CONSTRUCTIVIST MODEL TO SUPPORT THE MANAGEMENT OF EXTERNAL INNOVATION IN THE PORT SECTOR

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ACKNOWLEDGMENTS

To the Navegantes Port Terminal, particularly to the team of professionals from the Integrated Management System (IMS), and to the Brazilian government agency CNPq for the funding.

Keywords

Performance evaluation; innovation management; management support; ports.

Abstract

The maritime transportation mode is the primary means for global goods movement, transforming ports into pivotal logistics centers in the operationalization of the supply chain. Due to its significance, terminals are constantly pressured to seek improvements in operational efficiency, relying on innovations as a necessary alternative to achieve their objectives. In this research, a case study was conducted at the private port in the city of Navegantes, located in the state of Santa Catarina, Brazil, being one of the national leading in container handling volume. The research aims to develop a performance evaluation model to support the management of external innovation in the port. The intervention tool used was the Multicriteria Decision Aiding-Constructivist (MCDA-C) methodology, which, through primary and secondary data, enables the construction of a customized model according to the decision-maker's preferences and organizational context. The results presented by the model highlighted opportunities for improvement in the port's relationship with other external actors, as there is no formal and organized procedure for seeking external cooperation for the development of innovative solutions. At the same time, the management understands the importance of innovations for the sustainability of the company, investing, albeit in a decentralized manner, in improvements of both internal and external origin. The research contributes to the growth of the literature on the subject, in addition to offering practical contributions to the port of Navegantes in the form of a model capable of supporting innovation management, generating knowledge, highlighting critical points, and outlining improvement plans.

1 INTRODUCTION

Maritime transport, as the principal means of moving goods on a global scale, plays a vital role in the economic development of countries. Within this context, the efficiency of the port system becomes crucial to secure competitiveness and progress, taking a central role in the value logistics chain by integrating various stakeholders, such as industrial groups, transport operators, and shipowners [1]. Nonetheless, achieving satisfactory levels of efficiency in maritime modes is not a straightforward task, given the complexity and scale at which its processes are carried out [2]. In parallel, globalisation and economic advancement drive a marked increase in trade flow between nations, placing pressure on port terminals to consistently challenge the boundaries of their operational excellence [3]. The pursuit of enhancing the performance of organisations, including the port sector, acknowledges the importance of developing and adopting innovative solutions. Within the maritime industry, technological and environmental innovations have been taking on leading roles and steering the trend of projects developed, always aiming to tackle challenges and optimise operation at the terminals [4].

Nevertheless, the transport sector, in general, is often characterised by a more conservative approach compared to other economic segments, showing a relative slowness in the adoption of innovations [5]. The complexity and uncertainty inherent to the process of development, adoption, and dissemination of innovations present significant challenges for the success of these initiatives. To effectively enable an innovation, it is essential to gather precise and relevant information that can evaluate its potential performance and risk, thus facilitating its implementation process [6]. In the Brazilian port scenario, in 2022, 65% of cargo handled passed through private terminals, which differ from public ports in that they have greater decision-making freedom, precisely because they assume all the risk of the investment [7]. Thus, private ports demonstrate a greater interest in developing their innovation management, recognizing both its necessity and competitive advantage.

In the literature, Performance Evaluation (PE) is depicted as a process that enables the quantification of an activity's efficiency and effectiveness, thereby contributing to the enhancement of its performance [8]. The actualisation of PE occurs through the development, usage, implementation, and revision of the Performance Evaluation System (PES). This System consists of a suite of metrics designed to evaluate the performance of processes, activities, actions, or specific alternatives. The information generated plays the role of providing a foundation for and supporting decision-making aimed at the improvement of organisational performance [9].

In this context, the adoption and development of innovations in the port sector emerge as a crucial alternative to ensure greater efficiency, competitive advantage, and meeting market demands. However, there are still gaps that present challenges to the success of innovative initiatives, particularly regarding the recognition of benefits, valuation of innovations, performance measurement methods, and innovation management strategies [10]. Given this scenario, an opportunity arises for the present study, which aims to answer the following question: How can the performance of innovation management in the port sector be evaluated?

To answer the research question, a multicriteria-constructivist performance evaluation model was developed to support innovation management, with a focus on external innovation, in a case study conducted at the Port Terminal of Navegantes, located in the state of Santa Catarina, Southern Brazil. The intervention tool used to construct the model was the Multicriteria Decision Aiding-Constructivist (MCDA-C) methodology [11]. In this scenario, the application of the Multicriteria methodology proves to be appropriate for the performance evaluation of innovation in ports as this context is characterized as complex, conflicting, and uncertain [12]. The complexity arises from the broad range of multiple criteria involved in evaluating an innovative idea or project, often not fully clear to all decision-makers. The situation becomes conflicting due to the participation of various stakeholders with goals and values that are not always aligned. The uncertainty manifests itself through the lack of comprehensive knowledge about the quantitative and qualitative characteristics related to the decision-making about innovation [13]. Finally, each port has its own reality and characteristics, a factor that complicates the application of generalist instruments and supports the use of a constructivist approach to assess its performance [14].

2 PERFORMANCE EVALUATION OF INNOVATION MANAGEMENT IN PORTS

Innovation can be understood as technological, organizational, product (or service), or process change that reduces costs or improves the quality of the final product offered to customers [5]. In the port context, innovative projects have been developed based on the trend of smart ports and green ports, resulting in solutions with a strong technological influence and environmental concern. The concept of smart ports aligns with the smart cities movement, promoting principles related to freedom of access to information, efficient communication, automation, digitization, and collaboration [15]. On the other hand, green ports focus on developing innovative solutions aimed at improving sustainability and environmental care within the terminal and its adjacent processes [16]. Although these are two distinct movements, their processes can be integrated and harmonized, as technological innovations, although primarily aimed at cost reduction and increased operational efficiency, create opportunities for sustainable initiatives to be developed [17].

In addition to the development of innovations in the port sector, several studies have been conducted to evaluate the performance of these initiatives. Some examples include the assessment of the diffusion of dry ports [18], the performance evaluation of the use of 'physical internet' in ports [19], the performance evaluation of radical innovation projects [20], and the performance evaluation of environmental innovations [21]. However, these studies tend to focus on evaluating the results of these innovations in isolation, using specific performance measures that do not encompass a holistic perspective, nor consider the potential benefits of using an integrated system focused on innovation management.

Despite the lack of studies integrating innovation management, it is possible to identify collaboration among actors involved in the port innovation process as a unanimous trend in the literature [17]. Due to the nature of port activities, any changes in the sector are accompanied by significant financial investments and involvement of other stakeholders such as regulatory bodies, shipping companies, and carriers, requiring a cautious evaluation of potential risks and benefits [22]. Thus, collaboration among the actors involved is a trend that seeks to combine resources (human, financial, time, and information) while also sharing the associated risks [23]. All these elements interact to form a regional innovation system, which can be understood as a mechanism that integrates new knowledge to create opportunities capable of transforming the economy of a region linked to a port [24]. In regions that share similar characteristics, the port plays the role of mediator among various actors and can take on an active role in the development of innovations, going beyond mere management of goods flow. This approach can be an alternative to avoid stagnation and confinement to a pre-existing technological trajectory. Regional systems have the potential to stimulate knowledge exchange and collaboration among participants, resulting in external innovations. However, there is a risk of developing a technological trajectory that hinders reinvention and updating of that region [25].

