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Research Article

A Case Study of Complex Policy Design: The Systems Engineering Approach

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Design, structure, modelling, and analysis of complex systems can significantly benefit from a systematic approach. One way to address a complex system using a systematic approach is to combine creative and analytical methods, such as general morphological analysis and design structure matrix. The aim is to propose a framework to address complex systems in two stages: first, formulation and generation of alternatives through general morphological analysis, and second, improvement and integration with design structure matrix for sequence optimization and cluster analysis. Moreover, general morphological analysis is further optimized through a novel sensitivity analysis approach reducing up to 80% the iteration time. The proposed approach is showcased in a case study of sustainable policy formulation for a wastewater treatment plant at a pulp and paper industry in Brazil. The results show that it is possible to generate a solution space that highlights the best possible combinations of the given alternatives while also providing an optimal sequence and grouping for an optimized implementation. The paper contributes to the field of conceptual modelling by offering a systematic approach to integrate sustainability.

1. Introduction

1.1. Problem Definition. In recent years, tackling problems regarding water management policies has received considerable attention. Water management has embedded within complex issues such as industrial wastewater treatment, water protection and conservation, and rational water use. The growing complexity of water management systems generates increasingly difficult policy design problems [1]. Policy design is rather complex due to the increasing amount of policy measures available for addressing the problems of a system. Consequently, policy problems are often defined as "messy" [2] or "wicked" problems [3–5]. Rittel and Webber [5] stated that "Wicket Problems do not have an enumerable set of potential solutions." (Rittel and Weber [5] coin the term wicked problems, assigned ten characteristics to wicked problems, which have been further generalized by Conklin [4], to the following six characteristics: (1) Wicked problems cannot be understood until a solution has been developed. (2) Wicked problems have no stopping rules. (3) Solutions to wicked problems are not right or wrong they are better or worse. (4) Every wicked problem is essentially unique and novel. (5) Every solution to a wicked problem is a one-shot operation. (6) Wicked problems have no given alternative solutions.)

The term wicked problems is used to describe social complex problems that are multidimensional and possess nonquantifiable aspects, where causal modelling and simulation are not appropriate [6]. For example, in the industry sector, decision-making commonly includes complex problems associated with conflicting performance objectives and contradictory requirements, for which the application of traditional multiobjective decision-making approaches shows evident limitations [7]. In addition, there is a growing need to create a systematic approach to facilitate the definition

and structuring of relevant problems and the decision-making process among stakeholders for transparent decision support systems (DSS). A major challenge facing industrial organizations is "green policy" design and upgrading of policy measures [8]. This problem involves, for instance, knowledge management specialists, planners, and decision-makers, who all work with rather complex issues [9]. The task thus requires the creation of new tools to improve the understanding of the complexities embedded in tackling problems and reaching optimal solutions. Engineers frequently use analytical modelling methods to aid understanding the operation of complex systems, to gauge to what extent systems achieve overall their goals and targets, and how the systems in question can be improved [10].

Many traditional quantitative methods have been explored for dealing with multiobjective decision-making in the public policy realm. For example, Philips et al. [11] presented his work by applying quality function deployment (QFD) techniques to product design procedures, which are used to formulate annual policy, leading to designs that better reflect customer's requirements. Yeomans [12] applied the coevolutionary simulation-optimization modelling-to-generate-alternatives approach in order to generate effectively multiple solutions for environmental policy formulation to municipal solid waste management. Taeihagh et al. [13] proposed a network-centric policy design approach based on network analysis and ranking of alternatives [14], often done using multicriteria decision analysis (MCDA) methods, to select and analyse the internal properties of proposed measures and their interactions in the transport policy domain.

Moreover, Taeihagh et al. [15] argued that agent-based modelling could be used for the analysis of different combinations of policy measures, aiming at generating policy packages to advance sustainable transportation. However, traditional multiobjective optimization and simulation are not sufficient to tackle complex multidimensional and non-quantifiable problems. Besides, in the case of physical sciences and economics, research in the policy domain mostly focuses on the simulation and optimization of policy alternatives, instead of their synthesis and generation. Therefore, there is still a need for further research to enhance the capacity of policy generation and evaluation of this approach. Consequently, a systematic approach is imperative, particularly when addressing complex problems, such as sociotechnical systems.

The analysis of complex sociotechnical systems, like a set of policies, is a challenging problem [16]. The first reason is that the elements contained in the systems are often non-quantifiable, as they are of social, political, or cognitive nature. The second reason is that uncertainties characteristic for such complex problems are hard to be represented. The emerging need of specific tools, techniques, and systems to aid the generation, management, and enforcement of effective policies requires research on the suitability of various approaches in the context of policy instruments' choice [17].

Various problem-structuring methods (PSMs) have been presented in the literature. Among them, general morphological analysis (GMA) [6, 18, 19] is presented as a promising method for the generation of new concepts and finding the best solution. In principle, GMA is based on the "divide and conquer technique" [20], which tackles a problem using two basic approaches: "analysis" and "synthesis"—referred to as "the basic method for developing scientific models" by Ritchey [21]. In addition, some authors propose different creative methods to be used in early conceptual design to support new concept of business model creation [22] and new concept of selection [23, 24]. GMA, as a creative method, has been used widely and tested in various domains such as policy planning and scenario development [25], strategic foresight [26], technology forecasting [27–29], and idea creation [30–32]. The core objective of GMA is to structure and investigate the behaviour and solutions among stakeholders.

From the engineering design perspective, different matrix-based tools and techniques have been developed also to aid the design process. An example of this is design structure matrix (DSM), typically used to map, visualize, and analyse the dependences and relationships among properties of a product or activities in the design process. In other words, by applying the DSM, these dependencies can be reorganized so the process can be optimized.

However, no work has been done before on combining GMA with DSM. Furthermore, to the authors' best knowledge, GMA and cross-consistency assessment- (CCA-) based optimization techniques have not yet considered optimization of the iteration process through sensitivity analysis, nor have DSM-based simulation techniques been considered for reworking of policy improvements in areas such as policy design and policy measures. Therefore, the presented research fills this specific gap in the policy design literature.

In this paper, a case study example of the Brazilian pulp and paper mill industry related to wastewater treatment plant (WWTP) is shown in order to display the empirical use of the presented model for policy formulation. Brazil is an upper middle-income country with a fast-rising economy [33], which may eventually develop into the world's leading producer of pulp and paper. The pulp and paper industry is tackling a wide array of implementation of sustainability trends, such as (but not limited to) conservation and rational water use; development of sustainability measures for industrial wastewater treatment and water systems management becomes necessary. It is evident that there is a large potential for the adoption of sustainable practices in the pulp and paper industry in a developing country's environment.

1.2. Motivation and Purpose of the Study. This research is motivated by an attempt to assess the potential of integrating modelling methods in such a way that the integrated approach supports complex problem solving for policy design in water management systems, while supporting sustainable development in the organization.

The aim of this paper is to develop a systematic approach for generating, designing, and improving policy alternatives using a computational methodology that integrates the diverse modelling techniques of GMA, sensitivity analysis, and DSM. The specific goal is to interlink GMA and DSM as potential problem structuring methods to tackle wicked problems and to support the decision-making of policy formulation in complex systems.

By developing a systematic approach, it is possible to (a) better understand the problem structure and to decompose it into subproblems, (b) improve analysis and optimization of the environmental policy formulation process through sensitivity analysis, and (c) decrease the time required for problem analysis and problem solving. The proposed methodology will enable decision-makers and managers to generate and explore various alternatives and to promote combination of alternatives, their optimization, and improvement of the policy development process. The proposed approach includes sensitivity analysis for optimization of the iteration process of GMA, clustering analysis through DSM, and development of the configurations of policy measures included in the policy package so that they match the objectives of the organization.

This study focuses on specific objectives as the following: the first objective is to generate policy measures or alternatives using GMA for policy design. While policy measures can be extracted from literature or derived from an expert's opinions, different organizations can have different perceptions of policy measures to create a coherent policy. Therefore, the same policy measures may have different effects for different companies, industries, or countries. Hence, the reduced set of viable policy measures is then the subject of analysis by the stakeholders involved in policy formulation in various organizations. The second objective is to evaluate and improve the policy measures or alternatives. In light of this, a DSM approach is used for identifying the relationships of the policy measures in a qualitative manner [34].

The significance of this work, and how it differs from the other works, is that decision-makers can utilize the full potential of the proposed systematic approach to tackle wicked problems in the context of policy design and meet the companies' objective for increasing their sustainability scores.

The results are expected to further promote the use of modelling methods for policy formulation in sectors such as energy, environment, healthcare, food, water, and e-waste, in which modelling can be systematically employed as part of a DSS. Consequently, the work facilitates greater use of modelling procedures to address complex problems such as those found in environmental policy management.

1.3. Structure of the Paper. The remainder of this paper is organized as follows: first, key considerations in policy design, particularly sustainable policy design and problems of policy formulation, are briefly described. Then, the main features of the design modelling approaches used, GMA and DSM, are presented. The following section discusses the proposed approach integrating GMA, optimized through sensitivity analysis, with DSM. To illustrate the approach considered in this work, an illustrative case study is described. The findings are then revealed, and the paper concludes with the main results, discussion of contributions, limitations, and suggestions for future work.

2. Literature Review

When attempting to improve policy in areas such as water management and to mitigate problems arising from the complexity of modern sociotechnical systems, adoption of a systematic approach has become an essential part of policy design. Further consideration is given to the selection of appropriate methods, software, and tools to support understanding of the complexities embedded. For instance, Taeihagh et al. [32] developed a novel framework and design support system to ease and accelerate the design of polices to meet the CO_2 emission targets for the transport sector in the UK. The proposed method and computer implementation constituted the first general approach towards the development of a branch of computer-based systems that support environmental policy. Moreover, policy design research can be divided into several categories dealing with different types of objectives and criteria in public environmental policy formulation [13, 35].

In recent years, the topic of policy portfolios [36] and policy mix formulation has evolved from definition of problems via exploration of basic concepts, to development of policy measures and classification of policy measures into categories, and further to analysis of descriptive and normative scenarios. In addition, Howlett [17] defined that the nature of the criteria for effective policy design is a significant aspect in order to ensure the portfolio's effectiveness to policy formulation and its implementation. Current research trends focus on advanced and practical levels of design policies, which involve greater integration of the related concepts and methodologies [13, 15, 35, 37]. The perception of policy design has evolved from a "single-target/single-tool" approach towards a "multitarget/multitool" approach in order to tackle complex policy design [13, 37, 38].

Earlier work on policy design and policy formulation methodology was based on dynamic modelling approaches such as network analysis [13], agent-based modelling (ABM) [39], and multiple criteria decision analysis (MCDA) [40]. Taeihagh et al. [15] introduced ABM to formulation of transport policies and proposed a systematic approach for use of a virtual environment for the exploration and analysis of different configurations of policy measures. Furthermore, Wollmann and Steiner [41] proposed a model for strategic decision processes that takes into account the influence of limited rationality and organizational policy. The proposed model combines strategic decision-making, complex adaptive system (CAS), and the mathematical techniques analytic network process (ANP) and linear programming (LP) [41]. Also, complexity theory has been proposed as a complexity-driven approach to assist project management in decision-making, while defining complexity-based criteria [42].

