

A CONCEPTUAL FRAMEWORK TO ENHANCE STAKEHOLDERS' SYNERGIES FOR IMPLEMENTING SUSTAINABLE INNOVATIONS

Angie Ruiz, Silu Bhochhibhoya, Leentje Volker, André Dorée
Construction Management and Engineering Department, University of Twente
a.l.ruizrobles@utwente.nl

ABSTRACT

Multiple efforts have been made around the inclusion of the principle of sustainability in the asphalt road sector such as the development of eco-friendly materials, assessment tools, certifications, sustainable public policies, regulations, etc. However, in times of rapid change, strategies that promote the implementation of sustainable innovations (e.g. public policies, regulations, and evaluation instruments) struggle to keep up with new insights and legislation changes. This is because developing and improving these types of strategies require coordination between the different stakeholders in the public and private sectors, including the government, clients, contractors, consultants, and suppliers. Accomplishing this coordination is an iterative, usually informal, and complicated process because of the complexity at the organizational level. Therefore, a key step to strengthen the implementation innovations is to analyze the dynamics between global sustainability targets, public policies, individual project objectives, and decision-making processes. The current study proposes a framework for developing a conceptual model to represent the stakeholders involved in asphalt projects and their interactions, following a Complex Adaptive System perspective. To ensure a favorable outcome, it is important to create a common understanding of sustainable innovations in the sectors and to make a careful selection of the stakeholders that will be involved in the project. The framework aims to help to understand the mechanisms behind the implementation of sustainable asphalt innovations. Additionally, it proposes employing counterfactual analysis to develop strategies that help stakeholders to overcome confusion and reach coordination in the incorporation of sustainable innovations.

Keywords: *Sustainability, Stakeholders, Complex Adaptive Systems (CAS), Road infrastructure, Asphalt.*

1. INTRODUCTION

Road infrastructure plays a crucial role in increasing development capacity and competitiveness in any country. However, the development of this type of project generates negative impacts on the environment such as the depletion of non-renewable resources, energy consumption, and the generation of large amounts of waste (Lee et al., 2016). For this reason, the urgency of incorporating sustainability strategies in the development of asphalt pavement networks has been recognized around the world. Currently, there is not an official definition of sustainable pavement or sustainable strategies and the concept is evolving on time (Ozer et al., 2016). However, the goal is to develop pavement systems that, in addition to fulfilling the engineering function for which it was built, must preserve ecosystems, economically use financial, human, and environmental resources, while providing people with comfort, safety, and comfort (FHWA, 2017).

For purposes of this paper, implementation of sustainable innovations refers to the adoption of any type of strategy at any stage of the life cycle of asphalt road projects that aims to contribute to this goal. For example, eco-friendly materials, alternative techniques in production and construction processes, assessments tools, and sustainability certifications (Abdallah & El-

Rayes, 2016; Aurangzeb & Al-Qadi, 2014; CalRecycle, 2020; Kheradmand et al., 2014; United Nations, 2020). Nowadays, many efforts in the public and private sectors are geared towards the inclusion of these strategies. However, there is no official definition of impact categories, criteria, or databases when developing them. This creates confusion and disagreements in the sector regarding what strategies to employ and how to do so, since asphalt sustainable innovations developed are not comparable and are only applicable to projects under specific contexts. For example, is it right to employ recycled materials as an indicator of sustainability? Employing recycled materials decreased the need for raw materials and transportation distances but they also contain pollutant materials and affect the quality of the pavement structure (Aurangzeb & Al-Qadi, 2014; Robinette & Epps, 2010; Vidal et al., 2013), arising questions about their use. This shows how complex is the analysis of sustainability and that is really hard to move forward.

Coordination between different actors in the public and private sectors such as the government, clients, contractors, consultants, and suppliers is required to develop sustainability strategies (Vluggen et al., 2019). In an attempt to negotiate between stakeholders to promote sustainability in the sector, governments have resorted to strategies such as the use of public procurement, which is considered one of the best initiatives to interact between parties, especially between the public and private sectors (Vluggen et al., 2019). Public procurement is widely recognized as a driver of sustainability, supported by the reasoning that stimulating innovations through procurement lead to technological developments, competitiveness, and economic growth (Edler & Georghiou, 2007; Lenderink et al., 2018). However, recent studies have questioned the effectiveness of this type of strategy for achieving sustainability targets, especially in terms of individual projects (Brammer & Walker, 2011; Cheng et al., 2017; Ershadi et al., 2021).

