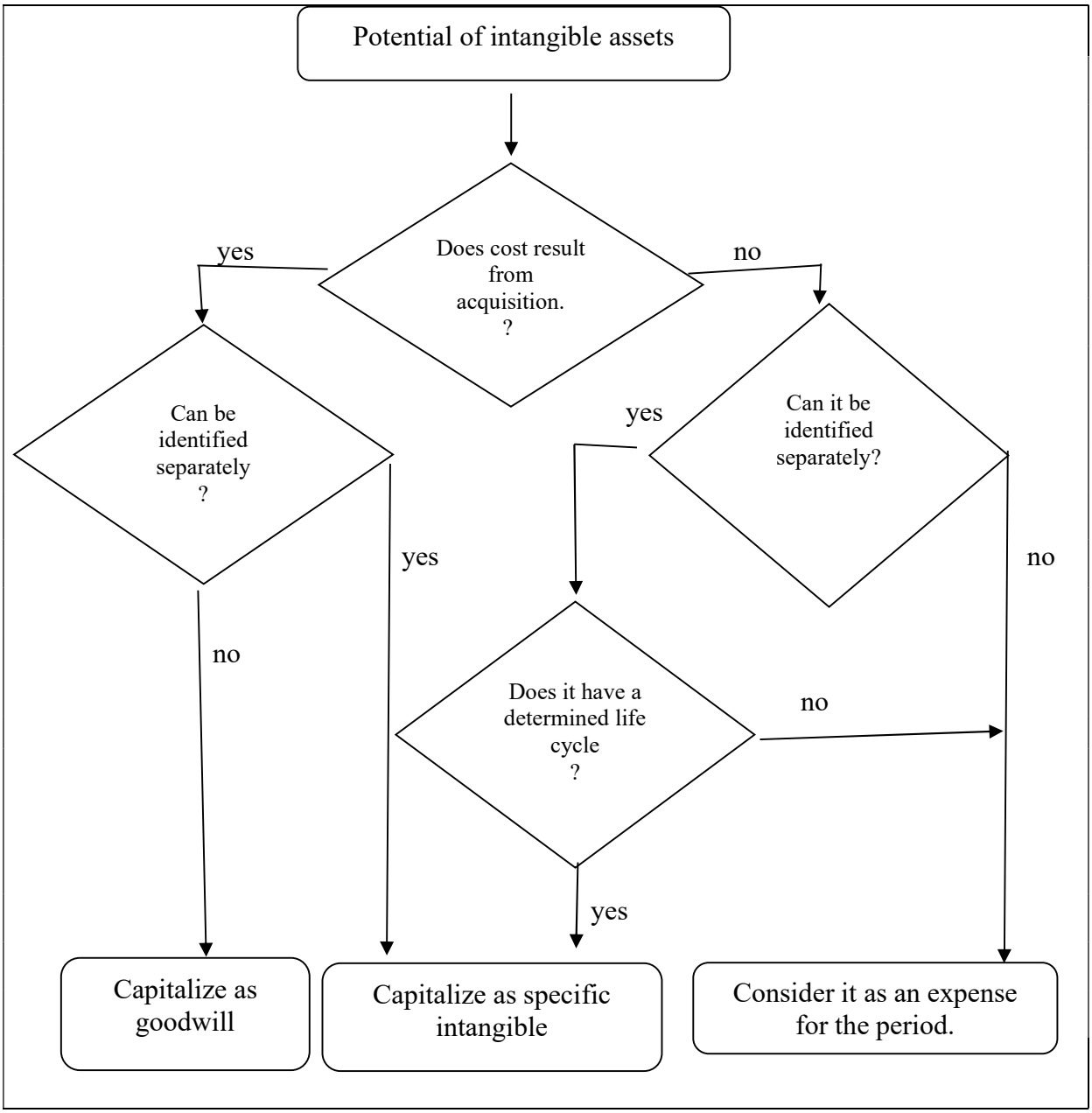

Figure 1: Potential identification of intangible assets
Source: Hoss, Rojo and Grapeggia (2010, p.40).

In order to check their structure and thus order them, there are several ways to classify intangible assets. In this sense, expenditures on goodwill and software are considered as investments; on the other hand, expenditures on brands, copyrights, knowledge, Research and Development (R&D) of the market are considered as expenses (Hoss *et al*., 2010).

Uncapitalized intangible assets hide an important part, which serves as a basis for internal management analysis, as well as for external purposes. It is also noteworthy that software expenses are exceptions that are usually capitalized as an investment (Hoss *et al.,* 2010).

For the aforementioned authors, the method for defining the economic potential of a company is not to list all intangible assets that are not included in the balance sheet estimate, but rather to seek the core competencies of the potential generators of intangible assets. In this sense, these competencies are determined by a combination of various techniques, such as examination of customer requirements and needs, as well as internal and external perspectives, presented in Frame 3.

- Skill and implicit knowledge; - Culture and values - Technology and explicit knowledge;	- Process management; - Assets such as images, customer relationships and networks

Frame 3: Core Competencies
Source: Study data

Given this, the secret of intangible assets is what economists call an increasing return to scale: the larger the user network, the greater the benefit for all (Hoss *et al*., 2010).

Intangible assets are part of one of the most complex areas of accounting (Hendriksen & Breda, 1999). These assets, considered non-monetary, identifiable and without physical substance, may be usable in the production or supply of goods and services, rented to third parties or used for administrative purposes (Schmidt & Santos, 2003).

2.2.1 Elements of Intangible Assets

Due to the complexity of definition and uncertainty regarding the measurement, value and useful life of intangible assets in Brazilian accounting, with the convergence to International Accounting standards, there is a certain difficulty in the treatment and accounting

disclosure of these assets. However, accounting for these assets' values information and innovation in society. In addition, it is a fundamental point for the development of a company (Mantovani & Santos, 2014)

As important drivers for wealth and economic growth of companies (Lev, 2001), there is still no consensus regarding the accounting definition of intangible assets (Andrienssen, 2004). In this sense, a compilation of the elements that make up intangible assets, generated internally, was presented by Sullivan (2000), in Figure 2.

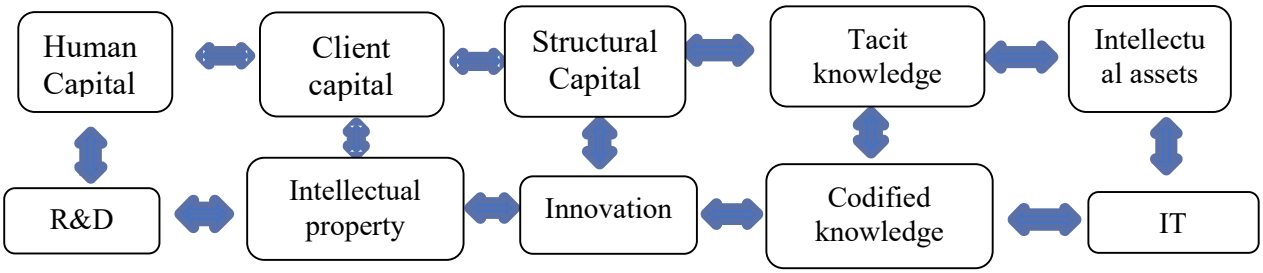

Figure 2: Elements of Intangible Assets
Source: Adapted from Sullivan (2000).

To understand the presented scenario, investments with employee training represent the element of human capital (Kannan & Albur, 2004); structural capital allows human capital to work within the organization (Edvinsson & Malone, 1997) and customer capital represents the values involved in the relationship with the customer (Kannan & Albur, 2004).

Tacit knowledge has the characteristic of accumulating over time (Stewart, 1997) and intellectual assets are, as a criterion, property of the asset. In this sense, based on accounting, the company owns the knowledge it will produce for the future (SMAC "Society of Management Accounts of Canada"; IFAC, 1998).

Intellectual property refers to the rights that the company has over the ownership of the intangible asset (Jacobs, 2002); codified knowledge represents the intellectual asset transformed into tacit knowledge, making it accessible to those who need it (Davenport & Prusak, 1998).

IT is a tool used for the communication channel (Lee & Lee, 2004); innovation is related to intangible assets focused on the company's research and development activities (Lev 2001). In turn, R&D is what contributes to productivity, growth and increased company value (Lev, 2001); it is considered as an indicator of structural capital with future profitability (Jardon & Martinez, 2021).

The structure of an organization, when consolidated in the manager, support personnel and leader, produces the capacity for successful management, regardless of the intangible

available to each element in the production of value (Sveiby, 1998). In this sense, the continuous search for profit maximization can meet the objectives of shareholders and stakeholders (Jansen, 2001).

With the increase in competitiveness in the various sectors of the economy, there is a growth in the strategic professionalization of business leaders and in the formatting of decisions centered on scenarios. In this sense, it contributes to the construction of strategic information in the decision-making process (Santos & Terra, 2012).

The knowledge of the market in which it operates, the choice of the administrator, sales strategies, equity and creativity of the entrepreneur are significant factors for the success of a company. In this sense, the company is a set of structured processes, systematized around its mission, in which people perform important activities (Santos & Terra, 2012).

Internal factors interfere with a company's market value, including knowledge that is influenced by the company's ability to generate positive results. Therefore, it is important to have quality to improve internal administration and external responsibility in institutions (Hoss *et al*., 2010).

From a qualitative and quantitative perspective, the drivers for intangible assets aim to guide the information production process. Due to their characteristics, they must be grouped and can be associated with the performance of companies, contributing to managers being able to achieve their objectives and goals (Hoss *et al*., 2010).

Researching suitable drivers for intangible assets is a strategic factor in the management plan for the company. Thus, they can be associated with importance according to the interest of their stakeholders (Hoss *et al*., 2010).

For the authors above, consumer satisfaction, innovation, human capital, organizational processes, customers and business relationships are significantly subjective drivers that can be identified as expenditure or not. In this context, in the evaluation of intangible assets, financial indicators are the fundamental components in this process.

The grouping of intangible assets represents a need to interpret the interdependence of these assets that seek to support the valuation process (Santos & Terra, 2012). In this sense, Butler, Cameron and Miles (2000) point out a grouping of four categories of intangible assets, verified in Frame 4.

- Human Capital, as an individual skill in solution for customers, skills and procedures;	- Organizational Capital, the organization's ability to compose knowledge and classify it in its sources as a

- Customer Capital, such as the strength of the customer relationship, superior value perceived by customers and increase in customized solutions;	knowledge base, business processes, shared culture, values and norms; - Intellectual Capital, that has the ability to generate return on assets for shareholders.

Frame 4: Categories of Intangible Assets
Source: Study data

Brooking's (2002) model, presented by Hoss *et al*., (2010), starts from the concept that the market value of companies is the sum of intangible assets and intellectual capital. This model has four clusters, forming a set of quantitative and qualitative indicators for measuring intellectual capital (Figure 3).

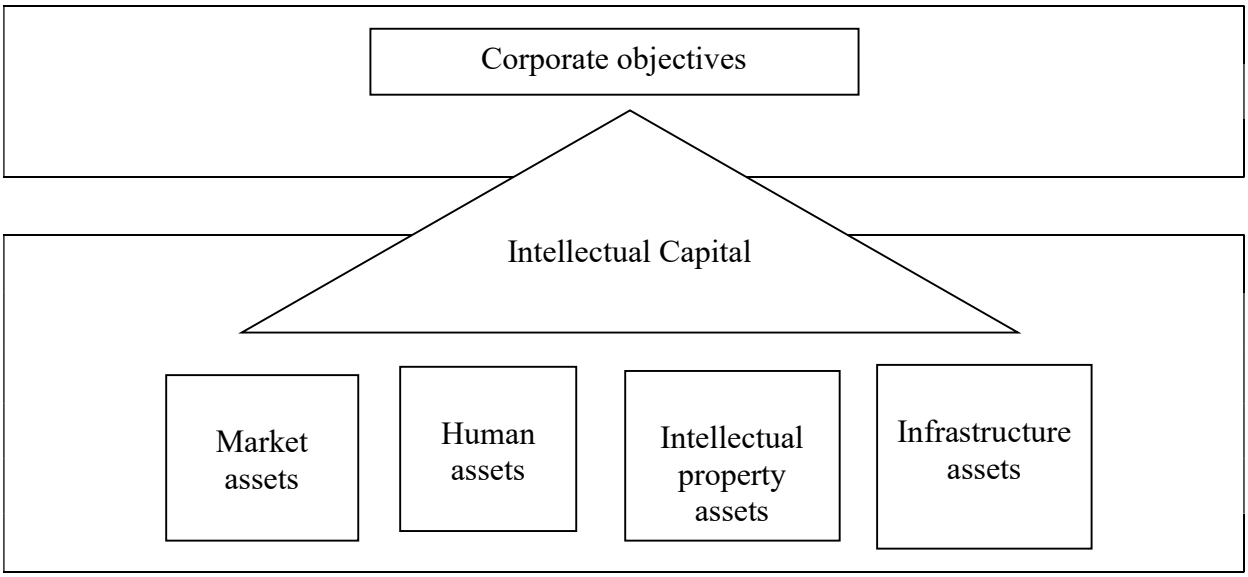

Figure 3: Categories of Intellectual Capital
Source: Hoss, Rojo and Grapeggia (2010, p.53)

In the Bontis (2002) model, presented by Hoss *et al.* (2010), the cause-and-effect relationships between the basic elements of intellectual capital and business results are studied. Such elements can be seen in Figure 4.

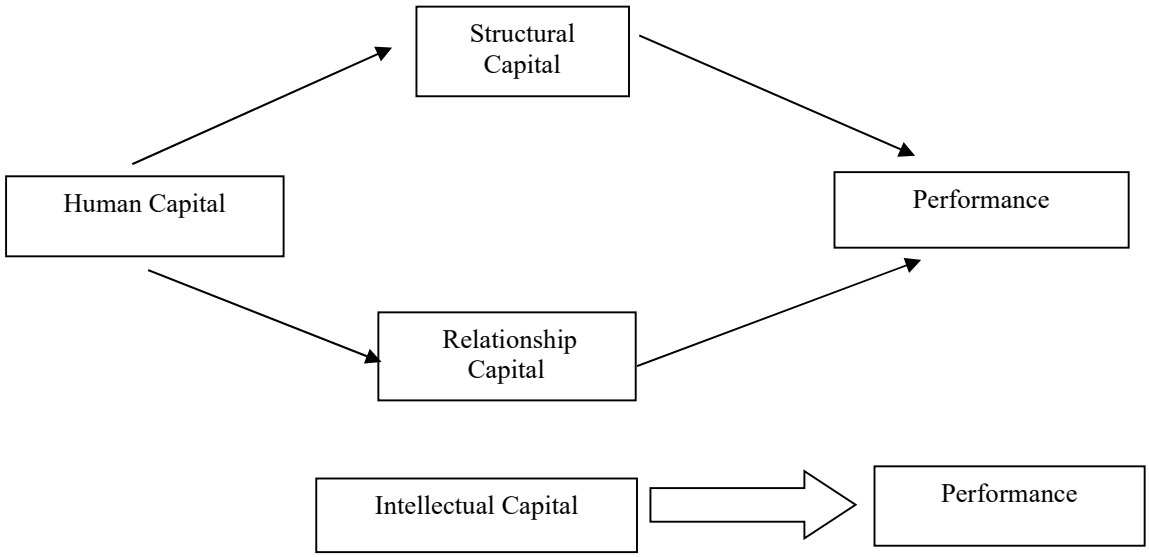

Figure 4: University of West Ontario Model
Source: Hoss, Rojo and Grapeggia (2010, p.53).

The model was successful due to the importance of Human Capital for the achievement of the goals and performance indicators desired by the company. Thus, it reaffirms the importance within the organizational culture when focused on intelligence in conducting the structuring of the organization of knowledge (Millán & Dias, 2010).

In the process of measuring intangible assets, one must take into account a company's ability to generate wealth from the past, present, and future. Thus, it is necessary to know the nature of the assets and identify the drivers for the necessary groupings (Hoss *et al.,* 2010).

Planned, systematized and applied strategy and competitive intelligence are important factors for the company to succeed (Santos & Terra, 2012). In this sense, by acting directly or indirectly in the means of production, through various types of service provision, humans can be considered as an asset creator and wealth generator (Botari & L. Santos, 2009).

Given the above, the provision of a public concession service, performed by a third party with a temporary delegation, is the institute to which the State assigns the exercise of a public service that then agrees to provide it on their own behalf (Mello, 2005). Thus, the delegation of this service, made by the public administration, under the concession regime, is exercised through an administrative contract at the contractor's risk, through a tariff paid by the user or another form of remuneration resulting from the exploitation of the granted service (Di Pietro, 2002).

IFRIC 12's International Accounting Standards recognize the accounting as an intangible asset of the amount of the grant paid in currency and measured at cost in the transactions of administrative public concession contracts at the signing of the contract for the exploitation of the public service (CVM, 2022). However, in the execution of construction services, the excess value of the amount of provisioned revenue must be recognized as an intangible asset or not, depending on the circumstances (CVM, 2022).

In order for the intangible assets of the concession and construction services to be recognized, they must be provided for during the term of the concession agreement at present value, based on the value of the construction revenue (CVM, 2022). Therefore, when defining the obligations of the charges of the concession contracts, the prices budgeted by the bidders must be compared with the reality of the market.

The amount that will be charged to users of public services must be limited to remunerating the investments made by the concessionaire. In this sense, the public concession arose from an interrelationship between the State and the private sector, with the objective of developing essential activities of interest to the community (Marçal Filho, 2003).

The business exploitation of the public service, through concession, is related to the concept of profitability. Therefore, there is the application of peculiar principles that are not within the scope of the state, such as protection of private property, free enterprise and free competition (Marçal Filho, 2003).

From the accounting internationalization process, investors, financiers and other market agents tend to seek ways to standardize the accounting language. In this context, these forms translate into financial statements, such as economic benefits for the past, present and future, efficient and competitive, derived from intangible assets.

2.2.2 Value creation, efficiency and competitive advantage

The company's ability to generate profit is associated with the definition of value (Barney, 2002). Research in R&D and innovation contribute to productivity, growth and increased company value (Lev, 2001). For the author, innovation, as a generator of value, is of great importance within organizations, thus, it is directly associated with intangible assets together with the organizational structure and human resources in creating value.

The efficiency of a company is related to costs and benefits, by applying resources as rationally as possible; thus, it tends to achieve the result in a more economical way. In this way, you can obtain an adequate result in production with a minimum number of resources (Castro, 2006).

Federal Law No. 8987/95, of the concession contracts, highlights, in its chapter VI, article 23, item II, the essential clauses of the contracts, related to the criteria, indicators, formulas and parameters defining the quality of the service and the result in the promotion of efficiency in the road sector. Thus, in chapter VII, article 29, as the granting authority, it stimulates the quality of the service, increased productivity, preservation and conservation of the environment and encouragement of competitiveness.

With regard to competitive advantage, it results in the ability of the company to efficiently carry out a set of activities, so that it generates a differentiated value for its buyers through a lower cost than its competitors (Vasconcelos & Cyrino, 2000).

The ability to create greater economic value than its competitor shows a great competitive advantage (Barney & Clark, 2007). This process generates a differentiation of the company, reporting lower costs and better performance. The outcome of a firm's non-financial performance reflects the organization's wealth in value creation in a completely different way (Barney & Clark, 2007).