2.1. Sustainable Policy Design. A policy is generally described using natural language, which makes it difficult to understand, especially when they occasionally compete and conflict with each other. According to Pohl [43], a "policy" is a "principle or guideline for action in a specific context" and "policy design" is "the task of selecting policy components and formulating overall policy." Policy formulation is defined as "the development of effective and acceptable courses of action to address items on the policy agenda" [8, 44]. Policy design involves the deliberate and conscious attempt to define policy goals and connect them to instruments or tools

expected to realise those objectives, and to formulate a policy, there is a need to follow a policy agenda that meets the standards and regulations [44]. It can be considered one of the most difficult parts of the policy design process [35], and it underlies the explicit actions of policy design [8, 44]. The development of successful and acceptable policy is usually a manual task involving various activities and several teams with different objectives and criteria for policy success [32].

Within environmental management studies, environmental policies have traditionally been defined as policies that assist successful decision-making to meet the requirements of sustainable development [45, 46]. To meet the criteria of sustainable development, policies have to address the legal, technological, social, economic, and environmental aspects.

Policy formulation and policy implementation are two very different activities. Policy formulation is an important phase devoted to "generating options about what to do about a public problem" ([47], p. 29) and is inherent to most, if not all, forms of policymaking [48]. The agenda-setting step in the policy cycle focuses on identifying *where* to go, while the policy formulation step focuses on *how* to get there [49]. Considering policy formulation as "a process of identifying and addressing possible solutions to policy problems or, to put it another way, exploring the various options or alternatives available for addressing a problem," then the development or use of *policy formulation tools* becomes a vital part of the policy formulation process ([47], p. 30). It is difficult to conceive, or properly study, policy formulation without thinking in terms of tools. According to Dunn [50], these are tools for forecasting and exploring future problems, tools for identifying and recommending policy options, and tools for exploring problem structuring.

Some of the most traditionally used approaches are cost-benefit analysis (CBA) and MCDA in the environmental policy domain [13, 51]. However, CBA has significant drawbacks such as difficulty to measure social costs and benefits, conflict between wellbeing and financial benefits, and assigning controversial monetary value to human displacement and human life [52]. Likewise, the methods that fall under the MCDA umbrella struggle to manage decisions with inherent uncertainty, are unable to address dependencies, are prone to manipulation, and face difficulties with problem structuring [51].

Currently, decisions on what to include in policies (their synthesis) is done manually, and considering the size of the space of alternative policies, a large portion of the design space is left unexplored [32]. Moreover, Howlett and Mukherjee [53] and Chindarkar et al. [54] conducted research on comparative policy analysis, making an emphasis on effectiveness and impact of managing the policy processes [55]. Furthermore, the knowledge and objectives of the different stakeholders involved (e.g., central authority, local authority, employees, company/industry, NGOs, local residents, and researchers from academia) may differ greatly and bring dissimilar attitudes to proposed solutions, which influences the decision-making process [56].

Therefore, traditional approaches to policymaking are not well suited for solving today's complex problems. A comprehensive methodology that supports the identification, design, modelling, and evaluation of policies to tackle complex problems is still missing, and existing methodologies and frameworks to tackle the complexity of sustainable policy formulation in organizations are not fully developed. Therefore, alternative approaches and tools are required in order to overcome the limitations of traditional approaches. One possibility is to integrate multiple methods based on policy design concepts. For example, GMA and DSM are both modelling methods that may be systematically employed in a DSS [57], and this paper proposes combining GMA and DSM to facilitate modelling procedures in problem solving of complex problems such as those found in sustainable policy design.

2.2. The Complex Problem of Policy Formulation. For policy design in general, and water management in particular, decisions regarding measures for inclusion in policy require exploration of a large pool of policy options as part of the problem space [32, 53, 54]. Furthermore, designing a sustainable policy is rather complex because of the influence of different factors—technical, legal, and ethical—an example of this is management of industrial wastewaters. These factors require the adoption of a large number of different policy measures. In addition, the multiple tasks to be carried out require input from multidisciplinary teams [58]; hence, policymakers still struggle with evaluating and improving the outcome of the policy design process.

To date, a single universal approach for sustainable policy design in wastewater treatment does not exist, and suitable policy measures need to be identified based on the organization's strategy and environmental aims. Utilization of a systematic approach to generate alternative policies by using GMA [18] and DSM [34] will help decision-makers to accelerate and improve policymaking. Furthermore, incorporating and adopting the diverse preferences from various interest groups and stakeholders will improve the policy's performance and acceptance.

While identification of feasible policy measures for complex industrial wastewater treatments can be obtained from literature review and expert inputs, it is worth noting that different companies might have different views regarding suitable policy measures. This paper considers well-defined policy measurement criteria such as legal, technical, financial, social, and environmental measures taking into consideration sustainability development goals (SDGs) [59].

The selection of policy measures to be considered is complex for several reasons. Under a simplified setting, a local company requiring an environmental permit for the installation of a WWTP would require a local permit, following regulations familiar to local experts. However, in this case study, the complexity is largely increased because it is an international company with headquarters in Finland, seeking an environmental permit for a WWTP in Brazil; thus, it requires following protocols from the company and from the location. Moreover, the specific location of the case study WWTP is next to a river separating two states, so both the regional regulation (Instituto Ambiental do Pantanal/Secretaria do Empresas y Meio Ambiente) IMAP/SEMA

Table 1: List of policy measures designed for an industrial WWTP in Brazil.

Parameters	Values
Implementation of legislation (legal aspects)	Requirements in Brazilian Environmental Law, Conama 20 EU-BAT Bref (2001) sectorial Best Available Technology listing and associated limit values World Bank/IFC EHS sectorial (pulp and paper industry) environmental performance limit values Parana river water quality requirements (Class II) local limit values for river water Saving water target to diminish water footprint of the mill Storm water control to prevent accidental impacts to the river water
Water/effluent quality (technical aspects)	Determination of the appropriate treated effluent quality for physical and chemical parameters Determination of the concentrations of organic compounds, nutrients, and absorbable organic halogens in treated effluent Determination of the organic compounds, nutrient, and absorbable organic halogens in treated effluent and temperature increase no more than 3°C at mixing zone in the river Determination of dissolved oxygen and turbidity in the river water Separation of uncontaminated and contaminated storm water to keep hydraulic design of the effluent treatment plant reasonable
Effluent treatment plant (financial aspects)	Implement specific process equipment (cooling towers) to achieve legal requirements Choose those pulping processes (oxygen delignification, ECF bleaching) to give lower emissions Choose an effluent treatment process (extended aeration) to give good treated effluent quality and less sludge production Create water management system for clean used process water (collecting, controlling, and recycling used clean waters) Storm water management by sectorial storage lagoons
Capacity building (social aspects)	Training courses for all at the site for safety measures Environmental training events for workers of production departments Detailed training of operators of effluent treatment plant concerning process, incomes and outcomes, and equipment and their control and maintenance
Monitoring (environmental aspects)	Preparation and implementation of an integrated program for monitoring river water Preparation and implementation of an internal program for monitoring untreated effluent for process upsets Preparation and implementation of an integrated program for monitoring treated effluent Preparation and implementation of an integrated program for monitoring groundwater at the production area Preparation and implementation of an integrated program for monitoring groundwater as a part of monitoring system of the landfill Preparation and implementation of an internal program for monitoring outlet of storm water lagoons

WWTP: wastewater treatment plant; BAT: best available technology; EFC: elemental chlorine free; Conama: Conselho Nacional do Meio Ambiente.

and the federal regulation (Conselho Nacional do Meio Ambiente) Conama 20 apply in this case. The selected 25 policy measures were thus extracted by the experts from the aforementioned regulations. This selection and the first stages of GMA analysis happened during the first day of the workshop.

The policy measures were divided into five categories based on sustainability criteria (law-related policy measures, technical-related measures, financial-related measures, social-related measures, and environmental measures) using expert evaluation (data collection and data analysis details are given in Sections 4.3.1 and 4.3.2). The specific policy measures identified are provided in Table 1.

2.3. GMA for Generating Alternatives. GMA was originally introduced by Zwicky [19] and Zwicky and Wilson [60] as a "non-quantified modelling method for identifying, structuring and studying complex problems." The GMA approach has been widely used for identification of possible combinations of problem variables in many different disciplines [29]. The GMA technique is a decomposition method that splits a system into subsystems with their parameters and selects the most valuable alternatives [61].

GMA enables problem representations using a group of parameters, which can take any of several values [62]. The identified conditions in each dimension can be combined to derive all the possible alternatives that can solve the problem. Yoon and Park [29] recommend a group of 5–7 experienced experts representing different aspects of the problem to be resolved. The specific way of application of GMA for this study is described further in Section 3.3.

The basic procedure of GMA is described by Wissema [63] as follows. First, in the morphological field, the system is decomposed into multiple parameters [29]. In the next step, the possible alternatives or values in each parameter are identified. The values for each parameter should be defined in a mutually exclusive manner [62]. A morphology matrix is then built with the obtained parameters and values. The whole system should be described in the morphology matrix as comprehensively as possible [23]. Finally, solutions are obtained by combining the values of each parameter. The number of possible solutions can be calculated by multiplying the number of values in each parameter [24].

GMA has been applied to a wide variety of fields and contexts like jet and rocket propulsion systems [19] and

computer-aided design modelling [64]. The research reported by Belaziz et al. [65] was aimed at simplifying computer-aided design model modification by integrating GMA into the design process. In addition, Ölvander et al. [66] proposed a computerized optimization framework for the morphological matrix applied to aircraft conceptual design. In the field of scenario space modelling and development, the research conducted by Coyle and McGlone [67], Coyle and Yong [68], Voros [69], and Johansen [25] confirmed that GMA has been extensively applied. Also, as reported by Haydo [70], GMA has been successfully applied to optimize complex industrial operation scenarios.

According to Ritchey [71], GMA is a "basic, conceptual (non-quantified) modelling method that can be compared with a wide range of other scientific modelling methods, including System Dynamics Modelling (SDM), Bayesian Networks (BN) and various forms of 'influence diagrams.'" Furthermore, Duczynski [72] developed general morphological analysis for application in organizational design and transformation, while Zeiler [73] used the morphology in conceptual building design. In addition, Buzuku and Kraslawski [74] proposed applying GMA to policy formulation for wastewater treatment. In particular, GMA provides a possibility for generating unexpected combinations of policy measures [18].

The morphological approach has several advantages, including discovery of the total set of new configurations and its suitability for utilization with work groups. The use of work groups increases scientific communication and enables integration of state-of-the-art knowledge from practitioners of different fields. However, the main advantage of this method lies in its ability to structure models for complex problems in a nonquantitative manner through systematic procedures [75]. Another significant advantage is the method's ability to provide an auditable trail [76].

Drawbacks of the method include issues with vague formulation, static analysis modelling of the values, nontreatment of variable interdependencies, and insufficient screening and selection of satisfactory combinations. Thus, the approach demonstrates limitations in defining and evaluating different parameters against each other and generating conditions within the problem space. Therefore, GMA requires support from other processes.

The most promising method in this context is DSM [34], which can describe different methods and enables visualization, analysis, and improvement of partial solutions. In this study, GMA is integrated with DSM as a screening, visualizing, and development tool [57].

2.4. DSM for Analysing and Improving Alternatives. DSM is an often-used efficient method for analysing complex systems by enabling the overview of the system and the interdependencies of the system's elements, developed by [77, 78]. DSM provides the representation of a complex system and the dependencies, relationships, and interactions of the system's elements [34]. In addition, DSM breaks down a complex problem into smaller problems and enables deconstruction of the organizational and functional components of a system by eliciting the relationship between components in ways that make trade-off analyses more understandable and manageable [10].

