Methodology to Evaluate the Environmental Impact of Wind Power Generation during the Planning Phase of the Facilities Projects

Mauricio Torres
Northern Kentucky University
torresm1@nku.edu

Antonio Cesar Silva Sacco
Paula Souza Technological Education Center
cesar.sacco@fatec.sp.gov.br

Abstract

Due to an increase in energy demand and environmental concerns, the quest for renewable sources of energy such as hydro and wind generation became paramount among government agencies and private entrepreneurs. Hydroelectric power generation is a mature technology; however, it is dependent on heavy investments, hydrology conditions, and (in most cases) extended areas to be flooded for water reservoirs. In view of these constraints, during the last two decades governments established concession policies towards wind power. Thus technology and markets for wind turbines and generators developed in a very fast pace. At first in Europe and USA, and then countries like Brazil, China and Turkey developed their wind power sector. It is estimated that by 2030, approximately 27% of energy consumption in Europe alone will be from renewable sources, mostly from wind power (Newell, 2018). Although wind power has performed well and the accumulated experience has been mostly positive, it also creates significant environmental impacts (Siddiqui & Dincer, 2017) that should not be overlooked.

Although wind farms are exempt from pollutant emissions, their operation and installation promote local physical changes, affecting local climate and geomorphology (Müller, 2015), noise pollution, and wildlife damage (Noetzold, 2017). Therefore, the basic engineering design phase should also include an environmental impact assessment of the project (Melo, 2016).

This paper proposes a methodology to evaluate the environmental impact of wind power generation during the planning phase of the implementation project. The methodology is developed based on the criteria defined by the meta-methodology proposed by Thomann (1973).

ISBN 978-1-60643-379-9

Introduction

Although the use of wind energy goes back to ancient times and has been used for more than 3,000 years in processes that required a source of mechanical energy (Noetzold, 2017), its use in electricity generation has a much more recent history, comprising the last 120 years (Leung & Yang, 2012; de Aquino, 2014). With the oil crisis in the 1970s and discussion associated with global warming, this renewable energy was established as an alternative to the energy demand associated with the evolution of the globalized economy (Noetzold, 2017; Leung & Yang, 2012). Thus, starting in the 1980s, investments were made in wind energy, and as a result, the generation of electricity by wind increased from 2.4GW in 1990 to 539GW in 2017 (Leung & Yang, 2012), supplying 5% of the world's electricity demand (WWEA, 2018). An issue that has received considerable attention is related to the environmental impacts from the installation and operation of wind farms (dos Santos, 2016; Saidur, R., Rahim, Islam, & Solangi, 2011; National Research Council, 2007). Since these plants are mostly onshore (Leung & Yang, 2012), the focus of this work is mainly onshore installations; the terms “wind power generation facilities” and “wind farms” are used interchangeably.

Environmental Impacts of Wind Farms

Given the irreversibility of the participation of wind energy in the global energy matrix, the understanding of the environmental impacts it generates must be better understood (dos Santos, 2016; Loureiro, Gorayeb, & Brannstrom, 2017). The following are the most common environmental hazards described in the literature and for which mitigation studies should be considered when designing the implementation project.

.

Visual Pollution

Due to the large area occupied by a wind farm, it is impossible to deny the changes in landscape and topology as a consequence of its implementation. The presence of the turbines creates a negative impact by the proximity to inhabited areas, reinforcing the perception of disturbances in the landscape (Zerrahn, 2017). The visual intrusion caused by the wind generators, the occupation of the land, and the presence of access roads and transmission lines negatively impacts the landscape. The role of these impacts in the regional socioeconomic context needs to be analyzed, in view of the way the local population accepts this landscape change (Bier, 2016). Because it is a recent technology, there is still no exact way of quantifying the visual pollution caused by wind power plants, mainly due to subjectivity of response. There are authors who suggest a visual simulation of the implementation of the enterprise involving the study of micrositing associated with public audiences with the local population (Noetzold, 2017; Melo, 2016; de Aquino, 2014; Saidur, et al., 2011). A temporal assessment of the landscape change, based on satellite photos, is suggested for monitoring visual impacts due to occupation and land use (Müller, 2015).

Noise Pollution and Health

The presence of homes near the wind farms, besides the visual/landscape issues, also brings noise pollution with negative impacts on residents. The noise generated by wind generators can cause psychological disturbances in people, although, according to studies, this will happen in a small part of the population exposed to noise (Zerrahn, 2017). Wind turbines generate noises that are uncomfortable to people in the proximity in two distinct ways: mechanical noise from gearboxes, generators and bearings, and aerodynamic noise from moving blades and tower structure (Leung & Yang, 2012; Julian, Jane, & Davis, 2007; Oerlemans, Sijtsma, & Méndez López, 2007). Stress manifests itself in the form of headaches, sleep disorders, and hearing loss (Punch, James, & Pabst, 2010). Knowing the sources of noise, steps can be taken to minimize their effects. The profile design of the blades and their dimensions are determining factors, as the air flow when passing through these causes the aerodynamic noise (Oerlemans, Sijtsma, & Méndez López, 2007; Richard, 2007). With regard to noises of mechanical origin, these can be minimized during the design phase of the moving parts with the application of internal acoustic insulation in the turbine's nacelle; installing anti-vibration dampers in the generator and reduction gear box can also help (Richard, 2007). Since the air flow through the system generates aerodynamic noise (and consequently mechanical noise), a study was conducted to identify a possible relationship between wind speed and noise level. The correlation was found to be relatively low at a distance of 300m from the wind turbine (Björkman, 2004), the minimum recommended distance from a habitation for the installation of a turbine (Ministry of Environment and Climate Change, 2008). Therefore, it is estimated that noise at distances greater than 350m is equivalent to that of a household refrigerator (Leung & Yang, 2012). No consideration was given to the temporary noises from the construction of the wind farm, such as those from heavy machinery for earthwork and soil compaction, as well as the traffic of trucks transporting materials (Loureiro, Gorayeb, & Brannstrom, 2015).