3 METHODOLOGY

The Multicriteria Decision Aiding-Constructivist (MCDA-C) methodology, in its constructivist approach, stands out for supporting the decision-making process through the generation of knowledge among the participants (decision-makers) about the analysed context. It structures and evaluates the aspects considered relevant to the decision-makers, promoting the dissemination of the generated learning [26]. Under this perspective, the decision-making context is not analysed directly as it is presented, but rather by the way the decision-maker perceives it [27]. Conversely, the traditional MCDA methodology adopts a rationalistic logic, seeking to identify an optimal solution among predefined alternatives [28]. Figure 1 indicates the phases of the MCDA-C methodology.

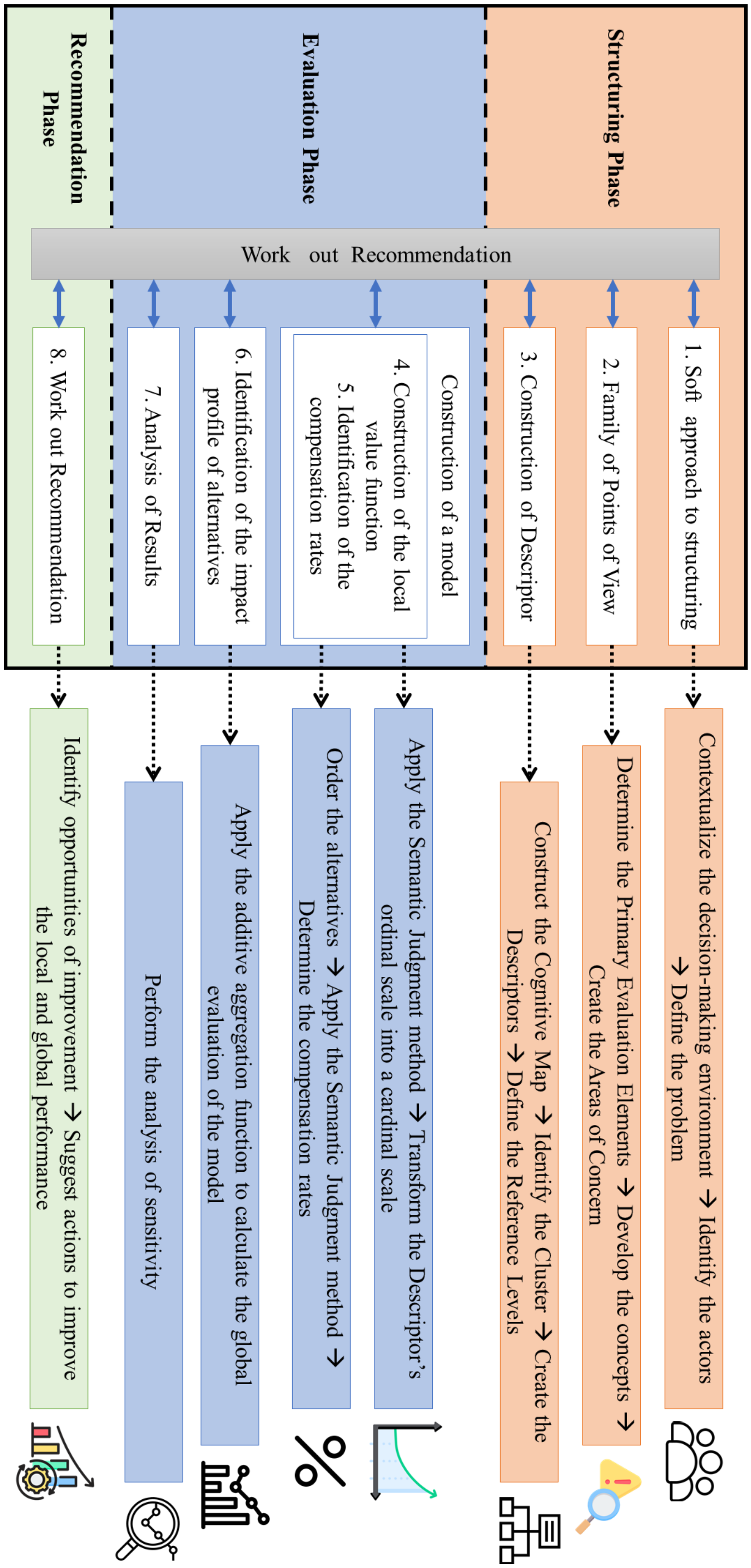


Fig. 1 Phases of the MCDA-C methodology (Source: [12, p. 81]).

The Structuring phase aims to establish a communication channel among the various stakeholders involved, identifying, organizing, and measuring aspects considered relevant by the decision-maker [13]. The entire model construction process occurs through the collection and analysis of primary data obtained from semi-structured interviews and direct observation, as well as secondary data sourced from literature or reports/documents provided by the organization under study. By recognizing the general characteristics of the decision-making context and the actors directly or indirectly involved, the methodology proceeds to identify the problem to be investigated and initiates the process of identifying the Primary Evaluation Elements (PEEs) that the decision-maker deems essential for measuring performance [27]. This information is integrated into the model during the analysis of collected data, further refined, grouped, and organized into cognitive maps. These maps depict the generated concepts in a logical, hierarchical, and end-structure of influence [28]. This process is repeated until clusters with the same concern can be defined, where each of them must be capable of measurement, being called Elementary Points of View (EPVs). Subsequently, an ordinal scale is constructed to measure these PVEs, along with their reference levels serving as parameters for assessing good and neutral performance, also known as descriptors [13].

The evaluation phase enhances the decision maker's comprehension by converting descriptors from ordinal scales to cardinal scales and determining compensation rates that represent their local and global preferences [31]. To convert the ordinal scale into a cardinal scale, the decision maker needs to indicate the difference in attractiveness between the reference levels. This information is utilized by the MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) software method, developed by Bana e Costa and Vansnick [32], to formulate cardinal scales, known as value functions, which adhere to the decision maker's preferences expressed in the form of semantic judgments. To consolidate the generated knowledge, it is essential for local scales to be integrable into a global evaluation. Hence, compensation rates signify the contribution of each EPV, according to the decision maker's perspective, when transitioning from the Neutral reference level to the Good level [13]. Similarly to the process for determining the value function, it is also possible to define compensation rates, enabling the calculation of the model's global performance. The sensitivity analysis of the results is conducted at the conclusion of this phase by varying the values of the compensation rates and assessing the impact, thereby ensuring the robustness and reliability of the outcomes [12].

The Recommendations phase aims to build knowledge about potential performance improvements evidenced by the model and their effects on the decision-maker's strategic objectives [28]. The construction of descriptors enables the identification, based on the status quo and the interaction between the decision-maker and the facilitator, of each one's contribution to enhancing performance in relation to the established goals. Additionally, this approach assists in creating strategies and an action plan aimed at improving performance. This phase does not have a prescriptive character; its objective is to support construction and understand the consequences of the actions taken [13].

To facilitate comprehension, the phases of the methodology will be presented in detail as the model construction unfolds in the results section.

3.1 Case Study

For this research, a case study was conducted at Portonave, a port terminal in the city of Navegantes, located in the state of Santa Catarina in southern Brazil. Portonave is a privately-owned terminal dedicated to container handling, operating since October 2007. With a total area of 400,000 m^2, capacity to store up to 30,000 TEUs (twenty-foot equivalent units) and employing over 1,100 workers, in 2022, the company was the second busiest terminal in Brazil in terms of container movement, reaching a mark of 1.1 million TEUs, and was crowned as the most efficient container terminal in the country, achieving a throughput of 88.5 units per hour [29]. Given its significant role within the national port sector, the Navegantes terminal was selected as the focal point of this research.