DSM generates a directed graph that describes relationships between elements or parameters for the design, management, and optimization of a complex system, organization member assignments, and activity scheduling, concentrated in an n by n adjacency matrix. A system of n number of parameters is represented by DSM in an n by n matrix, in which the elements are listed in the exact same order from 1 to n both in rows and in columns, where the dependencies between the parameters can be marked. When parameter a depends on parameter b, then the cell a, b (where both a and $b < n$) is marked in a binary manner with any symbol, e.g., with a "●." In case of no dependency, the cell a, b is left empty [79]. When the parameters are listed in the DSM in their execution order, if cell a, b is marked under the diagonal of the DSM matrix, it represents an output (or "outwards" relationship) from parameter a to b. However, if a cell a, b is marked over the diagonal of the matrix, it means that cell a receives feedback from b (a depends on b).

DSM has been used in the past to solve complex decision-making problems and to improve organizational performance [77]. Therefore, DSM is considered a consolidated approach to manage complexity [9, 80–82]. DSM is known as a contemporary method that has been used for modelling and managing complex systems in engineering [83, 84], design planning [85], and operation management [86]. According to Eppinger and Browning [34], DSM can be applied to public policy because public policy and social systems are multidimensional and uncertain complex problems. Environmental policy design and its implementation is a complex problem comprising a mix of numerous types of policy instruments or measures [87, 88] adopted by a range of organizations and stakeholder participation [89].

DSM visualization provides the advantage of compactness and clear representation of essential patterns. On the other hand, as the graph becomes larger with nodes and edges, it can become difficult to understand the overall network representation. Moreover, DSM further provides the option to improve the system's structure using matrix-based analysis techniques. Although the policy measures are listed as sequential steps in the DSM, the modelling process requires attention to their dependencies, interdependencies, and relations. The main advantage of DSM lies in combining elements/components in a novel and creative integrative framework, displaying, analysing, and improving satisfactory combinations. It is thus suitable for evaluating policy measures extracted from GMA ([90], 2015; [34]).

3. Methodology

In this section, the overall process mechanics of the two-part approach for generating and improving policy measures with experts' evaluation feedback is described. The experts interact with the stakeholders outside the frame of this study. The methodology proposes an integrative framework for designing a sustainable policy that helps to improve policy

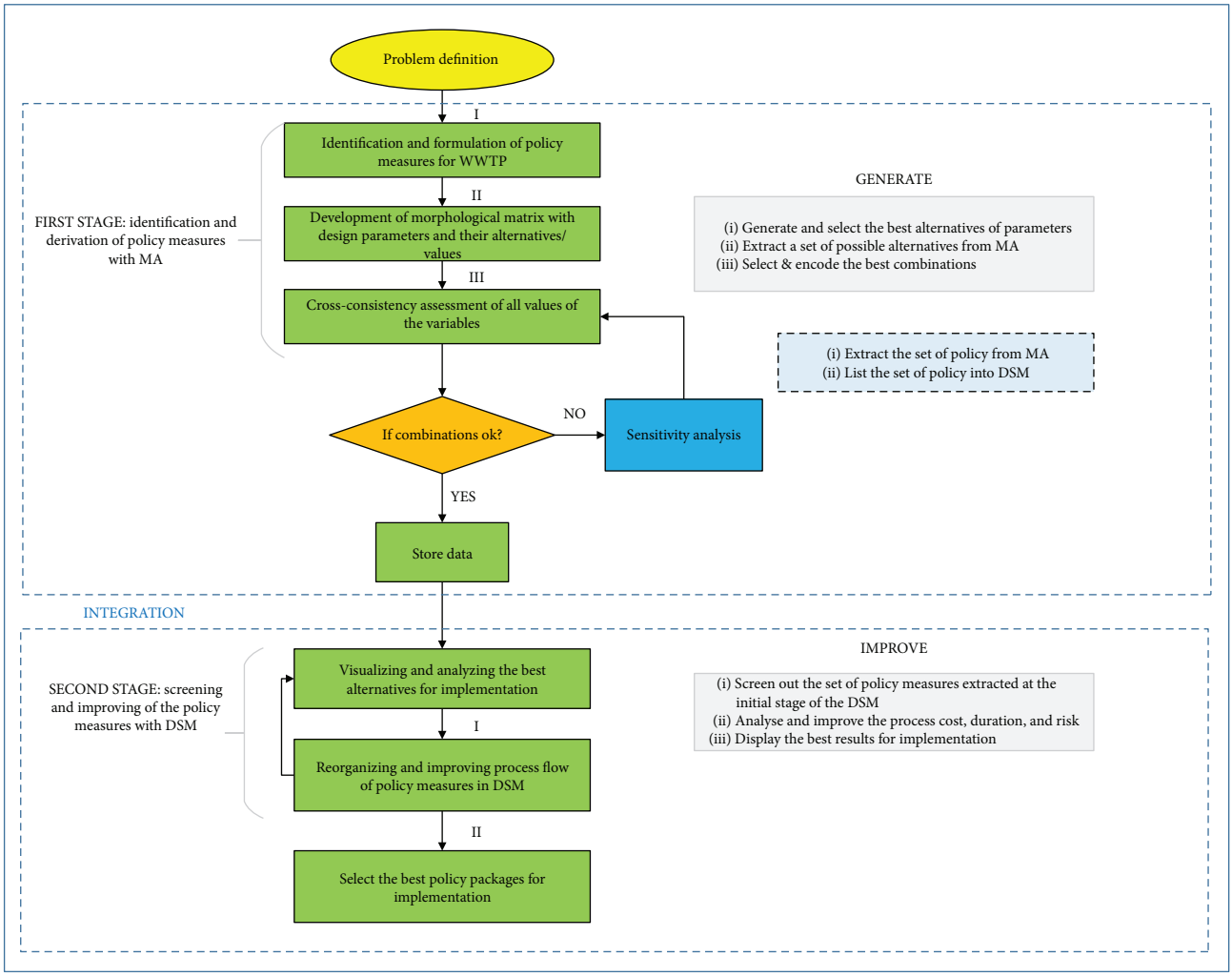

Figure 1: Process overview of the integrated general morphological analysis (GMA) and design structure matrix (DSM) method.

effectiveness, as well as a comprehensive system structure for sustainable management in organizations.

The proposed methodology is aimed at improving the impact of the different policy measures generated during policy formulation in the early stages of conceptual project design, when decision-makers start to set up and embed design solutions into problem-solving systems. During policy formulation, decision-makers and designers often model a functional net using a graph structure [91, 92], and they may produce a set of partial solutions (or alternatives) for a specific type of problem. Each set of partial solutions is interpreted and strengthened by a DSM in order to better manage the complexity and, subsequently, to aid reasoning about the sustainability of environmental policy formulation concepts.

Among alternative approaches, the choice had to be made between a matrix representation or a network representation. Network representations are often simple and easier to read; however, they are not as flexible for increasing or decreasing in size and can become almost impossible to follow if the number of inputs is very large. Ultimately, a matrix representation was chosen because a matrix can easily be rearranged, it is able to show parameters for a rather large number of inputs, it can always be expanded [93], and it can be mathematically analysed (in this case with sensitivity analysis), among other advantages.

The experts are quite familiar with the sustainability assessment of relevant environmental policy measure concepts, a very relevant factor for the evaluation of policy measures. The policy concepts themselves belong to either corporate, regional, or federal environmental regulations, and they were designed and assessed by their corresponding institutions. Moreover, the experts made it a specific goal to include or consider the most relevant policy measures that tackle the social, environmental, and technoeconomic requirements of a sustainable endeavour. Therefore, the sustainability assessment of the policy measures is not addressed in this paper.

3.1. Proposed Approach. This section examines the overall process and gives a brief explanation of each stage. The proposed new approach is divided into two stages (Figure 1):

(1) Generation: identification and derivation of policy measures with GMA, and optimization of GMA through sensitivity analysis

(2) Improvement: screening and improving the policy measures with DSM

The first stage comprises generation of sustainable policy measures or alternatives using GMA for policy design. The identification and derivation of policy measures with GMA entails the following steps: (a) identification and formulation of a library of policy measures, (b) development of a morphological matrix by building dimensions (parameters) and generating policy measures as named alternatives (values), (c) assessment of the consistency of all possible combinations of parameter values, and (d) optimization through sensitivity analysis.

The second stage consists of searching for improvements to the policy measures or alternatives using DSM clustering. Since GMA is not able to investigate and explore the dependence and interdependence relationships between policy measures or alternatives, the DSM approach is employed to analyse and better manage the policy design structure, thereby supporting the identification of the interdependencies and improving the overall process flow. The obtained results and the reduced sets of policy measures are analysed by the experts involved in policy formulation.

3.2. Problem Definition. The full complexity of water management systems and policy structure is difficult for managers and designers to understand using traditional modes of analysis. Hence, this study develops a systematic approach for exploring, generating, and improving the policy alternatives using GMA, sensitivity analysis, and DSM to identify, optimize, and improve the policy measure interactions of the system. The approach will enable managers and designers of water management systems and WWTPs to tackle the system's complexity more wisely, a topic increasingly relevant in developing regions like China and Brazil [94, 95].

The environmental policies, provided in Table 1, are virtually represented in the GMA matrix so that it is possible to analyse their effectiveness in the specific project. The main target of the resulting designed policies is the improvement of the quality of measures and their performance. In an optimal scenario, all stakeholders are involved.

3.3. First Stage: Generation of Policy Measures with GMA. The first stage of GMA comprises the identification and formulation of a set of specific policy measures related to the problem, in the illustrative case in this work, an industrial WWTP. The policy measures identified were categorized by experts into economic, environmental, social, and technical sustainability criteria, using the GMA tool to build the morphological box during the workshop.

There are multiple ways to conduct GMA. Zec and Matthes [96] elaborated in four possible ways the application of the method: (1) alone, (2) in a relaxed manner with like-minded individuals, (3) in a workshop with experts and stakeholders, and (4) in a distributed manner through remote online workshops. The third option, a workshop with experts and stakeholders further detailed by [97], is the approach chosen for this study. The exercise for evaluation of policy measures and classification into the categories they belong was performed with preprinted forms, white paper, and pen from a groupthink of experts in a workshop, described in Section 4.3.1.

The identification and derivation of policy measures with GMA comprise the following steps: (a) identification and formulation of a library of policy measures and classification by the experts, (b) development of a morphological matrix by building dimensions (parameters) and generating policy measures as named alternatives (values), (c) assessment of the consistency of all possible combinations of parameter values, and (d) optimization through sensitivity analysis for subsequent iterations.

The experience and knowledge of experts from a wide range of disciplines is required to develop the morphological matrix. A methodology to gather and organize this knowledge through a participatory dialogue process, such as a structured workshop, is also required. Approaches like CCA, invented by Ritchey [18], allow the number of alternatives and iterations to be reduced significantly. The reduced set is then the subject of process analysis by the experts involved in the policy formulation. The role of expert opinion and experts' participation in decision-making is crucial for environmental policy management [98].

The set of combinations of alternatives obtained from the morphological matrix is analysed, screened, and improved with DSM. The consistency of combinations is evaluated by exploring all possible combinations of the morphology matrix via CCA. The sensitivity analysis step proposed in this work can further optimize the CCA process and highlight the most relevant parameters.