Soil Erosion/Disruption

Erosion can be simply defined as the removal and dispersion of soil particles by means of a mechanical action (Eduardo, Carvalho, Machado, Soares, & Almeida, 2013). Although soil disruption is a natural process of soil alteration and decomposition, effected naturally by the action of the winds and rain (dos Santos, 2016), the installation and presence of wind turbines will accelerate the process of local soil erosion (Barbosa Filho & de Azevedo, 2013; Jaber, 2013). This phenomenon begins during the implementation of the wind farm, with the need to remove existing vegetation and earthwork for the construction of tower bases and the installation of buildings and internal access roads. This process increases soil exposure to weathering (Loureiro, Gorayeb, & Brannstrom, 2015; Henrique, 2017). To minimize this environmental impact, during the planning of the project, the planting of native vegetation species, slope protection, and a drainage system for rainwater should be considered (Noetzold, 2017; dos Santos, 2016). In addition to the environmental issues, erosion control is also necessary to ensure the longevity of wind turbine blades, since the particles removed from the soil by the wind have abrasive action on their surface, reducing their useful life and consequently burdening the operation (Dalili, Edrisy, & Carriveau, 2009).

Local Climate Change

The earthwork necessary for the preparation of the infrastructure for wind farm installation causes alterations of the local geomorphology, which may alter the hydrostatic level of the water table. This causes changes in groundwater flow, affecting local water availability (Loureiro, Gorayeb, & Brannstrom, 2015; Barbosa Filho & de Azevedo, 2013; Jaber, 2013). Still related to the water issue, the turbulence of the air at the output of the wind turbine causes the evaporation of the ground water to occur at a higher rate (Leung & Yang, 2012; Baidya Roy, 2011), and the same turbulence is associated with changes in temperatures near wind farms (Biello, 2010; Keith, DeCarolis, Denkenberger, Lenschow, Malyshev, Pacala, & Rasch, 2004). In view of these effects, models and simulations are used to search for solutions to this phenomenon (Baidya Roy, 2011; Porté-Agel et al., 2011[Baidya Roy & Traiteur, 2010).

Animal Death of Local and Migratory Species

The negative impact of wind turbines on wildland species begins when the site is being prepared. At that time, native vegetation is removed and the shape of the terrain is altered by heavy machinery Zerrahn, 2017), which affects the behavior of the animals and causes spatial disorientation. During this phase, terrestrial animals abandon their natural habitat, to return later after the completion of the implementation work. After this period, an interesting aspect is the noise-induced vulnerability by the turbines, which makes it difficult for small animals to hear the approach of predators (Helldin, Jung, Neumann, Olsson, Skarin, & Widemo, 2012). A similar situation occurs with birds and bats but with greater severity because they fly near the wind farm structures that invade the air space. This specific condition brings risks of impact with the structures installed and creates a barrier for the passage of birds and bats, which are also affected by air displacement due to the turbulence of the wind turbines (Drewitt & Langston, 2006). There is also an aggravating condition for bats, since the sound frequencies of wind turbines interfere with their orientation in flight (Ahlén, 2003; Kunz, et al., 2007). Although collision with the wind farm features (structures, turbines, etc.) is the main cause for animal deaths (Saidur et al., 2011; Barbosa Filho & de Azevedo, 2013), another cause of death for birds and bats has been discovered: pulmonary embolism due to the sudden pressure variation that occurs with the air flow during its passage through the wind generator (Baerwald, D’Amours, Klug, & Barclay, 2008).

Although there is a lack of quantitative data on environmental impacts, some metrics on bird and bat mortality are available. According to research, the mortality of birds and bats is measured in two different ways. One of them uses the number of annual deaths per turbine and, according to the compilation made for the USA in the last decade, for birds this indicator varied from 0.63 to 9.33 animals per turbine per year. According to this same criterion, in the case of bats, there was a regional variation of 0.01 to 42.7 deaths per turbine each year (Noetzold, 2017). A second form used is the number of deaths per MW generated each year. In a 2011 survey, using this indicator, the average number of deaths in the USA was 3.1 birds/MW/year and 4.6 bats/MW/year. Saidur et al. reveals a curious fact related to animal deaths: cats killed 6.7 thousand times more birds than wind turbines (2011). One way to reduce the mortality caused by wind turbines is to study the behavior of native and migratory species and to seek solutions that can minimize this environmental impact (Hüppop, Dierschke, Exo, Fredrich, & Hill, 2006).

Methodology

Definition

Methodology is defined as “a body of practices, procedures, and rules used by those who work in a discipline or engage in an inquiry; a set of working methods” (Collins, 2014), representing a package comprising practical ideas and proven practices for a given area of activity. Andreas (1983) states that methodology relates to how propositions (plans, scientific arguments) can be justified, having a bearing on what happens in practice, helping to provide elements for the definition of a decision situation.

Meta-Methodology

In this paper, the proposed methodology development will be structured according to the meta-methodology described by Thomann (1973) as a procedure designed to develop and test a methodology for a specific and definable purpose. It comprises seven basic steps:

1. Identify the area in which a methodology is needed.
2. Determine the purpose around which a methodology is to be developed.
3. Test the purpose against four criteria: desirability, operationability, practicability, and insufficient existing methodologies.
4. Design the methodology to produce its outline.
5. Operationalize the purpose.
6. Design procedures.
7. Test and revise the purpose and/or procedures, if necessary.

It should be noted that steps 6 and 7 can be done simultaneously, as step 7 can help the methodologist identify the gaps, and step 6 provides steps that can be tested by step 7.