Portonave is a company that prioritises operational excellence, demonstrating attention to good practices and emerging new technologies in the market. Innovations are incorporated in various areas of the organisation, with a special focus on the Operations, Maintenance, and Information Technology departments. Some notable evidence of pioneering and innovation include: (i) Electrification of Rubber Tired Gantries (RTGs): the company has adopted the electrification of these equipment, which previously operated on diesel. These machines play a crucial role in the movement of containers within the yard, between stacks and trucks; (ii) Acquisition of the first Eco Reach Stacker in Latin America: the Port has invested in acquiring the Eco Reach Stacker, an environmentally-friendly lift truck that achieves a significant reduction of up to 40% in greenhouse gas emissions; and (iii) ISO 37001 Certification for Anti-Bribery Management: standing out as the first Brazilian container port to receive this certification, Portonave demonstrates its commitment to ethical and transparent practices by implementing an Anti-Bribery Management System in accordance with international standards. Despite the positive actions showcased, the company recognises the significance and necessity of innovation, which requires a coordinated innovation management system. Presently, improvements and innovations are carried out in a decentralised manner, driven by a problem or a need for enhancement and led by the managers of each department.

4 RESULTS

4.1 Structuring Phase

The first step of the Structuring Phase is dedicated to contextualizing the decision-making environment in which the model will be applied. Within this decision-making context, the following 'actors' involved in the process were identified (Figure 2).

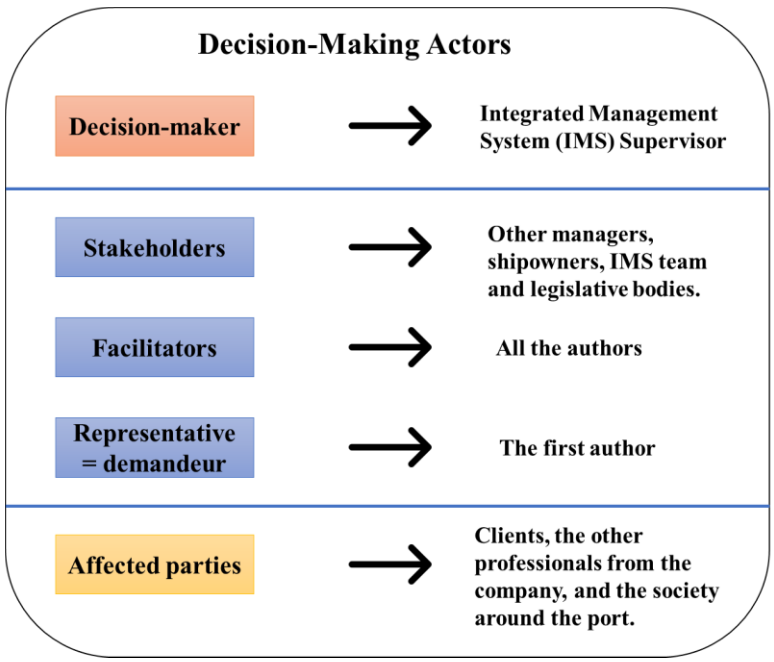


Fig. 2 Actors involved in the decision-making process (Source: Authors).

The decision-maker is the actor responsible for making decisions, being the one whose preferences and values are considered in constructing the model. For the construction of the current model, the Integrated Management System (IMS) Supervisor was designated as the decision-maker by the company, since this professional is responsible for developing the innovation management area within the company. At Portonave, besides overseeing innovation management, the IMS department is responsible for ensuring the quality, standardization, and continuous improvement of the conducted activities. On the other hand, the stakeholders are those who can influence the decision-maker's perception; in this case, they are the other managers, shipowners, IMS team and legislative bodies.

In this particular study, the first author assumed the roles of facilitator and representative. As a facilitator, his function is to provide support during the model construction process, as he has knowledge of the methodological procedures; he also functions as a representative, or 'demandeur,' being the one delegated by the decision-maker to represent him in the decision support process [30]. Here, he also articulates his opinion about the elements of the evaluate model. This situation was possible because the researcher had the opportunity to be actively working within the company for one year and three months, observing and assimilating the decisional context that involves innovation management. The other authors acted as facilitators, as they are specialists in the MCDA-C methodology.

Finally, the affected parties are those impacted by the model's construction in a passive manner, potentially participating indirectly in the decision-making process. In this instance, the clients, the other professionals from the company, and the society around the port are considered affected parties, being the main ones impacted by the model's operationalisation.

Following the iterative process of semi-structured interviews with the decision-maker and with the support of observations made by the facilitators, the following label was defined to represent the decision-maker's concern regarding the problem studied: Development of a Model for Innovation Management at the Port of Navegantes.

With the label established, the model construction process progressed through seven rounds of interviews exclusive with the decision-maker. Data collection was conducted mainly through semi-structured interviews, but also by direct observations, contact with the IMS team, experience with daily routines, and secondary data, such as minutes, reports, manuals, and other documents provided by the company. This combined approach allowed for a more in-depth understanding of the decision-maker's perceptions, preferences, and expressions, capturing the nuances of the decision-making process. The process began with a request for the decision-maker to freely express their perceptions of the problem context, exploring the theme until the decision-maker felt that all aspects they considered important in the evaluation of Portonave's innovation management had been articulated. Upon completion of this process, the complete recording of the interview was transcribed and analysed to identify the decision-maker's main concerns that he expressed during the conversation, these concerns are named Primary Evaluation Elements (PEEs). PEEs correspond to characteristics or properties of the context that the decision-maker believes represent their values in that specific environment. The in-depth analysis of the PEEs provides the foundation for the model's construction. Table 1 presents a sample of the 36 PEEs identified.

PEEs	PEEs
Suggestion Programme	Innovation Committee
Improvement Card	Innovation Events
Innovation Culture	Benchmarking and Networking
Professional Qualification	Association and Partnerships

Table 1 Sample of the PEEs identified (Source: Authors).

Based on the Primary Evaluation Elements, the MCDA-C methodology suggests expanding the understanding of these elements by seeking to identify the direction of preference expressed in each [27]. The result of this enhancement of PEEs is termed Concept or Action-oriented concept [13]. This action-oriented concept is fundamentally based on the decision-maker's preference [13] and is composed of two poles: the current pole; and the opposite psychological pole. The current pole reflects the objective, or the desired goal, directly linked to the original primary element. Meanwhile, the psychological pole reflects the minimum performance level deemed acceptable by the decision-maker, or the level to be avoided [12, 27]. This approach contributes to the construction of a model aligned with the specific context, based on the decision-maker's perspective. Table 2 presents a sample of the generated concepts.

PEEs	Nº Concept	Current pole	(...)	Psychological pole
Suggestion program	**1**	Having a program in place to capture improvement suggestions and ideas with innovative potential.	(...)	Missing the opportunity to leverage an idea that could benefit the company.

Improvement card	**2**	Having an appropriate channel/tool to receive ideas.	(...)	Capturing ideas in a random manner.
Innovation culture	**3**	Developing a culture of continuous improvement and innovation within the company.	(...)	Maintaining a stagnant culture, hindering the development of management.
Professional qualification	**4**	Providing constant training for professionals.	(...)	Neglecting the innovation potential of the professionals.
Innovation committee	**5**	Establishing a committee responsible for managing innovations at the strategic level.	(...)	Developing innovation initiatives in a departmentalized manner.

Table 2 Sample of the constructed concepts (Source: Authors).