In this context, the method of estimating the value of intangible assets, proposed by Gu and Lev (2003), appears to mitigate differences in the value of companies. It is based on three main classes: Physical Assets, Financial Assets and Intangible Assets.

The method contributes to the economic performance of companies, represented by: α* (Physical assets) + β* (Financial assets) + γ* (Intangible assets). It has, as a proposal, the reduction of asymmetries found in the information of accounting reports, organized in five stages: economic performance, determination of physical and financial assets, estimated financial performance of the company - IDEs, forecast of IDEs in three different periods and the determination of intangible capital.

Intangible assets are defined as identifiable, non-monetary and without physical appearance. These assets consist of rights and are fit for an evaluation (Jordan & Martinez, 2021).

To value intangible assets of institutions, it is necessary to do research that identifies the variables that add value and has the ability to generate wealth for the past, present and future (Hoss *et al.,*2010). However, retrospective metrics inform past performance (Kalafut & Low, 2001).

The approach proposed by this methodology will allow the company to measure the efficiency of its organization, without the asymmetries and prospects of future gains (Gu & Lev, 2003). Judging that it is possible to use the available resources to deliver good results.

Pulic's (2000) Value Added Intellectual Coefficient (VIAC^{TM}) is a method that measures how much and how efficiently intellectual capital creates value for the company. This method is based on invested capital, human capital and structural capital (Hoss *et al*., 2010).

2.3 EFFICIENCY METERS

With the increase in changes in the structure of the global economy, the concern of the markets grows, with efficiency and productivity in the various production chains. In this sense,

companies seek to reassess their methods in the commitment to their viability and business competitiveness.

Interest in studies and applicability of components, which measure the productive efficiency of intangible assets, has intensified, becoming an important step for companies living in competitive environments. This process tends to lead to considerable savings in resources, with subsequent gains in efficiency, value creation, growth and competitiveness (Hoss *et al.,* 2010).

Estimating the efficiency of a company's operations on intangible assets can help decisions about its current performance, or even the adoption of new technologies. In this context, the intangible assets of concession contracts combined with intellectual capital based on intangible assets tend to become an important factor in the performance and growth of organizations.

As a metric for analyzing the efficiency of intangible assets, the research presents two models, the Value Added Intellectual Coefficient (VAIC^{TM}) and Data Envelopment Analysis (DEA).

2.3.1 Value Added Intellectual Coefficient – VAIC™

Considered a metric used to measure the efficiency of financial capital in asset profitability, Pulic's VAIC™ method (2000) is intended to analyze the company's current performance. This metric aims to define the ability to generate value related to the classes of relational capital, human capital and structural capital.

Jordan and Martinez (2021) point out that indicators of relational capital classes, such as advertising spending, may reinforce the improvement in sales in the company. However, the relationship with suppliers and the company's image cannot be linked to this indicator.

In personnel expenses, as an indicator of human capital, for these authors, the quantity of the quality of human capital is covered, regardless of the contribution of each one within the organization. In this sense, this indication makes it difficult to identify which aspect of the human indicator is being valued (education, values, attitudes, etc.).

R & D expenditures, as an indication of structural capital, the authors highlight as an investment of future profitability. In addition, this investment promotes the culture of innovation and use of technology.

The possibility of using intangible assets, as an additional indicator of the intellectual capital stock, is to make it assume a proportional value between identified and unidentified intangible assets (Jordan & Martinez, 2021).

As an indicator of value in the company, the metric uses the added value, measured by revenue, minus current expenses (Pulic, 2000). In this sense, the economic value generated by the company, by external economic *inputs*, consists of the added value (Jordan & Martinez, 2021).

Pulic's VAIC™ method consists of three indices: Relational Capital (CEE), which represents Value Added (VA) / Capital Employed (CE); Human Capital (HCE), composed of Value Added (VA) / Human Capital (HC); Structural Capital (SCE), produced by Structural Capital (SC) / Value Added (VA).

Added value, used in Pulic's proposal, acts as an indicator of value, created by the intellectual work of knowledge workers. In this context, the tool used to measure value creation is the Income Statement as the Earned Value, with the ability to measure the value creation of investments in knowledge (Iazzolino & Migliano, 2014).

The result of the VAIC™ is the sum of the indices, constituting an indicator of the level of efficiency of the company as a whole. Thus, a company with a higher VAIC™ uses resources in a more efficient way, with the ability to achieve a higher market value than competitors that obtain a lower VAIC™ index (Pulic, 2000).

Pulic (2000) defines that the VAIC™ and its components produce concrete measures of a company's ability to generate value, since accounting and financial information reveal its origins.

Based on data from the companies' financial statements, the productive efficiency indicators of the VAIC™ components are objective and accurate to demonstrate the efficiency of the capital employed (Martins, Moraes & Isidro, 2012). In this sense, the model measures the value created by everything an organization invests in resources, per monetary unit of investment (Pulic, 2004), quantifying the company's value creation.

In measuring intellectual capital, the role of external reporting has demonstrated the relevance of the non-financial information that should be included in integrated reporting. These data, together with the financial information, clarify the entire *status* of the company. And thus, they meet the level of requirement for transparency and accountability by stakeholders, supporting the decision-making process (Santis, 2019).

The literature has shown a higher level of disclosure of Intellectual Capital in annual reports. The most reported components were Human capital and Structural capital based on

return on assets; the VAIC methodology has a significant positive relationship between VAIC and accounting performance (Gomes *et al*., 2021).

VAIC's Direct Intellectual Capital method estimates the monetary value of intangible assets, identifying their components. After being identified, they can be evaluated directly, individually or as an aggregate coefficient (Jurczak, 2008).

The Pulic method considers that the company generates value between its *outputs* (products and services sold) and its *inputs* (expenses with the production and marketing of products and services), in the use of its financial resources (intangible assets), human and structural (intellectual capital).

2.3.2 Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a performance evaluation method that studies efficiency based on the concept of productivity, presented in the studies of Farrell (1957). The method is a class of non-parametric productive efficiency technique, which empirically builds an efficiency frontier, which will serve as a basis for the analysis of efficiency (Mariano, 2007).

Farrell's (1957) study aimed to investigate a set of *Decision Making Units* (DMUs) in the performance and total efficiency of companies within the organization. Farrell was the precursor in the study of efficiency measures based on non-parametric techniques. Thus, he proposed an empirical model for calculating relative efficiency (Almeida, Mariano & Rebelato, 2006).

The DEA method has a characteristic of its own and has a set of models that represent the reality and the perspective in which it can be used (Mariano, 2007). The method allows each production unit to be evaluated in relation to the other units, forming a homogeneous and representative set (Brigatte, Gomes & Santos, 2011).

Data envelopment analysis aims to compare a determined amount of DMUs, which perform similar tasks and, at the same time, differ in the amounts of *inputs* they consume and *outputs* produced. It is a tool that serves to evaluate the relative efficiency of similar units and set goals for inefficient DMUs (Avelar, Millioni & Rabello, 2005).

The tool evaluates efficiency indexes for each DMU and identifies the best performance standards (*benchmark*), serving as a reference for inefficient DMU, which provides transparency to the process (Pereira & Ferreira, 2018).

DEA is presented in two classic models: the CCR model by Charnes, Cooper and Rhodes of 1978, which considers Constant Scale Returns (CRS), and the BCC model by Banker, Charnes and Cooper of 1984, which considers Variable Scale Returns (VRS), which does not assume proportionality between *input*s and *outputs*.

The BCC model presented a change in the CCR formulation, interpreting the fact that, at different scales, DMUs could present different efficiency parameters, since the conditions that influence production productivity are also diverse. To this end, Banker, Charnes and Cooper (1984) introduced the concept of size of the most productive scale.

By introducing the concept of the most productive scale size, the BCC model of Banker *et al.* (1984) changed the definition of CCR, with the interpretation that DMUs at different scales can present different efficiency parameters, influencing productivity conditions in production, which are also diverse.

The DEA method is based on a systematized and easy-to-solve linear programming model; it serves to compare several *inputs* and *outputs* that are difficult for operational units or decision makers to understand, with the purpose of measuring performance (Vilela, 2004). It is also known as a technique to measure efficiency, based on productivity (Souza, Bertolini & Araújo, 2019).

To measure performance in a model, the relationship of the result of an arithmetic division between the result obtained from an operation and the resources used in production is usually contemplated (Rodrigues Junior, 2012 p.67). The author contextualizes measurement as the ratio between two measures, being a productivity index defended by Cooper; Seiford and Tone (2006), which assimilates the production system, as shown in Figure 5.

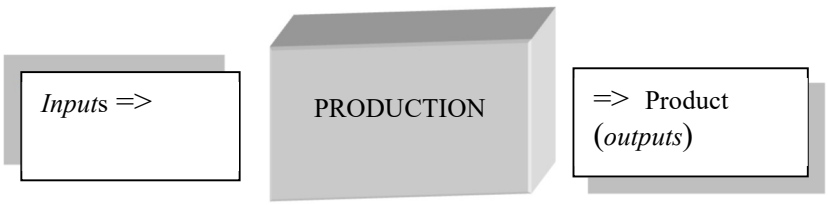

Figure 5: Production System
Source: Rodrigues Junior (2012).

Output is the result of the production of *inputs* and these *inputs* can be used to maintain, reduce or increase *output* and vice versa. It should be noted that the performance measure of an organization is generated by the arithmetic division of *input*s and products in the comparison of measures, making it possible to describe the productivity of a company (Rodrigues Junior, 2012).

DEA is a statistical alternative with a mathematical programming approach, which makes the verification of the relative efficiency of DMUs possible (Oliveira & Gomes, 2003), regardless of the points involving the limits of whether or not the productivity of the production unit is technically efficient (Lorenzett, Lopes & Lima, 2010).

The productive system is characterized by producing a set of *outputs* from a set of *inputs*, thus originating the concept of productive efficiency. Too much, this set of *outputs* and *inputs* will have a direct impact on the company's costs, competitiveness and income (Mariano, 2007).

In the orientation for maximizing *input*s, the DEA model is responsible for the reduction that can occur in *inputs* to remain at the same level, from the level of *output* production of a unit. In models oriented to maximize *outputs,* it will account for the highest level of *outputs* that can be achieved to keep the level of *input*s constant, based on the level of *inputs* used (Vilela, 2004; Almeida *et al*., 2006). This can be seen in the CCR/ CRS model, in Chart 1.

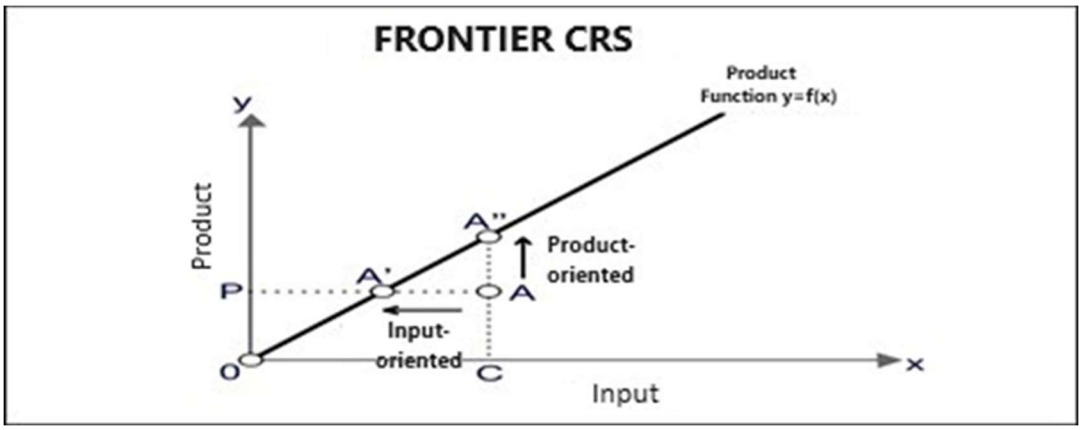

Chart 1: Input or output orientation model
Source: Lorenzett, Lopes and Lima, (2010).

Considered a seminal work in the academic world, the CCR model of Charnes *et al.* (1978) allows the application of efficiency analysis models for *n input* variables with *s output* variables. The original model contains a problem in the form of Fractional Programming (PFo), to calculate efficiency, in which it limits the inclusion of various *input*s and *outputs* (Rodrigues Junior, 2012).

To solve the problem of fractional programming, there is a CCR model in the Linear Programming Form (PLo), which can be performed with each of the DMUS, with the peculiarity of defining which orientation should be followed, whether *input* or *output*; this was the first model to generally use mathematical programming to achieve the degree of efficiency of DMUS (Rodrigues Junior, 2012).

For Charnes *et al.* (1978), the CCR model assumes constant or proportional returns. Thus, depending on the size of the company, the option for the frontier established in this model,

in the evaluation of the performance of a non-efficient DMU, may be subject to contingency factors, and may be impaired (Rodrigues Junior, 2012), being sensitive to the size or scale of the firm (Souza *et al*., 2019).

Banker *et al*. (1984), when reassessing the presumption of returns of constant or proportional scales of Charnes *et al.* (1978), in the analysis of a set of companies, realized that larger companies tend to have a lower performance, and may even present decreasing returns to scale.

In the BCC model, defended by Banker *et al*. (1984), the relationship between *inputs* and products is non-linear; the model analyzes the Technical Efficiency of DMUS in the performance of production units. In this sense, the model consists of the addition of a free variable, which represents the gap of the harmonization factor in the performance of companies (Rodrigues Junior, 2012).

In the efficiency frontier curve, as a reference to the other units evaluated by Charnes and Cooper (1985), from a parametric graph (a) and a non-parametric graph (b), it is possible to identify, in a set of five production units, the theoretical efficiency frontier (called A to E). In this sense, considering that they are subject to a single *input* and that it results in two products, they are represented in Chart 2.

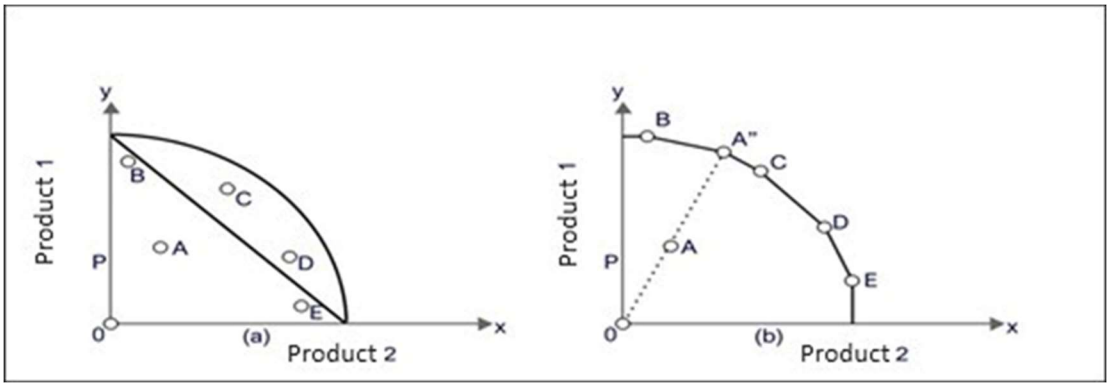

Chart 2: (a) Theoretical efficiency frontier (not known); (b) Efficiency frontier estimated by the non-parametric method.
Source: Lorenzett, Lopes and Lima (2010).

The non-parametric graph (b) shows that unit A is internal to the efficiency boundary and the distance ratio between "0A and 0A"; it presents a technical efficiency measure for this unit. However, units B, C, D, and E lie over the efficiency boundary.

The value provided for the unit under analysis, by means of the relative efficiency measures, corresponds to the deviation observed in relation to the units that are considered efficient. Efficiency development was based on two guidelines: *input* and *output* guidelines, based on reducing *input*s and raising the product level (Brigatte *et al.,* 2011).

For the DEA technique to be applied, it is necessary to provide all the numerical data of the *input*s and products of each DMU (Avelar, 2004 and Almeida *et al.,* 2006). Thus, the calculation of the efficiency of a set of DMUS will only be possible after the use of a linear programming model (PPL), differentiated for each DMU (Almeida *et al.,* 2006).

The relative efficiency score of the units evaluated in relation to the others will be evidenced in the PPL result, an indicator that can vary between 0 and 1. The result of an efficiency score equal to 1 evaluates the unit as efficient (Pimentel & Casa Nova, 2005; Almeida *et al.,* 2006).

The optimal solution for the BCC0 model is described by ($\theta B*$, $s-*$, $s+*$), in which $s-*$ represents the excess of *inputs* in the production system, $s+*$ the lack of the level of *outputs*, $\theta B*$ the value of efficiency, which differs from the level of efficiency for the CCR model. In order to be Efficient in the BCC model, a DMU, with ($\theta B*$, $s-*$, $s+*$), is required to meet two conditions; $\theta B*$=1 and over the gaps $s-* = 0$, $s+* = 0$. Failure to comply with these conditions for DMU0 will be considered BCC0 – Not Efficient (Rodrigues Junior, 2012).

The efficiency coefficient generated through the BCC model demonstrates that $Ef_{BCC} \geq Ef_{CCR,}$ consists of that the returns are not constant, or that they obtain any difference, between the results of the DMUS that had no impact on efficiency (Cooper, 1984; Cooper, Seiford & Tone, 2006). Thus, this is one of the reasons why the model is also called the *Variable Return Scale* (VRS) (Rodrigues Junior, 2012).

From the concepts of efficiency, Banker, Charnes & Cooper (1984) created a model considering the gains in scale in their calculation, called the VRS or BCC model. The model allows us to identify whether the scale return is constant with regard to the production scale, increasing in productivity rise or decreasing with reduction in productivity, thus inserting the concept of scale (Charnes; Cooper; Lewin & Seiford, 1994, Almeida *et al.*, 2006).

The model also allows the returns not to be constant among the results of the DMUS. In this context, it enables an analysis of the effective efficiency of DMUS in their best performance, considering their particularities (Rodrigues Junior, 2012).

Scale return and scale economy are characteristics of the area of economics, to designate the variation of production in relation to the variation of resources. Therefore, the term return to scale is the production function of a company that shows the behavior of the index of increases in *outputs* (production) in relation to the associated increase in *input*s (Melo, 2019).

All factors of production are variable and subject to change by virtue of a given increase in size (scale). In this sense, economies of scale show the effect of an increase in the level of

production, evaluating unit costs; scale return, on the other hand, focuses only on the relationship between the quantities of *inputs* and *outputs* (Melo, 2019).

The determinant of scale return, in the BCC model, in the form of multipliers, is represented by the variable "w". In the CCR model, in the form of the envelope, this return is considered the sum of the lambda variables "λ", plus the sum of the slacks. Thus, the variable "w" represents the restriction of convexity, which can be negative or positive, and serves to interpret the type of scale return (Mariano, 2012).

The Lambda variable "λ", as it is a determinant of scale returns in the CCR envelope model, can be considered as decreasing scale returns when situations of increasing scale $\sum_{k=1}^{z} \lambda k > 1$, a rise in scale return in situations of $\sum_{k=1}^{z} \lambda k < 1$ and constant returns to scale in any situation $\sum_{k=1}^{z} \lambda k = 1$, (Mariano, 2012).

In the BCC multiplier model, the variable “w”, when positive and with a BCC#CCR situation, considers increasing scale returns. In a negative situation of this variable, in which BCC#CCR is presented, the scale return is considered decreasing. For a situation of CCR = BCC, constant scale returns are considered (Seiford & Zhu, 1999).