Evaluation Methodology Design

The IDEF0 (1993) modeling architecture is selected to model activities related to this work. An IDEF0 model is an ordered collection of diagrams, related in a precise manner to form a coherent model of the subject. The activity that represents the simplest "diagram" form of an activity model is called a "context diagram" (Figure 1).

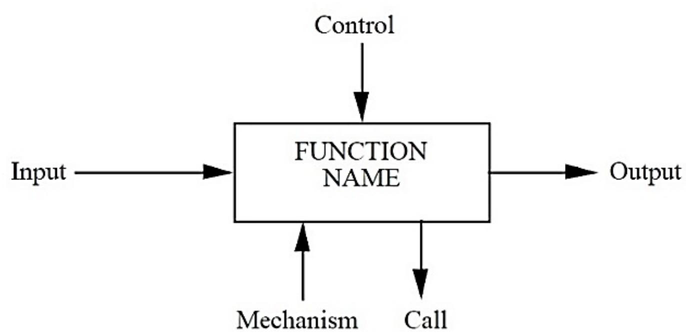

Figure 1. IDEF0 context diagram.

Only a single activity is shown in a context diagram. Multiple activities are shown in a "decomposition diagram." It is used to produce a function model, which is a structured representation of the functions of a system and related information and objects (Figure 2).

ISBN 978-1-60643-379-9

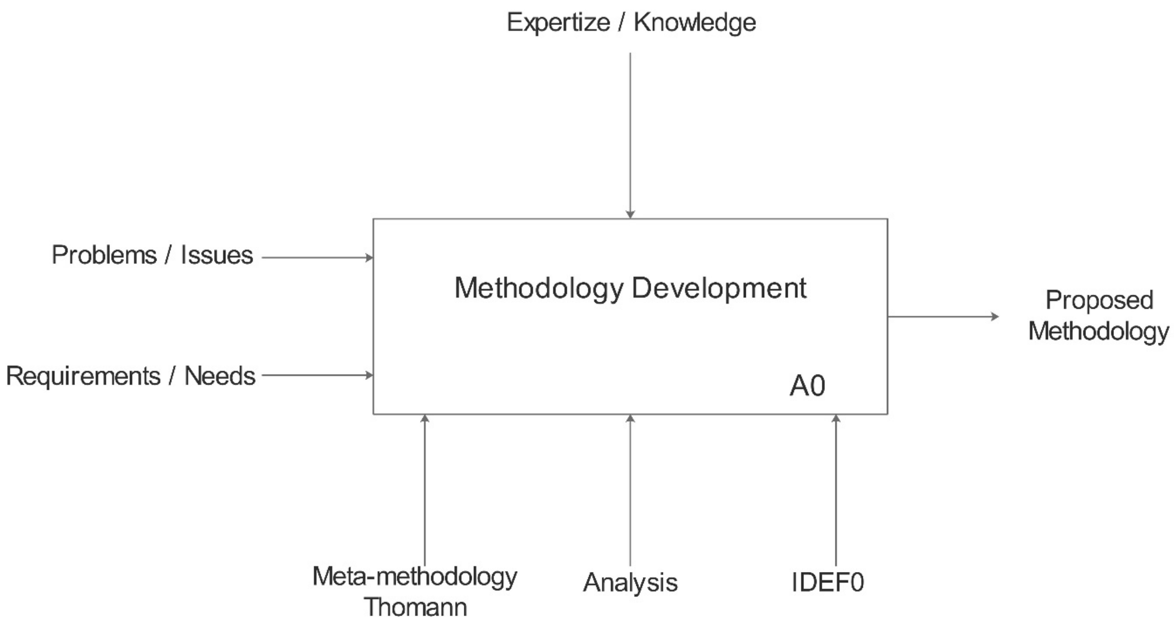

Figure 2. Methodology development, IDEF0.

The subject of the activity model is the systematic evaluation of the environmental impact of wind generation, by the use of inputs that are traceable by the evaluator. The validated evaluation report (output) captures the related processes (Figure 3).

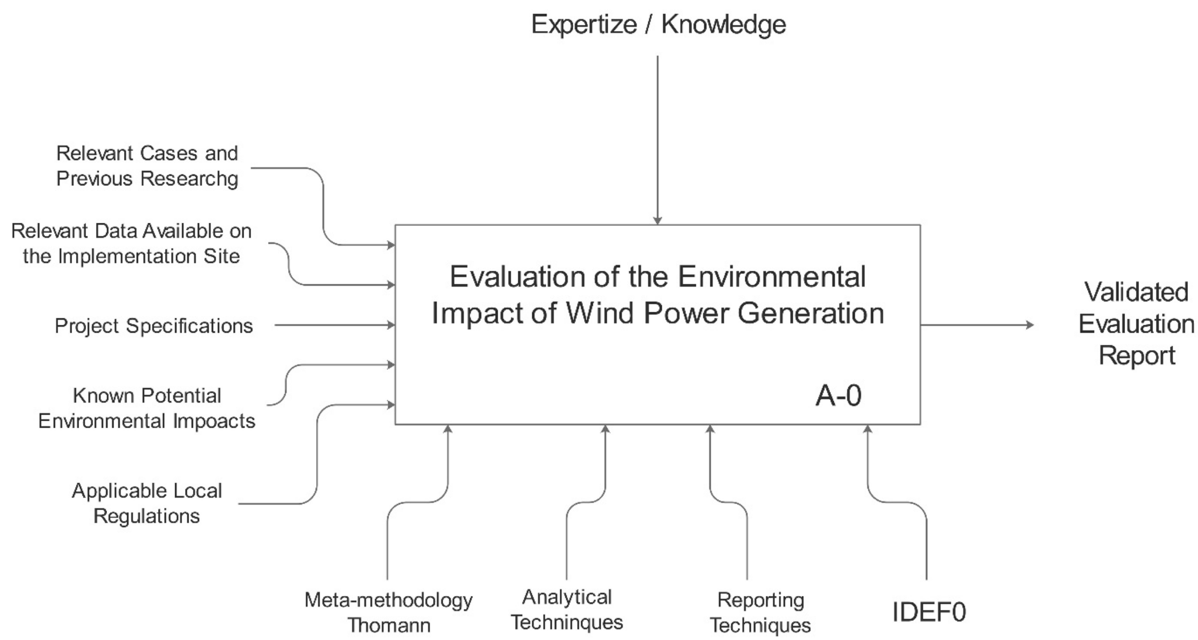

Figure 3. Methodology, node A-0

The IDEF0 modeling language prescribes that complex activities are broken up into smaller ones that can be more readily understood. This will result in a structure that is fashioned after the framework proposed by Thomann (1973). The node A-0 is decomposed, as shown in Figure 4.