In Table 2, the column where appears (...) should be read as 'rather than'. Therefore, for the example of concept number 5, it is preferable to read "Creating a committee responsible for managing innovations at the strategic level" rather than "Developing innovation initiatives in a departmentalized manner."

Analysing the concepts, it was observed that some were related to Internal Innovation, while others were related to External Innovation. Thus, a macro-level segregation was carried out. The concepts classified under Internal Innovation are related to the infrastructure and internal processes of Innovation Management, which do not involve or interact significantly with factors external to the organization. On the other hand, the concepts allocated to the category of External Innovation are linked to processes that seek, interact with, and are influenced by external organizations and factors.

Following that, the concepts addressing the same concern are grouped together, forming the so-called Areas of Concern in each macro separation. When grouping the concepts, it is necessary to identify with the decision-maker, among the concepts, which one represents each of the Areas of Concern, known as the Head Concept. Figure 3 presents the defined areas of concern.

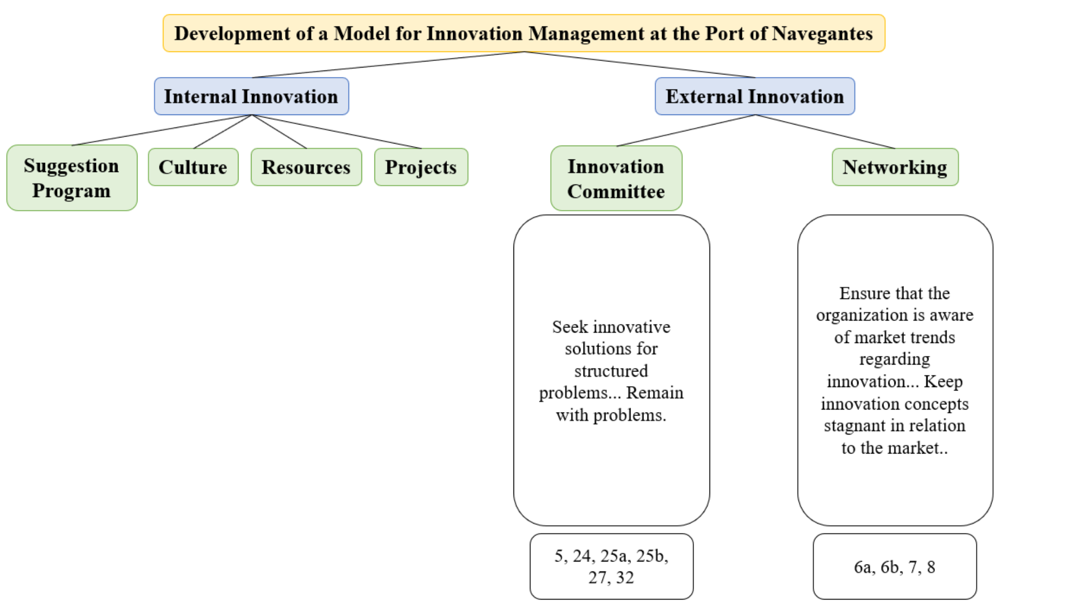


Fig. 3 Areas of Concern (Source:-Authors).

For this research, from this point on, only aspects related to the External Innovation of the model will be addressed. In the External Innovation grouping, two Fundamental Points of View (FPVs) were identified: FPV 5 - Innovation Committee; and FPV 6 - Networking.

The Fundamental Points of View represent the objectives by which the alternatives will be evaluated in the decision-making context, here related to Innovation. However, these objectives are not yet measurable as they are broad, containing several characteristics/properties that can represent them. Thus, it is necessary to unfold them until the characteristic/property that, according to the decision-maker, represents the FPV in this context is identified and according to which the innovation will be evaluated. This characteristic/property is called an Elementary Point of View (EPV), and for it, an ordinal scale is constructed (called a descriptor in the MCDA-C methodology) that informs the possible accepted performances for the action/alternative/statu quo in this EPV.

Thus, based on the concepts of each FPV, a Cognitive Map is constructed. The facilitators organize the concepts logically, highlighting the means and ends relationships, and submit them for the decision-maker's legitimization. If the decision-maker disagrees, the organization should be revised until he legitimizes it. This step is crucial for creating a clear visual representation of the hierarchical relationships between the concepts and their interconnections. The visualization of the Cognitive Map facilitates the understanding of priorities by highlighting the relationships of dependence and influence among the different elements identified in the model construction process. When performing the grouping and connecting process between the concepts, it is common to identify gaps that need to be filled with new concepts.

The Cognitive Map is formed by groups of concepts related to the same line of reasoning that highlight the connection between the means, ends, and the problem label [13]. These groups of concepts are called Clusters. Each of these Clusters is assigned a name that represents the focus of interest for the group, according to the perception and terminology that makes sense to the decision-maker. Figure 4 presents the Cluster of FPV 6 - Networking.

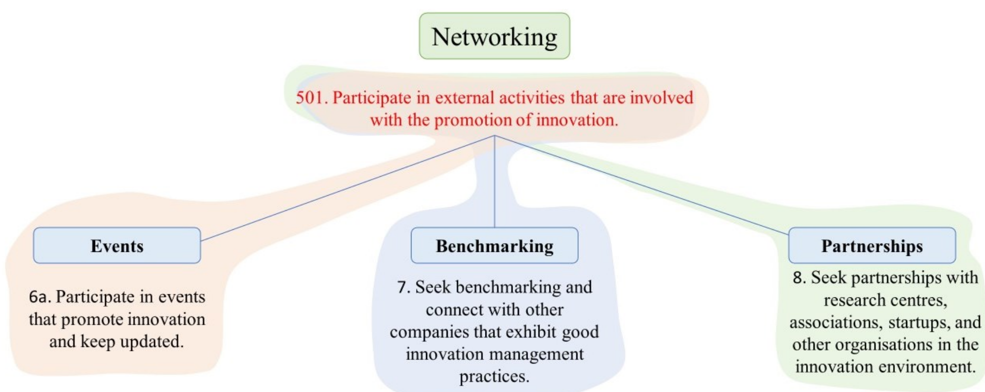


Fig. 4 Cluster of FPV 6 - Networking (Source: Authors).

To simplify the transmission of the information generated by the procedures carried out so far, it can be presented in the form of a Hierarchical Value Structure (HVS), as seen in Figure 5.

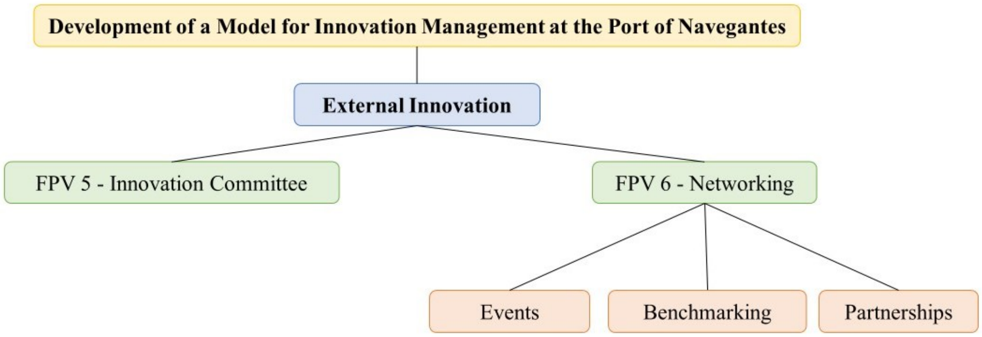


Fig. 5 Hierarchical Value Structure of FPV 6 - Networking (Source: Authors)

For the External Innovation Management of Portonave, six Elementary Point of View were identified: three for FPV 5 and three for FPV 6. The next step is the construction of ordinal scales capable of operationalising the measurement of each of the EPVs, termed descriptors in the MCDA-C methodology.