3.4. Second Stage: Improvement of Policy Measures with DSM. The use of DSM enables visualization of the dependencies and interdependencies of combinations of variables and values. Once optimal combinations of policy measures have been derived using GMA (described in detail in Section 4.1.3), it is necessary to integrate them into the DSM for screening and improvement of the policy measures and to select the most suitable set of policy measures for implementation. More specifically, the proposed approach (shown in Figure 1) can be used to observe the complex interactions and improve the understanding of underlying relationships between the policy measures. To perform the analysis of the policy correlations, this study suggests visualizing and identifying of the best alternatives for implementation, and reorganizing and improving the process flow of policy measures with DSM. Since results extracted from GMA are used as input to DSM, the DSM process can be applied from the analysis step.

4. Illustrative Case Example

The proposed approach is illustrated with a case study for the construction, operation, and maintenance of a large industrial WWTP. This case study was conducted with an

international engineering and consultant firm, hereafter, called "company A." Due to increasing pressure for sustainable wastewater treatment globally, particularly in the pulp and paper industry [95], there is a significant need to design and formulate sustainable policies that promise sustainable solutions for wastewater treatment facilities. The new plant was planned to become an integrated facility in the wastewater sector through collaboration with the local community, potential stakeholders, and enhanced engagement with the company in the region. Industrial water systems management, including wastewater treatment systems, is a complex problem that requires expert's knowledge and years of experience in a wide range of disciplines. The decision-making can be classified as a complex problem, the activity is situated on a federal river forming a border area between the states of Mato Grosso do Sul and Sao Paulo, Brazil, and there are large capital and operational costs involved, as well as involvements of multistakeholders. A relevant factor in the development of sustainability measures for industrial wastewater treatment is the participation of stakeholders from various levels and functional areas of society [99] involved in the process.

Some policy measures are of interest to both internal and external stakeholders. This interest generates a "policy measure-stakeholder" relationship. In the case in progress, stakeholders are

(i) *Central Authority*. The central authority commonly is responsible of taking care for the issues that could destabilise the relationships between the present stakeholders and any other possible conflict on stage.

(ii) *Local Authority*. The local authorities have interest in the issues related to the legal aspects of operation of the plant on their territory.

(iii) *Employees*. The main interest of the employees is in environmental aspects, health and safety (EHS) issues including training programs, and workshops aiming for the better quality of the working conditions.

(iv) *Company/Industry*. For the company or industry, and more specifically its top management level authority, the key interests are the health and safety conditions for the staff, aiming for the high quality of the work environment and other social aspects that are directly linked to the plant operation and its maintenance, and of course to profit from the activity.

(v) *NGOs*. The civil society and NGOs have interest in the topics that are related to broader perspectives, which target environmental, advocatory, and other social issues, e.g., human work rights.

(vi) *Local Residents*. Local residents and the community around usually have interest in the public services provided by WWTP, and having impact on their healthy lifestyle.

(vii) *Researchers from Academia*. The researchers from the academia typically have high interests in providing conditions for collecting data and sampling analysis for scientific research purposes.

The stakeholders provide feedback to the experts. Afterwards, with the acquired knowledge, the experts participated in the workshop. In this way, stakeholders remotely influence the decision-making in this case study. Nor were the experts or the stakeholders previously familiar with the methods used for this research.

4.1. Identification and Derivation of Policy Measures with GMA. The empirical knowledge of experts, stakeholders, and members of society is required to compile available environmental measures [99]. The compiled set of environmental policy measures has been generated as described in Section 2.2, and the selection is depicted in Section 3. Measures may be regulatory (e.g., legislation on emission limits), economic (e.g., taxation of wastewater discharge), technical (e.g., investment in best available technology), social (e.g., increase in social awareness), and environmental (e.g., decrease in pollutant concentrations in effluents). The measures can be quantitative or qualitative and affect all aspects of sustainability. The policy measures can be ranked by effectiveness, time of deployment, cost, risk, uncertainty, technical complexity, social acceptability, and organizational complexity, depending on whether the policy is meant to adapt or mitigate, or whether it is designed to reward improvements or punish noncompliance.

4.1.1. Development of the Morphological Matrix with Design Parameters or Dimensions and Alternatives or Values. After problem definition, the main task in GMA is generation of a morphological field comprising the most relevant dimensions (parameters) and production of design alternatives (values) for each parameter. Therefore, policy measures must be identified and formulated in accordance with sustainability criteria to achieve the environmental targets. These sustainability criteria are considered the constituents of the WWTP and can be used as the morphological field's parameters. The parameters of the morphological field are set in the header in the spreadsheet table, and their generated values are placed under each parameter. Figure 2 shows the development of a morphological field with five parameters—legal, financial, technical, social, and environmental dimensions—and their values. The specific WWTP parameters in the case study are written in bold. For each parameter, possible values are defined in their respective column.

Table 2 illustrates the combination of different design parameters and values obtained using the principles proposed by Zwicky [19] and Ritchey [18], and Table 1 shows the list of policy measures designed for the industrial WWTP in Brazil considered in the case study. The combination of policy measures of one partial solution from every column leads to the overall principle solution or policy formulation concept. Since GMA has many iterative steps [100], modifications in the morphological matrix can occur throughout the process [62]; thus, the proposed GMA optimization

Legal		Technical	Financial	Social	Environmental
RUN PRE HID G B / Parameters / values	P1 Implement legislation	P2 Water/effluent quality	P3 Effluent treatment plant	P4 Capacity building	P5 Monitoring
V1	Conama 20 Requirements – Brazilian Environmental Law	Temperature = 40°C, settleable solids = 1 ml/1 L	Cooling towers	Training for safety measures in the working place (for all)	River water (authorities)
V2	EU- BAT Bref (2001)	COD = 8 – 23 kg/ADt, AOX< 0.25 kg/ADt	Oxygen delignification, ECF bleaching	Training for general environmental aspects (for workers at various departments)	Untreated effluent quality
V3	World Bank/IFC EHS Guidelines	Temperature increase no more than 3°C at mixing zone	Extended aeration	Training for operators of the effluent treatment plant	Treated effluent quality
V4	Parana River Water Quality Requirements (Class II)	DO = 5 mg/l, minimum Turbidity 100 NTU, maximum	Collection, control, and recycling used clean waters		Groundwater (especially in the surroundings of big tanks)
V5	Water footprint	Separation of uncontaminated and contaminated storm waters	Storage lagoons		Groundwater (especially in the surroundings of big tanks)
V6	Storm water control				Outlet of storm water lagoons

Figure 2: Development of the morphological field with five parameters and their values. BAT: Best Available Technology; IFC EHS: International Finance Corporation Environmental Health and Safety; COD: chemical oxygen demand; ADt: air dry tons; AOX: absorbable halogen compounds; DO: dissolved oxygen concentration; NTU: nephelometric turbidity unit; ECF: elemental chlorine free; Conama: Conselho Nacional do Meio Ambiente.

Table 2: Combinations of parameters/values.

Values	Parameters				
	$P1$	$P2$	$P3$	$P4$	$P5$
$V1$	$P1V1$	$P2V1$	$P3V1$	$P4V1$	$P5V1$
$V2$	$P1V2$	$P2V2$	$P3V2$	$P4V2$	$P5V2$
$V3$	$P1V3$	$P2V3$	$P3V3$	$P4V3$	$P5V3$
$V4$	$P1V4$	$P2V4$	$P3V4$		$P5V4$
$V5$	$P1V5$	$P2V5$	$P3V5$		$P5V5$
$V6$	$P1V6$				$P5V6$

through sensitivity analysis described in Section 5.2 is thus justified.

The GMA approach outlined in this study may take practitioners and researchers up to several weeks to execute. The actual time and effort required for any GMA application depends on several factors, including familiarity with the process being modelled and the degree of difficulty of information gathering and defining and evaluating parameters and values. In the case of parameter building, Geum and Park [30] and Geum et al. [101] suggest that an expert-based qualitative approach provides more powerful results. Although some GMA models can be extracted automatically from project management models, most entail the direct involvement of experts.

4.1.2. Assessment of Consistent Combinations of All Parameter Values. CCA, proposed by Ritchey [18], can be used to evaluate all the feasible combinations of parameter values. CCA assesses compatibility for each value via pairwise comparison (one pairwise value from one column or morphological class with another pairwise value from another morphological class). To reduce the problem space, decision elements are compared pairwise by experts (further detailed in Section 4.3.1) in terms of their control criteria. Each condition is compared with another condition and evaluated for internal consistency, which is noted as their assigned values in a matrix called the CCA matrix.

Figure 3 presents the CCA matrix for this study. The assessment of the conditions, done by the experts, is carried out by evaluating the level of compatibility of two parameters during a workshop described in Section 4.3.1. For example, the question is asked to the experts: is P_1, V_4 "Parana River

	Temperature = 40°C, settleable solids = 1 ml/1 l	COD = 8 – 23 kg/ADt, AOX< 0.25 kg/ADt	Temperature increase no more than 3°C at mixing zone	DO = 5 mg/l, minimum turbidity 100 NTU, maximum	Separation of uncontaminated and contaminated storm waters	Cooling towers	Oxygen delignification, ECF bleaching	Extended aeration	Collecting, control, recycling used clean waters	Storage lagoons	Training for safety measures in the working place (for all)	Training for general environmental aspects (for workers at various departments)	Training for operators of the effluent treatment plant	River water (authorities)	Untreated effluent quality	Treated effluent quality	Groundwater (especially in the surroundings of big tanks)	Groundwater (especially in the surroundings of big tanks)	Outlet of storm water lagoons
Conama 20 Requirements Brazilian Environmental Law	3	1	2	3	1	3	1	1	2	3	1	3	3	3	2	3	3	3	3
EU- BAT Bref (2001)	1	3	1	2	1	1	3	3	2	1	1	1	3	1	3	3	1	1	3
World Bank/IFC EHS Guidelines	3	3	3	2	1	3	3	3	1	1	3	3	3	1	3	3	1	1	3
Parana River Water Quality Requirements (Class II)	1	2	3	3	3	2	1	2	3	3	1	3	3	3	2	3	3	3	3
Water footprint	1	2	1	1	3	3	1	1	3	3	1	2	2	1	3	1	1	1	1
Storm water control	1	2	1	1	3	1	1	1	3	3	1	2	2	3	1	1	1	1	3
Temperature = 40°C, Settleable solids = 1 ml/1 l						3	1	1	2	2	1	1	3	3	2	3	1	3	3
COD = 8 – 23 kg/ADt, AOX< 0.25 kg/ADt						1	3	3	2	2	1	2	3	2	2	3	1	1	3
Temperature increase no more than 3°C at mixing zone						3	1	1	1	3	3	3	3	3	1	3	1	1	1
DO = 5 mg/l, minimum turbidity 100 NTU, maximum						2	2	3	1	2	2	2	2	3	2	3	1	2	3
Separation of uncontaminated and contaminated storm waters						1	1	1	3	3	2	3	3	3	1	1	3	3	3
Cooling towers											3	3	3	3	3	3	1	1	1
Oxygen delignification, ECF bleaching											3	2	1	1	3	3	1	1	1
Extended aeration											1	2	3	1	1	3	1	1	1
Collection, control, recycling used clean waters											1	3	3	3	2	2	2	2	3
Storage lagoons											1	3	3	3	2	2	2	2	3
Training for safety measures in the working place (for all)														2	1	2	3	2	1
Training for general environmental aspects (for workers at various departments)														2	2	2	3	3	2
Training for operators of the Effluent treatment														3	3	3	2	2	3

Figure 3: Cross-consistency assessment matrix.

water quality requirements (Class II)" compatible, neutral, or incompatible with P_3, V_1 "Cooling towers"? When compatible, the interaction is evaluated as optimal (marked with a 3 in the CCA matrix). When neutral, the interaction is evaluated as acceptable (marked with 2). Finally, if the interaction is incompatible, it is evaluated as nonacceptable (marked with a 1). The values assigned in the example shown in Figure 3 are 122 (49.4% of the total) optimal combinations, 27 (11%) acceptable, and 98 (39.6%) nonacceptable.