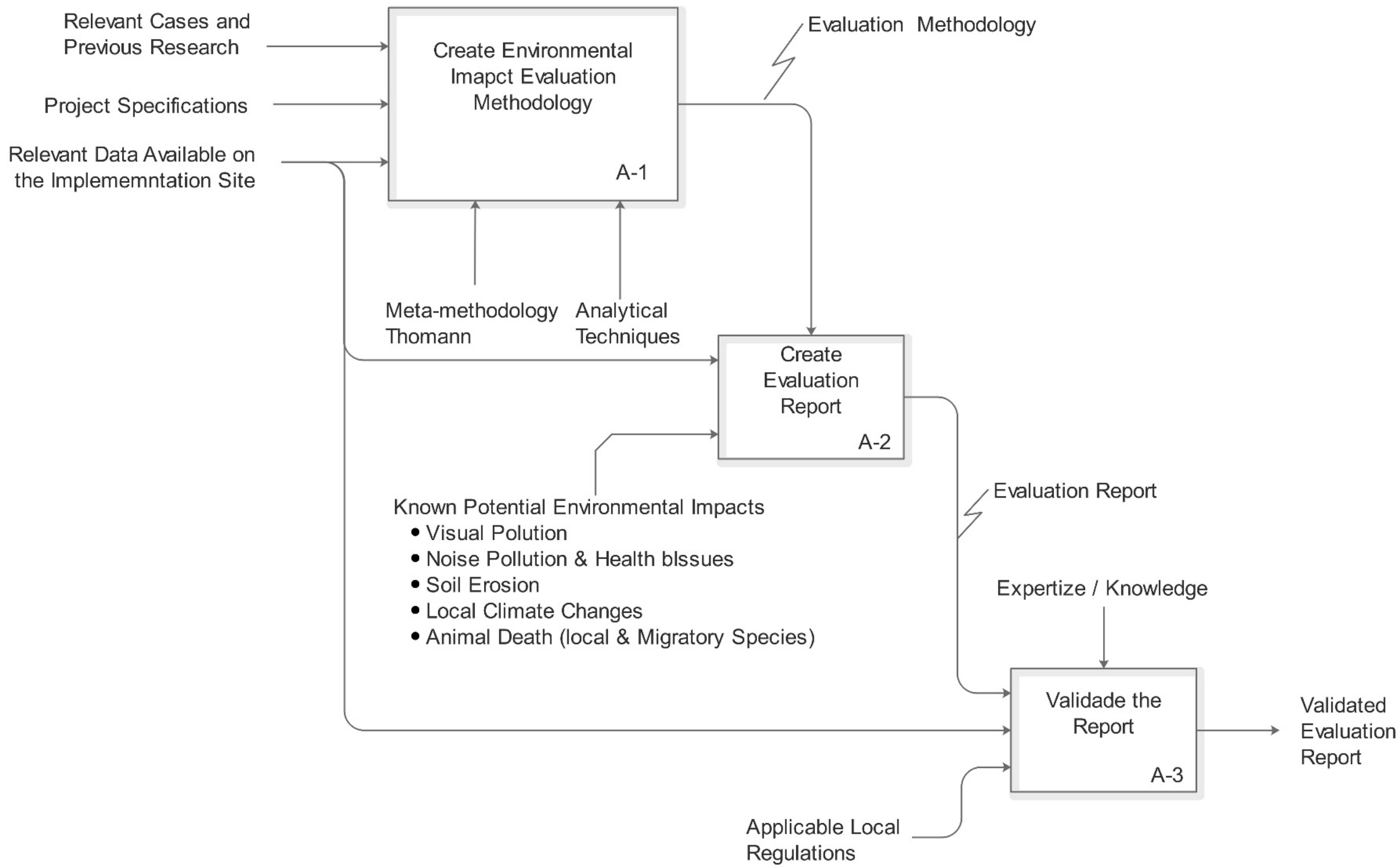

Figure 4. Creation of the evaluation report.

The evaluation procedure starts with submitting project specifications as well as site information, followed by retrieving the closest implementation match from a knowledge database. Also, if known metrics on impact from environmental factors exist, they are also retrieved. If enough previous references and/or data are not available, an alternative approach should be attempted, such as the application of fuzzy theory as proposed by Enea and Salemi (2001). The literature review indicates the most significant environmental impacts produced by the operation of wind farms as well as the recommended mitigation measures, as depicted in Table 1.

Table 1. Suggested mitigation measures.