The descriptor is composed of a set of performance levels ordered according to the decision-maker's preference, which describe the characteristics/properties, according to the defined unit of measure, of the EPV [30], by which an action/alternative/status quo will be evaluated. The definition of the unit of measure and the construction of the ordinal scale, one for each EPV, is a collaborative process between the facilitator and the decision-maker, with the support of all the knowledge generated up to the construction of the Hierarchical Value Structure (HVS).

After constructing the ordinal scales, it is necessary to define their reference levels, called the Good level and the Neutral level. These levels indicate the point from which performance is considered excellent (green range in Figure 6); competitive (yellow range in Figure 6); and compromising (orange range in Figure 6). The Good level informs the decision-maker of the target; the Neutral level indicates the threshold of performance that is still competitive for the decision-maker. Thus, any performance that falls below the Neutral level is considered compromising. Performance levels between Good and Neutral are considered competitive. With the reference levels defined, a descriptor is obtained. Figure 6 presents the descriptors – ordinal scales and their reference levels – for FPV 6.

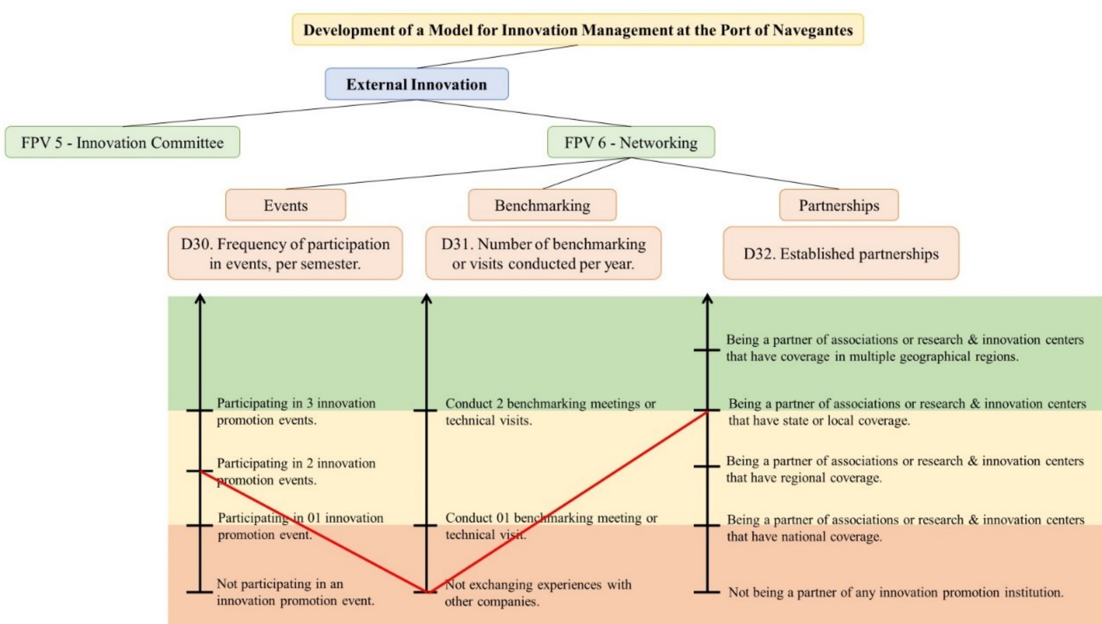


Fig. 6 Descriptors for FPV 6 - Networking and the performance profile of Portonave (Source: Authors).

Once the construction of the descriptors is finished, it is possible to identify the performance profile of an action, or alternative, or, here, the status quo of Portonave's external innovation management. Based on provided secondary data, such as meeting minutes, records, and other files, and the knowledge acquired by the representative, we were able to outline the status quo of FPV 6 - Networking in its three descriptors, depicted by the red line in Figure 6. This way, the Structuring Phase informs what are the necessary and sufficient objectives for the external innovation management of Portonave and what it expects to achieve in each of these objectives through a qualitative model.

4.2 Evaluation Phase

The evaluation phase aims to highlight the 'mathematical value' of this qualitative information; in other words, to translate the qualitative model into a quantitative model. Thus, it begins with the transformation of ordinal scales (qualitative) into cardinal scales (quantitative), constructing a value function for each descriptor of the model.

For the construction of the value functions, the MCDA-C methodology uses the Semantic Judgment method, using verbal descriptions. This method provides a pairwise comparison of the attractiveness difference between two potential actions, in order to establish the value function. The pairwise comparison is done based on the qualitative judgment of the decision-maker, using a semantic ordinal scale, indicating the intensity of attractiveness of one action to another [30]. For the development of this research, the Semantic Judgment method will be made using the Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) method, developed by Bana and Costa and Vansnick [32]. The method uses the semantic judgments of decision-makers to define the value function through Linear Programming models [30].

The MACBETH method involves interaction with the decision-maker, where he is asked to assess the attractiveness difference between potential levels of a descriptor using semantic categories. These categories present seven gradations ranging from 'no difference in attractiveness' to 'the difference in attractiveness is extreme.' Consequently, it is necessary for the decision-maker to communicate their preference judgment for all combinations.

Based on the obtained responses to the decision-maker's perception regarding the attractiveness difference from moving from a higher performance to an immediately lower performance, the MACBETH software proposes a numerical scale that is congruent with the decision-maker's absolute evaluations [32]. MACBETH examines whether there is consistency in the evaluations and, when necessary, identifies possible sources of inconsistency, allowing for the review of the evaluations in question. Figure 7 illustrates the process of constructing the value function for Descriptor 32 - Partnerships.

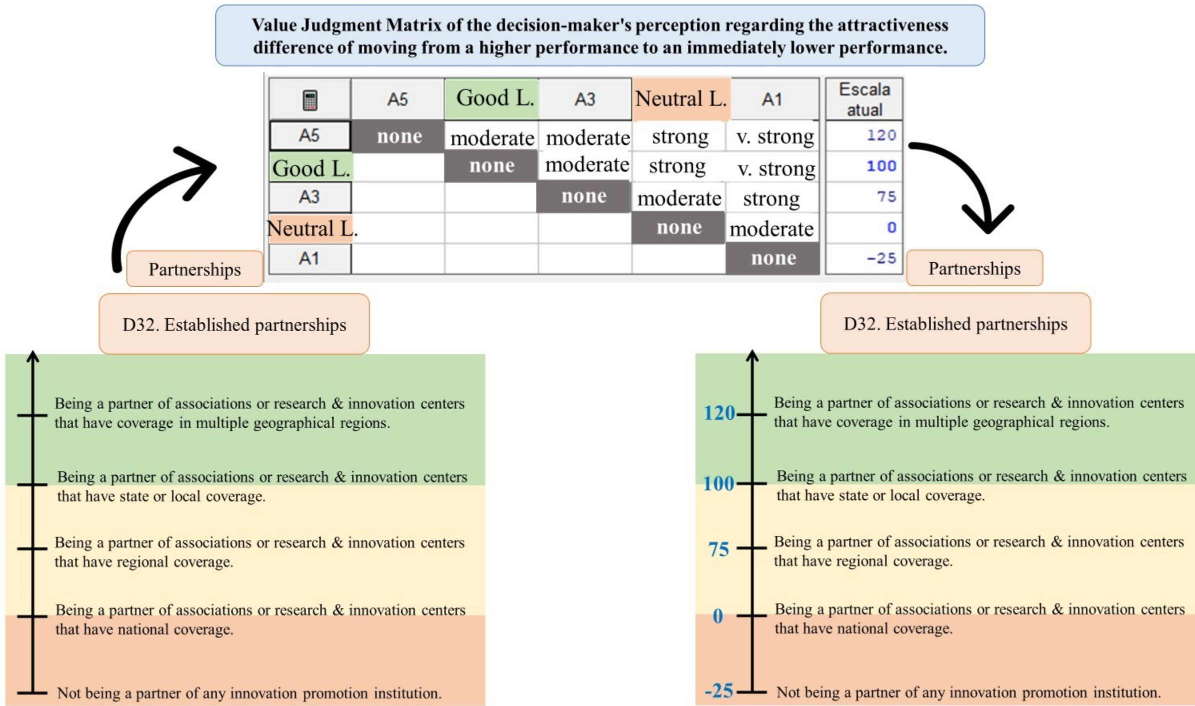


Fig. 7 Construction process of the value function (Source: Authors).