The CCA matrix reduces the total problem space to an internally consistent solution space. Furthermore, the CCA in a multidimensional matrix is then reduced to find an approximation for an optimal solution. A "parameter-block" is the two-dimensional block of cross-referenced values between two parameters and their values, and it is shown as alternate white and shaded blocks in Figure 3. In some cases, all the cells in the blocks will have optimal combinations, meaning that these two blocks do not constrain each other. If more than half of the block contains optimal values, the solution space will not reduce significantly. On the other hand, if more than half of the values are nonacceptable (or even fewer if distributed in large consecutive arrays), then it will risk choking the model, and no solution will be possible. Poorly and nonadequately defined parameters make the process difficult to manage, and parameters and values must be reformulated in such cases. This process can prove rather time-consuming, and consequently, it is very important to optimize the iteration. This work proposes the use of sensitivity analysis to address this issue.

Table 3: Detailed description of the parameters that combine optimally pairwise in policy 1.

Compared parameter		Combines optimally pairwise with values	
Parameter	Description	Values	Description
$P1V1$	Requirements in Brazilian Environmental Law, Conama 20	$P2V1$	Determination of the appropriate treated effluent quality for physical and chemical parameters
		$P2V4$	Determination of dissolved oxygen and turbidity in the river water
		$P3V1$	Implement specific process equipment (cooling towers) to achieve legal requirements
		$P3V5$	Storm water management by sectorial storage lagoons
		$P4V2$	Environmental training events for workers of production departments
		$P4V3$	Detailed training of operators of effluent treatment plant concerning process, incomes and outcomes, and equipment and their control and maintenance
		$P5V1$	Preparation and implementation of an integrated program for monitoring river water
		$P5V3$	Preparation and implementation of an integrated program for monitoring treated effluent
		$P5V4$	Preparation and implementation of an integrated program for monitoring groundwater at the production area
		$P5V5$	Preparation and implementation of an integrated program for monitoring groundwater as a part of monitoring system of the landfill
		$P5V6$	Preparation and implementation of an internal program for monitoring outlet of storm water lagoons

4.1.3. Generation of New Sets of Policy Concepts. As seen in Figure 3, some parameter values have more optimal combinations than others do. The parameters with the highest amount of optimal combinations share between each other nineteen satisfactory sets of policy concepts. These identified parameters are grouped into three clusters or packages as a final result of GMA. The mentioned clusters are the following.

The parameter value $P1$, $V1$ "requirements in Brazilian environmental law, Conama 20," seen in the first row of Figure 3, has eleven optimal pairwise combinations with other values. The parameter values $P2V1$, $P2V4$, $P3V1$, $P3V5$, $P4V2$, $P4V3$, $P5V1$, $P5V3$, $P5V4$, $P5V5$, and $P5V6$, described in detail in Table 3, optimally combine pairwise with $P1$, $V1$. For simplicity purposes, $P1$, $V1$ and its optimal combinations will be referred from this point onwards as policy 1. The high level of compatibility of policy 1 makes it relevant for WWTP and therefore is selected for further analysis in the next stages.

Likewise, the parameter value $P1$, $V3$ "World Bank/IFC EHS Guidelines" (third row in Figure 3) combines optimally pairwise with twelve parameter values. The parameters combining in an optimal manner with $P1$, $V3$ are $P2V1$, $P2V2$, $P2V3$, $P3V1$, $P3V2$, $P3V3$, $P4V1$, $P4V2$, $P4V3$, $P5V2$, $P5V3$, and $P5V6$, and from now on will be referred to as policy 2. Just as in the case of policy 1, the high compatibility of this cluster makes it relevant for further analysis and thus is selected to be taken to the next stages.

In the same manner, the parameter value $P1$, $V4$ "Parana River Water Quality Requirements (Class II)" (fourth row of Figure 3) combines optimally pairwise with twelve parameter values. The parameter values mentioned are $P2V3$, $P2V4$, $P2V5$, $P3V4$, $P3V5$, $P4V2$, $P4V3$, $P5V1$, $P5V3$, $P5V4$, $P5V5$, and $P5V6$ and henceforth constitute policy 3. Just like in the previous two cases, the high compatibility of policy 3 is enough to be taken for further analysis in the following steps. A list of the parameter values and the amount of optimal pairwise combinations is shown in Figure 4, where policies 1, 2, and 3 are highlighted in yellow.

After defining and identifying the packages or clusters (policies 1, 2, and 3), these clusters are presented back to the experts for their judgment and approval according to their experience. Figures 5 and 6 show the selection of the parameter values that generate optimal combinations of polices 1, 2, and 3 for new WWTP according to environmental experts' judgments. All the parameter values that present optimal combinations to either/or policies 1, 2, and 3 seen in Figure 4 are listed in Figure 5.

To facilitate visualization of the correlation between the policies and their optimal parameter values, a colour code was created and assigned to each policy, further improving understanding of the interactions of the parameter values contained within policies 1, 2, and 3. Red, blue, and green were assigned to the parameter values that combine optimally with policies 1, 2, and 3, respectively. When policies 1 and 2 share a common optimal parameter value combination, it is marked as magenta. Similarly, when policies 2 and 3 share optimal parameter values, it is marked as cyan, and for policies 1 and 3, yellow is used. When policies 1, 2, and 3 share a common parameter value, it is marked as purple.

Figure 6 shows the constitution of the policy packages and the parameter values they have in common. For example, policy package 1 is constituted by 11 parameter values, all of which appear common to either or both policy packages 2 and 3 as indicated in Figure 6. Likewise, it can be seen also for policy packages 2 and 3.

4.2. Optimization through Sensitivity Analysis. In order to establish a relationship between parameters to evaluate

P1,V1	P2,V1	P2,V4	P3,V1	P3,V5	P4,V2	P4,V3	P5,V1	P5,V3	P5,V4	P5,V5	P5,V6	
P1,V2	P2,V2	P3,V2	P3,V3	P4,V3	P5,V2	P5,V3	P5,V6					
P1,V3	P2,V1	P2,V2	P2,V3	P3,V1	P3,V2	P3,V3	P4,V1	P4,V2	P4,V3	P5,V2	P5,V3	P5,V6
P1,V4	P2,V3	P2,V4	P2,V5	P3,V4	P3,V5	P4,V2	P4,V3	P5,V1	P5,V3	P5,V4	P5,V5	P5,V6
P1,V5	P2,V5	P3,V1	P3,V4	P3,V5	P5,V2							
P1,V6	P2,V5	P3,V4	P3,V5	P5,V1	P5,V6							
P2,V1	P3,V1	P4,V3	P5,V1	P5,V3	P5,V5	P5,V6						
P2,V2	P3,V2	P3,V3	P4,V3	P5,V3	P5,V6							
P2,V3	P3,V1	P3,V5	P4,V1	P4,V2	P4,V3	P5,V1	P5,V3					
P2,V4	P3,V3	P5,V1	P5,V3	P5,V6								
P2,V5	P3,V4	P3,V5	P4,V2	P4,V3	P5,V1	P5,V4	P5,V5	P5,V6				
P3,V1	P4,V1	P4,V2	P4,V3	P5,V1	P5,V2	P5,V3						
P3,V2	P4,V1	P5,V2	P5,V3									
P3,V3	P4,V3	P5,V3										
P3,V4	P4,V2	P4,V3	P5,V1	P5,V6								
P3,V5	P4,V2	P4,V3	P5,V1	P5,V6								
P4,V1	P5,V4											
P4,V2	P5,V4	P5,V5										
P4,V3	P5,V1	P5,V2	P5,V3	P5,V6								

Figure 4: Results of cross-consistency assessment, highlighting the parameter values that generate optimal pairwise combinations.

P2,V1	Physical and chemical parameters	Policy 1
P2,V2	Organic compounds and nutrients	Policy 2
P2,V3	Temperature in the mixing zone	Policy 3
P2,V4	Dissolved oxygen and turbidity in the river	Policy 1 + 2
P2,V5	Separation of uncontaminated storm water	Policy 2 + 3
P3,V1	Implement specific equipement cooling tower	Policy 1 + 3
P3,V2	Oxygen delignification, EFC bleaching	Policy 1 + 2 + 3
P3,V3	Extended aeration for effluent quality	
P3,V4	Create water management system for clean used process water	
P3,V5	Storm water control to prevent accidents	
P4,V1	Training for safety measures	
P4,V2	Environmental training for production department	
P4,V3	Detailed training of operators of effluent treatment plant	
P5,V1	Integrated program for monitoring river water	
P5,V2	Integrated program for monitoring untreated effluent	
P5,V3	Integrated program for monitoring treated effluent	
P5,V4	Integrated program for monitoring groundwater	
P5,V5	Integrated program for monitoring system of the landfill	
P5,V6	Program for monitoring outlet of storm water lagoons	

Figure 5: Colour-coded selection of the parameter values that generate optimal combinations for policies 1, 2, and 3, for a new WWTP.

the compatibility of different combinations, meetings and workshops must be organized with experts and iterations must be repeatedly executed to achieve a desirable solution. A desirable solution requires that the number of optimal combinations is big enough to provide options for the decision-makers to analyse, but not so big that the decision-making within the optimal solutions becomes complex again. According to [102], there are no strictly defined higher or lower limits to how extensive the share of optimal combinations from the total possible combinations should be, as it is very case-specific. Nevertheless, the share of optimal combinations typically lies between 1% and 10% of total possible combinations.

However, gathering the required experts for the amount of time required to go through several iterations may be a difficult starting point for the project. In order to optimize the iteration process, a sensitivity analysis can be executed across the CCA matrix (Figure 3) to reduce the number of relationships to evaluate, thus reducing the time required for evaluative iteration.

Figure 7 shows the proportional distribution for pairwise combinations of the values shown in Figure 3. The ratio of combinations of Figure 7 is calculated by obtaining the amount of combinations of value exclusivity and in each cell (containing a parameter value) of the CCA matrix, then aggregating them row-wise. Value exclusivity in this case

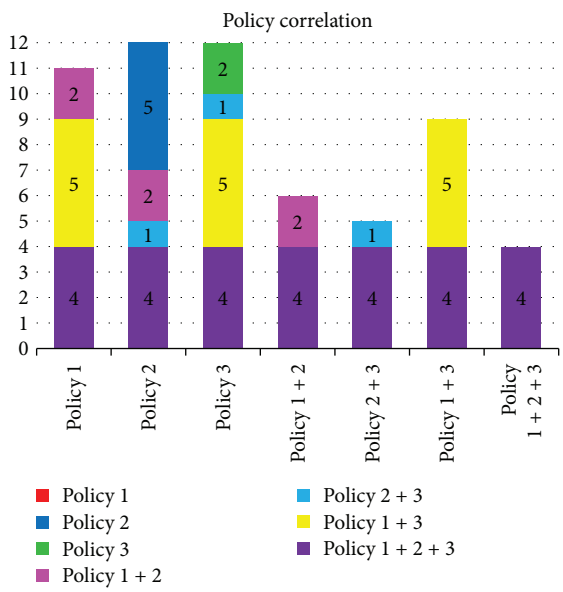

Figure 6: Overall view of the parameter value combinations and their correlations among policies 1, 2, and 3.

means that cells of value 3 are combined exclusively with other cells of value 3 in the matrix. While in theory the method can combine parameters of all values, an optimal solution in principle (and for this case) is considered to be constituted by a combination of optimal parameter values.