In the hypothesis of constant return to scale, *outputs* vary proportionally to *inputs* in all regions of the border. In the hypothesis of variable scale returns, it is considered that the variation of *outputs* does not need to be proportional to *inputs*, in this case, at the border, there will be three regions: (a) constant, in which proportionality exists; (b) increasing, in which *outputs* grow proportionally more than *inputs*; and (c) decreasing, when *outputs* grow proportionally less than *input*s (Mariano, 2012). This is depicted in Chart 3.

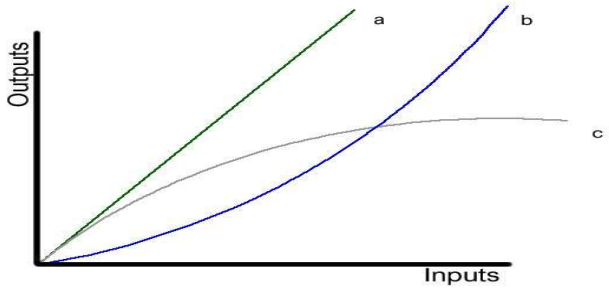

Chart 3: Variable Scale Returns
Source: adapted from Mariano (2012)

The hypotheses of constant scale returns in the constant returns to scale (CRS) model, in the convex technology of Charnes, Cooper & Rhodes (1978), show that efficiency is evaluated as a linear programming problem and the constraints represent a set of production

possibilities. In the objective function, the maximum contraction of i*nput*s in the *input*-oriented model or the maximum expansion of the product is evidenced, when oriented to the *output* (Pessanha, Souza & Larencel, 2007).

In the convex linear combination added by Banker *et al*. (1984), as a restriction to the CCR model in the creation of the BCC model, the hypothesis of variable returns to scale (VRS), increasing or decreasing, was contemplated. For this model, the evaluated DMUS, which used the lowest volume of *inputs* or produced the highest amount of *outputs*, are considered technically efficient (Pessanha *et al*., 2007).

By virtue of the differences between the types of scale returns, the efficiency of the CCR and BCC models are also different. The CCR model calculates total efficiency and the BCC model calculates technical efficiency, as shown in Figure 6.

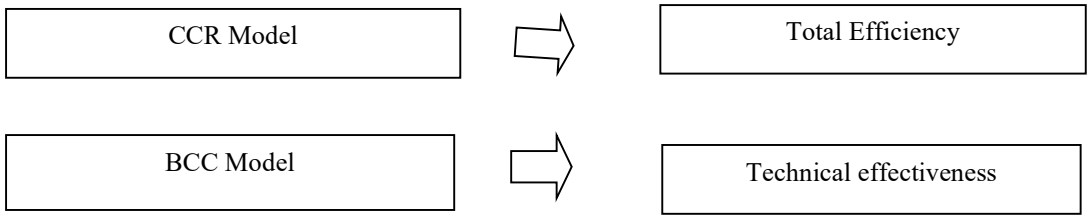

Figure 6: Correspondence of mathematical models and the type of efficiency calculated.
Source: Mariano, Almeida and Rebelatto (2006).

In this way, the total efficiency compares a DMU with all other units. Technical efficiency, on the other hand, compares the DMU only with the unit that operates similarly to it. In this sense, technical efficiency is considered a component of total efficiency (Mariano *et al.,* 2006).

Scale efficiency is a component of the model that can be defined as the efficiency at which the DMU is operating below or above its optimal scale. Thus, after calculating the total efficiency and technical efficiency, the scale efficiency is calculated (Mariano *et al.,* 2006).

The central hypothesis of this study is to verify whether a greater investment in externally acquired intangible assets, together with an effective development of relational, human and structural capital (internally produced intangible assets), is specifically related to efficiency in generating Net Operating Income in Brazilian highway concession companies. This is due to the ability of these resources to improve the quality of services, customer satisfaction and operational efficiency, resulting in an increase in the operating net income of companies in the sector.

In this sense, the research is characterized by the analysis of the efficiency of external intangible assets acquired from the right to grant highways, added to internally produced

intangible assets, represented by the Intellectual Capital – VAIC^{TM} adjusted components, as shown in Figure 7.

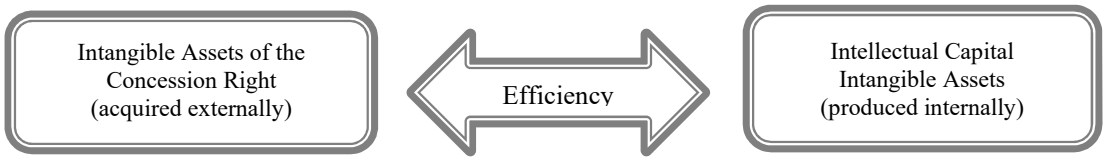

Figure 7: Components of efficiency analysis
Source: the author (2023).

In this chapter, the construction of the theoretical framework of the research was elaborated, presenting the value addition components that make up the VAIC^{TM}, which will serve as a basis for analyzing the technical efficiency of the Intangible Assets produced externally by the highway concession contracts, added to the components of the Intellectual Capital of the VAIC^{TM}, produced internally. This is adjusted in the effective result of operating net income, through Data Envelopment Analysis; thus, it is possible to build the research hypotheses, which will be empirically tested by the DEA technique.

Based on the above, the methodological study of the research aims to use the *input*-oriented DEA BCC model in the response to the research hypothesis. Thus, it is possible to define the theoretical model in Figure 8.

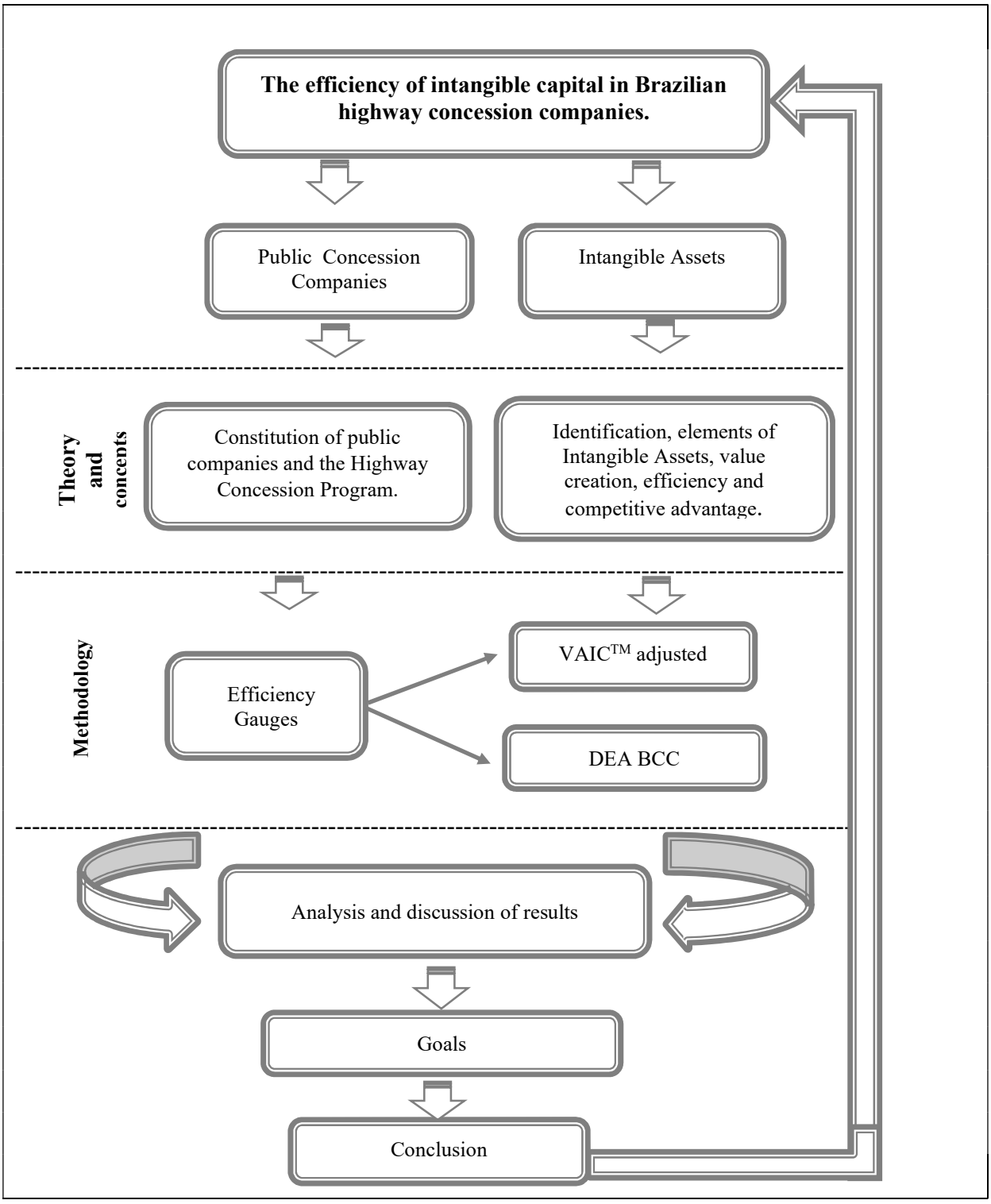

Figure 8: Theoretical model of the study
Source: The author (2023).

Once the theoretical model has been defined, the following chapter deals with the stages of the methodological construction of the work. The method and techniques of the research are presented below.

3 METHOD AND LEGAL RESEARCH TECHNIQUES

This chapter presents the research design, data collection and analysis procedures, considerations about the variables and limitations of the research methods and techniques in achieving the proposed objectives. It is subdivided into five sections; in the first, the research design, methodology and sample are presented. In the second, there are data collection procedures, with secondary and public data from the companies' financial statements, structure and composition of the adjusted VAIC^{TM} intellectual capital value aggregation model. In the third, there are the data analysis procedures with the development of the non-parametric DEA model. In the fourth, there are considerations about the variables and their use. In the fifth and final section are the limitations of the research method and techniques.

3.1 RESEARCH DESIGN

To analyze the efficiency of the intangible assets of highway concession companies, the research is characterized as of the applied type, supported by the positivist epistemological paradigm, using the deductive method, with a quantitative, descriptive and documentary approach. The sources, on the other hand, were taken from secondary data with a transversal time frame (Richardson, 2017). The research design is shown in Table 1.

Survey Type	Applied
Epistemological-Paradigm	Positivist
Method	Deductive
Objectives	Descriptive
Procedure	Documentary
Approach	Quantitative
Data Source	Secondary
Time Clipping	Transversal (Year: 2019 to 2021)
Data analysis method	Data Envelopment Analysis (DEA)

Table 1: Research design
Source: Research data (2023).

The design was formulated to reproduce the effectiveness of the productive efficiency of the intangible assets of the contracts, added to the indexes of the components of the intellectual capital value aggregation model (VAIC^{TM}), which is adjusted to the Brazilian highway concession companies; in this context, they use financial information from the balance

sheet of the concessionaires. Therefore, the non-parametric DEA technique is the main core of the evaluation of the productive and managerial efficiency of this study.

The data collection of the research used a sample of 14 (fourteen) highway concession companies, listed on Bovespa. To better visualize them, they were represented in Table 2.

No.	DMUS
1	CCR S.A.
2	Concessionária Auto Raposo Tavares S.A.
3	Conc. Ecovias Imigrantes S.A.
4	Concessionária Rio Teresópolis S.A
5	Concessionária Rodovia Ayrton Senna e Carvalho Pinto S.A.- Ecopistas
6	Concessionária Rodovia Oeste SP Via Oeste S.A
7	Concessionária Rodovias do Tietê S.A.
8	Concessionária Rota das Bandeiras S.A.
9	Concessionária do Sistema Anhanguera-Bandeirante S.A. Autoban
10	Ecorodovias Concessões e Serviços S.A.
11	Ecorodovias Infraestrutura e Logística S.A.
12	Rodovias das Colinas S.A.
13	Tpi - Triunfo Participação e Investimento. S.A
14	Triângulo do Sol Auto Estradas S.A

Table 2: Research Sample
Source: Research data (2023).

It is worth mentioning the existence of different dimensions of the DMUS represented in the sample, be it because of the volume of movements, use of technologies and economic and financial performance. In addition, the singularities presented by the DMUS in the comparison of the different levels of efficiency are accepted by the analysis method used.

3.2 DATA COLLECTION PROCEDURES

The research data will be of the secondary and public type and are available on the BM&FBovespa website. They were collected from the annual reports, evidenced in the income statements and balance sheet of the 14 companies, for the years 2019 to 2021, represented in Table 3.

DMUS	Added Value (AV)			Personnel Expenses (HC)			Capital Employed (CE)		
	2019	2020	2021	2019	2020	2021	2019	2020	2021
1	6.659.131	5.786.443	8.346.835	1.300.567	1.330.576	1.551.049	30.792.822	30.881.216	38.988.871
2	236.408	219.775	279.679	27.500	33.032	41.544	2.407.324	3.056.411	2.900.236
3	810.663	782.742	853.277	39.178	36.993	41.692	1.857.627	1.778.398	2.427.267
4	196.693	157.395	171.209	19.434	17.126	21.067	175.221	168.789	167.854
5	192.102	176.510	224.719	25.511	24.524	28.271	1.567.886	1.479.540	1.594.571
6	-215.596	679.133	824.150	45.603	44.109	44.375	581.711	273.267	223.130
7	22.906	42.050	22.238	22.486	25.379	26.115	2.993.460	2.993.460	2.993.460
8	557.045	531.587	576.555	35.928	37.863	38.573	2.993.460	3.178.116	3.512.998
9	1.635.073	1.527.618	1.696.790	76.641	69.192	71.532	2.574.162	1.692.056	999.451
10	1.761.793	2.152.627	2.589.233	302.344	297.380	349.287	9.416.310	9.555.561	14.538.557
11	1.771.190	1.789.543	2.699.560	407.989	376.745	440.488	10.829.172	10.176.976	15.521.433
12	457.447	414.755	465.508	38.947	37.312	63.324	2.431.767	2.380.700	2.171.780
13	537.017	787.060	579.583	144.915	132.325	133.200	3.423.587	3.104.256	2.965.113
14	421.048	420.883	425.366	40.118	56.566	54.224	888.304	544.928	446.468

Table 3: Financial Statement Data in R$1,000
Source: Study data (2023).

The index, which defines the three components of the intellectual capital value aggregation model (VAIC^{TM}), is represented by the equation: VAIC™ = CEE + HCE + SCE, reformulated in tables 5 and 7, with the indicators shown in Table 08. In this sense, the indices are represented by Relational Capital (CEE), which shows the Value Added (VA) / Capital Employed (CE); Human Capital (HCE), composed of Value Added (VA) / Human Capital (HC); Structural Capital (SCE), produced by Structural Capital (SC) / Value Added (VA). This is depicted graphically in Figure 9.

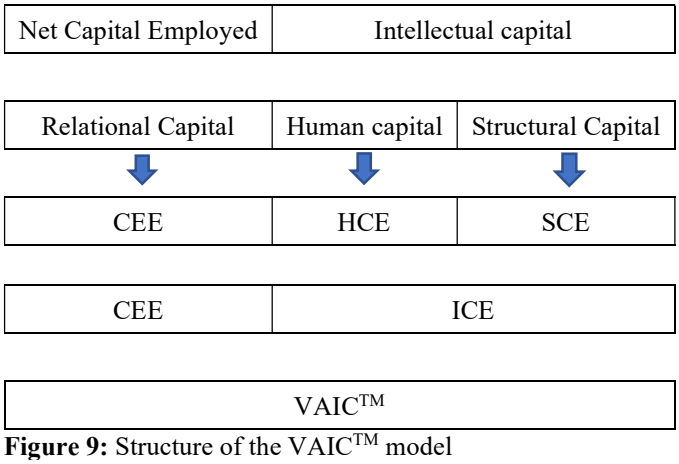

Figure 9: Structure of the VAIC^{TM} model
Source: Martins, Moraes and Isidro, 2012 (Adapted from Pulic, 2000a)

The composition of Pulic's (2000) VAIC™ Value Added (VA) indices, as an indicator of value, can be obtained from value added. It is represented by the formula in Table 4.

VA = OP + CE + D + A	
VA	Added Value
OP	Operating Profit
CE	Capital Employed = Personnel Expenses
D	Depreciation
A	Amortization

Table 4: VAIC™ Earned Value
Source: Research data.

The calculated VA for this research was reformulated according to Pulic (2000), Sullivan (2000) and Iazzolino and Migliano (2014). The indexes presented as *inputs* are shown in Table 04 and reformulated in Table 5.

VA = RADFI + CE + D + A + R & D + IT	
VA	Added Value
RADFI	Income before depreciation, financing and taxes
CE	Capital Employed = Personnel Expenses
D	Depreciation
A	Amortization
R&D	Research and Development
TI	Computer Technology: Hardware, software, network bank

Table 5: Reformulated Earned Value of the Survey
Source: Research data (2023).

The creation of added value for payment of salaries and generation of gross operating profit is essential for stakeholders. Thus, the higher the value of the VA, the greater the expectation of satisfying employees and shareholders (Iazzolino & Migliano 2014).

There are equations that make up the calculation of Pulic's efficiency evaluators (2000). This is represented in Table 6.

CEE= VA / CA	Relational Capital Coefficient (CR)
HCE = VA/HC	Human Capital Coefficient (CH)
SCE = SC/VA	Structural Capital Coefficient (CE)
VA	Added Value
CA	Capital Employed = Net Capital
HC	Salary expenses
SC	Composition of hardware, software, organizational structure, trademarks and patents.

Table 6: Pulic Efficiency Evaluators
Source: Study data (2023)

This study performed a composition of the equations for the calculation of the efficiency evaluators in the formulation of Pulic (2000), Iazzolino and Migliano (2014), of the indexes of the *inputs* shown in Table 6. This composition is depicted in Table 7.

CEE = AV/CE	Relational Capital Coefficient (RC)
HCE = VA/HC	Human Capital Coefficient (HC)
SCE = SC/AV	Structural Capital Coefficient (SC)
AV	Added Value
CE	Capital employed = Own resources, long-term debt and loans
HC	Staff Costs
SC = AV – HC	Structural Capital

Table 7: Reformulated Research Efficiency Evaluators
Source: Study data (2023)

As a basis for obtaining the indicators of *inputs* 1, 2 and 3, the productive efficiency indices of the VAIC^{TM} value components were calculated, reformulated in the compositions of tables 5 and 7. They are presented in Table 8.