Upon completing the construction of the value functions for all the descriptors, it is possible to perform the local evaluation (in the EPV) of Portonave's status quo. However, for a global assessment to be viable, it is necessary to identify how much each EPV (considering the transition from the Neutral level to the Good level) represents in the FPV, in the area of concern, and in the model. The element that enables this information and integration of local (partial) performances into global performance is the Compensation Rate. The procedure used to determine the compensation rates is similar to that used for the construction of value functions, through pairwise comparison and the Semantic Judgment, with the assistance of the MACBETH method.

The process of constructing compensation rates is carried out for the EPVs at the same hierarchical level as an FPV, starting from the lower levels of the Hierarchical Value Structure, i.e., from the EPVs to the upper levels of the FPVs. Therefore, for each set of EPVs at the same hierarchical level, the decision-maker is questioned about their preference when comparing hypothetical alternatives with different performances. Each alternative has a Good level of performance in only one of the EPVs, and in the others, it has a Neutral level of performance. For this, a fictitious alternative is introduced that has a Neutral level of performance (A0) in all the EPVs [30]. Figure 8 illustrates this process.

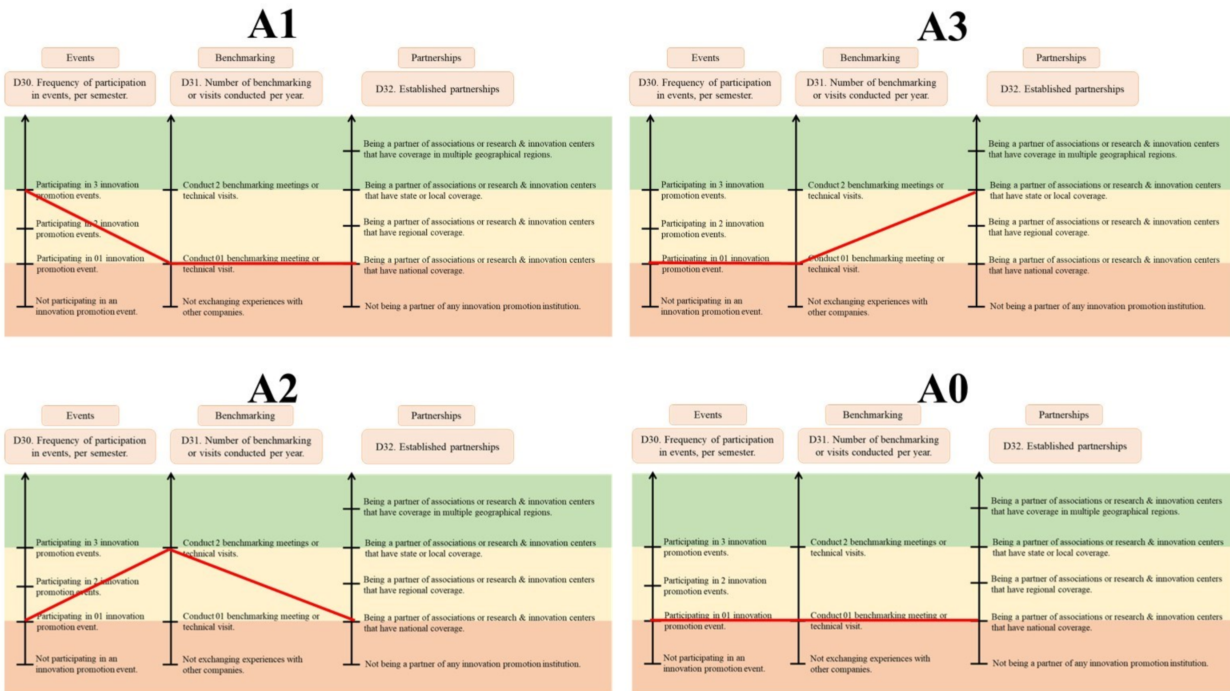


Fig. 8 Hypothetical alternatives with different performances for the construction process of the compensation rates (Source: Authors).

The decision-maker should rank these alternatives. To assist in the ordering of preferences for the Points of View, the Robert's Matrix can be used. This method involves comparing each pair of alternatives, assigning "1" to the preferred alternative, and "0" to the other, as illustrated in Table 3.

	A1	A2	A3	A0	Summation	Ranking Order
A1		1	1	1	3	1º
A2	0		1	1	2	2º
A3	0	0		1	1	3º
A0	0	0	0		0	4º

Table 3 Example of using the Robert's Matrix for ordering alternatives (Source: Authors)

Armed with the ordered alternatives, the process is carried out similarly to that used for the construction of the value functions, using MACBETH. Figure 9 presents the compensation rates for the EPVs of the model. It is worth noting that, upon identifying the compensation rate of the EPV, a criterion is established, according to the MCDA-C methodology.