Environmental impact factor	Mitigation measures
Visual pollution	Is suggested visual simulation of the implementation of the enterprise involving the study of micrositing associated with public audiences with the local population. A temporal assessment of the landscape change, based on satellite photos, is suggested for the monitoring of visual impacts due to occupation and land use
Noise pollution and health	In the design phase of the moving parts: application of internal acoustic insulation in the turbine's nacelle; installing anti-vibration dampers in the generator and reduction gear box.
Soil erosion / disruption	Planting of native vegetation species, slope protection and a drainage system for rainwater
Local climate change	models and simulations are used to search for solutions to this phenomenon
Animal death of local and migratory species	Study the behavior of native and migratory species and to seek solutions that can minimize this environmental impact

The report will then be validated in view of local applicable regulations. In node A-3 the requirements from local regulations are appended to the analysis. Although the requirements for the licensing of wind farms vary greatly within different administrative spheres (local, state, federal, international, etc.), in general three types of environmental permits are considered: preliminary license, installation license and operating license (de Aquino, 2014).

The evaluation report is the output of the evaluation process using the proposed methodology. Haffar and Searcy (2018) propose a context-based environmental reporting framework by analyzing environmental performance indicators. This is defined as "observed value representative of a phenomenon under study," which provides "information about the main characteristics that affect the sustainability of products and processes from a sustainability viewpoint" (Herva, Franco, Carrasco, & Roca, 2011). The activities in node A-1 are further decomposed, as depicted in Figure 5.

ISBN 978-1-60643-379-9

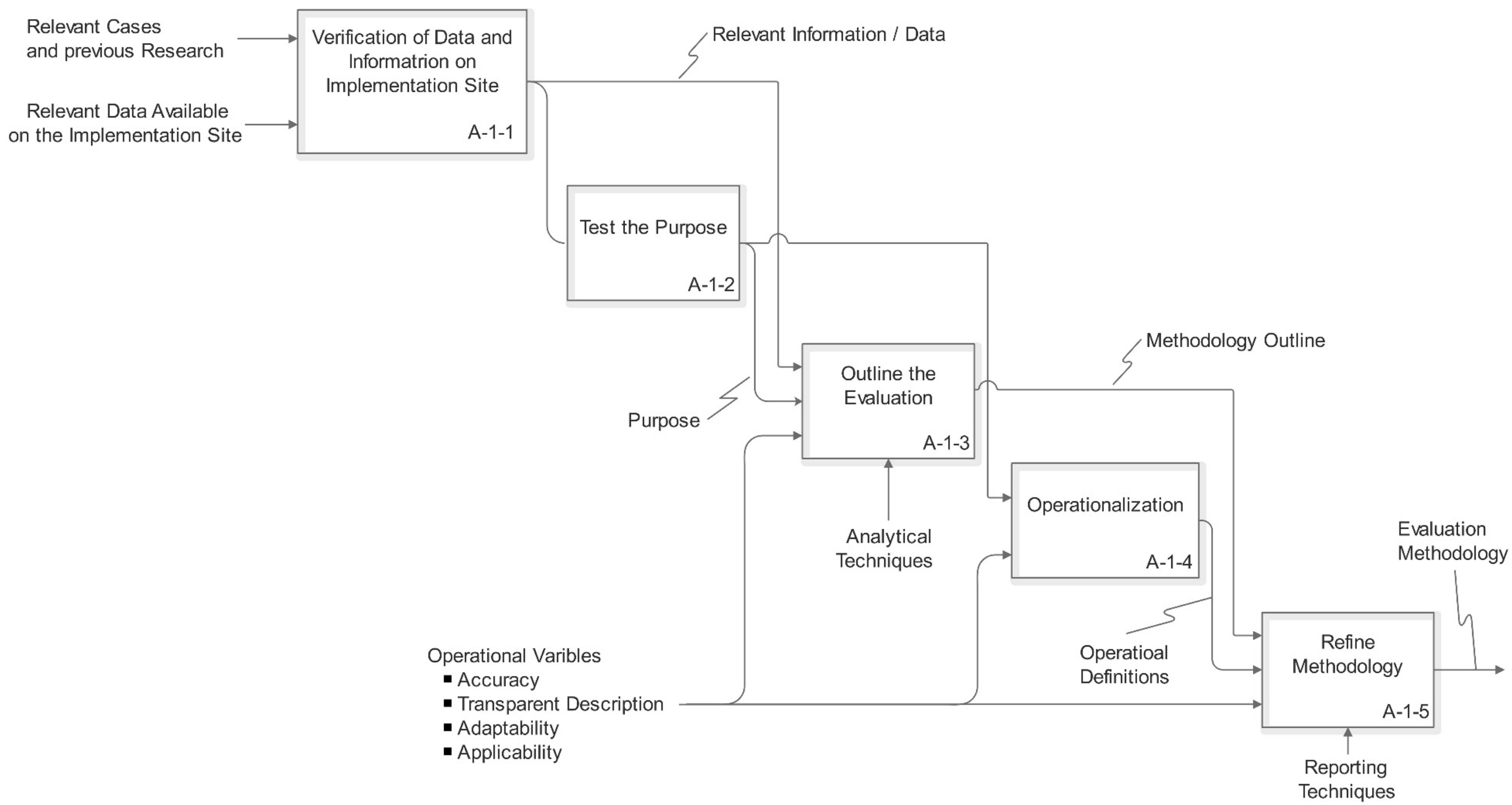

Figure 5. Environmental impact evaluation methodology design, node A-1.

Node A-1-1 identifies the area in which the required methodology is needed; e.g., addressing the need to evaluate environmental impacts in the implementation of wind power facilities. The availability of relevant data is assessed, and this analysis determines if the evaluation is technically feasible, if the currently available knowledge is adequate to meet the requirements.

In the node A-1-2, the purpose is tested for four criteria: desirability, operationability, practicability, and insufficient existing methodologies. Due to the intensity and variety of potential environmental problems caused by wind farms, an accurate dimensioning of its impacts is not being appropriately conveyed by environmental impact studies. For this reason, lawsuits have been filed in different judicial instances and in some cases, those reports were deemed insufficient to assess possible environmental impacts. Social and political movements have been initiated in opposition to the way that evaluation has been done, while environmental experts are recommending a more precise approach in the evaluation process before the installation permit is granted (de Aquino, 2014).