		Input 1			*Input* 2			*Input* 3		
	Stages	Relational Capital (RC)			Human Capital (HC)			Structural Capital (SC)		
	DMUS	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**
1	CCR S.A.	0,216	0,187	0,214	5,120	4,349	5,381	0,805	0,770	0,814
2	Auto Raposo Tavares S.A.	0,098	0,072	0,096	8,597	6,653	6,732	0,884	0,850	0,851
3	Ecovias Imigrantes S.A.	0,436	0,440	0,352	20,692	21,159	20,466	0,901	0,891	0,877
4	Rio Teresópolis S.A	1,123	0,932	1,020	10,121	9,190	8,127	0,901	0,891	0,877
5	Ayrton Senna e Carvalho Pinto S.A	0,123	0,119	0,141	7,530	7,197	7,949	0,867	0,861	0,874
6	Rodovia Oeste SP Via oeste S.A	-0,371	2,485	3,694	-4,728	15,397	18,572	1,212	0,935	0,946
7	Rodovias do Tietê S.A	0,008	0,014	0,007	1,019	1,657	0,852	0,018	0,396	-0,174
8	Rota das Bandeiras S.A	0,186	0,167	0,164	15,504	14,040	14,947	0,936	0,929	0,933
9	Sistema Anhanguera-Bandeirante S.A	0,635	0,903	1,698	21,334	22,078	23,721	0,953	0,955	0,958
10	Ecorodovias Concessões e Serviços S.	0,187	0,225	0,178	5,827	7,239	7,413	0,828	0,862	0,865
11	Ecorodovias Infraestrutura e Logistica	0,164	0,176	0,174	4,341	4,750	6,129	0,770	0,789	0,837
12	Rodovias das Colinas S.A	0,188	0,174	0,214	11,745	11,116	7,351	0,915	0,910	0,864
13	Triunfo Part. e Investimento. S.A	0,157	0,254	0,195	3,706	5,948	4,351	0,730	0,832	0,770
14	Triângulo do Sol Auto Estradas S.A	0,474	0,772	0,953	10,495	7,441	7,845	0,905	0,866	0,873

Table 8: Sample of the indicators of the value components of the reformulated VAIC
Source: the author (2023).

Considering the components of the reformulated VAIC in Table 8, the indicators of the three exercises for each DMU were added. Thus, they are presented in Table 9.

	DMUS	Reformulated VAIC™		
		2019	**2020**	**2021**
1	CCR S.A.	6,141	5,306	6,410
2	Auto Raposo Tavares S.A.	9,579	7,575	7,680
3	Ecovias Imigrantes S.A.	22,08	22,552	21,769
4	Rio Teresópolis S.A	12,145	11,014	10,024
5	Ayrton Senna e Carvalho Pinto S.A	8,520	8,178	8,964
6	Rodovia Oeste SP Via oeste S.A	-3,887	18,817	23,212
7	Rodovias do Tietê S.A	1,045	2,067	0,685
8	Rota das Bandeiras S.A	16,626	15,136	16,044
9	Sistema Anhanguera-Bandeirante S.A.	22,922	23,935	26,376
10	Ecorodovias Concessões e Serviços S.A	6,843	8,326	8,456
11	Ecorodovias Infraestrutura e Logística S.A	5,274	5,715	7,139
12	Rodovias das Colinas S.A	12,848	12,214	8,389
13	Triunfo Part. e Investimento. S.A	4,593	7,033	5,317
14	Triângulo do Sol Auto Estradas S.A	11,874	9,079	9,670

Table 9: Reformulated VAIC Sample Totals
Source: the author (2023)

In the aggregation of the indicators in Table 9, the total sample value of the indicators of the reformulated VAIC^{TM} components for the DMUS is presented, which will be evaluated in the DEA model. In the evaluation of the adjusted VAIC^{TM} Intellectual Capital, company 9 presented itself with the highest intellectual capital in value creation in the three years analyzed, achieving continuous efficiency for the three periods; this sample showed that 50% of DMUS obtained a substantial increase in their intellectual capital in 2020.

As an indicator of *input* 4 for the DEA, the calculation of the intangible assets of the concession contracts, recognized and measured by legislation and technical pronouncement (Mantovani & Santos, 2014), will be used in the financial statements of the companies, resulting from the improvement constructions and the concessionaire's right to grant, identified as intangible capital (IC). Likewise, the *output* indicator will represent the Operating Net Income (LLO), associated with the definition of value (Barney, 2002), in order to maintain or maximize profit to meet the objectives of shareholders and stakeholders (Jansen, 2001). This is presented in Table 10.

Stages	*Input* 4			*Output*		
	Intangible Capital (CI) (in R$1,000)			Operating Net Income (LLO) (in R$1,000)		
DMUS	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**
1	17,507,639	16,306,042	21,347,825	1,295,582	86,113	805,596
2	2,325,897	2,303,470	2,326,851	8,374	203,093	-68,397
3	1,304,236	1,300,700	1,894,897	371,832	375,482	369,720
4	93,918	56,041	46,508	48,408	24,739	61,977
5	1,430,076	1,438,030	1,468,627	31,556	38.320	55,172
6	596,240	435,613	440,801	-601,268	272,005	47,499
7	1,301,569	1,312,546	1,349,746	-150,106	-158,252	-255,474
8	3,043,673	3,135,361	3,297,360	30,505	25,746	-48,060
9	1,785,774	1,582,308	1,607,455	765,599	729,848	709,340
10	7,482,768	8,148,103	11,444,080	109,113	415,589	421,702
11	7,893,920	8,155,441	11,447,683	-185,460	-423,988	367,262
12	1,216,880	1,245,131	1,254,398	187,442	190,056	185,974
13	5,694,133	5,738,872	5,694,133	-216,435	168,574	4.984
14	975,846	982,542	985,591	199,211	196,678	214,501

Table 10: Calculation of Intangible Assets of concession contracts and Net Operating Profit
Source: Research data (2023).

In the DEA model, variables of four *input* factors or *inputs* and one *output* factor or product (*outputs*) were used. For the *inputs*, the indexes of the VAIC^{TM} components adjusted from Table 8 were used, such as Proxys for the value of the intellectual work of the intangible asset. The fourth *input* used intangible capital representing the Proxy for the intangible asset concession contracts. For the product, the result of the net operating profit for the year (profit/loss) was used, as productive economic efficiency.

For the application of the data envelopment analysis, the sample of 4 *inputs* and 1 *output* (product) is considered compatible with the total number of variables used in the DEA model, which should not exceed one third of the number of DMUS (Sinuany-Stern & Barboy, 1994) and be worked under the same conditions (Mariano, 2012). The next section presents the data analysis procedures.

3.3 DATA ANALYSIS PROCEDURES

In the study, the non-parametric model DEA CCR and BCC was applied in the form of *input*-oriented Multipliers (Charles et al., 1978 and Banker *et al.,* 1984), using Excel Max DEA software. Thus, the technical efficiency levels of the intangible assets of the highway concession agreement, added to the value-added components of the adjusted VAIC^{TM} intellectual capital, belonging to the period 2019 to 2021, were evaluated.

The empirical work was developed in 8 phases. They were described in Figure 10.

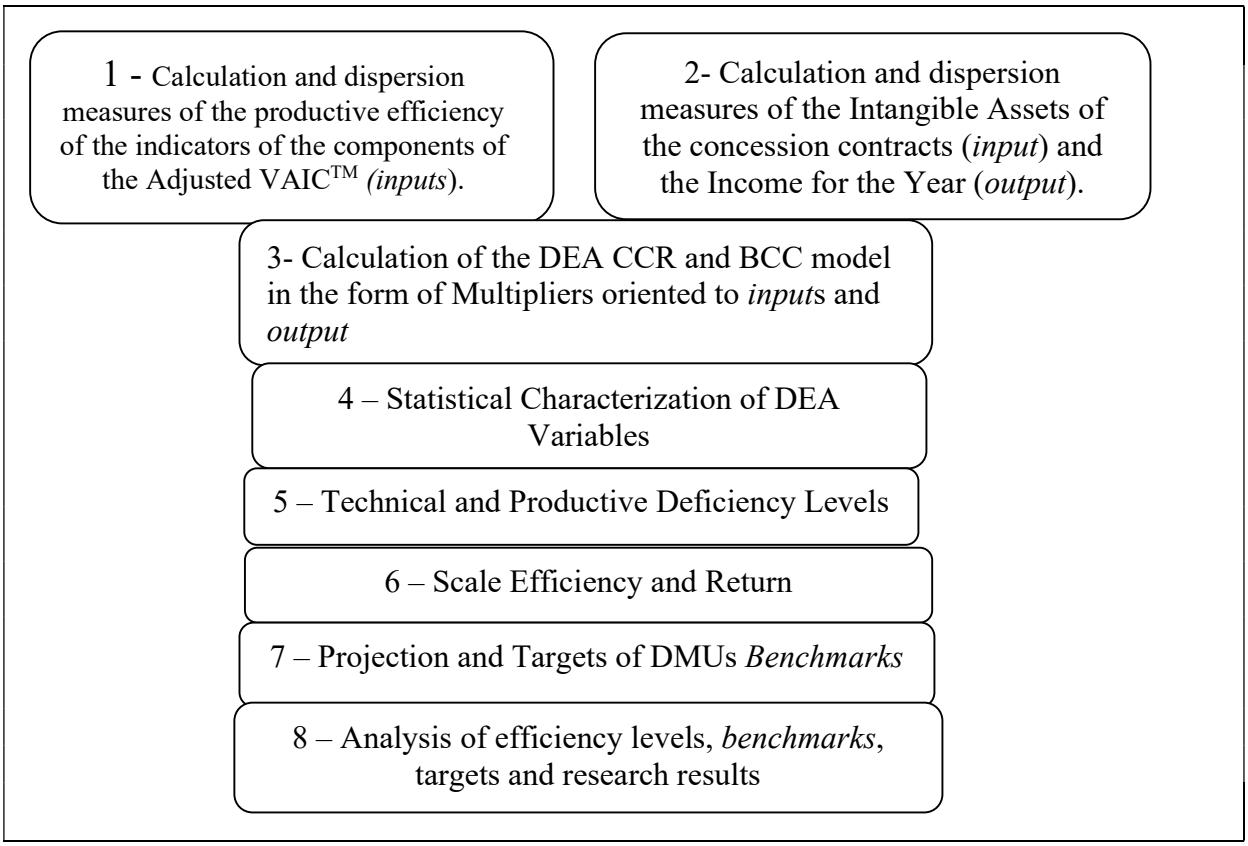

Figure 10: Phases of the empirical model
Source: the author.

The DEA CCR or CRS model of Charnes *et al.* (1978), in the form of *input*-oriented multipliers, as a linear programming problem, is formulated with the functions and objectives, which should be optimized, (1) and the constraints of the problem (2) and (3). This is represented below by primal *input*-oriented modeling (Almeida *et al*., 2006).

$$MAX = \sum_{i=1}^{m} u_i \cdot y_{i0} \qquad (1)$$

Subject to:

$$\sum_{j=1}^{n} v_j \cdot x_{j0} = 1 \qquad (2)$$

$$\sum_{i=1}^{m} u_i.yik - \sum_{j=1}^{n} v_j \cdot x_{jk} \leq 0, with\ k = 1,2 \ldots . z \qquad (3)$$

Where:

u_i = calculated weight for product i
v_j = calculated weight for *input* j
x_{jk} = quantity of *input* j for unit k
y_{ik} = quantity of product i for unit k
x_{j0} = quantity of *input* j for the unit under analysis
y_{i0} = quantity of the *input* i for the unit under analysis
z = number of units under evaluation
m = number of product types
n = number of *input* types
u_i e $v_j \geq 0$

The BCC or RSV model of Banks *et al*. (1984), in the form of multipliers, oriented to *inputs,* allows to identify whether the scale return is constant (does not influence the production scale), increasing (with increase in scale, ensures an increase in productivity) or decreasing (with increase in scale, causes a decrease in productivity) and the efficiency of the scale incorporated by Charnes *et al*. (1994). This is represented with the objective function of the BCC model to be optimized in (4); the constraints regarding this function are evidenced in (5) and (6). Thus, they graphically describe the primal BCC model oriented to *inputs.*

$$MAX\ PO\ = \sum_{i=1}^{m} ui \cdot yio + u \qquad (4)$$

Subject to:

$$\sum_{j=1}^{n} v_j \cdot x_{j0} = 1 \qquad (5)$$

$$\sum_{i=1}^{m} u_i \cdot y_{jK+u} - \sum_{j=1}^{n} v_j \cdot x_{Jk} \leq 0, \qquad with\ k = 1,2 \ldots . z \qquad (6)$$

Where:

$u_i = calculated\ weight\ for\ product\ i$
$v_j = calculated\ weight\ for\ input\ j$
$x_{jk} = quantity\ of\ input\ j\ for\ unit\ k$
$y_{ik} = quantity\ of\ product\ i\ for\ unit\ k$
$x_{j0} = quantity\ of\ input\ j\ for\ the\ unit\ under\ analysis$
$y_{i0} = quantity\ of\ the\ product\ i\ for\ the\ unit\ under\ analysis$
$z = number\ of\ units\ under\ evaluation$
$m = number\ of\ product\ types$
$n = number\ of\ input\ types$
$u = scale\ return\ coefficient$
$u_i\ e\ v_j \geq 0$
$u\ no\ signal\ restriction$

The proposed model presents the level of technical efficiency of highway concession contracts, the scale returns (*inputs*) as a contribution to the efficiency level of DMUS (weight), in which the DMUs are compared with their *benchmarks* and projected targets for non-efficient DMUs, in order to maximize their efficiency. In this way, the scale efficiency can be calculated by means of expression 1.

Scale Efficiency = Total Efficiency / Technical Efficiency (1)

In which:
Total efficiency = Efficiency calculated by CCR model
Technical efficiency = Efficiency calculated by the BCC model

The data were applied to the DEA CCR models and the DEA BCC models, oriented to *input* and *output*, for the 14 DMUS, involving the period from 2019 to 2021. In the evaluation of DMUS, 4 *inputs* and 1 *output* were used. The indexes for three *inputs* will be used from the value components of the reformulated VAIC™ Intellectual Capital (Relational Capital, Human Capital and Structural Capital) and 1 *input* of the calculation of Intangible Assets of Non-Current Assets of the Balance Sheet of highway concessionaires. For the *output,* the amount of the result of the Net Operating Profit of the DRE of the concessionaires for the three different periods will be used.

The reformulation of the added value of VAIC™ was composed according to Pulic (2000), Sullivan (2000) and Iazzolino and Migliano (2014). The model used in the work can be seen in Figure 11.

Input-oriented BCC model				
Name	*Inputs*	Input Formula	The input comprises	*Output*
	Relational Capital (RC)	**CEE = VA/CE** VA = RADFI + CE + D + A + R & D + IT **Value Added** (+) Net Sales (-) Operating Expenses (=) Operating Profit (Before financial expenses and taxes (RADFI/EBIT) CE = Net Capital Employed D = Depreciation A = Amortization	The Technical Efficiency of the amount of invested capital related to the capital employed, considering the value added to the remuneration of operating profit in relation to the capital employed as an expectation for management strategies.	

Reformulated VAIC™ Model	Human Capital (HC)	R&D = Research and Development IT = Hardware, software, network bank		Net Profit Operational (LLO)
		HCE = VA/HC VA = Value Added HC = Expenses with personnel	The Technical Efficiency of the amount of capital invested in the employees of the concessionaires considering the remuneration of operating profit in relation to salary expenses as an expectation to meet the satisfaction needs of employees (HC).	
	Structural Capital (SC)	**SCE = SC/VA** SC = VA – HC	The Technical Efficiency of the capital invested with the reduction of personnel expenses, considering the remuneration of the remainder of the amount invested as an expectation for the needs of the shareholders (SC), in the creation of value for the company (affecting or not the company value)	
Balance Sheet	Intangible Capital (IC)	**Non-current Assets**	The Technical Efficiency of the amount of Intangible Assets in companies with a highway concession contract, as an expectation for the needs of the State regarding the administration of its infrastructure by these companies, as well as the competitiveness of their performance in the bidding process.	

Figure 11: BCC DEA Model - Variables used in the research .
Source: the author (2023).

The results generated in the DEA model were obtained from the Microsoft Excel Software, through the linear solver programming model. The model is a tool that runs hypothesis tests to find the optimal value of a target cell by changing the values in the cells used to calculate the target cell.

The formulations in the solver tool were automated by the author, according to functions, variables and restrictions of the CCR model and BCC model, in the form of multipliers and envelopes oriented to *inputs* and *output*. Thus, the purpose of the study was to analyze the technical efficiency of the sum of the Intangible Assets of the highway concession contracts, added to the productive efficiency index of the components of the reformulated VAIC^{TM} value aggregation model in highway concession companies from the perspective of *inputs.*

From this context, the study aims to verify the existence of levels of technical efficiency in the object of study, if there is a significant change in statistics among the 4 DEA models used; in addition, it aims to understand the levels of technical efficiency of the intangible capital of the concession contracts added to the components of the reformulated VAIC^{TM} value aggregation model *(inputs*). Moreover, it aims to verify that these assets are being well managed to effectively enjoy the result of the concessionaires' net operating profit (*output*).

3.4 VARIABLE CONSIDERATIONS

In the DEA model, it is not recommended to use as *input* or *output* a variable that is of the "ratio" type; this impossibility is due to the fact that variables arising from the division of two other variables may hinder the convexity assumption of the border existing in the DEA (Emrouznejad & Amin, 2009). The author proposes that, in the use of variables of this type, they be dismembered, one for *input* and the other for *output.*

It is also noteworthy that the use of "ratio" variables in models with Variable Scale Returns is recommended, especially in these cases, when working with this type of variable (Hollingsworth & Smith, 2003).

This research adopted the Scale Variable Returns model and used "ratio" variables in the *inputs*, as they are indexes that represent the intellectual value coefficient, which defines the ability to generate intangible value through added value. Dismembering them would damage the efficiency analysis and greatly increase the amount of *inputs* and *outputs*, thus reducing the DEA's discrimination feature.

It is also worth mentioning that the "ratio" variables, used as *inputs,* will be added to the *input* of the calculation of the Intangible Assets of the contracts of the highway concession companies in the conduct of the technical efficiency analysis of this set of *inputs*. However, the

output variable is the representation of the Operating Net Income (LLO), resulting from the Statement of Income for the Year (DRE) of these companies.

The LLO variable has the purpose of reporting the equity situation and financial result of a company, taking into account all its obligations, assisting stakeholders in decision making, as well as the result of a given management. Therefore, the choice of this variable is justified because it is considered the return on invested capital for a certain period of great interest to partners and shareholders to meet their peculiar needs.

The variables can present themselves as positive or negative, since they represent the return of an investment deducted from the expenses that were required by such investment. However, the return-oriented DEA model cannot handle negative or zero returns unless the data is transformed (Vogt *et al*. 2018).

Negative variables were transformed by the Log function into logarithms in base 10. For this, it was necessary to add a constant (e.g. 1) before the transformation into log, using the expression x+1 (2012). This method has become very practical, because it simplifies the necessary calculations (Vogt *et al*. 2018; Liu *et al.,* 2015)

3.5 LIMITATIONS OF RESEARCH METHODS AND TECHNIQUES

In the DEA analysis technique, some limitations are reflected; the analysis is sensitive to noise, such as measurement errors in outliers*,* in which as the number of variables increases, the possible number of efficient units increases; when the problems are large, they require high computational capacity; as for relative performance, it is well estimated by the DEA, since the absolute does not present the same result because it is based on observed data and not on the desirable or the optimal (Boussofiane, Dyson & Thanassoulis,1991 and Craycraft,1999).

In complications, when DMUs develop different activities and insensitivity to intangible components and categorical variables, DEA adds several aspects of efficiency (Boussofiane *et al.,* 1991). In non-efficient DMUS, DEA can be considered a tool to assist the planning and management of resource reallocation in obtaining products with better quality (Souza *et al*., 2019).

For Metters, Frei and Vargas (1999), the DEA technique is the beginning of an analysis and not its end; when used properly, this technique can make relevant contributions to the field of quantitative methods and performance evaluation (Souza *et al.,* 2019). The next chapter presents the analysis and discussion of the results of this study.

