Measuring the performance of Science and Technology Parks: a proposal of a multidimensional model

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Abstract - This paper aims to propose a multidimensional model for monitoring and evaluating (ME) the performance of similar groups of Science and Technology Parks (STPs), instead of having a generic ME system. The development of this model considered STPs’ business models and value propositions, their objectives and goals, development stage, stakeholder’s commitment, and respective legal and governance structures. Firstly, we put into perspective the complexity and multidimensionality of measuring and evaluating performance of STPs. In sequence, we review the literature associated with STPs’ performance assessment, covering the period of 1996-2016 and focusing on the dimensions/variables and methods that have been considered in previous works. Then, as a core part of this paper, we present the measurement framework itself describing the building blocks it is composed. Aiming to demonstrate the applicability of this model in the context of different science and technology parks in Brazil, an empirical study, focusing on the planning phase of the model, was carried out during 2016 with 26 participants of the 1st Course for Managers of Parks and Environments of Innovation, offered by the Brazilian Association of Science Parks and Business Incubators (Anprotec). The main contributions of the research are a flexible model for measuring and evaluating the performance of technological parks and sets of indicators and metrics associated with different types of parks.

1. Introduction
Science and Technology Parks (STPs) play a crucial role in creating an eco-system to promote innovation, new businesses at the local level, transfer of technologies, cooperation with the industry, impacting the development of knowledge economy. However, STPs’ performance is a particularly problematical measure given the different objectives of the various types of science parks and incubators. There is a need to consider the interaction between objectives and the nature of performance. Additionally, there is a need to undertake further explication on the nature of governance and incentives for science parks and incubators [1].

In fact, a STP model can be considered a complex interaction of multiple factors of value, which enhance the park’s capacity to achieve their goals and objectives. The main factors include governance and organization; knowledge creation, due to close links to universities, research institutes, public and private firms; value added services; attractive environment for tenant companies; creation of start-ups, spin-offs
from universities or independent inventors, or also from resident companies; territorial influence in regional
development public policies; and networking [2; 3; 4].

These aspects reinforce the need for a structural contingency perspective that associates the different
types of STPs with diverse institutional circumstances and roles [5]. Thus, we argue that a conceptual model
which generates measurement frameworks customized to groups of STPs – with common goals and
characteristics – should be in best interest of managers and policy makers. The previous discussions lead to
the following central research question, which will guide the whole development of an empirical study
covering 26 STPs in Brazil:

“How to measure the performance of Science and Technology Parks (STPs), considering their business
models and value propositions, objectives and goals, development stage, stakeholders’ commitment, and
respective governance structures?”

As an attempt to meet this challenge, this paper proposes a multidimensional measurement framework
for monitoring and evaluating (ME) the performance of Science and Technology Parks’ similar groups,
instead of having a generic system.

2. Theoretical background
A systematic literature search was performed on peer-reviewed articles that were published between
January 1996 and July 2016. Table 1 summarizes the measurement models and systems reviewed,
highlighting the methods and the analytical grids adopted in these previous works [6; 7; 8; 9; 10; 11].

