



Roadblocks to responsible innovation: Exploring technology assessment and adoption in U.S. public highway construction[☆]



Shawn C. Kimmel^{a,*,1}, Nathan M. Toohey^b, Jason A. Delborne^{c,2}

^a Booz Allen Hamilton, 20 M St. SE, Suite 1000, Washington, DC 20003, USA

^b Department of Civil and Environmental Engineering, Colorado School of Mines, 1500 Illinois St., Golden, CO 80401, USA

^c Department of Forestry and Environmental Resources, North Carolina State University, 5221 Jordan Hall Addition, Campus Box 8008, Raleigh, NC 27695, USA

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ABSTRACT

U.S. public highway construction industry professionals are responsible for assessing and adopting new technology that can improve the cost and quality of roadways. This paper investigates features of the technology assessment and adoption process in the U.S. public highway construction industry that both facilitate and hinder responsible innovation. Often technological innovations are incongruent with current specifications, i.e., regulatory construction standards, whereby specification reform serves as a precursor to implementation. We examine this aspect of technology assessment and adoption through a novel application of Kingdon's theory of policy agenda setting to a highly technical state bureaucratic institution using a case study on Intelligent Compaction. Specification reform relating to Intelligent Compaction is occurring in nearly a quarter of U.S. states. Analysis of interviews with industry professionals revealed that institutional incentives for supporting innovations were not the main drivers for adoption, and there exists a conservative culture that inhibits change. Individuals that go against this grain by championing change do so based on their personal character, ideological affiliations and a perceived sense of social obligation, which coincides with the principles set forth in the responsible research and innovation literature. These individuals, whom we identify as Kingdon's policy entrepreneurs, appear to present themselves in four roles in this industry: explorer, pioneer, gatekeeper, and leader. Our findings indicate that alignment of these roles creates an environment conducive to responsible technology assessment and adoption, and therefore greater societal benefit. Ultimately, we hope this study will benefit U.S. Highway Construction Industry regulatory environments by enhancing identification of specification processes, key roles, and personal/ethical ideologies that may be conducive to fostering a culture of responsible innovation.

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1. Introduction

The condition of the United States highway system is

deteriorating, with only 50% of roads in good condition, according to a recent report by the American Association of State Highway and Transportation Officials (AASHTO) [1]. The problem impacts not only state transportation budgets, but also individual motorists who spend on average \$355 annually on vehicle maintenance due to poor road conditions [1]. One primary way to relieve this problem is for technological innovation to deliver faster, cheaper, and higher quality road construction [2]. However, the public road construction sector is notoriously resistant to adopting innovative technologies [3]. Technology assessment and adoption in road construction requires a delicate balance between public safety and risk, under relentless fiscal constraints.

This study extends the consideration of technology assessment and adoption, which has been the focus of investigation within a

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^{*} Corresponding author.

E-mail addresses: me@shawnkimmel.com (S.C. Kimmel), ntoohey@mines.edu (N.M. Toohey), jason_delborne@ncsu.edu (J.A. Delborne).

¹ Previously affiliated with the Department of Mechanical Engineering, Colorado School of Mines, during the entirety of this work.

² Previously affiliated with the Division of Liberal Arts and International Studies, Colorado School of Mines, for initiation of this work.

number of industries, including agro-food [4], clean energy [5,6] and wastewater treatment [7], to the field of highway construction. The highway construction industry presents a particularly compelling site for investigating technology assessment and adoption because (a) policy reform occurs concurrently with technology assessment and adoption – embodied by the drafting and adoption of new construction specifications, even for experimental pilot projects, and (b) the industry is highly technical, bureaucratically decentralized, and risk averse. These characteristics create a charged policy environment that faces significant hurdles in harnessing technological improvement to produce social benefits.

In order to investigate this challenging confluence of technology assessment and adoption and policy making, we engage Kingdon's [8] theory of public policy agenda setting, as demonstrated in the literature (e.g., [9–11]) to be a powerful tool for understanding policy reform. Given that much of the literature addressing agenda setting has focused on politicized issues at the federal level [e.g. [9–11], this application of Kingdon's theory to a highly technical and bureaucratically decentralized industry represents a novel contribution. Transportation technology policy making in the US is bureaucratically decentralized, with most technology decisions occurring at a state, and even district level. State DOTs employ a majority of technical positions, and encourage the hiring of engineers into non-engineering roles, resulting in a highly technical workforce [12]. Scholars have suggested that Kingdon's theory may be applied to such technical decision making environments, referred to as scientific-bureaucratic institutions, but have only looked at federal systems in the US [9]. Furthermore, the risk-averse nature of the highway construction industry poses considerable challenges to technology assessment and adoption, in large part due to inherent uncertainty and potential disruptions of social institutions and critical infrastructure [4]. The highway construction industry struggles particularly with emerging technologies, which are the single largest contributor to risk at a project level [13].