For the CCA matrix presented in Figure 3, the optimal combinations of parameter values of the cell $P1, V3$–$P2, V1$ presented in Figure 8(b) is larger than $P1, V1$–$P2V1$ shown in Figure 8(a) and $P1, V4$–$P2, V3$ in Figure 8(c). Simultaneously, the aforementioned cells have more optimal correlations than, for example, $P1, V4$–$P2, V1$. Based on this premise, by analysing the CCA matrix (Figure 3), it is possible to extract the number of correlations of every combination pair (cell) and then compare the number of correlations to the total number of combinations of a selected value, which is done taking into account each parameter value (optimal, acceptable, or nonacceptable) separately.

All cells in a row are then aggregated according to their parameter value, as shown in Figure 7. For example, the row $P1V1$ adds up to 286 unique combinations when only cells of the same value are combined, out of which 226 are of optimal value, 30 are acceptable, and 30 are nonacceptable (or 79.2% optimal, 10.4% acceptable, and 10.4% nonacceptable).

Figure 7 also shows the total distribution of optimal, acceptable, and nonacceptable combinations (right-hand column). The high number of optimal combinations (49.1%) means further iterations can be considered to revaluate the combinations if considered necessary, in order to reduce the number of optimal combinations. The proposed sensitivity analysis is aimed at identifying the effect of modifying the dependence value between two specific elements in the total number of solutions. As expected, some combinations are strongly correlated to more parameters than others.

Figure 8 shows all the unique optimal combinations (value 3) present for the cells: (a) $P1V1$–$P2V1$ (20 combinations), (b) $P1V3$–$P2V1$ (27 combinations), and (c) $P1V4$–$P2V3$ (20 combinations). The rows containing these cells ($P1, V1$, $P1V3$, and $P1, V4$, respectively) contain the largest number of optimal correlations, both in relative numbers (columns 1, 3, and 4 of Figure 7) and in absolute numbers. Therefore, these rows, and the elements contained within them, are thus selected to be the policy packages *policy 1*, *policy 2*, and *policy 3*, chosen for analysis in DSM. The large number of optimal combinations present in these specific cells highlights the potential impact of modifying the values in such cells whilst, for example, changing the value of cell $P1V5$–$P2V5$ could only reduce 4 optimal combinations from the solution space.

Figure 8 shows also something that is not so clear at first glance. For every additional parameter block, the amount of combinations increases in an exponential manner, at a ratio proportional to the number of parameter values of that parameter block. Likewise, the larger number of parameter values within a parameter block would increase significantly the amount of combinations. For example, if an additional parameter block of the size of $P4$ (the smallest parameter block from the example as visible in Figure 2) is added, the total possible amount of combinations would triple. This can potentially become rather problematic, as the evaluation time and computational time can eventually increment beyond the capabilities of a workshop. Hence, decreasing the amount of parameter pairs to be evaluated becomes paramount, opening a gap for sensitivity analysis to select only the most influential values to evaluate, based on their relative weight, thus decreasing dramatically the array of evaluations to be made by experts in one iteration.

Equation 1 shows the method used to calculate the relative weight (RW). The RW of an element pair in respect to the total combinations "K" (subsequent combinations calculated as indicated by Ritchey [18] and exemplified in Figure 8) of value "x" (1, 2, or 3 in the example) in position (a, b) (where "a" is the row and "b" is the column of the CCA matrix). In the equation, "R" stands for the total number of rows; "C" stands for the total number of columns. For example, if the number of combinations of value "3" of the element pair (3,4) is seven $(K_{3(3,4)} = 7)$ and the total of subsequent combinations of all element pairs is one thousand, $\Sigma^R \Sigma^C K_{3(\mathrm{i,j})} = 1000 =$ then the $\mathrm{RW}_{3(3,4)}$ would be 0.7%

$$\mathrm{RW}x_{(a,b)} = \frac{Kx_{(a,b)}}{\sum_{i=1}^{R} \sum_{j=1}^{C} Kx_{(i,j)}}. \tag{1}$$

Figure 9 shows the relative weight of all element pairs, colour-coded to facilitate the evaluation; the colour coding and sensitivity limits assigned for this case are also shown.

Once the RW of all element pairs has been analysed and classified, it is possible to focus on reiteration of the combinations with higher RW value. By revaluating only the combinations with higher RW, shown in red and yellow in Figure 9, up to 54.4% of the total combinations can be shifted from one value to another. This means reducing the optimal solution space by revaluating and possibly changing a combination value from optimal to acceptable, for example, while reiterating only 45 out of the 247 element pairs that

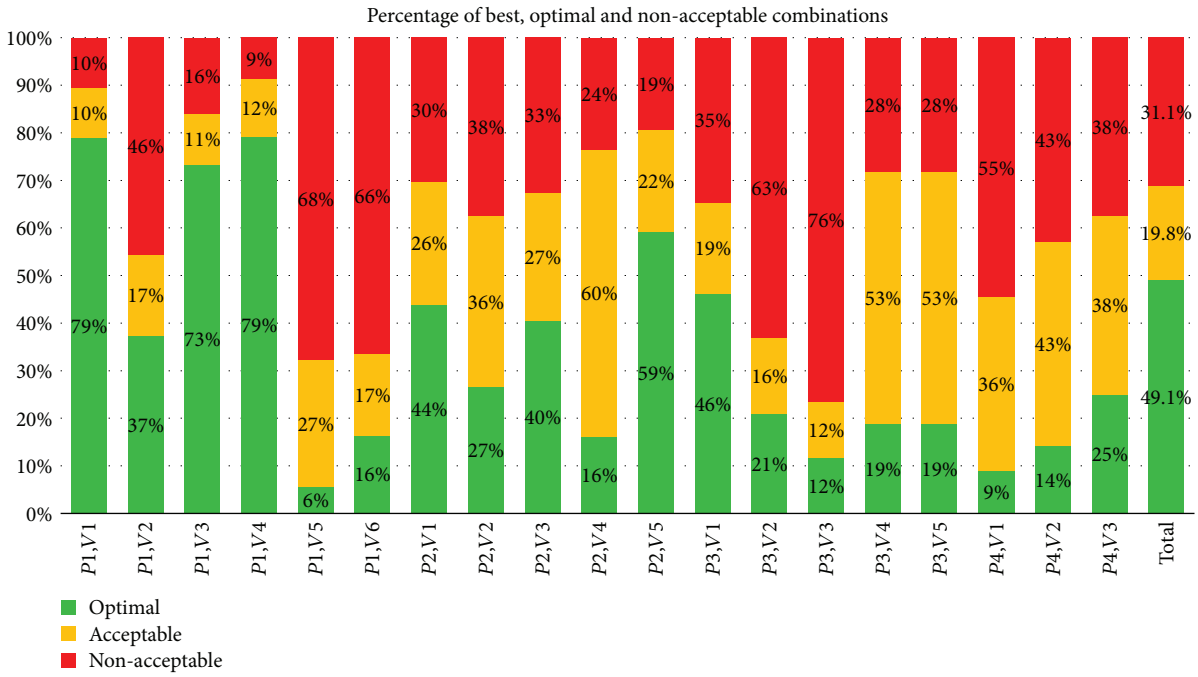

FIGURE 7: Percentage of optimal, acceptable, and non-acceptable pairwise combinations of parameter values.

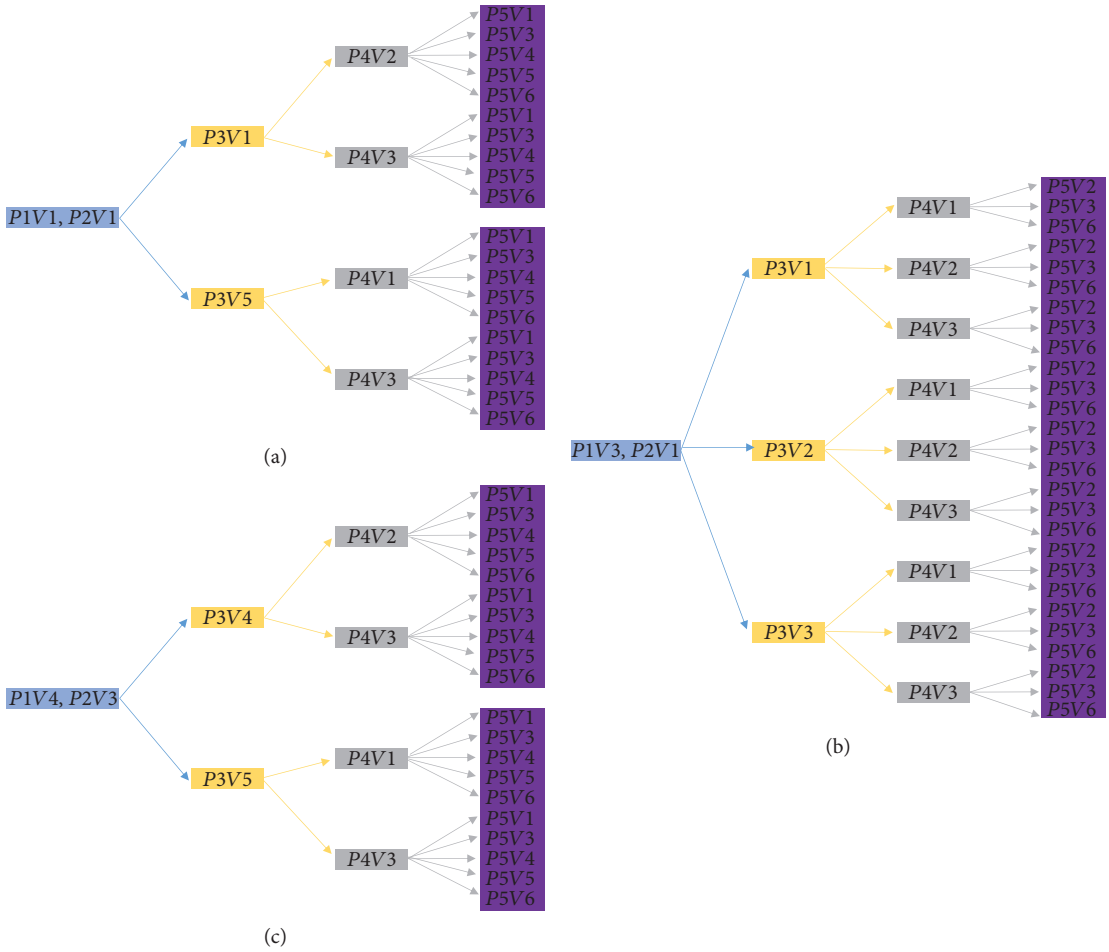

FIGURE 8: Example of unique optimal combinations for the cells associated with policies 1, 2, and 3 (a, b, and c, respectively).