| Authors                  | Methodological approach | Evaluation method                                                                 | Dimensions/ Variables                                                                 |
|--------------------------|-------------------------|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Guy (1996)               | Ex-ante, mid-term, ex-post. | Case study; Definition of an operational agenda for performance improvement. | Resources; inputs; structure variables; process variables; output variables; and impact variables characterizing the effect outputs have on the broader environment. |
| Hogan (1996)             | Ex-ante, mid-term, ex-post. | Written survey and face-to-face interviews. Statistical analysis of data. KSIs metrics. | Dimensions: inputs; structures; processes; outputs; impacts. Set of 35 indicators considering key success indicators (KSIs). |
| Staton (1996)            | Ex-ante, mid-term, ex-post. | Goal oriented planning including the logic model of performance assessment.        | Set of input, output, and impact indicators.                                          |
| UKSPA/Angle Technology (2003) | Ex-ante, mid-term, ex-post. | Survey and statistical analysis of data. Indicators' metrics.                     | Economic performance of tenant firms. Innovation and technology commercialization performance of their tenant firms. |
| Bigliardi et al. (2006)  | Ex-ante, mid-term, ex-post. | Case study. Indicator metrics.                                                    | Alignment with STP mission; major stakeholders’ commitment; regional economic conditions; legal forms; nature of the scientific competence base available within research centers; and STP’s life-cycle stages. |
| Monck & Peters (2009)    | Ex-ante, mid-term, ex-post. | Survey and statistical analysis of data. Indicators' metrics.                     | Two levels of impact evaluation: (i) direct effects; (ii) indirect and strategic added value (SAV) effects. (i) inputs; activities; gross outputs; outcomes; impacts; (ii) gross outputs; outcomes; impacts. |
| Authors | Year | Methodology | Key Points |
|---------|------|-------------|------------|
| Monck & Peters (2009) | Ex-ante, mid-term, ex-post | Survey and statistical analysis of data. Indicators’ metrics. | Two levels of impact evaluation: (i) direct effects; (ii) indirect and strategic added value (SAV) effects. (i) inputs; activities; gross outputs; outcomes; impacts; (ii) gross outputs; outcomes; impacts. |
| Dabrowska (2011) | Balanced Scorecard | KPIs’ metrics associated to BSC dimensions. | Model for 3G STPs comprising five dimensions: commercial; shareholder’s perspective; owner’s perspective; brand and reputation; and internal business processes. |
| Nosratabadi, Pourdarab & Abbasian (2011) | Ex-ante, mid-term, ex-post | Survey and combined multi-criteria decision methods with fuzzy logic. | Constraints; Degree of integration with national or global markets; professional qualifications; managerial capabilities; stakeholder’s interests; size; technological capabilities; maturity of the business; venture capital. |
| Hemati & Mardami (2012) | Balanced Scorecard | KPIs’ metrics associated to BSC dimensions. | Four BSC perspectives: finance, customer, internal process and employee learning and growth. |
| Andreeva (2013) | Balanced Scorecard | KPIs’ metrics associated to BSC dimensions. | Four BSC perspectives: finance, customer, internal process and employee learning and growth. Indicators are associated with the above dimensions, considering two roles of a given STP: (i) as the center of an innovative cluster; and (ii) as a commercial organization. |
| Wang et al. (2014) | Balanced Scorecard | Case study. KPIs’ metrics associated to BSC dimensions. | Four BSC perspectives: finance, customers, internal processes and organizational learning and growth. |
| Kbar & Ally (2015) | Ex-ante, mid-term, ex-post | Survey and combined multi-criteria decision methods. Case study for validation. | Alignment with the 4th generation STPs. Dimensions: R&D; business; management; and infrastructure. The optimum performance value of STPs can be estimated. |
| CMI (2015) | Business model generation (BMG) | Participative workshop. KPIs’ metrics associated to BMG blocks. | The BMG is a strategic management that is a build-up of nine blocks: customer segments, customer relationships, key partners, key resources, key activities, channels, revenue stream, cost structure, and value proposition. |
| Ferrara, Lamperti & Mavilia (2016) | Ex-ante, mid-term, ex-post | Survey and Choquet integral based Multi-Attribute Value Theory to elicit stakeholders’ preferences on different dimensions of STPs’ performances. | The index aggregates eight indicators associated with two dimensions: (i) innovation; and (ii) entrepreneurship. For innovation the indicators refer to research centers; patents; scientific network; projects. And for the second dimension: growth; employees; entropy; and geoconsistency. |

Sources: [6; 7; 8; 9; 10; 11].

As can be observed in table 1, several practitioners and academicians and have made significant efforts to overcome the challenge to measure and assess the performance of STPs, by using different methodological approaches, but with emphasis on surveys and Balanced Scorecard methodologies, with the support of multiple criteria decision-making (MCDM) methods. In fact, STPs have specific goals and objectives, according to their missions, and can be in different stages of development. Besides, their activities can impact multiple stakeholders – from internal and external researchers to local government agencies, entrepreneurs, firms, and universities.
3. Methodology
The research methodology comprised: (i) literature and documental review on central themes and subthemes from the perspective of measuring the performance of groups of STPs, considering their business models, objectives and goals, maturity levels, and stakeholder’s commitment; legal and governance structures; (ii) preliminary conceptual framework as a basis for the development of an empirical study in Brazil; (iii) development of this empirical study, with participation of representatives of 26 Brazilian STPs; (iv) discussion from the empirical study and formulation of recommendations for diffusing the model among other STPs around the world.