In the node A-1-3, the main problem is further decomposed into simpler sub-problems, which allows a more focused approach during development. All the available information and data is screened by its relevance and categorized (node A-1-3-1). Processes for site evaluation as well as comparative models and metrics are established (nodes A-1-3-2 and A-1-3-3). A procedure for analysis will be defined, and the appropriate tools will be chosen. These tools are statistical methods, mathematical models, simulation, etc. At this stage a preliminary methodology for the environmental impact evaluation is outlined (Figure 6).

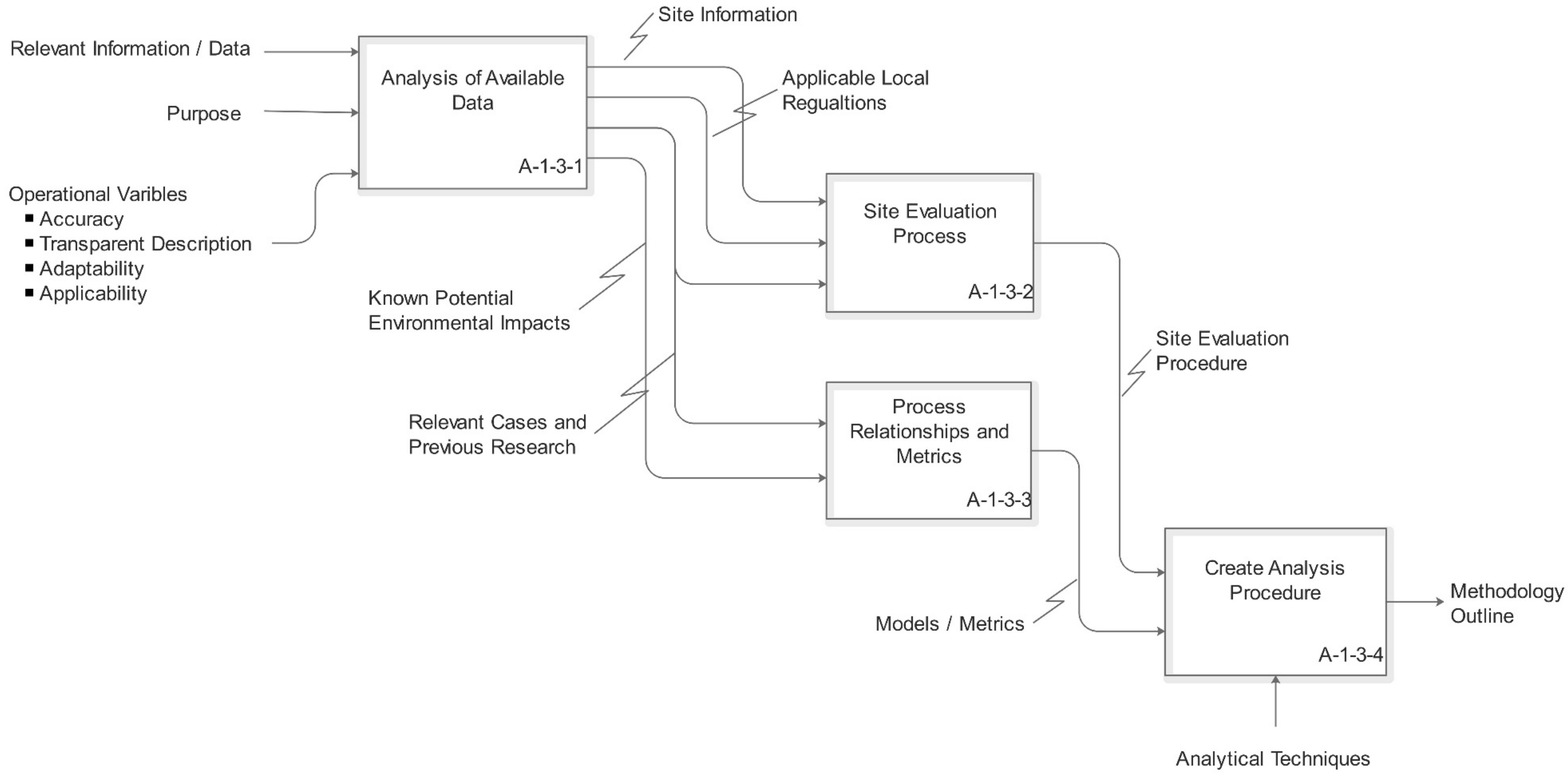

Figure 6. Outlining the methodology, node A-1-3.

The environmental impact report is based on available specifications for the project, site information, and knowledge of possible environmental impact factors (and metrics). As wind power generation is a relatively new power engineering field, the technology is not yet extensively understood in all aspects; the availability of data for analysis and metrics is limited, and for this reason the methodology approach is case and process knowledge-based.

The operationalization of the methodology (node A-1-4) assures the correct answers to the appropriate questions. For this purpose, a set of operational definitions are established considering the methodology requirements, as depicted in Table 2.

Table 2. Operationalization of the purpose.

Concept	Variable	Operational Definitions
Methodology to Evaluate the Environmental Impact of Wind Power Generation	Accuracy	The methodology provides acceptable accuracy
		The methodology provides good enough accuracy to enable its widespread use.
		The methodology provide acceptable accuracy in a reasonable period of time.
	Transparent description of environmental impacts	The environmental impacts analyzed using the methodology are depicted in enough details.
		The methodology exposes the appropriate context
	Adaptability	The methodology allows continuous acquisition of knowledge.
		The methodology provides the ability to pass over any knowledge that is no longer essential or applicable.
		The methodology is transparent to changes in technology and resources availability
	Applicability	The methodology is applicable to the environmental impact analysis in different instances
		The methodology is applicable to complex projects in a practical fashion.

