Chapter 17
Evaluating the Use of Electronic Door Seals (E-Seals) on Shipping Containers

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ABSTRACT
In this study, electronic door seals (E-seals) are tested on shipping containers that traveled through ports, over borders, and on roadways. The findings show that using RFID devices increases supply chain efficiency and improves the security of containerized cargo movements, particularly when E-seals replace common mechanical seals. Before the benefits of E-seals can be realized, several barriers must be addressed. A lack of frequency standards for E-seals is a major problem, hindering their acceptability for global trade. Routine use of E-seals also requires new processes that may slow their acceptance by the shipping industry. Disposable E-seals, which decrease industry concerns about costs and enforcement agency concerns about security by eliminating the need to recycle E-seals, are not common because they must be manufactured in large quantities to be cost effective. Compatibility with existing highway systems could also promote E-seal acceptance, as containers could be tracked on roadways.

INTRODUCTION
Around the world, millions of standardized intermodal shipping containers are used to transport freight. Because of the sheer volume of containers, securing them from threats such as terrorist attacks while also efficiently processing the containers through the freight supply chain is a major challenge. One technology application that potentially addresses both security and processing concerns is the use of RFID (radio frequency identification device) electronic seals (E-seals) to secure the doors of the containers. (Zhang & Zhang, 2007;
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Mueller, 2005; Tsilingiris, Psaraftis & Lyridis, 2007a, 2007b; Moskal, 2009)

Since the late 1990s, the United States Department of Transportation (USDOT) and the Washington State Department of Transportation (WSDOT) have been testing E-seal technology. E-seals replace the mechanical, one-time use seals commonly used by the shipping industry. E-seals, which are functionally transponders, have the capability to record and transmit information about the integrity of the sealed container at pre-defined intervals. Information can also be recorded when the container passes by a stationary reader, or when it is read by a handheld reader.

The USDOT and WSDOT funded three tests of E-seals along trade flows that occurred primarily in Washington state. The goal of the tests was to evaluate whether it was possible to use this technology to minimize the processing delays associated with container inspections at port terminal gates and border crossings and to improve cargo security. WSDOT, in particular, explored whether E-seals could expedite the truck transport of containers over the State of Washington–Province of British Columbia, Canada, international border.

The tests involved a series of international container movements, mainly from the Puget Sound ports of Seattle and Tacoma but also through the land border at Laredo, Texas. Participants in the project included ports, marine shipping lines, trucking companies, and U.S. federal border enforcement agencies. Several different types of E-seals were tested between 2001 and 2008.

**E-SEAL OVERVIEW**

E-seals are transponders that can be used by shippers and enforcement agencies desiring to track shipments and that can also help determine shipment status and shipment integrity. E-seals can report their positions and are able to record the time that they were activated, compromised, or removed (Zhang, Liu, Yu, & Zhang, 2007; Kim et al., 2007). E-seals are electronic replacements for common mechanical container door seals (Figure 1) and use the locking bar on the container’s back door. The European Conference of Ministers of Transport, in a review of container security, noted that E-seals were an “appealing solution” for both security and processing concerns but also called for more technical standards and operational experience before the technology is mandated and concluded that a complicated hardware and software infrastructure must be developed for E-seals to be effective (2005, p. 54).

Different E-seal designs have been developed over the last decade and include devices that communicate by using RFID, infrared, direct contact, long-range cellular, or satellite transmissions. While each seal has its own characteristics, RFID E-seals were selected for the State of Washington test because they were a relatively mature product that showed promise for both increasing container security and reducing processing delays for cargo inspections. The RFID E-seal design involved relatively simple technology that potentially could be mass-produced at a reasonable cost. The RFID E-seal is the most common type in use today because of its reliability and ease of integration with current infrastructure (Wolfe, 2002; Le-Pong & Wu, 2004).

RFID E-seals are typically either active or passive. A passive seal relies on a signal from the reader to activate the E-seal from a period of inactivity and electronically prompts the unit to transmit its information. This information can include the E-seal identification number; time and date when the seal was affixed; whether the seal has been tampered with; and the time of any event that occurred since the seal was activated. These E-seals tend to be short-range and directional because they rely on the power from readers.

Because a passive E-seal does not require a constant power source, it can usually be operated for an extended period of time with batteries. The batteries power the signal transmission when the seal is interrogated by a reader. They also keep an