In addition, we analyze the behavior of professionals in this risk-averse environment by applying concepts from the burgeoning field of Responsible Research and Innovation (RRI), which considers risks and potential rewards in the context of perceived ethical motivations and societal obligations of professionals [14]. Expanding the occupational role of engineers to include socially responsible policy making is a hallmark of responsible innovation literature [15], but in practice, this expansion faces cultural barriers from the profession [3,16]. The highway construction industry provides an excellent opportunity to study these tensions, testing the limits of RRI in a significant way.

This paper expands on a case study of intelligent compaction (IC) [17], discussing technology assessment and adoption processes in the highway construction sector. IC is an emerging technology for soil compaction quality assurance (QA) at various stages of adoption across the United States. IC requires the adoption of new specification policies in order to be implemented, even in the case of pilot projects. In these situations, departments of transportation (DOTs) must employ simultaneous technology assessment and policy reform to drive adoption.

Our data emerge from semi-structured interviews of industry professionals and academics and a review of technical literature. We consider the practical impact of IC on the highway construction community, in the context of owners, contractors and end-users. We are able to classify the dynamic processes of technology assessment and adoption, identify the roles of key players in the diffusion process and illuminate the critical resources and personality traits that make these players influential.

Our paper begins with an overview of Kingdon's theory. We

then provide a succinct description of IC, followed by a section explaining highway construction specifications and the organizational structure of this industry. Additionally, we detail the formal process by which specifications are changed. The third section ties together the case study and Kingdon's theory by defining the critical components of Kingdon's policy agenda setting theory in the context of highway construction specification reform. The fourth section discusses the methodology and analysis underlying this study. The final section presents insights gained through the application of Kingdon's framework and RRI concepts to the key people and processes that have played a part in the diffusion of IC.

2. Kingdon's theory of public policy making

Scholars and other external observers have sought to understand the manner by which public policy manifests change (e.g., [18]). Perhaps the most widely used framework in this area is John Kingdon's *Agendas, Alternatives, and Public Policies* [8], which presents a formalized approach to analyzing policy reform activities. Kingdon begins by identifying the plethora of topics associated with a given domain, which individually may or may not be paid serious attention. Of particular interest is the narrowing process by which specific issues and initiatives become selected to a decision agenda from what could otherwise be described as an infinite realm of possibilities. Kingdon's theory of public policy making establishes a framework that enables us to understand and identify the motivations and drivers behind setting the decision agenda within a given institution.

Kingdon's theoretical framework describes public policy agenda setting as a confluence of three streams: problem definition, policy solutions, and political environment. A problem must be defined to attract sufficient attention and ultimately warrant resolution. A number of policy solutions may evolve that fit certain criteria including demonstrating technical feasibility and aligning with specific problem related values. Finally, the prevailing political environment must be conducive to changes in the domain in question [10].

Kingdon's *stream* analogy exemplifies the dynamism associated with each of the three components of policy formulation. These processes develop and evolve coincidentally rather than according to a formal or linear progression [10], as borrowed from the Garbage Can model of Cohen et al. [19]. Policy reform results from streaming confluence under a window of opportunity opened by both specific causality as well as probabilistic serendipity [18].

Kingdon conceptualizes the interaction of three streams in the context of decision agenda-setting and policy making at the federal level of US Government. Scholars have suggested that Kingdon's framework may, however, apply more generally to all policy environments. Kingdon's analysis approach has been applied to policy environments such as state legislative bodies (e.g., [11]) and federal scientific-bureaucratic institutions [9]. In nearly all cases, authors have ultimately identified theoretical limitations with respect to specific application outside Kingdon's original lens.

3. Intelligent compaction

Intelligent Compaction is a technology used for monitoring soil compaction quality during soil compaction. We first describe the traditional practice of soil compaction and specification thereof that is common to nearly every highway project. We then explain how IC changes this activity – not just by adding a new tool, but by improving efficiency and quality of roadway construction.

Every structure that interfaces with the earth must have a mechanically stable foundation. Roadways typically use compacted soil for this foundation. While there are several practices for

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