At this point, the evaluation report will be outlined, and environmental impact assessed, taking into consideration the operational definitions set in node A-1-4 of the methodology. In node A-1-5 the methodology is screened for inconsistencies and other possible shortcomings in view of the operational definitions.

Conclusion

The implementation of wind power generation facilities (wind farms) requires a comprehensive environmental impact assessment to support necessary actions and mitigation measures towards minimizing such impacts (Haffar & Searcy, 2018).

In this work, a methodology to evaluate the environmental impact of wind power generation during the planning phase of the facilities is proposed in the form of a structured scheme. This scheme aims to develop environmental impact reports by deploying analytical and reporting techniques, available site information, and knowledge based on previous cases. The proposed methodology will guide the evaluator in the process of creating location-specific documentation. It will also be an aid to agencies (governmental or private) in the bid equalization process, if there is no such procedure in place. This work is also the first of a series of managerial tools intended to provide a structured approach for the planning of wind power generation projects.

References

Ahlén, I. (2003). *Wind turbines and bats—A pilot study*. Eskilstuna, Sweden: Swedish Energy Agency.

Andreas, F. (1983). Critical rationalism and planning methodology. *Urban Studies, 20*(3), 265-278.

Baerwald, E. F., D'Amours, G. H., Klug, B. J., & Barclay, R. M. R. (2008). Barotrauma is a significant cause of bat fatalities at wind turbines. *Current Biology, 18*(16), R695-R696.

Baidya Roy, S. (2011). Simulating impacts of wind farms on local hydrometeorology. *Journal of Wind Engineering and Industrial Aerodynamics*, *99*(4), 491-498.

Baidya Roy, S., & Traiteur, J. J. (2010). Impacts of wind farms on surface air temperatures. *Proceedings of the National Academy of Sciences*, *107*(42), 17899-17904.

Barbosa Filho, W. P. & de Azevedo, A. C. S. (2013). Impactos ambientais em usinas eólicas [Environmental impacts of wind farms]. *Agrener GD*, 1-17.

Biello, D. (2010). How wind turbines affect your (very) local weather. *Scientific American.* Retrieved from https://www.scientificamerican.com/article/how-wind-turbines-affect-temperature/#

Bier, L. L. (2016). Estudo da paisagem: percepções sobre o Complexo Eólico de Osório/RS [Landscape study: Perceptions on the Osório RS, wind farm complex]. *Dissertação de Mestrado—Instituto de Geociências, Universidade Federal do Rio Grande do Sul. Monography*.

Björkman, M. (2004). Long time measurements of noise from wind turbines. *Journal of Sound and Vibration, 277*(3), 567-572.

Collins English dictionary. (12 ed.) Glasgow, Scotland: Collins, 2014.

Dalili, N., Edrisy, A., & Carriveau, R. (2009). A review of surface engineering issues critical to wind turbine performance. *Renewable and Sustainable Energy Reviews,* 13(2), 428-438.

ISBN 978-1-60643-379-9

de Aquino, I. B. (2014). Aspectos do licenciamento ambiental e produção de energia eólica no litoral do Estado do Ceará [Environmental aspects licensing and wind energy production in Ceara state seaboard]. *Dissertação de Mestrado, Programa de Pós-Graduação em Geografia, Universidade Estadual do Ceará, Fortaleza.*

dos Santos, W. A. A. (2016). Atuação, monitoramento e análise de processos erosivos no âmbito de parques eólicos: Estudo de caso nas regiões litorânea e agreste do Nordeste brasileiro [Monitoring and analysis of eroding processes within wind farms–Case study in the seaboard and mainland of Brazilian northeast]. *Revista de Geociências do Nordeste, 2*, 133-142.

Drewitt, A. L., & Langston, R. H, (2006). Assessing the impacts of wind farms on birds. *Ibis, 148*(1), 29-42.

Eduardo, E. N., Carvalho, D. F. d., Machado, R. L., Soares, P. F. C. & Almeida, W. S. d. (2013). Erodibilidade, fatores cobertura e manejo e práticas conservacionistas em argissolo vermelho-amarelo, sob condições de chuva natural [Erosion, cover factors, handling and conservation practicies in yellow-red claysoil under natural rain conditions]. *Revista Brasileira de Ciência do Solo, 37*, 796-803.

Enea, M., & Salemi, G. (2001). Fuzzy approach to the environmental impact evaluation. *Ecological Modelling*, *136*(2), 131-147.

Haffar, M., & Searcy, C. (2018). The use of context-based environmental indicators in corporate reporting. *Journal of Cleaner Production, 192*, 496-513.

Helldin, J. O., Jung, J., Neumann, W., Olsson, M., Skarin, A., & Widemo, F. (2012). *The impacts of wind power on terrestrial mammals*. Report 6510. Stockholm: Swedish Environmental Protection Agency.

Herva, M., A. Franco, A., Carrasco, E. F., & Roca, E. (2011). Review of corporate environmental indicators. *Journal of Cleaner Production*, *19*(15), 1687-1699.

Henrique, F. (2017). Estudos dos impactos ambientais negativos de empreendimentos eólicos como subsidio para a resolução do CONAMA 462/2014 [Study of the wind energy enterprises' negative environmental impacts as a support for the CONAMA 462/2014 Resolution]. *Dissertação de Mestrado—Universidade Federal de Santa Catarina*.

Hüppop, O., Dierschke, J., Exo, K. M., Fredrich, E., & Hill, R. (2006). Bird migration studies and potential collision risk with offshore wind turbines. *Ibis*, *148*(1), 90-109.

Integration definition for function modeling (IDEF0). (1993). Gaithersburg, MD: National Institute of Standards and Technology.

Jaber, S. (2013). Environmental impacts of wind energy. *Journal of Clean Energy Technologies, 1*(3), 251-254.