4. Results
The methods and analytical grids identified during the literature review on models for measuring the performance of STPs embodied the basis for designing a multidimensional framework for monitoring and evaluating the performance of STPs’ similar groups, considering their business models and value propositions, objectives and goals, development stage, stakeholder’s commitment, and legal and governance structures.

In STPs’ context this type of ME system allows managers to modify and adjust both the theory of change [12] and the implementation processes to the achievement of desired objectives and outcomes. That was the central idea of the empirical study involving 26 Brazilian STPs, which participated in an Executive Program for STP Managers sponsored by the Anprotec.

The process flow diagram of the model in three phases is presented in Figure 1.

Figure 1: Proposed model for measuring and evaluating STPs’ performance

The multidimensional model encompasses ten main blocks: (i) analysis of the contextual conditions of the focused STP; (ii) analysis of its stakeholders’ commitment; (iii) analysis of its legal structure and governance; (iv) design of the STP’s business model (Canvas); (v) classification of the STP in function of its development stage; (vi) classification of the STP according to a chosen STP’s typology; (vii) defining evaluation dimensions and methods for STPs groups; (viii) selecting key indicators for STP groups; (ix)
building performance baselines on key indicators; and (x) establishing goals, initiatives, and action plans for the focused STP. Due to space limitations, we will not be able to give a detailed description of each block. Nevertheless, the whole model is already published in a MSc. dissertation, on which this article was based [13].

By way of illustration, we present in table 2 a subset of indicators associated to one of the strategic objectives of the Technology Park of the Lutheran University of Brazil (Ulbratech), located in Canoas, Rio Grande do Sul, Brazil. The general manager of this STP participated in the Executive Program for STP Managers sponsored by the Anprotec and Ulbratech was one of five chosen STPs for the multi-case study developed during this Program.

Table 2: Proposition of indicators and metrics for monitoring and evaluating the performance of the Ulbratech: short term (2 years)

| Objective hierarchy  | Objectives                                                                 | Goals                                                                 | Indicators                                                                 | Metrics                                                                 |
|----------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------|----------------------------------------------------------------------------|-------------------|
| Strategic Objective  | 1. To provide a favorable environment for Lutheran University (Ulbra) and resident companies of Ulbratech | Innovation involving cooperation between the Brazilian                  | Area of coworking spaces for collaborative activities and business incubation | Area of coworking spaces (m²)                                      |
|                      | 1.1. To deploy creative and collaborative environments to stimulate entrepreneurship and innovation | business incubation implemented (1 year).                           | Occupancy rate of coworking spaces (%)                                      | Degree of satisfaction of the users of the coworking spaces (Likert scale) |
| Short-term objectives (2 years) | 1.1a. Coworking spaces for collaborative activities and business incubation implemented (1 year). | Area of coworking spaces for collaborative activities and business incubation | Growth rate of new jointly R&D and business projects                        | Number of new jointly R&D projects / period. |
|                      | 1.1b. Generation of new jointly R&D projects and new businesses (2 years). | Workshops on strategic issues for Ulbratech residents                  | Number of pre-incubation candidates / period.                                | Number of new jointly R&D projects / period. |
|                      | 1.1c. Quarterly workshops on business modeling, intellectual property and technology transfer and other strategic issues | Workshops on strategic issues for Ulbratech residents                  | Number of workshops held per year / number of planned workshops              | Number of workshops held per year / number of planned workshops |
|                      | 1.2. To revitalize common areas within the area of Ulbratech               | Index of revitalization of common areas                               | Revitalized areas/period (m²)                                               | Degree of satisfaction of the users of the coworking spaces (Likert scale) |
|                      | 1.2a. Revitalized common areas for creating new coworking spaces (2 years) | Visual communication and signaling of Ulbratech’s external and internal areas concluded (1 year) | Occupancy rate of coworking spaces (%)                                      | Degree of accomplishment of the projects of visual communication and signaling of Ulbratech’s external and internal areas |
|                      | 1.3. To improve visual communication of Ulbratech’s external and internal areas | Ulbratech Alive!                                                      | Number of cultural opening events held / period.                            | Degree of satisfaction of participants/event (Likert scale). |
|                      | 1.4a. Monthly cultural opening events held in Ulbratech’s Central Building | Ulbratech Alive!                                                      | Number of cultural opening events held / period.                            | Number of participants/cultural opening event. |