4 ANALYSIS AND DISCUSSION OF RESULTS

This section presents the analysis and discussion of the results achieved in the application of the DEA models of highway concession companies, related to the study of the technical efficiency of the intangible assets of concession contracts added to the productive efficiency of the components of the Intellectual Capital value aggregation model (reformulated VAIC^{TM}).

The companies participating in the research have the nature of a public limited company and are owned by national capital. They are part of the highway transport activity sector in the country, considered large public companies, with more than 100 employees; on average, they have an annual revenue of 2.8 million reais.

The chapter is divided into 5 sections: the first section presents the formation, validation and correlation of the variables that will be applied in the model; the second analyzes the levels of technical and productive efficiency and the results obtained; the third observes and discusses technical efficiency and scale return; the fourth section presents the projection of goals of the DMUS *benchmarks*; the fifth and last section discusses the result of this study.

4.1 STATISTICAL VALIDATION OF BCC MODEL VARIABLES

In order to evaluate the result of the technical efficiency indicator of the Intangible Assets of the concession contracts, added to the components of the Intellectual Capital value added model (VAIC^{TM}), the VA= Value Added and the three indicators of the VAIC^{TM} value components, Relational Capital (CR), Human Capital (CH) and Structural Capital (CE), worked from the perspective of Value Added (VA), were reformulated.

The sample obtained an average of 5,563 million reais of Capital Employed (CA) for the 14 DMUs for the periods 2019 to 2021 and the average Operating Net Income (LLO) was 620,248 thousand reais, obtaining an operating financial return of 1.12 percent in the period. It appears that, in the operational economic-financial relationship, the return for these DMUS was not adequate for the period, that is, the financial return of the LLO for the period did not meet the needs of the interested parties.

To validate the variables that will be analyzed in the AED BCC, the statistical calculation of the annual variability was used in order to verify the existence of dispersion and the conditions of distribution of the sample through the boxplot. In this sense, the variable

Relational Capital (RC), calculated in the sample for the 14 DMUS of the indicators in Table 8, is detailed in Table 11.

MEASUREMENT	Relational Capital (CR)		
	2019	2020	2021
Average	0.259	0.494	0.650
Median	0.187	0.206	0.205
3rd Quartile	0,446	0.932	0.970
1st Quartile	0.116	0.155	0.158
Minimum	-371	0.014	0.007
Maximum	0,635	0.932	1.698

Table 11: Productive Efficiency of the CR Variable (CEE)
Source: the author (2023).

The general average of the productive measures of the CR variable, for the three periods analyzed, was 0.468; the median was 0.199; the minimum was - 0.117, and the maximum was 1.088 of the capital invested by the company to the capital employed. This is depicted in Chart 4.

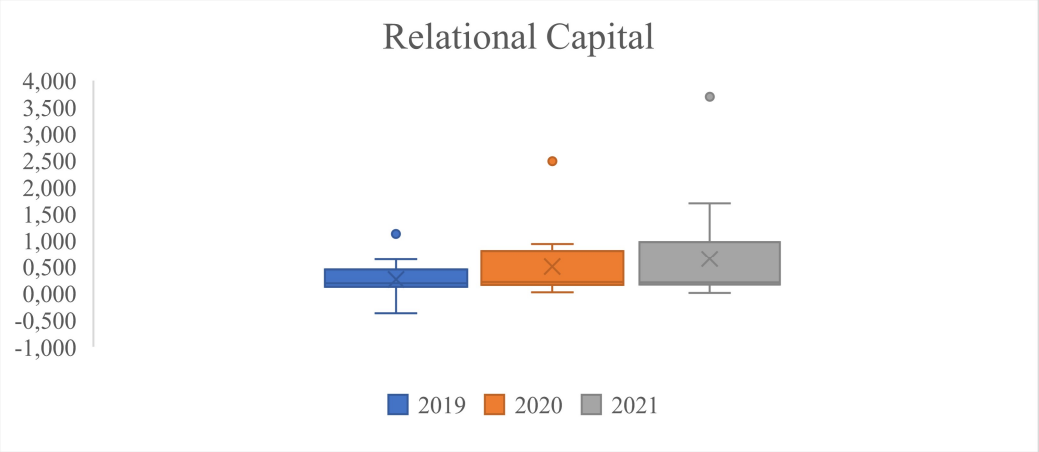

Chart 4: Dispersion and Distribution of Relational Capital
Source: Study data (2023)

The productive efficiency of the CR variable showed the greatest variability in 2021. That is, the volume of Value Added (VA) and Capital Employed (CA) varied more in 2021 than in 2019 and 2020, bringing unpredictability in this period for this variable. The variable presented a growing situation of outliers for the three periods, which demands to be investigated.

The measures of productive efficiency of the Human Capital (CH) variable, referring to the capital invested in the employees of the concessionaires, considering the remuneration of operating profit in relation to salary expenses, are presented in Table 12.

MEASUREMENT	Human Capital (HC)		
	2019	2020	2021
Average	8,665	9.872	9,988
Median	8,063	7 340	7.629
3rd Quartile	12.685	14.379	15.853
1st Quartile	4,182	5.648	5,942
Minimum	-4.728	1.657	0.852
Maximum	21.334	22.078	23.721

Table 12: Productive Efficiency of the HC Variable (HCE)
Source: the author (2023)

For the CH variable, the overall average of the productive measures for the three periods analyzed was 9.508; the median was 7.70; the minimum was – 0.740 and the maximum was 22.378 of the capital invested by the company in the employees. This is depicted in Chart 5.

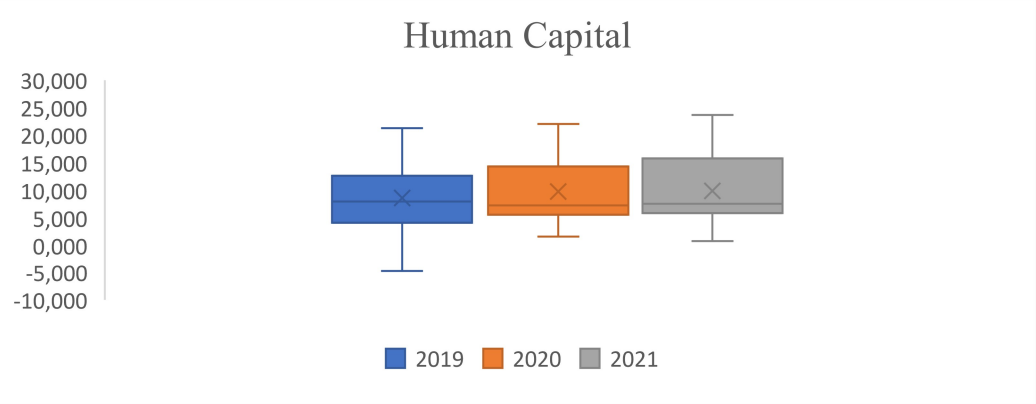

Chart 5: Dispersion and Distribution of Human Capital
Source: Study data (2023)

It can be seen that the variable HC presented, in Chart 4, a variation in the productive efficiency in the capital invested in the employees of the concessionaires, in 2019, with an increase in 2020. The greatest variability was in 2021, demonstrating a period of unpredictability for future investigation.

The productive efficiency of the invested capital with deduction of personnel expenses, considering the remuneration of the remainder of the applied value of the Structural Capital (SC) variable, as an expectation for the needs of shareholders (SC), is presented in Table 13.

MEASUREMENT	Structural Capital (SC)		
	2019	2020	2021
Average	0.834	0.843	0.803
Median	0.892	0.864	0.869
3rd Quartile	0.940	0.930	0.936
1st Quartile	0.796	0,821	0.831
Minimum	0.730	0.770	0.803

Maximum	0.953	0.955	0.958

Table 13: Productive Efficiency of the EC Variable (SCE)
Source: the author (2023)

The SC variable presented, on average, productive measures, for the three periods of 0.826, the median 0.875, the minimum of 0.768 and the maximum of 0.955, of the capital invested by the companies, disregarding the remuneration of the employees. This is depicted in Chart 6.

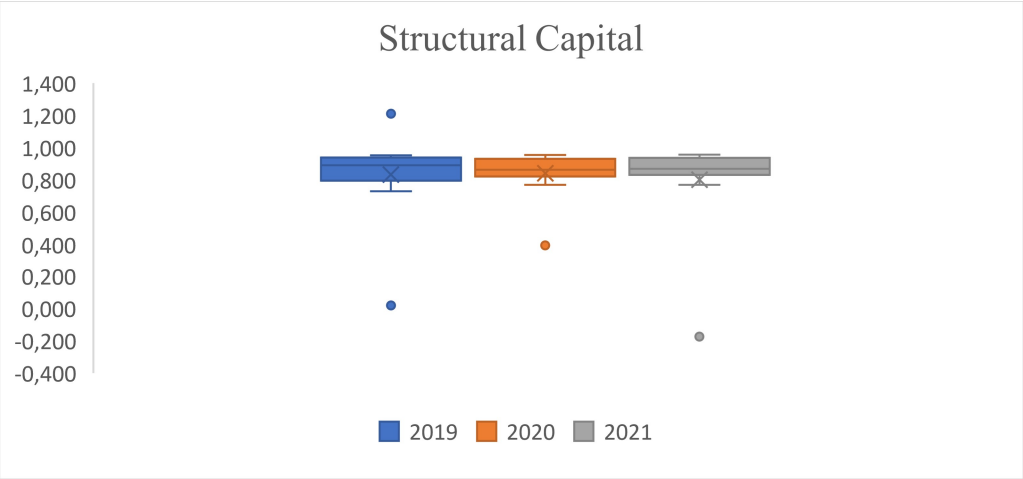

Chart 6: Dispersion and Distribution of Structural Capital
Source: Study data (2023)

The variation in the productive efficiency of the SC variable (shareholders) occurred in 2019, reducing considerably in 2020 and 2021. Superior and inferior atypical data were observed in the sample; the outliers for the three periods of this variable stand out for the research.

The variable Intangible Capital (IC), arising from the intangible assets of the State's infrastructure concession contract, presents the following measures in R$ for the period from 2019 to 2021. This is evidenced in Table 14.

	Intangible Capital (IC)		
MEASUREMENT	2019	2020	2021
Average	3,760,898	3,724,300	4,614,711
Median	1,607,925	1,510,169	1,751,176
3rd Quartile	6,141,292	6,341,180	7,131,620
1st Quartile	1,156,622	1,179,484	1,187,196
Minimum	93,918	56,041	46,508
Maximum	7,893,920	8,155,441	11,447,683

Table 14: Intangible Capital Dispersion (IC) Measures in R$
Source: the author (2023)

The overall average of the dispersion of Intangible Capital of the concession contracts, for the three periods, was R$4,033,303; the median was R$1,623,090; the minimum presented a value of R$65,489 and the maximum of R$9,165,681. This can be seen in Chart 7.

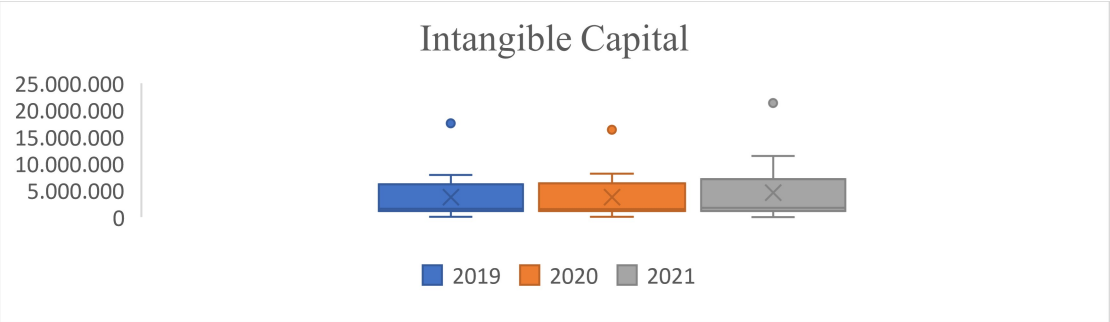

Chart 7: Dispersion and Distribution of Intangible Capital (CI)
Source: Research data (2023)

The lowest variability, for the variable Intangible Capital (IC) of the contracts, was in 2019, obtaining a successive increase in 2020 and 2021. This variable presented higher outliers for the three periods, intensifying in 2021, which is a reason to be investigated.

The variable Operating Net Income (LLO), representing the productivity effectiveness of operations carried out efficiently by the variables RC, HC, SC and IC, corresponds to the needs of stakeholders. This is presented in Table 15.

	Operating Net Income (LLO)		
MEASUREMENT	2019	2020	2021
Average	135,311	153,143	205,128
Median	338,982	179,315	123,976
3rd Quartile	242,366	297,874	382,716
2nd Quartile	158,945	25,494	-8,277
Minimum	-601,268	-158,252	-255,474
Maximum	765,599	415,589	805,596

Table 15: Measures of Dispersion of Operating Net Income in R$
Source: the author (2023)

The dispersion of the overall average of the LLO, for the three periods, was R$164,527; the average is R$214,091; the minimum presented a negative value of R$338,331 and the maximum value of R$662,261. This is visualized in Chart 8.

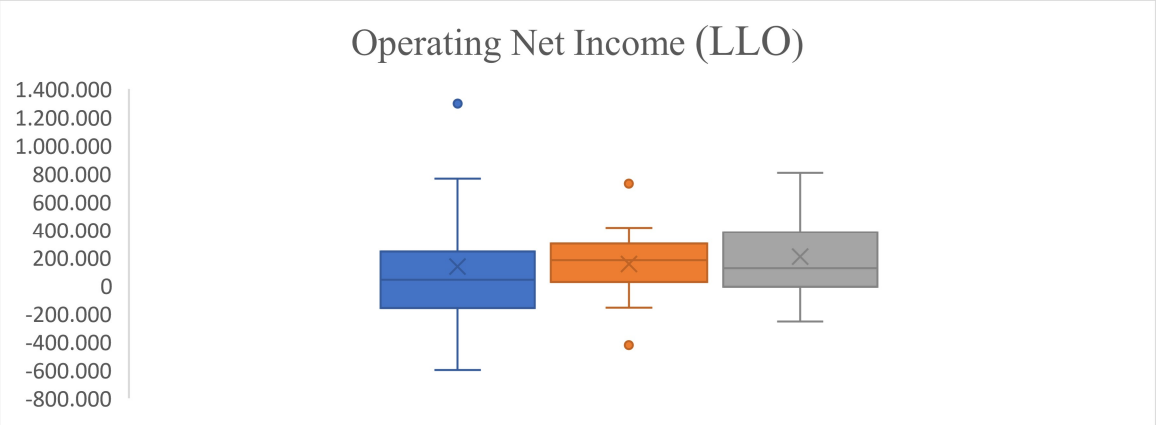

Chart 8: Dispersion and Distribution of Operating Net Income (LLO)
Source: Research data (2023)

Graph 8 shows that the greatest variability in the LLO dispersion was recorded in 2019. In 2020, the reduction of this variability became evident in the Diagram presented. For the 2021 period, the dispersion obtained a considerable reduction compared to 2020. This variable presented superior outliers in 2019 and superior and inferior outliers for the year 2020, demonstrating the need for an analysis.

The variables, which make up the adjusted VAIC, presented, in 2019, the lowest variability for the HC (employees) and the RC (managerial), intensifying in the periods of 2020 and 2021. Thus, the RC variable (managerial) presented, for the three periods, the presence of outliers. The SC (shareholders), on the other hand, obtained the greatest variability in 2019, presenting itself with several outliers, which radically distanced themselves from the other components of the sample within the three exercises.

It was verified, in the period from 2019 to 2021, that there was no quality in the distribution of the sample components for all the component variables of the DEA, but the presence of outliers, verified in the boxplot graphs 3, 5, 6 and 7.

In view of this, a weak negative correlation was found between the variables of the adjusted VAIC^{TM} and Intangible Capital for the periods analyzed. In this way, as relational, human and structural Capital increases, Intangible Capital decreases, seen in Table 16.

		Relational Capital (RC)	Human Capital (HC)	Structural Capital (SC)	Intangible Capital (IC)
		Input 1	*Input 2*	*Input 3*	*Input 4*
2019	*Input 1*	1			
	Input 2	0,485	1		
	Input 3	0,294	0,373	1	
	Input 4	-0,259	-0,297	-0,093	1
2020	*Input 1*	1			
	Input 2	0,458	1		
	Input 3	0,373	0,686	1	
	Input 4	-0,342	-0,413	-0,162	1
2021	*Input 1*	1			
	Input 2	0,588	1		
	Input 3	0,307	0,585	1	
	Input 4	-0,317	-0,321	0,025	1

Table 16: Correlation measures between variables.
Source: the author (2023)

Overall, this analysis presented data that indicate that the companies surveyed were not administratively organized to obtain an efficient result in their investments, considering a period characterized as the Global COVID-19 Pandemic. At this time, of a global pandemic, decreed on 03/11/2020, by the World Health Organization (WHO), companies were forced to make an unexpected adjustment in their management, in order to meet immediate needs, generating losses to stakeholders.

Therefore, the validated variables, based on the statistical measures, showed that measuring the technical efficiency of the intangible assets of the concession contracts, added to the components of the reformulated Intellectual Capital value aggregation model, tends to be a complex task, verified in the outliers presented in the samples. Thus, the indexes of the variables of the components of the intellectual capital value aggregation model (adjusted VAIC^{TM}), to measure and technical efficiency, in order to achieve effectiveness in Net Operating Income for the Year, depend on the adequate allocation of intangible assets to Value Added (VA), as it is an important condition for the result of the value components of the VAIC^{TM} model.

Therefore, measuring the technical efficiency of these variables in the DEA may or may not confirm the productive efficiency achieved by the DMU in the VAIC; thus, it is possible to generate productive goals to obtain efficiency in the result of the Net Operating Profit considering costs and expenses.

4.2 TECHNICAL AND PRODUCTIVE EFFICIENCY LEVELS

The joint evaluation of the analyzed variables of the 14 highway concession companies (DMUS), listed on the BM&Fbovespa, through the *inputs* and *outputs* in the DEA CCR and BCC models, in the form of the *input*-oriented Multipliers, presents, as a result, the standard value of the model at 100% efficiency. Thus, the model showed, for 21.4% of the companies analyzed, in 2019, Productive Efficiency in the CCR model and 50% with Technical Efficiency in the BCC model.

In 2020, the Productive Efficiency in the CCR model of the analyzed variables was presented for 28.5% of the companies, while, for the Technical Efficiency in the BCC model, it was 64% of the DMUs analyzed. Finally, in 2021, the standard value in the CCR model of productive efficiency of these variables was around 35.7% and Technical Efficiency in the BCC model of 57% of companies.

It is also noted that the average of the standard value of the Efficiencies of the variables for the three years of the companies was 28.5%, for the CCR model, and 57% in the BCC model. This represents a 50% difference for most companies that can achieve Technical Efficiency, when analyzed from the perspective of the BCC model.

From this context, the DMUS, presented with standard technical and productive efficiency, considered efficient in investments in intangible assets acquired externally and produced internally in the *input*-oriented DEA model, are represented through figures. Thus, the levels of technical and productive efficiency of highway concession companies in these investments, applied in the DEA model, for the period from 2019 to 2021, can be seen in Table 17; these levels represent the data highlighted in Tables 8 and 10.