Implementing asphalt sustainable innovations requires budget and resources, while the public sector is supported by the government, the private sector is always restricted by budget availability. Therefore, the decisions in the private sector when including sustainable innovations are made from a cost-benefit perspective (Lember et al., 2014). This translates into different motivations in the sector due to the variety of stakeholders involved. Usually, stakeholders work separately and the innovations do not have the impact they could. How much time and effort are we wasting because we are unable to reach an agreement sooner? Various authors have pointed out that stakeholders are a key factor in the implementation of sustainable innovations, stating that they can be both a driver or a barrier (Dhull & Narwal, 2016; Giunipero et al., 2012). Therefore, a good understanding of stakeholders is vital to take proper actions to strengthen the efficiency of procurement processes and other public policies, and thus coordinate efforts to speed up the implementation of asphalt sustainable innovations.

In the last few decades, several studies have been conducted to identify the main barriers encountered in the infrastructure sector when implementing sustainability. Recent studies have focused on exposing the limitations and questioning the efficiency of sustainability practices (materials development, evaluation tools, public policies, etc.). Some researchers have highlighted and discussed barriers that prevent the success of sustainable strategies like budgetary constraints, lack of awareness and knowledge, political commitment, lack of incentives, inadequate training, inadequate control, etc. (Brammer & Walker, 2011; Cheng et al., 2017; Ershadi et al., 2021). However, they do not provide practical solutions for approaching those limitations. Next to identifying the main challenges, recent literature has highlighted the need of analyzing relationships among actors involved in sustainable projects development to strengthen the success of sustainability policies (Lupova-Henry & Dotti, 2019; Onnich Dahl et al., 2020; Pot, 2021). Research should focus on interactions of stakeholders,

specifically, on their motivations, perceptions, social and organizational structures that impact the implementation of sustainable innovations in asphalt projects.

This paper aims to introduce a framework for analyzing the sustainability-related factors in the asphalt sector. Specifically, for identifying key elements that influence the implementation of sustainable innovations, including motivations, interactions, and decisions of the stakeholders. The proposed framework adopts a Complex Adaptive Systems (CAS) and can be employed for the development of a guideline for all stakeholders to speed up the implementation of sustainable innovations in the sector and strengthen strategies that encourage sustainability, including procurement procedures. And thus, increasing the active engagement of all stakeholders and speeding up the smooth implementation of asphalt innovations.

2. COMPLEX ADAPTIVE SYSTEMS AND ROAD INFRASTRUCTURE

Accomplishing sustainability is a continuous process framed in a constantly changing environment where stakeholders respond to internal and external factors (Mitleton-Kelly, 2011), analyzing the dynamics between global and national sustainability targets, public policies, and individual projects' objectives and actions is a key step to speed up the implementation of sustainable asphalt. Employing a CAS perspective will allow the researchers to incorporate the social dimension in the analysis of problems, highlighting the role of organizations and technology in the creation of learning and adaptability (Naudé, 2012) required to speed up the implementation of sustainable practices in the asphalt sector.

The framework described in this paper employs a Complex Adaptive System (CAS) perspective, which provides a construct for understanding the dynamics and outcomes of sustainable strategies at the infrastructure industry level. CASs are defined as systems consisting of large numbers of adaptive components, often called agents, that are highly connected and interdependent (Gell-Mann, 1994). The interactions among the agents are dynamic (change over time) and non-linear resulting in an emergent and system-level behavior (Teose et al., 2011). Researchers have explained how infrastructure systems can be modeled as a CAS, highlighting that they exhibit properties such as diverse agents, dynamics, irreversibility, self-organization, and emergence (Oughton et al., 2018). Similarly, scholars have pointed out the utility of CAS for understanding decision-making processes when analyzing challenges in the infrastructure sector (Nikolic et al., 2009). Analyzing the aspects that affect decision-making processes will offer valuable insight for identifying strategies to reach coordination among stakeholders. Policy-makers must achieve coordination among stakeholders' interests, understanding that the diversity of interests is reflected in different sustainability targets, affecting plans adopted in each organization as well as the execution of strategies like procurement (Vluggen et al., 2019). Accomplishing this coordination is an iterative, usually informal, and complicated process because of the complexity at the organizational level (Stermann, 2015). Hence, there is a strong need for a framework that supports stakeholders to reach coordination when implementing sustainable innovations in asphalt projects.