	P2,V1	P2,V2	P2,V3	P2,V4	P2,V5	P3,V1	P3,V2	P3,V3	P3,V4	P3,V5	P4,V1	P4,V2	P4,V3	P5,V1	P5,V2	P5,V3	P5,V4	P5,V5	P5,V6
P1,V1	0.8%	0.0%	0.0%	0.8%	0.0%	1.0%	0.0%	0.0%	0.0%	1.1%	0.0%	1.3%	1.5%	1.3%	0.0%	1.3%	0.8%	0.8%	1.3%
P1,V2	0.0%	0.6%	0.0%	0.0%	0.0%	0.0%	0.6%	0.7%	0.0%	0.0%	0.0%	0.0%	1.3%	0.0%	0.7%	1.2%	0.0%	0.0%	1.2%
P1,V3	0.8%	0.8%	0.8%	0.0%	0.0%	1.0%	0.9%	1.0%	0.0%	0.0%	1.0%	1.3%	1.5%	0.0%	1.1%	1.5%	0.0%	0.0%	1.5%
P1,V4	0.0%	0.0%	0.8%	0.8%	0.9%	0.0%	0.0%	0.0%	1.0%	1.2%	0.0%	1.3%	1.6%	1.3%	0.0%	1.4%	0.9%	0.9%	1.4%
P1,V5	0.0%	0.0%	0.0%	0.0%	0.5%	0.5%	0.0%	0.0%	0.4%	0.6%	0.0%	0.0%	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%	0.0%
P1,V6	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.5%	0.7%	0.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	1.1%
P2,V1						0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	1.0%	0.0%	1.0%	0.0%	0.5%	1.0%
P2,V2						0.0%	0.4%	0.5%	0.0%	0.0%	0.0%	0.0%	1.2%	0.0%	0.0%	1.1%	0.0%	0.0%	1.1%
P2,V3						0.7%	0.0%	0.0%	0.0%	0.8%	0.6%	0.9%	1.2%	1.2%	0.0%	1.3%	0.0%	0.0%	0.0%
P2,V4						0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.9%	0.0%	1.0%	0.0%	0.0%	1.0%
P2,V5						0.0%	0.0%	0.0%	0.7%	0.9%	0.0%	1.0%	1.3%	1.1%	0.0%	0.0%	0.7%	0.7%	1.2%
P3,V1											0.5%	0.8%	1.1%	1.0%	0.7%	1.1%	0.0%	0.0%	0.0%
P3,V2											0.4%	0.0%	0.0%	0.0%	0.5%	1.0%	0.0%	0.0%	0.0%
P3,V3											0.0%	0.0%	1.0%	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%
P3,V4											0.0%	0.7%	1.0%	1.0%	0.0%	0.0%	0.0%	0.0%	1.0%
P3,V5											0.0%	0.7%	1.0%	1.0%	0.0%	0.0%	0.0%	0.0%	1.0%
P4,V1														0.0%	0.0%	0.0%	0.4%	0.0%	0.0%
P4,V2														0.0%	0.0%	0.0%	0.4%	0.4%	0.0%
P4,V3														0.8%	0.4%	0.9%	0.0%	0.0%	0.9%

Red = RW > 1.5%
Yellow = 1% < RW < 1.5%
Blue = 0.5% < RW < 1%
Green = RW < 0.5%

Figure 9: Colour-coded relative weight (RW) of element pairs.

would otherwise be reiterated. Assuming that experts would require roughly the same amount of time to evaluate every combination, conducting a sensitivity analysis in the iteration presented reduced the iteration evaluation time by 81.8% in this example. To put it into numbers, the evaluation of 247 combinations was done in this case during a two-day workshop described in general by Ritchey [97] and in detail for the case study in Section 4.3.1. Considering 9 hours of work (9 hours of the second long day of the workshop) to evaluate 247 combinations, the time required breaks down into an average of one combination evaluated every 2.2 minutes, a rather fast pace due to the high level of experience from the experts. If only 45 element pairs are evaluated instead (as in the example), the whole iteration process would take approximately one hour and forty minutes.

Using the same method, a reduction of over 80% was achieved in all iteration experiments carried out with different variants of the values obtained from the case study. Moreover, through a 1000 loop of randomly generated values for a matrix of the same dimensions (done in Matlab R 2014), it was found that by revaluating an average of 12.2% of total cells, the solution space can be reduced by an average of 73.9%. Even considering that the revaluation of certain combinations would require a different amount of time from others, still by the amount of revaluations avoided the potential for optimization is clear.

Furthermore, sensitivity analysis can be done automatically and directly from the CCA matrix with a spreadsheet to further optimize the iteration process, since the RW of different combinations would change after every iteration and single-cell evaluation.

4.3. Screening and Improving Policy Measures with DSM

4.3.1. Data Collection. The data gathering was conducted through a workshop preceded by interviews and feedback with design practitioners at the industry. In the case under study, a two-day workshop was organized with the participation of 10 experts. Among them were designers and engineers, planners, and managers of different backgrounds and specializations, to rate the sets of policy measures and derive suggestions for reorganization and improvements. Their opinions serve as the directional driver for policy design improvements towards sustainability. The formed group of experts consisted of one general manager, one financial manager, one environmental manager, two heads of manufacturing plants, two designers, two senior planning analysts, and one IT manager with more than 10 years' experience. None of the workshop participants had any experience with GMA or CCA. One of the advantages of carrying out the evaluations of the pairwise combinations in a group of 10 experts is that the individual bias factor is greatly mitigated, as the ultimate chosen value is the result of a consensus between all 10 experts.

The workshop held had a duration of two full days in March 2016 at the facilities of the engineering and consulting company. The experts in the workshop participated on a voluntary basis. A meeting face-face with the experts for a detailed interview preceded the workshop. The abovementioned participants selected and evaluated 25 policy measures for the WWTP during the workshop. The first author was personally involved in the workshop as a facilitator and direct observer and responsible for data collecting. The interviews and the workshop were not recorded due to confidentiality, but detailed notes of answers and their feedback were taken from each interview and the workshop. The members of the multidisciplinary group validated the policy measures for further procedures of the DSM model.

4.3.2. Data Analysis. When building a DSM model, the main objectives are to highlight the information in the system's elements, to design parameters or elements that can be represented in a DSM graph, and to identify the intensity of

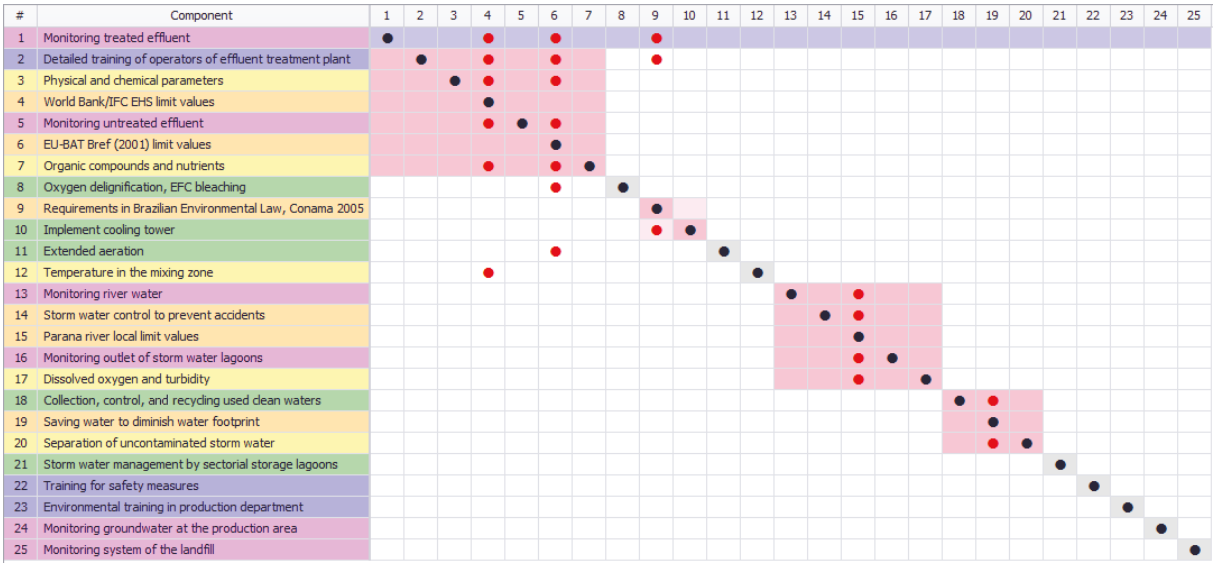

Figure 10: WWTP policy formulation process DSM after partitioning.

dependencies among those elements. A dataset involving policies 1, 2, and 3 with their 19 attributes obtained from GMA (see Figures 4 and 6) was used to build the elements of the DSM matrix. The data was used to examine options for chunking components into subsystems. The analysis was conducted for each dimension of dependency and for the overall DSM.

First, the policies and their elements or policy measures were mapped on a 25×25 square DSM (that includes all policy measure of the system for consistency), where these policy measures are listed vertically in the "Component" column. Second, the dependencies of the elements to be analysed are defined. Based on the dependencies, a DSM graph structure was built and analysed using the ProjectDSM v2.0 (http://www.projectdsm.com) software, which provides an automated DSM optimization step for triangulation. By running the software, the input data is analysed using an algorithm for optimization that consists of two steps: sequencing and clustering. The sequencing step rearranges the order of the parameters to improve the flow based on their dependencies, while the clustering step groups the elements that are strongly interconnected.

The total interactions for each of the 19 elements were assessed, resulting in 22 entries (red dots in Figure 10) in the dataset. The screening mechanism was conducted and implemented using the ProjectDSMv2.0 project planning software. This is extremely helpful for users to optimize the policy sequence within coupled blocks. Therefore, analysing and optimizing the interactions and sequence of policy measures can significantly improve the performance of the policy formulation process [90].

4.3.3. Model Analysis and Visualization of the Policy Measures for Implementation. The policy measures obtained from GMA are listed in the DSM as rows and columns symmetrically. All policy measures' dependencies used for the DSM were obtained during the first day of the workshop for the identified policy measures. The corresponding interaction levels are identified and evaluated in joint collaboration with the experts, chosen, based on their familiarity with the system.

The DSM results are formulated through clustering and partitioning, which, in turn, are used for future work on development of business process diagrams. The second stage of the proposed approach consists of visualization and analysis of the optimal clustering alternatives in order to estimate and reduce the process costs' required time and evaluate risk (high, medium, and low) and effort (days). The visual representation of the policy measures' dependencies provides further insight into the relationships within a complex system, sometimes highlighting information that otherwise could have been missed. This type of evaluation is a fundamental characteristic of design-science research.

The improved sequence of policy in the DSM is shown in Figure 10, indicating the elements and their interdependencies after clustering of the original matrix. This DSM analysis resulted in four clusters, each of which was then defined as a development sequence of policies. The four coupled blocks (in sequence) are (1, 2, 3, 4, 5, 6, 7), (9, 10), (13, 14, 15, 16, 17), and (18, 19, 20). Each block is visualized separately and independently, and this places the most connected elements in the matrix. It can clearly be seen that four shaded blocks along the diagonal were defined based on interdependencies that generally require reorganizing policies with stakeholders.

From the elements' interactions shown in Figure 10, the elements in the lower part of the matrix require inputs from the elements of the upper part of the matrix. Because of this, the elements in the upper part of the matrix should be given higher priority, in order to improve the flow of the policy by executing first the elements that are input to others.