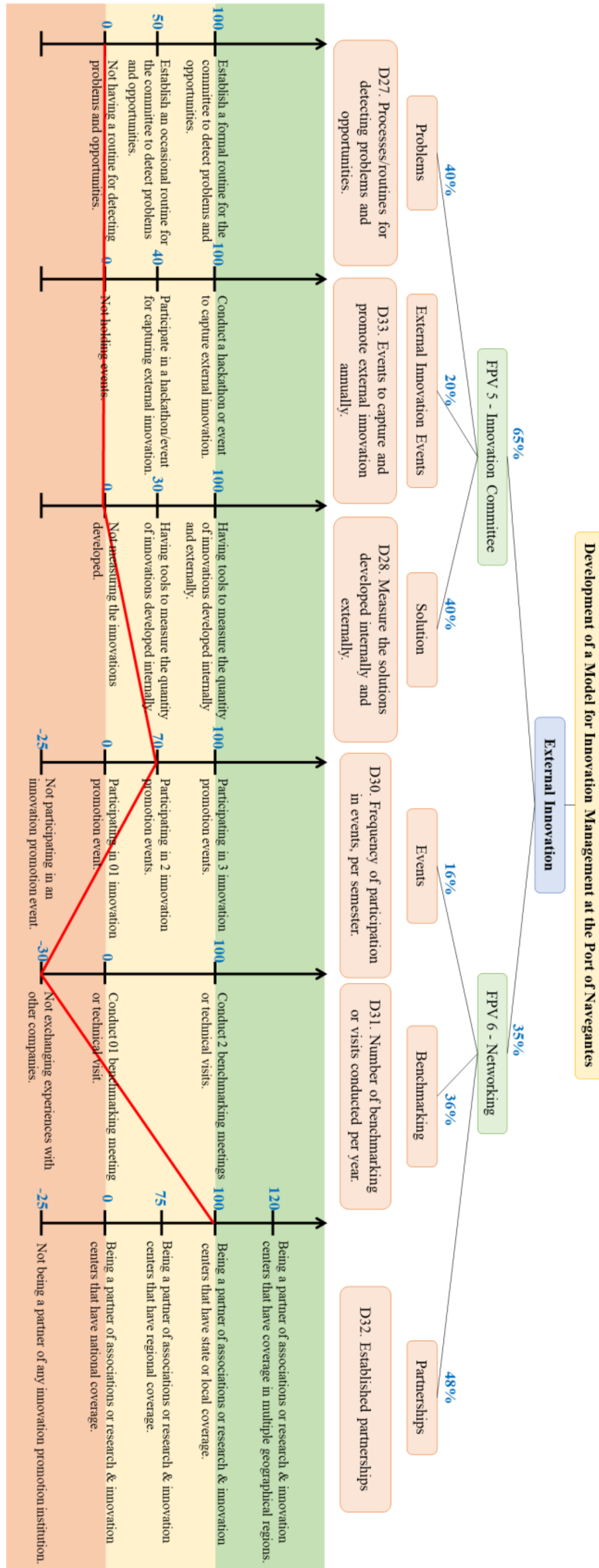


Fig. 9 Compensation rates for the EPVs (Source: Authors).

Having these criteria, it is possible to proceed with the global evaluation of an action/alternative or status quo. The MCDA-C methodology, working in a scenario where a decrease in performance in any of the criteria (EPVs) can be compensated by an increase in other EPVs, adopts the method of Aggregation to a Single Synthesis Criterion for the quantitative model. Therefore, the global evaluation of the model is done through an additive aggregation model, where each FPV must have a defined value function with established preference intervals [12]. The mathematical outcome of the global evaluation is obtained through the following equation:

$$V(a) = \sum_{j=1}^{m} w_j [V_{FPV_j}(a)] \quad (1)$$

Where:

V(*a*) = global value of alternative *a*, where *a* ∈ A;

A = set of all action/alternative/status quo possibilities;

w*j* = compensation rate for criterion *j*;

VFPV*j* (*a*) = partial (local) value of alternative *a* in FPV*j*.

In this way, it is possible to calculate the overall assessment for the External Innovation Management of Navegantes Port Terminal. For this purpose, an additive aggregation function is constructed in the form of a weighted sum based on the compensation rates. Therefore, for FPV 6 – Networking, all the compensation rates of the associated EPVs could be defined. Consequently, the FPV(*a*) performance can be calculated for any alternative *a*. To illustrate, the calculation development follows:

$$V_{FPV6}(a) = 0{,}16 * V_{EPV30}(a) + 0{,}36 * V_{EPV31}(a) + 0{,}48 * V_{EPV32}(a)$$

$$V_{FPV6}(a) = 0{,}16 * 70 + 0{,}36 * (-30) + 0{,}48 * 100$$

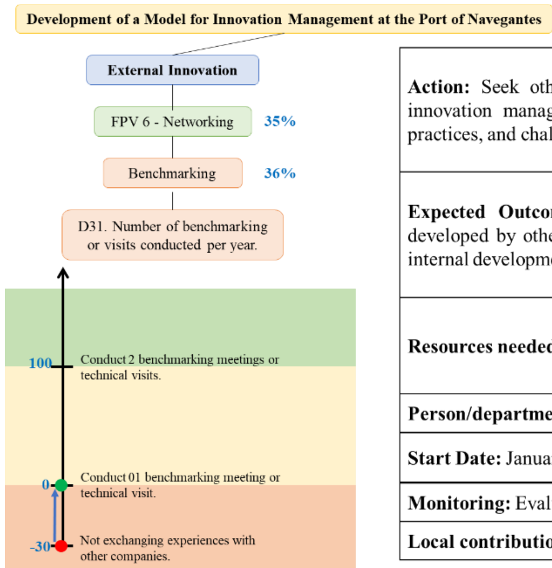
$$\mathbf{V_{FPV6}(a) = 48{,}4}$$

Therefore, the overall performance of Navegantes Terminal, in FPV 6, was 48.4. Applying the same weighted sum system for FPV 5, the overall result obtained was zero. Therefore, by aggregating the results of FPVs 5 and 6, the global value of 16.94 is reached for the performance of innovation management at Navegantes Terminal in the aspect of External Innovation.

To evaluate the robustness of the model and the scores of alternatives, a sensitivity analysis is conducted. Within the MCDA-C methodology, sensitivity testing involves varying the compensation rates of the model between 0 and 1 and observing the resultant impacts on potential action valuations [30]. Consequently, it becomes imperative to adjust all compensation rates within the model to ensure their collective sum totals one. When varying the compensation rates of the model, a variation as expected was noted and legitimized by the decision-maker.

4.3 Recommendations Phase

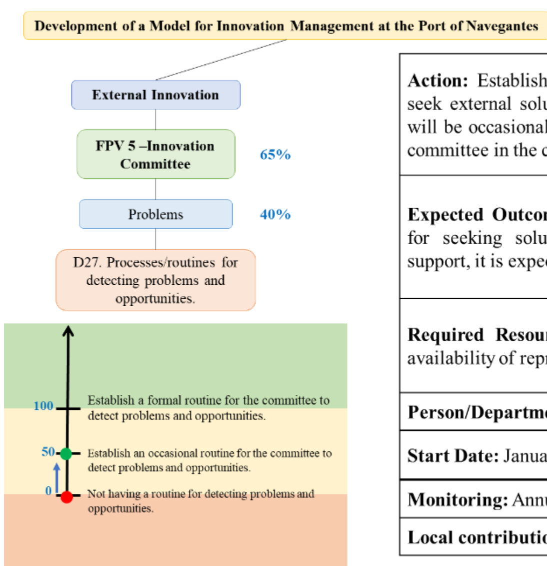
The aim of the Recommendations Phase is to identify improvement opportunities highlighted by the model and to propose actions to enhance the local and global performance of innovation management at Navegantes Port Terminal. During this phase, the analyses and results obtained previously are used as a basis to guide the recommendations. These recommendations can range from specific adjustments in certain elements to more comprehensive proposals to enhance innovation management as a whole. The focus is on identifying practical actions that can contribute to the continuous improvement of the decision-making process and the effectiveness of the innovation strategies adopted by Navegantes Port Terminal. Next, action plans to improve the performance of Navegantes Port Terminal in the EPVs that compose external innovation will be presented.



Action: Seek other companies in the port segment that have developed innovation management for benchmarking. Observe their processes, best practices, and challenges encountered.	
Expected Outcome: Capture best practices in innovation management developed by other port terminals, aiming to avoid mistakes and accelerate internal development.	
Resources needed: Labor from the innovation management team.	
Person/department in charge: Innovation management team.	
Start Date: January 2024	**End Date:** December 2024
Monitoring: Evaluate biannually the possibility of contacts..	
Local contribution to global performance: From -3,78 to 0.	

Fig. 10 Action plan for Navegantes Port to improve its performance in EPV 31 (Source: Authors).