CAS helps to understand how the interactions between the environment, external, and internal factors generate changes at all levels in the infrastructure sector. It offers the theoretical construction to formulate the research problem as a complex system: the interactions of agents (set of factors) result in changes in technological and public values, leading to the development of sustainable infrastructure (Brown et al., 2012; Loorbach & van Raak, 2005). Figure 1 illustrates how the implementation of asphalt sustainable innovations can be represented as a CAS. At the micro-level, the stakeholders (e.g. suppliers, contractors, clients) interact according to the rules set by the context (Klijn & Koppenjan, 2006). The rules can be

interpreted as the high-end policies pursuing sustainability development, e.g. sustainable procurement practice. Next to the rules, other factors like lessons learned in past projects, preferences, prior knowledge, and abilities influence the behavior of the stakeholders, leading them to take specific actions. The interactions among the stakeholders make them adapt to fit the context. This property is known as self-organization and it is one of the main attributes of CASs (Gell-Mann, 1994). The interactions among agents not only generate changes at the micro-level but affect the system at a macro-level, which means it affects the sustainability performance of the sector. This is known as emergence in CAS theory and describes how the patterns observed at higher levels are the results of interaction at lower levels (Rhodes & MacKechnie, 2010). The emergent patterns affect the context making it adapt and influence the future behavior of the agents. This results in feedback processes where the micro-levels and macro-level are constantly exchanging information and thus changing over time. To achieve specific outcomes at any level of the system is vital to understand how the feedback processes work.

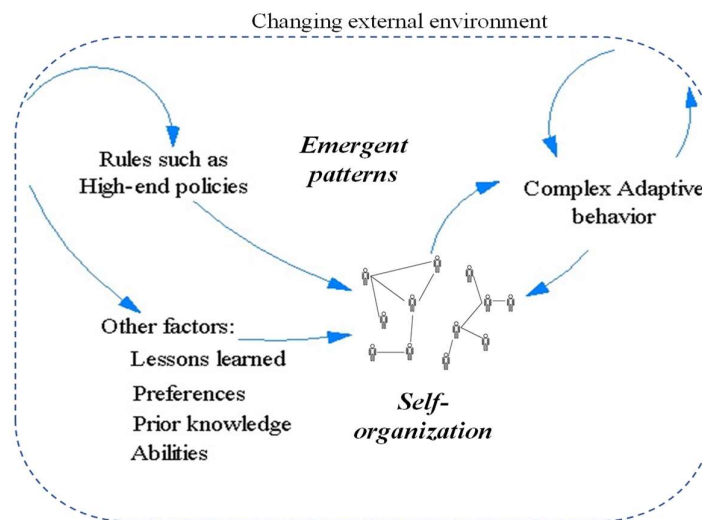


Figure 1. Implementation of asphalt sustainable innovations and CAS concepts (adopted from Andrus, 2005) .

3. PROPOSED FRAMEWORK

This paper proposed a framework based on Complex Adaptive systems for analyzing the implementation of sustainable innovations in the asphalt industry, including the interactions between actors involved in sustainability projects. It consists of four steps, as shown in Figure 2. The first step is an exploratory stage to analyze the perspectives of the stakeholders and the dynamics among them, and thus identify the main factors influencing the implementation process. Then, the factors and their interaction are conceptualized as a CAS to understand the mechanisms behind the implementation process. Steps 3 and 4 are focused on developing strategies that lead the system to be more sustainable through counterfactual analysis. The purpose is to identify actions that help the stakeholders to implement and evaluate sustainable innovations while complying with public demands.