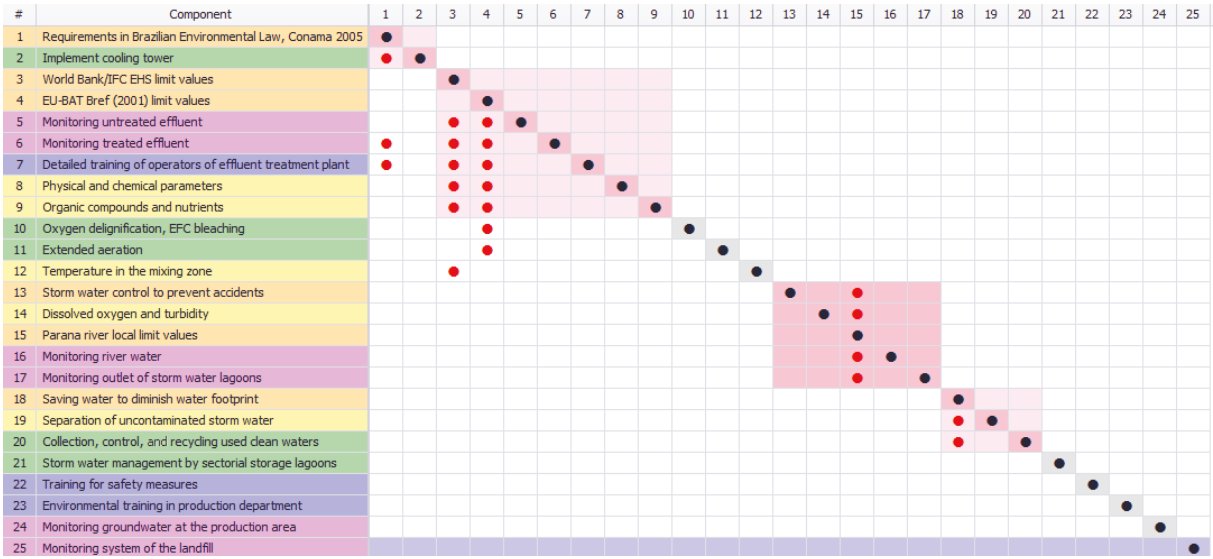

Figure 11: Partitioned DSM.

4.3.4. Reorganization and Improvement of the Process Flow of Policy Measures in DSM. The last stage consists of the reorganization, screening, and improvement of policy process flow understanding via DSM sequence optimization. In the proposed framework, different interaction types in DSM clustering (given in Figure 10) document the original structure of the policy design system in the case study. Next, the DSM partitioning function reveals the most interdependent elements in the matrix. Last, the policy design structure is reorganized and optimized by splitting the larger interdependent clusters into smaller subgroups (shown in Figure 11) that are more manageable.

Although various criteria have been proposed to evaluate policy measures and packages [37, 103], details for a policy package have rarely been revealed with DSM. In this study, interdependent elements were identified and analysed for improvements in the presence of domain specialists and experts involved in the project, who found the process and its resulting sequence of policy measures quite valuable.

The reorganized structure of the DSM matrix through partitioning in Figure 11 proposes an improved organizational structure for the policy measures in the system, thus minimizing the instances of rework. For instance, Figure 11 shows that the element in row 2 "Implement cooling tower" is related to the element "Requirements in Brazilian Environmental Law, Conama 20" under subsystem "Implement legislation," which makes perfect sense. This element in row 2 "Implement cooling tower" originally belonged to the effluent treatment plant (financial aspects in GMA matrix). As a result, managers and designers should consider to restructure their policy design system by reassigning row 2 to "Implement legislation," for better coordination. Through several computational clustering iterations, optimal solutions are reached while considering internal and external block dependencies under certain assumptions. The results were approved by the panel of environmental experts, engineers, and managers who participated in the workshop.

5. Discussion and Managerial Implications

5.1. Policy Measure Development vs. Policy Formulation. GMA and DSM were conducted with the participation of a panel of domain experts in a two-day workshop that resulted in a policy measure reduction model. The concept of policy measures is very complex, since the policies are generally described using natural language, making them difficult to be interpreted, especially when they are competing and conflicting with each other. Another important characteristic of policy measures is that they are intangible, and due to this, it is very hard to systematically break down, analyse, and improve. This is especially difficult considering integration of the sustainability aspects in the early stage of conceptual design. Hence, DSM allows the mentioned analysis and improvement.

5.2. Development of Parameters and Development of Values in GMA. The two morphology constituents, parameters and values, are very different in nature. The definition of parameters requires comparatively more consideration of an expert in comparison to a value, because the interaction of parameters should comprehensively represent the policy concept. To achieve the development of innovative solutions of policy concepts, parameters must be mutually exclusive and collectively exhaustive. Furthermore, the iterative process of GMA and CCA receives a significant improvement through the use of sensitivity analysis [104]. Sensitivity analysis as an optimization tool can be performed with any set of values, in every iteration, and target any type of combination (optimal, acceptable, and nonacceptable). It is a powerful and adaptable tool capable of obtaining desirable solutions in a fraction of the time required otherwise. The analysis can also be automated in a spreadsheet. In addition, the sensitivity limits can be tailored to adapt the method to CCA matrixes of any dimensions, adding another layer of flexibility.

5.3. Defining Information Flow, Dependencies, and Interdependencies in DSM. The most important constituents of DSM—system elements, defining the strength of these element dependencies and interdependencies, and cluster analysis—set the foundation for the advantages of DSM usage. The approach itself helps to illustrate the power of the process architecture, provides a clustering and reorganizing method, and shows all possible information hidden in the policy design and its measures or alternatives. A key insight from the model is the difference between planned and unplanned iterations. With this tool, it is possible to increase the overall understanding of environmental sustainability policy design of wastewater treatment system management among different experts and decision-makers.

5.4. Involvement of Field Experts. The proposed approach of combining GMA and DSM can effectively and efficiently be used for managing complexity of environmental policy formulation. Both GMA and DSM approaches are qualitative methods, and the involvement of the expert's judgment has high impact in the evaluation of solutions, elimination of contradictions in the GMA, building of the elements, and analysis and evaluation of DSM dependencies. In addition, close collaboration between academic or research institutions and companies could facilitate the work of domain experts in order to make optimal decisions.

5.5. Managerial and Practical Implications. The current manuscript has multiple implications for policy design science and society. The main contribution is facilitation of the decision-making process for decision-makers and industry experts. It allows designers and managers to become aware of the complexity of policy measures' generation, policy improvement, and policy implementation in a DSS context. Once the basic understanding of these policy measures and issues is acquired, the relevant authorities have further insights for addressing and tackling counterproductive measures implemented in the industry. The authorities also become more capable of recognising the most important policy measures in order to coordinate efforts to create effective strategies. This work finally aids decision-makers to prepare and practice the implementation of DSS. The proposed approach may assist decision-makers to identify and assess the environmental policy measures, while enabling them to enhance the sustainability of the companies implementing the measures.

The results show the potential of applying DSM to significantly improve the development of policy alternatives, accelerate the design of policies, and improve the entire system's policy structure towards sustainable management. The findings obtained in this work are aimed at further promoting the use of modelling methods in policy formulation with the purpose of performance and effectiveness improvement of policies.

In this sense, the proposed approach targets to support decision-making and to address specific problems in a systematic manner.

6. Conclusions

Environmental policy formulation is a rather complex process that is affected by several uncertain factors, nonquantifiable problems, and unspecified targets. In this paper, a new systematic integrative approach to environmental policy formulation based on structural modelling techniques was presented. The goal of the proposed approach is to support the design of policy, management, and planning in the early stages of conceptual design. The aim was to integrate GMA and DSM, using a case study for generation and improvement of policy measures. The approach consisted of two stages:

(1) First stage: generation, identification, and derivation of policy measures with GMA

(2) Second stage: improvement and screening of the policy measures with DSM

Furthermore, GMA optimization was achieved by reducing iteration time using sensitivity analysis. The methodology for combination of GMA with DSM and avenues for their integration was discussed in detail.

The effectiveness of this integrated approach was illustrated with a real case study of industrial WWTP management planning. The results show the potential of applying GMA and DSM to significantly generate and improve the development of policy alternatives, hasten the design of policies, and improve the whole system's policy structure for sustainable management in WWTP for pulp and paper companies.

The main results of this paper are as follows:

(i) The integration of DSM with GMA improves the overall process from conception and design to integration for improvement and management of complex systems

(ii) The combination of DSM with GMA significantly reduces the policy design process time

(iii) GMA optimization using sensitivity analysis reduces the iteration time

(iv) Combined GMA and DSM methods can define absolute priority importance in a DSS

6.1. Contributions

6.1.1. Theoretical Contribution. This study has several contributions to the field of the sustainable policy design literature. First, from the fundamental research perspective, this work opens the door for further studies of theoretical aspects of the integration of system modelling methods beyond GMA and DSM.

Second, from a methodological point of view, this work expands to the utilization in policy formulation area, by applying systematic modelling methods to sustainable policy design. The presented approach contributes to and promotes research in the domain of multicriteria analysis

and multiobjective optimization using the complex and challenging example of industrial water systems management. Third, the proposed optimization method of CCA through sensitivity analysis is showcased.

6.1.2. Empirical Contribution. From the practical perspective, the suggested approach will help decision-makers and managers in dividing a complex problem into subproblems in the process of policy design. Using creative and analytical modelling methods and decision tools can further improve environmental decision-making performance of policy formulation. Finally this study is, to the authors' best knowledge, the first attempt to develop a systematic integrative approach for environmental policy formulation. Therefore, the suggested approach may be used for future policy design in the current and potentially other fields.

6.2. Limitations. Along with these contributions, however, there are some limitations. First, the GMA-based structural model was not an easy task to implement by the participants in the workshop. All participants needed several iterations of the exercise and guidelines from the facilitator on how to develop the parameters and generate the values in order to familiarize them with the methods. The proposed approach, particularly development of parameters and values in morphological space, is rather significant and strongly dependent on the expert's judgment. Second, the suggested optimization of GMA and CCA through sensitivity analysis should be tailored by the user to matrixes of varied dimensions, as well as decide specific sensitivity limits for each case. Since a large number of combinations are generated in a solution space, appropriate optimization methods and tools can be considered and procedures should be prepared to facilitate the process.

Third, the DSM visualization and clustering method is required to validate the relationships of the policy measures. However, it is still unclear how to prioritize the implementation of policy measures within the clusters. Currently, the scope of this study is limited to the sustainable policy design for water management system and WWTP. Further research and application of the proposed approach to other contexts is still required and will be addressed in future work.

Data Availability

The data used to support the findings of this study have not been made available because of privacy agreements with the interviewees and their respective companies. However, the form used to gather information from the interviewees is available and attached in Appendices A, B, and C.

Additional Points

Highlights. (i) Proposes an integrated framework for generation and improvement of policy measures. (ii) Shows the benefits of combining general morphological analysis and design structure matrix. (iii) Proposes optimization of general morphological analysis through sensitivity analysis. (iv) Presents a case study to show strengths and weaknesses of methods in policy design.

Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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Supplementary Materials

Appendix A: the list of questions used in the first day of the workshop for building the MA matrix. Appendix B: a blank morphological matrix used to build and analyse the parameters and values in GMA in the first day of the workshop with participation of stakeholders. Appendix C: cross-consistency assessment (CCA) matrix used in the second day of the workshop with experts for assessment of parameters and their values. *(Supplementary Materials)*

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