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Due to space limitations, we will not be able to present the Ulbratech’s objectives, goals, indicators, and metrics for medium- and long-term (5 years). The Ulbratech’s complete table, as well as similar tables of performance indicators and metrics related to the other four STPs are already published in [13].

5. Conclusion

In this paper, an attempt was made to present a flexible and adaptive model, according to one of the STPs’ taxonomies reported in the literature [14]. The applicability of this model for monitoring and evaluating the performance of similar groups of STPs, could be demonstrated through an empirical study involving 26 Brazilian STPs’ managers, which participated in an Executive Program for STP Managers sponsored by the Anprotec. The proposed model distinguishes from the existing systems reported in the literature, because it will allow decision-makers to measure and compare the performance of STPs belonging to the same group and then prioritize actions which will add the most value to their business and programs, individually. It considers the common characteristics of these STPs’ groups concerning business models and value propositions, strategic objectives and goals, development stage, stakeholder’s commitment, and legal and governance structures.

6. References

[1] Phan P H, Siegel D S and Wright M 2005 Science parks and incubators: observations, synthesis, and future research. Journal of Business Venturing 20 165–182
[2] Allen J 2007 Third Generation Science Parks. Manchester Science Parks Ltd
[3] Wasim M U 2014 Factors for science park planning. WTR 3 97–108
[4] Nauwelaers C, Kleibrink, A and Stancova, K 2014 The Role of Science Parks in Smart Specialisation Strategies. Report EUR 26701. European Commission Joint Research Centre Institute for Prospective Technological Studies. Seville, Spain
[5] Donaldson L 2001. The Contingency Theory of Organizations. Thousand Oaks, CA: Sage Publications
[6] Dabrowska J 2011 Measuring the success of science parks: performance monitoring and evaluation. In: Proceedings of XXVIII IASP Conference on Science and Technology Parks, Kopenhagen, Denmark, 2011
[7] Hemati M, Mardami M 2012 Designing a performance appraisal system based on balanced scorecard for improving productivity: case study in Semnan Technology and Science Park. Management Science Letters, 2 1619–1630
[8] Andreevna M A 2013 The balanced scorecard for estimation of science and technology parks. World Applied Sciences Journal 25(5) 720–727
[9] Wang G, Wan J and Zhao L. 2014. Strategy map for Chinese science parks with KPIs of BSC Journal of Science and Technology Policy Management 5 (2): 82 – 105
[10] Ferrara M, Lamperti F and Mavilia R 2016. Looking for best performers: a pilot study towards the evaluation of science parks. Scientometrics 106 (2) 717–750
[11] Albahari A, Catalano G and Landoni P 2013 Evaluation of national science park systems: a theoretical framework and its application to the Italian and Spanish systems Technology Analysis & Strategic Management 25(5) 599-614
[12] Kusek J Z and Rist R C 2004. Ten steps to a results-based monitoring and evaluation system. World Bank, Washington, DC.
[13] Lyra, R M 2017 Monitoring and evaluating the performance of science and technology parks: proposal of a conceptual adaptive model. Rio de Janeiro, 171 p. MSc. Dissertation – Postgraduate Programme in Metrology. Pontifical Catholic University of Rio de Janeiro
[14] Associação Nacional de Entidades Promotoras de Empreendimentos Inovadores. Anprotec 2008 Parques Tecnológicos no Brasil: Estudos, Análise e Proposições. Anprotec, Brasília, Brazil.