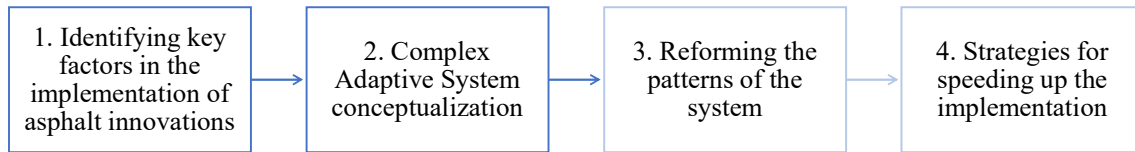


Figure 2. Conceptual research framework.

3.1. Identifying key factors in the implementation of sustainable asphalt innovations

The first step is to identify the main factors, including the actors, that influence the implementation of sustainable asphalt innovations. The data collection in this initial stage is done through interviews in both private companies and public institutions. To validate the findings, triangulation of data should be done by reviewing multiple sources of evidence like administrative documents, progress reports, formal studies, notebooks notes, or any other record made by the stakeholders involved (Yin et al., 1985). The main expected outcome of this step is a qualitative description of the main factors influencing the implementation of the sustainable asphalt innovations, categorizing and prioritizing them.

3.2. CAS conceptualization

The second step is to conceptualize the implementation of sustainable asphalt innovations as a CAS (Brown et al., 2012; Naudé, 2012). After the main factors are identified and categorized, it is necessary to build the dynamics of the system. For this, the CAS approach is employed to organize and understand the interaction among factors, and thus identify the emergent patterns in the system. In this step, observations will be the main source of data. Observations are a valuable source for providing information about the structures behind interactions, relevant context, and environment conditions (Polkinghorne, 2005; Yin, 2015). This is a key step for conceptualizing the research problem as a complex system.

Employing a case study methodology (Yin, 2015), debated issues of innovation in sustainable asphalt should be documented. Specifically, researchers must document the processes and how the stakeholders interact when implementing asphalt innovations. The objective is to identify mechanisms behind the implementation process, focusing on what interactions lead to a certain outcome. For example, how do they choose which type of innovation to use? It is also essential to understand the reasons and motivations behind the interactions. Specifically, it is important to identify if they are triggered by targets, regulations, policies, etc. During this step, researchers must engage in conversations with the stakeholders that encourage them to share their stories, opinions, and perceptions in their own words. This is crucial to complement the observations of the current situation and to reconstruct past experiences of the stakeholders in the development of sustainable asphalt projects. Reconstructing past experiences is important to improve the understanding of the implementation process and to collect lessons learned. As in the previous step, the findings are validated through data triangulation.

The main outcome of step 2 is the dynamic conceptualization of the implementation processes in the asphalt sector. Specifically, a qualitative description of the process as a CAS that includes the main factors with their static and dynamic attributes, representing their interactions under a specific context, and exposing the mechanisms that govern the behavior of the system over time. Mechanisms are understood as the set of conditions and processes that explain why certain decisions are made or why certain outcomes are obtained. Once the system is conceptualized, it must be validated. The validation consists of testing its accuracy in representing the implementation of sustainable innovations in the asphalt sector. For this, the dynamic conceptualization will be judged by performing focus groups. Focus groups are a well-known

qualitative technique to obtain expert judgment about model structure and behavior (Ibrahim et al., 2021). The conceptualization and validation can result in an iterative process based on the feedback of the experts.

3.3. Reforming the patterns of the system

The next step is to identify a set of strategies to reform the current patterns that govern the system behavior to lead the system into a more sustainable performance. This is done based on the lessons learned in past experiences collected in steps 1 and 2 and through counter-factual reasoning. First, the lessons learned help to identify the “best practices” and main barriers encountered in the sector when implementing sustainability innovations. Second, the counter-factual reasoning is performed employing the CAS conceptualization developed in step 2. For this, “what if” scenarios are developed, proposing changes in specific factors to see how the behavior of the system is affected. The scenarios created should be supported by theory and/or the data collected in the previous steps.