Julian, D., Jane, X., & Davis, R. (2007). Noise pollution from wind turbine, living with amplitude modulation, lower frequency emissions and sleep deprivation. *Proceedings of the Second International Meeting on Wind Turbine Noise*. New Brighton, Merseyside, UK: INCE Europe.

Keith, D. W., DeCarolis, J. F., Denkenberger, D. C., Lenschow, D. H., Malyshev, S. L., Pacala, S., & Rasch, P. J. (2004). The influence of large-scale wind power on global climate. *Proceedings of the National Academy of Sciences*, *101*(46), 16115-16120.

Kunz, T. H. et al. (2007). Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. *Frontiers in Ecology and the Environment*, *5*(6), 315-324.

Leung, D. Y. C., & Yang, Y. (2012). Wind energy development and its environmental impact: A review. *Renewable and Sustainable Energy Reviews, 16*(1), 1031-1039.
Loureiro, C. V., Gorayeb, A., & Brannstrom, C. (2015). Implantação de energia eólica e estimativa das perdas ambientais em um setor do litoral oeste do Ceará, Brasil," [Implementation of wind energy and environmental losses estimation in a sector of the Ceará state west seaboard, Brazil]. *Geosaberes: Revista de Estudos Geoeducacionais, 6*(1), 24-38.
Loureiro, C. V., Gorayeb, A., & Brannstrom, C. (2017). Análise comparativa de politicas de implantação e resultados sociais da energia eólica no Brasil e nos Estados Unidos [Comparison of implementation policies and social results of wind energy in Brazil and in the USA]. *Raega-O Espaço Geográfico em Análise*, *40*, 231-247.
Melo, J. L. (2016). Análise das etapas de desenvolvimento de projetos de energia eólica: estudo de caso [Analysis in the development phases in wind energy projects—Case study]. *Encontro Internacional sobre Gestao Empresarial e Meio Ambiente Curitiba*.
Ministry of Environment and Climate Change. (2008). *Noise guidelines for wind farms*. Retrieved from https://www.ontario.ca/page/noise-guidelines-wind-farms
Müller, M. d. L. (2015). Análise da degradação no espaço temporal entre os balneários da barra do Chuí e do Hermenegildo, Santa Vitória Do Palmar/RS [Analysis of the degradation in the temporal space between the Barra do Chui e Hermenegildo e Santa Vitoria do Palmas RS spas]. *Monografia (Especializaçao—Instituto de Geociências, Universidade Federal do Rio Grande do Sul*.
National Research Council. (2007). *Environmental impacts of wind-energy projects*. Washington, DC: The National Academies Press.
Newell, D. (2018). Implementing wind power policy—Institutional frameworks and the beliefs of sovereigns. *Land Use Policy, 72*, 16-26.
Noetzold, R. (2017). Impactos ambientais diretos constatados na operação de usinas eólicas [Observed environmental impacts in wind farms operations]. *Monografia (Especialização)—Universidade Federal do Paraná*.
Oerlemans, S., Sijtsma, P., & Méndez López, B. (2007). Location and quantification of noise sources on a wind turbine. *Journal of Sound and Vibration*, *299*(4), 869-883.
Porté-Agel, F., Wu, Y.-T., Lu, H., & Conzemius, R. J. (2011). Large-eddy simulation of atmospheric boundary layer flow through wind turbines and wind farms. *Journal of Wind Engineering and Industrial Aerodynamics, 99*(4),154-168.
Punch, J., James, R., & Pabst, D. (2010). Wind turbine noise: What audiologists should know. *Audiology Today, 22*(4), 20-3.
Richard, G. (2007). *Wind developments: Technical and social impact considerations*. Retrieved from http://www.orkneywind.co.uk/projects/Wind%20Developments%20-%20planning%20considerations.pdf
Saidur, R., Rahim, N. A.. Islam, M. R., & Solangi, K. H. (2011). Environmental impact of wind energy. *Renewable and Sustainable Energy Reviews, 15*(5), 2423-2430.
Siddiqui, O., & Dincer, I. (2017). Comparative assessment of the environmental impacts of nuclear, wind and hydro-electric power plants in Ontario: A life cycle assessment. *Journal of Cleaner Production, 164*, 848-860.
Thomann, J. (1973). Meta-methodology: An overview of what it is and how it was developed. *Proceedings of the American Educational Research Association 58th Annual Meeting*. Washington, DC: AERA.

WWEA. (2018). *World power capacity reaches 539 GW, 52,6 GW added in 2017*. Retrieved from http://www.wwindea.org/2017-statistics/

Zerrahn, A. (2017). Wind power and externalities. *Ecological Economics*, *141*, 245-260.

Biographies

MAURICIO TORRES is currently an assistant professor in the Engineering Technology programs at Northern Kentucky University. Dr. Torres received his BS in Business Administration from City University of Sao Caetano do Sul, BS in Mechanical Industrial Engineering from Braz Cubas University, Brazil, MS in Engineering Management and PhD in Industrial and Systems Engineering from Florida International University. He has extensive experience in manufacturing, and his interests are manufacturing processes, enterprise engineering, and engineering/technology education. Dr. Torres can be reached at torresm1@nku.edu.

ANTONIO CESAR SILVA SACCO is currently an associate professor in the Information Technology programs at Paula Souza Technological Education Center, São Paulo, Brazil. Dr. Sacco received his BS in Mechanical Industrial Engineering from School of Industrial Engineering of São José dos Campos, Brazil, MS in Biotechnology, and PhD in Biotechnology (Bioinformatics) from São Carlos Federal University, Brazil. He has extensive experience in manufacturing, and his interests are manufacturing processes, enterprise engineering, business process modeling, green IT, and bioinformatics. Dr. Sacco can be reached at cesar.sacco@fatec.sp.gov.br (website URL: http://www.fatectatui.edu.br).