Input Oriented Efficiency Levels

	DMUS	2019		2020		2021	
		Productive CCR	Technical BCC	Productive CCR	Technical BCC	Productive CCR	Technical BCC
1	CCR S.A.	1	1	0.345	0,926	1	1
2	Auto Raposo Tavares S.A	0.034	0.679	1	1	0.012	0.555
3	Ecovias Imigrantes S.A	0.701	0.997	0.960	1	1	1
4	Rio Teresópolis S.A.	1	1	0.707	1	1	1
5	Ayrton Senna and Carv. P.S.A	0.147	0,872	0.215	0.924	0,327	1
6	Rod. Oeste SP S.A	0.045	1	1	1	0.208	0.758
7	Rodovias do Tietê S.A.	0,074	1	0,055	1	0,086	1
8	Rota das Bandeiras S.A	0,081	0.502	0.089	0.618	0.007	0.387
9	Anhanguera Bandeirantes S.A	1	1	1	1	1	1

10	Ecorod. Concessões e Serv.S.A	0.167	0.484	1	1	0.863	0.985
11	Infraestrutura e Logística S.A	0.004	0.227	0.010	0.502	0.761	0.927
12	Rodovia das Colinas S.A	0.697	1	0.934	1	1	1
13	Triunf. Part.e Investimento S.A	0.005	0.265	0.528	0.841	0.018	0.721
14	Triangulo do Sol S.A.	0,520	1	0.767	1	0.863	1

Table 17: Efficiency level, oriented to *inputs*
Source: the author (2023)

The 2020 fiscal year, represented in Table 17, presented a higher number of DMUS, with maximum technical efficiency (1.0) in the *input*-oriented BCC model, of the 14 DMUS analyzed, DMUS 2, 3, 4, 6, 7, 9, 10, 12 and 14 reached almost 64% of the total in this period. In the following years, there was a reduction in the number of DMUS that reached technical efficiency, and in 2021, the maximum efficiency was 8 DMUS, number 1, 3, 4, 5, 7, 9, 12 and 14, reaching just over 57%. Thus, in 2019, it was possible to verify only 50% of DMUS with maximum efficiency in these investments, those numbered 1, 4, 6, 7, 9, 12 and 14.

Given this context, it was found that DMUS 4, 7, 9, 12 and 14 stood out in the *input*-oriented model, since they obtained maximum technical efficiency in the three exercises analyzed. Thus, DMU 1 had maximum efficiency in 2019 and 2021; DMU 3 had maximum efficiency in 2020 and 2021; in turn, DMU 6 reached maximum efficiency in 2019 and 2020.

Constant efficiency levels for the two guidelines were verified only for *Concessionária do Sistema Anhanguera-Bandeirante S.A.* (DMU 9) CCR = BCC. This DMU showed constant scale return efficiency in total efficiency and technical efficiency, oriented to *input* as to *output* for intangible assets, produced internally and acquired externally.

For other DMUS, such as number 5, it is observed that it reached maximum efficiency in 2021, as well as DMUS 2 and 10, which showed this efficiency only in 2020, a period considered critical for COVID-19. Thus, only DMUS 8, 11 and 13 did not obtain technical efficiency in the DEA model, in any of the three periods, seen in Chart 9.

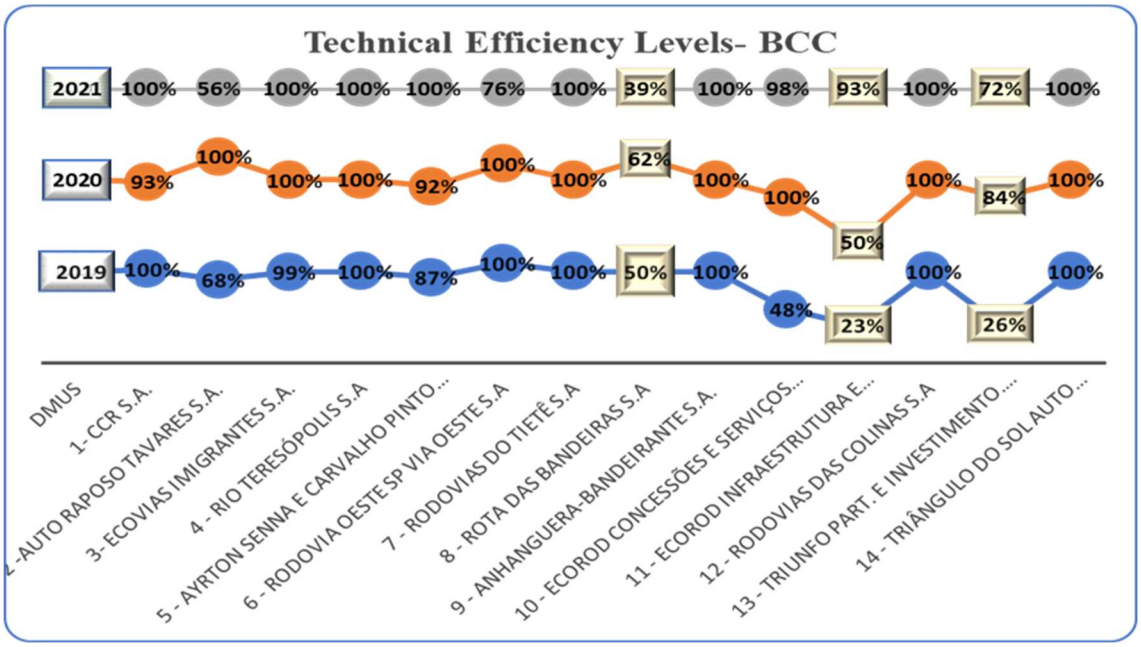

Chart 9: Efficiency level, oriented to inputs - BCC Model
Source: Study data (2023)

It is shown in Graph 9 that the concessionaires *Rota das Bandeirantes S/A*, *Infraestrutura e Logística S/A* and *Triunfo Participações e Investimentos S/A* were DMUS that did not reach 100% technical efficiency levels, in their intangible assets, for the three periods analyzed in the BCC model, oriented to the *input.* Thus, for the other DMUS, all achieved total efficiency in this model for at least one period studied, with emphasis on the concessionaires *Rio Teresópolis S/A*, *Rodovias do Tietê S/A*, *Sistema Anhanguera-Bandeirante S/A*, *Rodovias das Colinas* and *Triângulo do Sol Auto Estradas S/A*, which achieved 100% technical efficiency for the three exercises in the model studied.

From this context, the technical efficiency in the BCC model, called pure efficiency, isolates the influence of production scale on efficiency. Thus, in the production scale, the production efficiency of the CCR model is influenced by the technical efficiency of the BCC; that is, by the ability of the DMU to transform *inputs* and *outputs* and in the production efficiency by the quantity produced.

4.3 TECHNICAL EFFICIENCY AND SCALE RETURN

The BCC model predicts that the *outputs* do not vary proportionally to the *inputs* and compares each of the DMUS with the DMUS that are operating similar to their scale, however, the technical efficiency varies with the size of the production scale.

The scale concerns the simultaneous changes of *inputs* and *outputs* without changing their dimensions (minimum number of variables). Thus, the optimal production scale (constant) is the one that guarantees the maximum use of *inputs*, but, due to market problems, a DMU will not always be able to operate on an optimal scale. Therefore, the closer to the optimal scale a DMU is, the greater the scale efficiency.

Increasing scale returns indicate an increase in the volume of a production *input*, so that it will determine a greater proportional increase in the quantity of the final product. Thus, when the final product increases by less than the proportional change in all *inputs*, there will be decreasing returns to scale. This is depicted in Tables 18 and 19.

	DMUS	2019		2020		2021	
		Technical Efficiency	Scale Return	Technical Efficiency	Scale Return	Technical Efficiency	Scale Return
1	CCR S.A.	1	Constant	0,37	Crescent	1	Constant
2	Auto Raposo Tavares S.A.	0,05	Crescent	1	Constant	0,02	Crescent
3	Ecovias Imigrantes S.A.	0,70	Crescent	0,96	Crescent	1	Constant
4	Rio Teresópolis S.A	1	Constant	0,71	Crescent	1	Constant
5	Ayrton Senna e Carvalho Pinto S.A	0,17	Crescent	0,23	Crescent	0,33	Crescent
6	Rodovia Oeste SP Via oeste S.A	0,04	Crescent	1	Constant	0,27	Crescent
7	Rodovias do Tietê S.A	0,07	Crescent	0,06	Crescent	0,09	Crescent
8	Rota das Bandeiras S.A	0,16	Crescent	0,14	Crescent	0,02	Crescent
9	Anhanguera Bandeirante S.A.	1	Constant	1	Constant	1	Constant
10	Ecorod. Concessões e Serviços S.A	0,35	Crescent	1	Constant	0,88	Crescent
11	Ecorod. Infraestrutura e Logística S.A	0,02	Crescent	0,02	Crescent	0,82	Crescent
12	Rodovias das Colinas S.A	0,70	Crescent	0,93	Crescent	1	Constant
13	Triunfo Part. e Investimento. S.A	0,02	Crescent	0,63	Crescent	0,02	Crescent
14	Triângulo do Sol Auto Estradas S.A	0,52	Crescent	0,77	Crescent	0,86	Crescent

Table 18: Technical Efficiency and Scale Return *Input* Orientation
Source: Study data (2023)

The results in Table 18 show that, in 2019, DMUs 1,4 and 9 were the ones that presented 100% technical efficiency in their intangible assets, reaching the optimal production scale, with constant scale return, both to *input* (Table 18) and *output* (Table 19). Based on this context, DMUS 6, 7, 12 and 14, as they presented technical efficiency verified in Table 17, an increasing scale return was projected in the range of the optimal scale, both for input and *output.* Regarding DMUS 2, 3, 5, 8, 10, 11 and 13, verified in Table 17, they did not present productive efficiency or technical efficiency. For these DMUS, an increasing scale return was projected for both *input* and *output*, as they presented, in the sum of the lambdas, in the CCR envelope model, a measure less than 1; the values of "w", in the BCC multiplier model, were positive.

In 2020, DMUS 2, 6, 9 and 10 reached the maximum production scale. In this sense, for DMUS 3, 4, 7, 12 and 14, an increasing scale return was projected in the range of the optimal

scale, oriented to both *input* and *output,* as they achieved technical efficiency, verified in Table 15. Thus, for DMUS 1, 5, 8, 11 and 13, an increasing scale return oriented to *input* or *output* was projected, as they presented the positive "w" value in the BCC multiplier model; the sum of the lambdas in the CCR envelope model was less than 1.

In 2021, DMUS 1, 3, 4, 9 and 12 achieved optimal production scale, working with maximum *input*-oriented efficiency, in the production of constant scale return, in which each of these DMUS was compared with its similar size. Thus, at the optimal scale in scale returns, for DMUS 5, 7 and 14 of 2021, an increasing *input*-oriented or *output*-oriented return was projected.

	DMUS	2019		2020		2021	
		Technical Efficiency	Scale Return	Technical Efficiency	Scale Return	Technical Efficiency	Scale Return
1	CCR S.A.	1	Constant	0,47	Crescent	1	Constant
2	Auto Raposo Tavares S.A.	0,54	Crescent	1	Constant	0,80	Crescent
3	Ecovias Imigrantes S.A.	0,71	Crescent	0,96	Crescent	1	Constant
4	Rio Teresópolis S.A	1	Constant	0,71	Crescent	1	Constant
5	Ayrton Senna e Carvalho Pinto S.A	0,35	Crescent	0,44	Crescent	0,33	Crescent
6	Rodovia Oeste SP Via oeste S.A	0,04	Crescent	1	Constant	0,99	Decreasing
7	Rodovias do Tietê S.A	0,07	Crescent	0,06	Crescent	0,09	Crescent
8	Rota das Bandeiras S.A	0,80	Crescent	0,97	Decreasing	0,91	Crescent
9	Anhanguera Bandeirante S.A.	1	Constant	1	Constant	1	Constant
10	Ecorod. Concessões e Serviços S.A	0,83	Crescent	1	Constant	0,89	Crescent
11	Ecorod. Infraestrutura e Logística S.A	0,92	Crescent	0,85	Crescent	0,87	Crescent
12	Rodovias das Colinas S.A	0,70	Crescent	0,93	Crescent	1	Constant
13	Triunfo Part. e Investimento. S.A	0,89	Crescent	0,81	Crescent	0,52	Crescent
14	Triângulo do Sol Auto Estradas S.A	0,52	Crescent	0,77	Crescent	0,86	Crescent

Table 19: Technical Efficiency and Scale Return Orientation to *output*
Source: Research Data (2023)

Table 17 shows the lack of technical efficiency for DMUS 2, 3, 5, 8, 10, 11 and 13, for the year 2019, oriented to the *input*. Because they present an increasing scale return in Table 19, they will be closer to the border when oriented to the *output.* In this sense, it is accessible for these DMUS to reach the border, improving their *inputs*, maintaining their *output.*

In 2020, DMUS 1, 5, 8 and 13, because they do not obtain the technical efficiency, verified in Table 17, will be close to the border when oriented to the *output,* reducing their *inputs* in obtaining an increase in their *output,* because they have obtained returns of increasing scale. The exception was for the *output*-oriented DMU 8, which obtained decreasing scale returns, due to an increase in its production less than the proportional change in *inputs*.

In 2021, DMU 6, when projected in the *output*-oriented frontier, obtained a decreasing scale return, its production obtained smaller increases than the proportional change in *inputs*. Thus, DMUS 2, 8, 10, 11 and 13, of the 2021 fiscal year, as they do not obtain technical

efficiency, verified in Table 17, when oriented to *output,* will be able to reach the efficiency frontier due to their increasing scale, reducing their *inputs* with an improvement in their *outputs*.

From these results, technical efficiency levels were identified with 100% constant scale return in the BCC model for DMUS 1, 4 and 9, both for *input* and *output* in the three periods analyzed. Only DMU 9 obtained production efficiency and technical efficiency of 100%, with constant scale return in all DEA models, oriented to both *input* and *output* for the three exercises analyzed.

4.4 TARGET PROJECTION OF DMUS BENCHMARKS

The *benchmarks* of the BCC model efficient multipliers that represent the projections in the achievement of the efficiency of the highway concession companies for the year 2019, presented in Chart 9, were: CCR S/A (DMU 1), *Concessionária Rio Teresópolis S/A* (DMU 4), *Concessionária Rodovia Oeste SP Via Oeste S/A* (DMU 6), *Concessionária Rodovias do Tietê S/A* (DMU 7), *Concessionária do Sistema Anhanguera Bandeirante S/A Autoban* (DMU 9), *Rodovias das Colinas S/A* (DMU 12) and *Triângulo do Sol Auto Estrada S/A* (DMU 14).

For the fiscal year 2020: *Concessionária Auto Raposo Tavares S/A* (DMU 2), *Ecovias Imigrantes S/A* (DMU 3), *Rio Teresópolis S/A* (DMU 4), *Rodovia Oeste SP Via Oeste S/A* (DMU 6), *Rodovias do Tietê S/A* (DMU 7), *Sistema Anhanguera Bandeirante S/A Autoban* (DMU 9), *EcoRodovias Concessões e Serviços S/A* (DMU 10), *Rodovias das Colinas S/A* (DMU 12) and *Triângulo do Sol Auto Estrada S/A* (DMU 14).

In 2021, the following stood out: *Concessionária CCR S/A* (DMU 1), *Ecovias Imigrantes S/A* (DMU 3), *Rio Teresópolis S/A* (DMU 4), *Rodovia Ayrton Senna e Carvalho Pinto S/A – Ecopistas* (DMU 5), *Rodovias do Tietê S/A* (DMU 7), *Sistema Anhanguera Bandeirante S/A Autoban* (DMU 9), *Rodovias das Colinas S/A* (DMU 12) and *Triângulo do Sol Auto Estrada S/A* (DMU 14).

It was observed that the concessionaire *CCR S/A* (1) presented technical efficiency in 2019 and 2021; *Auto Raposo Tavares S/A* (2), only in 2020; *Ecovias* (3) presented efficiency in 2020 and 2021; *Rio Teresópolis S/A* (4) obtained efficiency in the three exercises of the BCC model; *Ayrton Senna and Carvalho Pinto* (5) had efficiency only in 2021; *Rodovia Oeste SP* (6), in 2019 and 2020; *Rodovia do Tietê* (7) achieved efficiency in the BCC model for the three periods; *Rota das Bandeirantes* (8) did not obtain efficiency in any of the exercises; the *Anhanguera Bandeirantes System* (9) was the one that surpassed all, obtaining constant

efficiency in all BCC models in the three consecutive years; *EcoRodovias Concessão e Serviços* (10) obtained efficiency only in 2020; *Ecorodovias Infraestrutura e Logística* (11) did not obtain efficiency in the three exercises. *Rodovias das Colinas* (12), on the other hand, obtained efficiency in the three exercises in the model; *Triunfo Participação e Investimento* (13) did not obtain efficiency in any of the periods and, finally, *Triângulo do Sol Auto Estradas* (14) obtained efficiency in the BCC model for the three periods analyzed.

For some companies that did not achieve technical efficiency in the *input*-oriented BCC model, it was possible for the model to design *output*-oriented goals, as they achieved scale efficiency.

The goals projected by the model may not be applied, however, they indicate a proposed path in achieving efficiency for the set of companies that make up the analysis sample (Pereira; Venturini; Ceretta & Dutra, 2009). Thus, in order to maintain Intangible Capital and increase Net Operating Profit (LLO), in the search for efficiency, some DMUS demand a reduction in their *outputs*. As observed for the year 2019, in Table 20.

	DMUS	*Input 1*		*Input 2*		*Input 3*		*Input 4*		*Output*	
		Relational Capital (RC)		Human Capital (HC)		Structural Capital (SC)		Intangible Capital (IC)		Operating Net Income (LLO)	
		2019	Meta	2019	Meta	2019	Meta	2019	Meta	2019	Meta
2	Auto Raposo Tavares S.A.	0,098	0,098	8.597	8,158	0,884	0,884	2.325.897	2.325.897	8.374	132.599
3	Ecovias Imigrantes S.A	0,436	0,436	20,692	14,929	0,952	0,927	1.304.236	1.304.236	371.832	375.306
5	Ayrton Senna e Carvalho Pinto S.A	0,123	0,123	7,530	7,530	0,867	0,867	1.430.076	1.430.076	31.556	75.964
8	Rota das Bandeiras S.A	0,186	0,186	15,504	10,898	0,936	0,905	3.043.673	3.043.673	30.505	304.769
10	Ecorod. Concessões e Serviços S.A	0,187	0,187	5,827	5,827	0,828	0,465	7.482.768	7.482.768	109.113	541.470
11	Infraestrutura e Logística S.A	0,164	0,164	4,341	4,341	0,770	0,589	7.893.920	7.893.920	2.270	596.242
13	Triunfo Part. e Investimento. S.A	0,157	0,045	3,706	0,569	0,730	0,386	5.694.133	609.764	2.337	428.055

Table 20: *Output*-Oriented DMUS *Benchmarks* Targets – 2019
Source: Study data (2023)

The projected *output*-oriented target of *benchmarks* DMUs for DMU 5 in 2019, shown in Table 20, showed an increase in Operating Net Income of 141% and no change for the four *inputs* of this DMU. This, seen in Table 21.