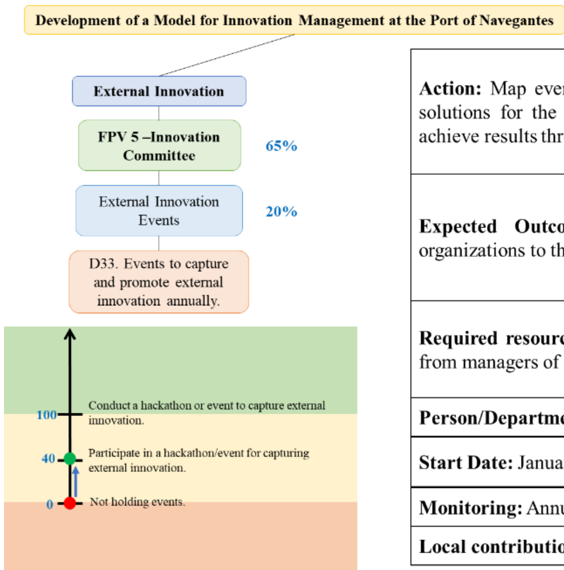
Figure 10 presents an action plan for Navegantes Port to improve its performance in EPV 31 regarding benchmarking, highlighting the opportunity with other ports on the topic of innovation. The company, despite developing innovative projects, is still in the early stages of its innovation management process. Within the departments, benchmarking or technical visits at other ports are common, but the theme of innovation management is not yet seen as the main focus.



Action: Establish a committee to identify issues, detect opportunities, and seek external solutions/innovations for the company. Initially, the meetings will be occasional, whenever a need is detected, similar to the existing crisis committee in the company.	
Expected Outcome: By formalizing a multidisciplinary group responsible for seeking solutions and identifying which problems require external support, it is expected that the results will be more efficient and effective.	
Required Resources: Labor from the innovation management team and availability of representatives from all areas.	
Person/Department in Charge: Innovation management team.	
Start Date: January 2024	**End Date:** December 2024
Monitoring: Annual evaluation of activities carried out.	
Local contribution to global performance: From 0 to 13.	

Fig. 11 Action plan for Navegantes Port to improve its performance in EPV 27 (Source: Authors).

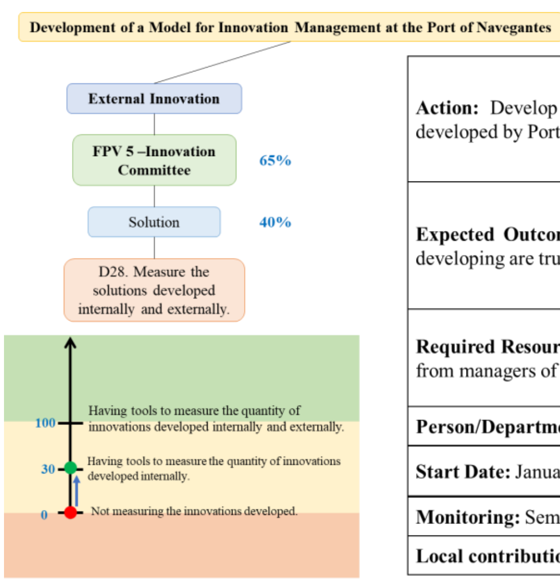
Navegantes Port shows zero performance in innovation management for FPV 5 – Innovation Committee. This is due to the absence of the Innovation Committee up to this point, thus there are no activities being executed to contribute to the status quo, resulting in zero contribution across all of its EPVs. Despite the impaired performance, the company understands the importance of formalizing and structuring its innovation management, establishing routines, and defining a multidisciplinary team. Figure 11 suggests the establishment of occasional routines so that the Committee can seek problems or improvement opportunities that require external support, similar to the current system of the Crisis Committee. However, the Committee would be focused on problem-solving and improvement that requires external support.



Action: Map events/hackathons aimed at identifying/developing innovative solutions for the port to participate and present its challenges in order to achieve results through external innovation.	
Expected Outcome: Solve problems with the support of external organizations to the port.	
Required resources: Labor from the innovation management team, support from managers of other areas, and financial resources.	
Person/Department in Charge: Innovation management team	
Start Date: January 2024	**End Date:** December 2024
Monitoring: Annual evaluation of activities carried out.	
Local contribution to global performance: From 0 to 5,2.	

Fig. 12 Action plan for Navegantes Port to improve its performance in EPV 33 (Source: Authors).

Figure 12 presents the company's concern in becoming part of the regional innovation system, participating in or even organizing marathons/events where it is possible to present a problem it has been facing and to identify potential solutions, be it from startups, universities, or research centers/units. The company has broadened its scope to attend events with an innovation theme, as discussed in EPV 30 - Events. However, active participation, or even organization, is something that still needs to be developed.



Action: Develop metrics to identify how many innovative solutions are developed by Portonave, with or without external support.	
Expected Outcome: to gauge whether the projects that the port has been developing are truly innovative.	
Required Resources: Labour from the innovation management team, support from managers of other areas.	
Person/Department in Charge: Innovation management team	
Start Date: January 2024	**End Date:** December 2024
Monitoring: Semi-annual monitoring of innovative projects developed.	
Local contribution to global performance: From 0 to 7,8.	

Fig. 13 Action plan for Navegantes Port to improve its performance in EPV 28 (Source: Authors).

Figure 13 presents one of the deficiencies that the Port faces in terms of the need for basic metrics to measure certain activities. EPV 28 relates to metrics for solutions considered innovative, developed internally or externally, aiming to assess, at first, the number of projects that can truly be deemed innovative, and then to gauge the extent of external stakeholders' support in these endeavours.

With the implementation of the suggested improvement opportunities, it is expected that the overall performance of External Innovation Management will increase from 16.94 to 46.72, while the contribution of FPV 6 – Networking would increase from 48.4 to 59.20 and the FPV 5 – Innovation Committee went from 0 to 40.

5 CONCLUSION

With the construction of the Multicriteria model to assess the performance of Portonave's External Innovation Management, it was possible to generate knowledge for the decision-maker regarding the studied context, as well as to identify critical points and to outline action plans to implement the recommended improvement projections.

In conversation with the decision-maker, it became clear that Navegantes Port Terminal is still in the early stages of its External Innovation Management process, as it initially chose to foster Internal Innovation. Furthermore, it was stated that despite the visibly compromised performance of the external approach, the decision to start the process internally cannot be considered a mistake, given that each port scenario is unique, and there is no universal solution. At the same time, it is recognized that External Innovation plays a critical role in fostering innovations, and it is essential for Portonave to have an active role within the regional innovation system.

By identifying critical points, it was possible to develop action plans to enhance the performance of External Innovation Management. With the implementation of the first round of improvements, a growth in the overall performance of External Innovation Management from 16.94 to 46.72 is expected, a gain of over 175%. This significant value is due to the fact that the entire FPV 5 – Innovation Committee has been non-existent until now, compromising the overall performance of the model. However, the current performance in FPV 6 – Networking is closer to the expected result for the company's situation, at 48.4. As the company's results itself demonstrate, Navegantes Port Terminal has developed innovative projects; however, its metrics for measuring these aspects need to be created and/or improved.

The present research contributes by presenting a performance evaluation model of innovation management, not limited to just measuring the results of a specific innovation, but rather answering at what level of performance the organization's innovation management is at. Furthermore, it provides practical contributions by delivering a model that allows for the generation of knowledge, diagnosis, planning of recommended actions, and expectations of planned changes for the company under study. In this way, the research impacts the innovation management of Navegantes Terminal, in the person of its managers, but also indirectly affects the entire regional innovation ecosystem. As the main limitation of the research, it is important to highlight that the model has been constructed but has not been through a review stage due to lack of time. For future research development, it is suggested to follow up with the model to verify its accuracy and keep it updated, specifically for FPV 5 - the Innovation Committee, which still needs to be created and formalized.

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