3.4. Strategies for speeding up the implementation

Finally, it is crucial to identify strategies that help stakeholders to speed up the implementation of sustainable innovations. It is necessary to determine which actions must be taken to foment the “positive” interactions and reduce the “negative” ones. This is done by identifying which interactions favor (positive interactions) and which harm (negative interactions) the implementation of the innovations based on the results of the counterfactual analysis. This will result in a set of strategies for stakeholders in the asphalt business to promote positive interactions in their companies, in such a way that the implementation process is accelerated.

Lastly, the strategies must be validated. This involves anticipating the effects of the proposed strategies. Specifically, the validation consists of predicting if the strategies are feasible solutions. As the validation of the model, this is going to be done through focus groups. During the focus group sessions, the framework and relevant findings are shared with a group of experts to generate discussion about the meaning of the results and stories generated by the model and strategies proposed (Ibrahim et al., 2021). Depending on the results, surveys or questionnaires can be useful to complement the validation stage.

4. DISCUSSIONS

The paper describes a framework for understanding the implementation of sustainable innovations in the asphalt industry and developing strategies for improving them. The first step is an exploratory study that aims to describe the implementation process from a system perspective, identifying external and internal factors that influence them. The findings of the first step are crucial since the upcoming steps strongly depend on them. Specifically, the results of the first study will serve as the criteria for defining the scope, methodologies, relevant case studies, etc., of the remaining stages of the research project.

As described before, the data collection and analysis in the first step are carried out by employing qualitative methods such as observations, interviews, and focus groups. Qualitative methods have been highlighted as the most suitable for collecting mental data (Luna-Reyes & Andersen, 2003), which refers to the knowledge in the stakeholder’s head in this study. However, using them carries some risks. First of all, the main source of information will be the stakeholder interviews. Therefore, it is necessary to make a very careful selection of experts. It is required to determine: (1) how many actors should be interviewed; (2) should they belong to a specific sector?; (3) are there any institutions or companies that must be part of the study?;

(4) are certain opinions more relevant than others? etc. It is very important to have a representative sample by identifying the actors that can offer the best insights and that play a crucial role in the implementation process. Additionally, it is also vital to develop a systemic framework for the analysis of the interviews' content. The extraction and analysis of data of the interviews are interpretive processes where the subjective influence of the author plays a crucial role. It is indispensable to develop a systemic and traceable methodology to reduce bias and to validate the findings.

Similarly, there are many notions and interpretations around the concept of sustainability. This represents a risk in the investigation since it complicates establishing the boundaries of the project. Therefore, another vital step for applying this framework is to generate a common understanding of sustainability. This implies defining what is considered a sustainable innovation. Is it important to establish the scope of the project by defining what types of sustainable innovations exist in the sector? Is it necessary to analyze them all? Which ones are more important? Which ones can better represent the problems of the sector? Next to clarifying the concept of "sustainable asphalt innovations", it is crucial to determine which stages of the life cycle must be considered in the research project. In the definition given in the introduction section, it was established that sustainable practice could be employed at any stage of the life-cycle but is this a correct assumption? Should the research consider all stages? Or are there key stages like the design, material selection, and construction? To ensure the success of this framework, it is very important to define these aspects before starting the data collection.

5. CONCLUSIONS

In this paper, a framework for analyzing the dynamics behind the implementation of sustainable innovations in the asphalt industry is proposed with the aim of identifying strategies for speeding up the process. By adopting a CAS approach, it will provide insights into how the decisions in matters of sustainability are made in both the public and private sector. This is a key step to understand why sustainability-oriented efforts in both sectors still struggling to be implemented and sometimes might be contradictory.

The framework can be used to map out areas where organizations should focus their attention to develop effective methods when implementing sustainable practices. It can also be employed for providing advice for both the private and public sectors to coordinate when reaching sustainability targets in the infrastructure domain. For example, to help the private sector to translate public requirements into action plans for the implementation of innovations and to inform the public sector about the interests and needs of construction clients. This will lead to the development of strategies that consider all perspectives, enhancing commitment from all parties, and thus helping to achieve sustainability targets in the built environment.

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