	DMUS	Relational Capital (RC)	Human Capital (HC)	Structural Capital (SC)	Intangible Capital (IC)	Operating Net Income (LLO)
		Input 1	*Input 2*	*Input 3*	*Input 4*	*Output*
2	Auto Raposo Tavares S.A.	0%	-5%	0%	0%	1483%
3	Ecovias Imigrantes S.A	0%	-28%	-3%	0%	1%
5	Ayrton Senna e Carvalho Pinto S.A	0%	0%	0%	0%	141%
8	Rota das Bandeiras S.A	0%	-30%	-3%	0%	899%
10	Ecorod. Concessões e Serviços S.A	0%	0%	-44%	0%	396%
11	Infraestrutura e Logística S.A	0%	0%	-23%	0%	26166%
13	Triunfo Part. e Investimento. S.A	-71%	-85%	-47%	-89%	18216%

Table 21: Relative target of *output*-oriented *benchmark*s DMUS - 2019
Source: the author (2023)

Table 21 shows that the best projection of the target in achieving the efficiency of *Benchmarks* DMUS in 2019 was for DMU 2, with a 5% reduction in Human Capital (*input* 2), to achieve an increase of more than 1,400% in Net Operating Profit (*output*). For *Rodovia Ayrton Senna e Carvalho Pinto S/A* (DMU 5), for having presented 100% efficient *DMUS benchmark*s, the model projected a 0% reduction in all its *inputs* and an increase in *output* of 141%.

Thus, the increase in the *outputs* of the DMUS *benchmarks* for *Infraestrutura e Logistica S/A* and *Triunfo Participação e Investimento S/A* in 2019 should be investigated. These DMUs presented negative Net Operating Profit for this year.

	DMUS	*Input 1*		*Input 2*		*Input 3*		*Input 4*		*Output*	
		Relational Capital (RC)		Human Capital (HC)		Structural Capital (SC)		Intangible Capital (IC)		Operating Net Income (LLO)	
		2020	Meta	2020	Meta	2020	Meta	2020	Meta	2020	Meta
5	Ayrton Senna e Carvalho Pinto S.A	0,119	0,119	7,197	7,197	0,861	0,731	1.438.030	1.438.030	38.320	78.894
8	Rota das Bandeiras S.A	0,167	0,167	14,040	8,078	0,929	0,861	3.135.361	3.135.361	25.746	281.183
11	Ecorod. Infraestrutura e Logística S.A	0,176	0,150	4,750	4,750	0,789	0,693	8.155.441	8.155.441	2.628	201.126
13	Triunfo Part. e Investimento. S.A	0,254	0,155	5,948	5,948	0,832	0,760	5.738.872	5.738.872	168.574	258.282

Table 22: *Output*-Oriented DMUS *Benchmark*s Targets – 2020
Source: the author (2023)

The estimated projection of DMUs *benchmarks* for DMU 5 oriented to the *output* in 2020, verified in Table 22, generated a reduction for this DMU only in *input* 3. In this year, there was no reduction for Intangible Capital (*input* 4), for any of the non-efficient DMUS.

	DMUS	Relational Capital (RC)	Human Capital (HC)	Structural Capital (SC)	Intangible Capital (IC)	Operating Net Income (LLO)
		Input 1	*Input 2*	*Input 3*	*Input 4*	*Output*
5	Ayrton Senna e Carvalho Pinto S.A	0%	0%	-15%	0%	106%
8	Rota das Bandeiras S.A	0%	-42%	-7%	0%	992%
11	Ecorod. Infraestrutura e Logística S.A	-15%	0%	-12%	0%	7553%
13	Triunfo Part. e Investimento. S.A	-39%	0%	-9%	0%	53%

Table 23: Relative target of *output*-oriented *benchmarks* DMUS - 2020
Source: the author (2023)

For 2020, the projection for DMU 5 showed a 15% reduction in Structural Capital (*input* 3), obtaining a 106% increase in Operating Net Income. Thus, for *Triunfo Participação e Investimento S/A* (DMU 13) achieves a 53% increase in Net Operating Profit (*output*), it will have to make a reduction of 39% in its Relational Capital (*input* 1) and 9% in Structural Capital (*input* 3).

Although DMU 11 presents negative Operating Net Income in 2020, the model generated a relative target of 7,553% increase in its LLO for this year. This increase should be analyzed, due to the deduction rates presented, for Relational Capital and Human Capital.

	DMUS	*Input 1*		*Input 2*		*Input 3*		*Input 4*		*Output*	
		Relational Capital (RC)		Human Capital (HC)		Structural Capital (SC)		Intangible Capital (IC)		Operating Net Income (LLO)	
		2021	Meta	2021	Meta	2021	Meta	2021	Meta	2021	Meta
2	Auto Raposo Tavares S.A.	0,096	0,096	6,732	5,617	0,851	0,307	2.326.851	2.326.851	1.841	122.178
6	Rodovia Oeste SP Via oeste S.A	3,694	1,191	18,572	12,066	0,946	0,897	440.801	440.801	47.499	225.502
8	Rota das Bandeiras S.A	0,164	0,164	14,947	0,899	0,933	0,106	3.297.360	2.532.822	1.690	219.997
10	Ecorodovias Concessões e Serviços S.A	0,178	0,178	7,413	6,657	0,865	0,844	11.444.080	11.444.080	421.702	432.593
11	Ecorod. Infraestrutura e Logística S.A	0,174	0,174	6,129	6,129	0,837	0,788	11.447.683	11.447.683	367.262	420.997
13	Triunfo Part. e Investimento. S.A	0,195	0,195	4,351	4,351	0,770	0,535	5.694.133	5.694.133	4.984	147.696

Table 24: Targets DMUS *benchmarks* oriented to *output* – 2021
Source: the author (2023)

To increase Net Operating Income, the model projected deductions in *input* 3 of DMUS *benchmarks* for all non-efficient DMUs in fiscal year 2021, as shown in Table 24. In view of this, DMUs 11 and 13 were the only ones that received model projection for reduction only in *input* 3. The others generated projections for two or three *inputs* in this exercise.

	DMUS	Relational Capital (RC)	Human Capital (HC)	Structural Capital (SC)	Intangible Capital (IC)	Operating Net Income (LLO)
		Input 1	*Input 2*	*Input 3*	*Input 4*	*Output*
2	Auto Raposo Tavares S.A.	0%	-17%	-64%	0%	6536%
6	Rodovia Oeste SP Via oeste S.A	-68%	-35%	-5%	0%	375%
8	Rota das Bandeiras S.A	0%	-39%	-48%	0%	12918%
10	Ecorodovias Concessões e Serviços S.A	0%	-10%	-2%	0%	3%
11	Ecorod. Infraestrutura e Logística S.A	0%	0%	-8%	0%	15%
13	Triunfo Part. e Investimento. S.A	0%	0%	-43%	0%	2863%

Table 25: Relative target of *output*-oriented *benchmarks* DMUS - 2021
Source: The author (2023).

The relative projection of the target for DMU 11 in 2021 of the DMUS *benchmarks,* verified in Table 25, shows a reduction of 8% in *input* 3. This reduction represents a 15% increase in Net Operating Income (*output*) for this DMU. Therefore, the increase in LLO of 2863% for DMU 13, predicts a 43% reduction in *output* 3.

The percentages presented for DMUS 2 and 8 for Operating Net Income must be analyzed; as a result, these companies presented negative LLO in 2021.

For *Auto Raposo Tavares S/A* (DMU 2), *Rodovia Oeste SP Via Oeste S/A* (DMU 6) and *Rota das Bandeiras S/A* (DMU 8), the deductions presented by the model in the Relational, Human and Structural Capital (*inputs* 1,2 and 3) of the DMUS *benchmarks*, may not be feasible for these DMUS. Thus, the target projections, oriented to the Operating Net Income for the year 2021, present a deduction for *inputs* 1, 2 and 3, in the non-efficient DMUs, without reduction in Intangible Capital (*input* 4).

Therefore, DMUS that are not efficient by the model are able to be projected at the border due to their scale efficiency in the search for intermediate targets. In this way, they can get closer to the optimal scale of the efficiency of the *benchmarks* DMUs, when oriented to the *output* in the BBC envelope model.

In this context, the managerial goal corresponds to the gap and the target; however, the gaps are not proportional to all variables together. Thus, the analysis of targets and time off may serve as support for decision making (Souza Junior, 2019).

4.5 THE EFFICIENCY OF INTANGIBLE CAPITAL IN BRAZILIAN HIGHWAY CONCESSION COMPANIES

With the projection of the targets to the efficiency levels of the DMUs *benchmarks*, through the Data Envelopment Analysis (DEA) and the achievement of the technical efficiency levels of the highway concession companies, the analysis of this efficiency of the intangible assets of the concession contracts is carried out, added to the productive efficiency indexes of the Intellectual Capital value aggregation model; all adjusted in relation to the Operating Net Income for the year of the highway concession companies in Brazil.

The evaluation of *inputs*, projected in Tables 20 to 25 of the relative target of *benchmark* DMUS, oriented to *outputs*, in order to maximize the final product of highway concession companies, may become an important tool in the production of efficiency for inefficient DMUS, so that they are able to project themselves at the efficiency frontier.

It is important to evaluate the critical points (implications) that benefit the technical efficiency of highway concessionaires as a competitive advantage in the public and private spheres. In this sense, the targets and gaps of the *inputs* and *output* analyzed by the DEA also contribute by indicating which sources are not efficient and how the DMU can go in search of efficiency. This is presented in Tables 26, 27 and 28.

2019	1	2	3	4	5	6	7	8	9	10	11	12	13	14
DMUS	CCR S.A.	Auto Raposo Tavares S.A.	Ecovias Imigrantes S.A.	Rio Teresópolis S.A	Ayrton Senna e Carvalho Pinto S.A	Rodovia Oeste SP Via oeste S.A	Rodovias do Tietê S.A	Rota das Bandeiras S.A	Sistema Anhanguera Bandeirante S.A.	Ecorodovias Concessões e Serviços S.A	Ecorodovias Infraestrutura e Logística S.A	Rodovias das Colinas S.A	Triunfo Part. e Investimento S.A	Triângulo do Sol Auto Estradas S.A
Eficiência	1	15,83	1,01	1	2,41	1	1	9,99	1	4,96	262,66	1	183,16	1
Input 1 (CR)	0,22	0,10	0,44	1,12	0,12	0,14	0,01	0,19	0,64	0,19	0,16	0,19	0,16	0,47
Alvo	0,22	0,10	0,44	1,12	0,12	0,14	0,01	0,19	0,64	0,19	0,16	0,19	0,16	0,47
Folga	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Percentual	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Input 2 (CH)	5,12	8,60	20,69	10,12	7,53	0,76	1,02	15,50	21,33	5,83	4,34	11,75	3,71	10,50
Alvo	5,12	8,16	14,93	10,12	7,53	0,76	1,02	10,85	21,33	5,83	4,34	11,75	3,71	10,50
Folga	0,00	0,44	5,76	0,00	0,00	0,00	0,00	4,66	0,00	0,00	0,00	0,00	0,00	0,00
Percentual	0%	-5%	-28%	0%	0%	0%	0%	-30%	0%	0%	0%	0%	0%	0%
Input 3 (CE)	0,80	0,88	0,95	0,90	0,87	1,21	0,02	0,94	0,95	0,83	0,77	0,91	0,73	0,90
Alvo	0,80	0,88	0,93	0,90	0,87	1,21	0,02	0,91	0,95	0,46	0,59	0,91	0,69	0,90
Folga	0,00	0,00	0,02	0,00	0,00	0,00	0,00	0,03	0,00	0,36	0,00	0,00	0,00	0,00
Percentual	0%	0%	-3%	0%	0%	0%	0%	-3%	0%	-44%	23%	0%	6%	0%
Input 4 (CI)	17.507.639	2.325.897	1.304.236	93.918	1.430.076	596.240	1.301.569	3.043.673	1.785.774	7.482.768	7.893.920	1.216.880	5.694.133	975.846
Alvo	17.507.639	2.325.897	1.304.236	93.918	1.430.076	596.240	1.301.569	3.043.673	1.785.774	7.482.768	7.893.920	1.216.880	5.694.133	975.846
Folga	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Percentual	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Output (LLO)	1.295.582	8.374	371.832	48.408	31.556	2.780	2.179	30.505	765.599	109.113	2.270	187.442	2.337	199.211
Alvo	1.295.582	132.599	375.312	48.408	75.964	2.780	2.179	304.774	765.599	541.470	596.242	187.442	428.055	199211
Percentual	0%	1483%	1%	0%	141%	0%	0%	899%	0%	396%	26166%	0%	18216%	0%

Table 26: Target and *output*-oriented gaps in the DEA model – Fiscal Year 2019
Source: the author (2023)

Table 26 shows an efficiency of 1583% for the *Auto Raposo Tavares S/A* concessionaire (DMU 2), the model projected a target of 8.16 in the Human Capital index (*input* 2); thus, it

shows a gap of 0.44 of the *benchmarks* DMUS, which indicates a 5% reduction in Human Capital (*input* 2), considering to maximize the Net Operating Profit (*output*) by 1.483%. For this DMU to achieve technical efficiency across the frontier in the form projected by the model for the 2019 fiscal year, it will have to increase personnel expenses by 5%.

For *Ayrton Senna e Carvalho Pinto S/A* (DMU 5), the model presented a target in the Net Operating Profit (*output*) of R$75,964, resulting in an increase of 141% in this *output*, without any reduction for the *inputs.* However, it is observed that this DMU obtained, as *benchmarks*, *CCR S/A* (DMUS 1), *Concessionária Rodovia Oeste SP Via Oeste S/A* (DMU6), *Rodovias do Tietê S/A* (DMU 7), *Sistema Anhanguera-Bandeirante S/A Autoban* (DMU 9) and *Rodovias das Colinas S/A* (DMU12), which have 100% technical efficiency for the year 2019.

Thus, it is worth exploring more deeply why the *output*-oriented model does not present percentages of reduction in any of the *inputs* for *Ayrton Senna e Carvalho Pinto S/A* concessionaire in this year, which represents an increase of 141% in Net Operating Profit. However, the objective of this stage of the work is limited to demonstrating the proper treatment of the data from the managerial perspective of the *inputs* of internally produced and externally acquired intangible capital, in the achievement of the necessary objectives.

2020	1	2	3	4	5	6	7	8	9	10	11	12	13	14
DMUS	CCR S.A.	Auto Raposo Tavares S.A.	Ecovias Imigrantes S.A.	Rio Teresópolis S.A	Ayrton Senna e Carvalho Pinto S.A	Rodovia Oeste SP Via oeste S.A	Rodovias do Tietê S.A	Rota das Bandeiras S.A	Sistema Anhanguera Bandeirante S.A.	Ecorodovias Concessões e Serviços S.A	Ecorodovias Infraestrutura e Logística S.A	Rodovias das Colinas S.A	Triunfo Part. e Investimento S.A	Triângulo do Sol Auto Estradas S.A
Eficiência	1	1	1	1	2,06	1	1	10,92	1	1	76,53	1	1,53	1
Input 1 (CR)	0,19	0,07	0,44	0,93	0,12	2,49	0,01	0,17	0,90	0,23	0,18	0,17	0,25	0,77
Alvo	0,19	0,07	0,44	0,93	0,12	2,49	0,01	0,17	0,90	0,23	0,15	0,17	0,16	0,77
Folga	0	0	0	0	0	0	0	0	0	0	0,03	0	0,10	0
Percentual	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	-15%	0%	-39%	0%
Input 2 (CH)	4,35	6,65	21,16	9,19	7,20	15,40	1,66	14,04	22,08	7,24	4,75	11,12	5,95	7,44
Alvo	4,35	6,65	21,16	9,19	7,20	15,40	1,66	8,08	22,08	7,24	4,75	11,12	5,95	7,44
Folga	0	0	0	0	0	0	0	4,01	0	0	0,00	0	0	0
Percentual	0%	0%	0%	0%	0%	0%	0%	-42%	0%	0%	0%	0%	0%	0%
Input 3 (CE)	0,77	0,85	0,95	0,89	0,86	0,94	0,40	0,93	0,95	0,86	0,79	0,91	0,83	0,87
Alvo	0,77	0,85	0,95	0,89	0,73	0,94	0,40	0,86	0,95	0,86	0,69	0,91	0,76	0,87
Folga	0,00	0,00	0,00	0,00	0,13	0,00	0,00	0,07	0,00	0,00	0,10	0,00	0,07	0,00
Percentual	0%	0%	0%	0%	-15%	0%	0%	-7%	0%	0%	-12%	0%	-9%	0%
Input 4 (CI)	16.306.042	2.303.470	1.300.700	56.041	1.438.030	435.613	1.312.546	3.135.361	1.582.308	8.148.103	8.155.441	1.245.131	5.738.872	982.542
Alvo	16.306.042	2.303.470	1.300.700	56.041	1.438.030	435.613	1.312.546	3.135.361	1.582.308	8.148.103	8.155.441	1.245.131	5.738.872	982.542
Folga	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percentual	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Output (LLO)	86.113	203.093	375.482	24.739	38.320	272.005	2.202	25.746	729.848	415.589	2.628	190.056	168.574	196.678
Alvo	86.113	203.093	375.482	24.739	78.894	272.005	2.202	281.183	729.848	415.589	201.126	190.056	258.282	196.678
Percentual	0%	0%	0%	0%	106%	0%	0%	992%	0%	0%	7553%	0%	53%	0%

Table 27: Efficiency, targets and o*utput*-oriented gaps in the DEA model – Fiscal Year 2020
Source: the author (2023)

The 206% efficiency demonstrated for the Concessionaire *Ayrton Senna e Carvalho Pinto S/A- Ecopistas* (DMU 5), in 2020, verified in Table 27, projected for Structural Capital

(*input* 3) a target of 0.73 for a gap of 0.13 of the DMUs *benchmarks*. In this sense, a reduction of 15%, for this *input*, will obtain an increase of 106% in Net Operating Profit (*output*).

For DMU 5 to achieve technical efficiency across the frontier in fiscal year 2020, it will have to apply the 15% reduction in the items that make up the added value (VA), and thus maximize the Net Operating Profit for fiscal year 2020 by 106%.

In the same year, *Rodovias do Tiête S/A* (DMU 7) presented a negative Operating Net Income. The analysis made by the model for this DMU showed 100% technical efficiency for this exercise.

2021	1	2	3	4	5	6	7	8	9	10	11	12	13	14
DMUS	CCR S.A.	Auto Raposo Tavares S.A.	Ecovias Imigrantes S.A.	Rio Teresópolis S.A	Ayrton Senna e Carvalho Pinto S.A	Rodovia Oeste SP Via oeste S.A	Rodovias do Tietê S.A	Rota das Bandeiras S.A	Sistema Anhanguera Bandeirante S.A.	Ecorodovias Concessões e Serviços S.A	Ecorodovias Infraestrutura e Logística S.A	Rodovias das Colinas S.A	Triunfo Part. e Investimento S.A	Triângulo do Sol Auto Estradas S.A
Eficiência	1,00	66,36	1,00	1,00	1,00	4,75	1,00	130,18	1,00	1,03	1,15	1,00	29,63	1,00
Input 1 (CR)	0,21	0,10	0,35	1,02	0,14	3,69	0,01	0,16	1,70	0,18	0,17	0,21	0,20	0,95
Alvo	0,21	0,10	0,35	1,02	0,14	1,19	0,01	0,16	1,70	0,18	0,17	0,21	0,20	0,95
Folga	0,00	0,00	0,00	0,00	0,00	2,50	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Percentual	0%	0%	0%	0%	0%	-68%	0%	0%	0%	0%	0%	0%	0%	0%
Input 2 (CH)	5,38	6,73	20,47	8,13	7,95	18,57	0,85	14,95	23,72	7,41	6,13	7,35	4,35	7,84
Alvo	5,38	5,62	20,47	8,13	7,95	12,07	0,85	9,16	23,72	6,66	6,13	7,35	4,35	7,84
Folga	0,00	1,12	0,00	0,00	0,00	6,51	0,00	5,79	0,00	0,76	0,00	0,00	0,00	0,00
Percentual	0%	-17%	0%	0%	0%	-35%	0%	-39%	0%	-10%	0%	0%	0%	0%
Input 3 (CE)	0,81	0,85	0,95	0,88	0,87	0,95	0,07	0,93	0,96	0,87	0,84	0,86	0,77	0,87
Alvo	0,81	0,31	0,95	0,88	0,87	0,90	0,07	0,49	0,96	0,84	0,77	0,86	0,44	0,87
Folga	0,00	0,54	0,00	0,00	0,00	0,05	0,00	0,44	0,00	0,02	0,07	0,00	0,33	0,00
Percentual	0%	-64%	0%	0%	0%	-5%	0%	-48%	0%	-2%	-8%	0%	-43%	0%
Input 4 (CI)	21.347.825	2.326.851	1.894.897	46.508	1.468.627	440.801	1.349.746	3.297.360	1.607.455	11.444.080	11.447.683	1.254.398	5.694.133	985.591
Alvo	21.347.825	2.326.851	1.894.897	46.508	1.468.627	440.801	1.349.746	3.297.360	1.607.455	11.444.080	11.447.683	1.254.398	5.694.133	985.591
Folga	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percentual	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Output (LLO)	805.596	1.841	369.720	61.977	55.172	47.499	2.409	1.690	709.340	421.702	367.262	185.974	4.984	214.501
Alvo	805.596	122.178	369.720	61.977	55.172	225.502	2.409	219.997	709.340	432.593	420.997	185.974	147.696	214.501
Percentual	0%	6536%	0%	0%	0%	375%	0%	12918%	0%	3%	15%	0%	2863%	0%

Table 28: Efficiency, targets and *output*-oriented gaps in the DEA model – Fiscal Year 2021
Source: the author (2023)

The targets and gaps presented by the model in 2021, for *EcoRodovias Infraestrutura e Logística S/A* (DMU 11), in Table 28, showed an efficiency of 115%. The model projected, for the Structural Capital (*input* 3) of this DMU, a target of 0.77 and a gap of 0.07 of the DMUs *benchmarks*; thus, it was possible to maximize the Net Operating Profit (*output*) by 15%.

To achieve technical efficiency, through the frontier in 2021, DMU 11 will have to reduce the equivalent of 8% in the Structural Capital coefficient (*input* 3). Therefore, it will have to apply this reduction to the items that make up the Earned Value (VA) and, thus, maximize the Net Operating Profit (LLO) by 15% in 2021.

The Operating Net Income of DMUS 2, 7 and 8 in 2021 was negative. However, for DMU 7, the model showed 100% efficiency in this exercise.

In general, in order to reach the efficiency frontier, oriented to *output*, the model did not present a deduction in Intangible Capital (*input* 4) in the three years analyzed for non-efficient DMUS, thus maintaining the value of the intangible assets of the concession contracts unchanged in the scope of efficiency. However, with a reduction in *inputs* 1 (Relational Capital), 2 (Human Capital) and 3 (Structural Capital), to reach the efficiency frontier, without deducting the Intangible Assets from the concession contracts for these three periods, there is a substantial increase in the Operating Net Income (LLO) of the concessionaires.

In response to the research question, it appears that investments in relational, human and structural capital affect the efficiency in the competitive advantage of highway concession companies thus, reducing the Operating Net Income for the year.

In this context, the result of the efficiency presented by the *Anhanguera Bandeirante S/A System* (DMU 9) presented an efficient Operating Net Profit for the period analyzed. This demonstrates internally acquired and externally produced intangible investments effective by DMU 9 in generating value and competitiveness in concession contracts.

The efficiency of the relative contribution of *inputs* and *outputs,* presented by the model, is a way of evaluating the performance of concessionaires for decision making by managers in relation to the object studied. Thus, the relative contribution of the DEA can serve as a managerial subsidy in the evaluation of the efficiency of the evaluated object, providing elements for changes in management practices (Souza Junior, 2019). Verified in Table 29.

		2019					2020					2021				
	DMUS	Relational Capital (RC)	Human Capital (CH)	Structural Capital (SC)	Intangible Capital (IC)	Operating Net Income (LLO)	Relational Capital (RC)	Human Capital (CH)	Structural Capital (SC)	Intangible Capital (IC)	Operating Net Income (LLO)	Relational Capital (RC)	Human Capital (CH)	Structural Capital (SC)	Intangible Capital (IC)	Operating Net Income (LLO)
		Input 1	*Input 2*	*Input 3*	*Input 4*	Output	*Input 1*	*Input 2*	*Input 3*	*Input 4*	Output	*Input 1*	*Input 2*	*Input 3*	*Input 4*	Output
1	CCR S.A.	0%	14%	0%	86%	1.295.582	0%	100%	0%	0%	86.113	1%	17%	0%	82%	805.596
2	Auto Raposo Tavares S.A.	20%	36%	2%	42%	8.374	3%	34%	0%	63%	203.093	5%	0%	0%	95%	1.841
3	Ecovias Imigrantes S.A.	24%	0%	0%	76%	371.832	16%	1%	40%	43%	375.482	13%	0%	46%	41%	369.720
4	Rio Teresópolis S.A	0%	96%	0%	4%	48.408	50%	47%	0%	3%	24.739	97%	0%	0%	3%	61.977
5	Ayrton Senna e Carvalho Pinto S.A	29%	37%	3%	30%	31.556	7%	45%	0%	49%	38.320	60%	0%	0%	40%	55.172
6	Rodovia Oeste SP Via oeste S.A	7%	0%	48%	45%	2.780	0%	21%	69%	11%	272.005	0%	0%	81%	19%	47.499
7	Rodovias do Tietê S.A	0%	0%	1%	99%	2.179	1%	0%	0%	99%	2.202	1%	0%	0%	99%	2.409
8	Rota das Bandeiras S.A	47%	0%	17%	36%	30.505	12%	0%	80%	8%	25.746	6%	0%	0%	94%	1.690
9	Anhanguera Bandeirante S.A.	0%	87%	0%	13%	765.599	0%	64%	32%	4%	729.848	35%	0%	30%	35%	709.340
10	Ecorod. Concessões e Serviços S.A	0%	30%	0%	70%	109.113	0%	29%	39%	32%	415.589	55%	0%	0%	45%	421.702
11	Ecorod. Infraestrutura e Logística S.A	0%	96%	4%	0%	2.270	0%	0%	100%	0%	2.628	45%	6%	0%	49%	367.262
12	Rodovias das Colinas S.A	52%	0%	30%	19%	187.442	7%	46%	17%	30%	190.056	20%	0%	0%	80%	185.974
13	Triunfo Part. e Investimento. S.A	0%	96%	4%	0%	2.337	0%	70%	0%	30%	168.574	0%	58%	0%	42%	4.984
14	Triângulo do Sol Auto Estradas S.A	23%	1%	26%	50%	199.211	35%	38%	0%	27%	196.678	12%	22%	40%	26%	214.501

Table 29: Relative Efficiency BCC *Input*-Oriented Multipliers
Source: the author (2023)

The relative efficiency, shown in Table 29, showed, in 2020, that the *input*-oriented Concessionaire CCR S.A. (DMU 1)*,* considered a large company, used 100% of its resources available only for Human Capital (*input* 2), becoming inefficient for the period. It is also

verified that, in the same year, *EcoRodovias Infraestrutura e Logística S/A* (DMU 11) was not efficient because it made 100% of its resources available only to Structural Capital (*input* 3). This DMU suffered a loss in this year.

This analysis highlights *Rodovias do Tietê S/A* (DMU 7). This concessionaire obtained a net operating loss in the three years analyzed, on the other hand, it was considered efficient by the BCC model for the three periods, for having invested 99% in the intangible capital of the concession contracts in this period.

The DEA technique allows the improvement of methods, strategies and internal processes, in order to achieve the management efficiency of the concessionaires, aiming at a better performance in meeting the objective function (Souza Junior, 2019). Thus, it is possible to maximize the result to satisfy the stakeholders.

Based on this context, this study first performed the statistical validation and the correlation of the studied variables. In view of this, it verified the presence of outliers and a weak negative relationship between the variables. Thus, the results indicated inefficient investments in intangible assets of the concessionaires.

In the search for efficiency for non-efficient DMUs, targets were projected in the BCC model oriented to *output* from the *benchmark* DMUs. This projection allows contributing to stakeholders, managers and shareholders in the management of intangible assets.

The projection, presented by the *input* model, results in the maximization of the final product of the concessionaires. This is one of the processes that the model considers as a tool capable of producing efficiency for non-efficient DMUs.

Evaluating the critical point of the non-efficiency of the concessionaires' intangible assets, based on the result of the analysis of the DEA technique, may present benefits for the generation of efficiency and creation of value for the Net Operating Profit. And, thus, be able to compete in the bidding processes, in the public and private spheres, on equal terms with its competitors.

The targets and clearances of the DMUs *benchmarks*, considered by the model, contribute as a projection in obtaining the technical efficiency of the concessionaires through the efficiency frontier. Thus, the efficiency presented of 1583%, from the target and clearance for the *Auto Raposo Tavares S/A* Concessionaire (DMU 2), in 2019, considered to maximize, by more than 1,400%, the Net Operating Profit (*output*).

The achievement of technical efficiency is indicated by the model for DMU 2 in 2019, considering a 5% reduction in Human Capital (*input* 2). This reduction gave emphasis to the concessionaire to increase personnel expenses.

The 206% efficiency, indicated by the model, from the targets and clearances for the Concessionaire *Rodovia Ayrton Senna e Carvalho Pinto S/A* (DMU 5), in 2020, considered a 15% reduction in the Structural Capital (*input* 3) of this DMU. In this situation, in order to achieve technical efficiency, through the efficiency frontier, in 2020, DMU 5 needs to reduce value-added (VA) items by 15% and, thus, maximize Net Operating Profit (*output*) by 106% for the period.

Finally, with an efficiency of 115%, considered for the Concessionaire *EcoRodovias Infraestrutura e Logística S/A* (DMU 11), in 2021, the model projected, from the target and the gap, a reduction of 8% in Structural Capital (*input* 3). This percentage, applied to the added value, may maximize the Net Operating Profit by 15%, thus reaching the efficiency frontier.

The result "0" (zero), found in the DMUS on the gaps in the BCC model, presented in tables 26, 27 and 28, confirms the efficiency condition described by Rodrigues Junior (2012); a DMU, in order to be efficient in the BCC model, with ($\theta B*$,$s-*$,$s+*$), needs to meet two conditions; $\theta B* = 1$ and on the gaps $s-* = 0$, $s+* = 0$; failure to comply with these conditions, for the DMU0, will be considered BCC0 – Not efficient. Therefore, the DMUS that achieved an efficiency result other than "1" and a score on the gaps other than "0", meet the condition of Not Efficient.

The score of the result, in the performance of the relative efficiency of the units evaluated in relation to the others, in the Tables already named, ranged between 0 and 1. Therefore, the findings prove the result of the efficiency score equal to 1, which evaluated the unit as efficient, confirming the relative efficiency score of Pimentel & Casa Nova (2005) and Almeida *et al.* (2006).

The DEA technique determined the value of the relative efficiency of *inputs* and *output*, revealing the relative contribution of these variables; the higher the value of *input* or *output*, the greater the contribution of efficiency to the DMU. This efficiency can be considered as a way to evaluate the performance of the concessionaires in decision making and serve as a management subsidy.

A detailed analysis of the efficiency values of the evaluated object, involving strategic issues for the control of operations, may offer elements for the change in management praxis. From this, one should seek to understand new market practices and thus contribute to increasing organizational efficiency.

The results of the research indicate the existence of levels of efficiency in the intangible assets oriented to the *input* of relational, human and structural capital, produced internally, which can impact the performance of the intangible capital produced externally of the

concessionaires. However, this impact had no effect when worked together with these components, oriented *output*.

The work went beyond the literature presented, as it evaluates the technical efficiency of the intangible assets of the concession contracts, acquired externally, added to the intangible assets produced internally in the components of the value aggregation model of the adjusted VAIC^{TM}, in the production of value and competitive advantage for the Net Operating Profit in the periods from 2019 to 2021, with the application of the DEA methodology for 14 highway concession companies of the Brazilian public service, listed on the BM&Fbovespa, according to the resources used, in the achievement of the general objective. Thus, the analysis identified surplus demands in the *inputs* that characterize the inefficiency of the studied variable.

The Human Capital and Structural Capital factors, oriented to *output*, were decisive to project the achievement of effective technical efficiency and competitive advantage, maximizing the Operating Net Profit of *Concessionária Auto Raposo Tavares S/A* (DMU 2), in 2019, of *Rodovia Ayrton Senna e Carvalho Pinto S/A- Ecopistas* (DMU 5), in 2020 and *EcoRodovias Infraestrutura e Logística S/A* (DMU 11), in 2021.

The factors characterized in the previous paragraph are important drivers of expenses with employees and value added items. However, the result of these factors did not present the optimal solution in the model for the other DMUS, as evidenced for *Anhanguera-Bandeirante S/A Autoban System* concessionaire (DMU 9), for the three exercises analyzed.

The results presented by the DEA technique may serve as an aid to managers in decision making, providing data on the performance of the concessionaire and its competitors. Thus, it is possible to improve methods, strategies and processes in meeting the objective function.

5 FINAL CONSIDERATIONS

Highway concessionaires emerged in order to efficiently explore activities to improve the state's highway infrastructure, with the purpose of reducing transportation costs and stimulating economic growth, increasing their assets. From this perspective, the highway concession program emerged, with the responsibility of supervising and regulating the concession contracts for these activities, through Laws and regulations.

In this context, the State is concerned with the measurement and accounting with the intangible asset of the gains earned by the concessionaires in the use of the service by the users. These assets are considered strategic for the competitiveness and generation of value in the Net Operating Profit of these companies, thus enabling negotiations with their stakeholders.

In the COVID-19 pandemic period, which demanded a national public health emergency, the research identified inefficiency in investments in intangible assets for some concessionaires. In view of this, it presented an increase in the human capital indexes and deductions from the intangible assets of the concession agreement.

However, to produce an efficient performance in the intangible asset, which satisfies the stakeholders, it is important that the concessionaire have a strategic planning, with a clear distinction of what he expects and what may happen in the future. After considering this, then, obtaining an evaluation system that interprets this performance, so that it safely distinguishes the necessary financial deductions.

Through the use of the DEA model, the study contributes to improving the performance of intangible assets produced internally and those acquired externally from public highway concession companies, by presenting targets of DMUS *benchmarks*, targets and clearances, as support for management. In this way, the DMU will be able to achieve technical efficiency through the frontier; and thus, maximize the Net Operating Profit for the period.

Data Envelopment Analysis (DEA) is a technique that can assist decision making and the evaluation of internal processes, aiming to improve strategic methods in the face of competitors and market conditions; and thus, improve the efficiency in the performance of entities in meeting the objective function.

To evaluate the evolution of the technical efficiency of highway concessionaires in Rio Grande do Sul, for a period of four years, Possamai (2006) used the DEA method aimed at reducing *inputs*. The author considered the technology of variable returns and issues relating to scale. This analysis allowed us to identify that there is no homogeneity in the management of companies in the different poles, since the results were different in terms of business efficiency,

image and security. In this context, there was a low correlation in being efficient from the point of view of serving the user and being efficient in obtaining profit.

In the evaluation of five federal toll roads, by Gomes, Mello, Neto & Meza (2012), applying the DEA CCR model, in the evidence of scale gain, the results indicated that it is an approach that can be used successfully to determine a single quality index, allowing to verify the trend of improvement of the efficiencies of the concessionaires over time. For these authors, the updated data would be necessary to ratify or reject this trend.

In the evaluation of efficiency in the service provision of 14 federal highway concessionaires, in relation to the difference in the efficiencies of the first and second stages of the federal concession program De Resende Salgado, Wilbert and Rosano-Peña (2016), the results showed that the second stage concessions obtained the best level of efficiency in the provision of services in relation to the first stage.

In 2019, Neves and Bertussi measured the efficiency of federal highway concession contracts, using data from 2012 and 2016, considering all contracts in force in the three stages of the concession program, whose efficiency was calculated and evaluated through the DEA and Stochastic Frontier Analysis (SFA). The authors concluded, through efficiency scores, that, on average, dealerships can produce 84% of the maximum possible *output* and the most efficient dealership can produce 92%.

For the present study, to analyze the efficiency of intangible assets produced internally and acquired externally from 14 Brazilian highway concession companies in the period from 2020 to 2021, the literature presented the empirical model of the DEA technique. This model has a characteristic of its own and a set of models that represent reality and perspective and in which view it can be used.

The weak negative correlation verified between the *inputs* of the variables analyzed by the DEA justified the excess demands on the *inputs* that characterize the inefficiency of some variables, identified by the model in this research. Thus, to meet the general objective, the model pointed out that the intact, relational, human and structural capital, produced internally, have an impact on the performance of the Intangible Assets of the concession contracts acquired externally from the companies studied, which affects the efficiency of the competitive advantage. However, this impact had no effect when worked together with these components, oriented to *output*.

Due to the central hypothesis of this study, it was found that the efficient result in generating profit from effective investments in internally produced and externally acquired intangible assets was achieved. Thus, *Anhanguera Bandeirante S/A* was the only one of the 14

companies analyzed by the model to achieve maximum efficiency, that is, a score of 1.0 in all DEA models for both *input* and *output*, in the three exercises analyzed, showing an efficient and competitive LLO.

The model presented results that may not be practiced; as well as data that may be of interest for future research, in the efficiency and financial performance of companies, and as an aid in decision making.

This study may have been one of the few studies that analyzed the efficiency of the intangible assets of the concession contracts together with the components of the adjusted VAIC^{TM} Intellectual Capital value aggregation model, with a view to adding value to the Net Operating Profit, using the non-parametric DEA methodology; and thus, enable the competitiveness of public highway companies in concession contracts. Thus, it is indicated as future research to analyze this efficiency in relation to gross revenue, in order to add financial value to these companies.

The tool used in this research, in the analysis of efficiency, represents a sample of many possibilities that are presented in the literature, to compare the results obtained in this work. In this scenario, a tool that is evidenced as a possibility for new research of this sample is the Malmquist-DEA index, which allows verifying the evolution over time of the efficiency of internally produced intangible assets and externally acquired intangible assets of highway concession companies in the construction of the production frontier.

The efficiency ratios of the intangible assets of the concession contracts, added to the components of the value aggregation model of the adjusted VAIC^{TM}, were formed to verify the non-efficient DMUS, with the possibility of reaching the efficiency frontier through the DEA model. Thus, the research contributed to the evaluation of the efficiency of these DMUS and the recognition of the variables that form this efficiency and its *benchmarks*, so that it generated goals, as an aid to stakeholders, and created a database that can be used in future works.

Therefore, this study had a descriptive character, in order to analyze the efficiency of investments in intangible assets of the concession contracts, added to the components of the adjusted VAIC^{TM}, which affects the efficiency in the competitive advantage in relation to the operating net income.

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