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# Green Sustainability Using Radio Frequency Identification: Technology-Organization-Environment Perspective Using Two Case Studies

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***Abstract*—**This qualitative case study seeks to understand and explain the deployment of radio frequency identification (RFID) systems in two countries (i.e., in Taiwan for the adoption of electric scooters and in Finland for supporting glass bottle recycling) using the "Technology-Organization-Environment" theoretical framework. This study also seeks to highlight the relevance and importance of pursuing environmental sustainability in firms and in society in general due to the social urgency of the issues involved.

***Keywords*—**Environmental sustainability, radio frequency identification, technology-organization-environment framework

## I. Introduction

THE more aware and "enlightened" firms have been perceived as those who pay attention to the environmental impacts of their business operations. This paper features two brief case studies of organizations that have used radio frequency identification or RFID as a key aspect of their drive to be environmentally friendly. The theory called the "Technology-Organization-Environment" (TOE) framework will be used as the conceptual lens through which the RFID implementation initiatives of both organizations are interpreted and understood. RFID is a technology that uses electromagnetic energy to allow exchange of information between an RFID reader (i.e., transceiver) and the RFID tag (i.e. transponder) which contains information on the individual product item, case, or pallet it is attached to [1].

As the use of RFID increases through the years, concern for environmental sustainability using the technology will be paramount. At this time, the more comprehensive studies on the use of RFID to attain environmental sustainability involves the deployment of RFID in green supply chains. Dukovska-Popovska et al. [2] describe the current state of RFID use in supply chains, specifically, within the tasks involved in product distribution, transportation, reverse logistics, and product safety. They also focus, in particular, on the deployment of what they refer to as "ad hoc" RFID systems which can be rapidly deployed in order to monitor a specific part of the supply chain process (e.g., track temperature, humidity, etc., that the product is exposed to) since they require minimal IT infrastructure support. Bertoni et al. [3] also provide a comprehensive view of the current state of supply chain management and green logistics and specifically suggest a model that combines a number of existing frameworks on forward and reverse logistics involving RFID systems. Logistics refers to the management of the flow of resources between the point of origin, which is usually the point of manufacture, to the point of consumption. Forward logistics denote the operations involved in the delivery of physical products to both individual and institutional buyers. Reverse logistics, on the other hand, refer to the operations involved in the management of product returns, reuse of products, and disposal of these products.

There are occasional case studies that describe the use of RFID for environmental sustainability such as those detailed by [4]: Wal-Mart uses RFID at various points of its supply chain to reduce its carbon emissions; DHL SmartTruck increases the efficiency of its package pickup and deliveries using RFID; Smart Vareflyt manages the challenges of moving perishable goods through its supply chain using RFID; Promise tracks the recycling of plastics used in automobile production using a decision support system enabled by RFID; and Multi Life Cycle Center uses RFID in sorting, tracking, and evaluating the residual value of used electronic equipment headed for recycling.

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## II. Research Question

This study seeks to answer this research question: "How can we explain and understand the implementation of an RFID system in two specific case studies (i.e., PALPA/Lassila & Tikanoja in Finland and Kentfa Advanced Technology in Taiwan) in pursuing their respective environmental sustainability goals using the TOE framework?"

## III. Literature Review

### *A. Literature Review on the Technology-Organization-Environment (TOE) Framework*

This study will use the technology-organization-environment (TOE) framework introduced by [5] that uses three elements that influence technological adoption - the environmental context, the organization context, and the technological context.

#### 1. Environmental Context

The environmental context is the arena surrounding a firm, consisting of multiple stakeholders such as industry members, competitors, suppliers, customers, the government, the community, etc. They can influence how a firm interprets the

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need for innovation, its ability to acquire the resources for pursuing innovation, and its capability for actually deploying it. These stakeholders could either support or block technological innovation.

Changing market and competitive conditions prod firms to use various forms of innovation. Government regulation is also another powerful tool for constraining a firm's operational activities, increasing costs of production, and instigating an investigation of technologies that must meet specified criteria. Finally, dominant customer firms could exert their power to shift their suppliers' production activities to comply with its requirements.

2. Organizational Context

A range of descriptive measures characterize the "organizational context": firm size; the centralization, formalization, and complexity of its managerial structure; the quality of its human resources; the amount of slack resources available internally; formal and informal linkages within and outside the firm; decision making and internal communication methods; and boundary spanning mechanisms to communicate with the external environment. "Organic" and "mechanistic" organizational systems are also relevant here [6]. Frequent lateral communication, decentralization of leadership and control, and active networking both within and outside the firm are hallmarks of the "organic" system. Building interorganizational collaboration mechanisms is fundamental in meeting the needs of electronic coordination linkages enabling supply chain partnerships.

Top executives can energize major organizational changes by [7]: (1) communicating a clear image of the firm's strategy, core values, and role of technology in meeting this strategy; (2) sending consistent signals within and outside the firm about the value of the innovation; and (3) creating a team responsible for crafting a vision relevant to the innovation.

3. Technological Context

The TOE framework suggests a method of implementing a technology innovation which will be referenced in the analysis of the deployment of the sustainability initiative by 7G. The following steps described below comprise the "systems design" perspective depicted by [5], which incorporates the best aspects of the following methods used in implementing technology solutions: technocentric, sociocentric, conflict/ bargaining, systems life cycle, and socio-technical systems approaches. Different aspects of these approaches could be more prominent in the one or more steps discussed below.

The technocentric approach was derived primarily from industrial engineering and its key distinguishing feature is its exclusive focus on the hardware components and embedded knowledge domains to the exclusion of social, human end user needs and issues [8],[9].

In direct contrast, the sociocentric approach focuses on the organizational and social setting of the IT innovation, with its origins from organizational sociology [10], [11], organizational behavior [12], and communications [13]. The sociocentric approach espouses the following implementation activities: (1) measure the innovation's effectiveness in terms of the social system's social functioning; (2) consider the social and organizational issues when planning and pacing the implementation of the innovation; (3) allow for flexibility in the organizational design while keeping coordination and organizational purpose; and (4) support the innovation implementation with appropriate human resource development practices [5].

The conflict/bargaining perspective recognizes that decisions involving initiatives that include multiple parties will be challenged by their clashing interests [14], [15]. Thus, the implementation initiative should embrace all affected stakeholders and promote practices and processes that encourage cooperation and collaboration to resolve their differences.

The systems life cycle approach, also commonly referred to as the SDLC, is a methodology used to develop IS solutions [16], [17]. SDLC encompasses the following phases: (1) systems planning and selection (i.e., identification, planning, and selection of a development project based on priorities); (2) systems analysis (i.e., gaining a thorough understanding of the current business processes surrounding the problem area of the project); (3) systems design (i.e., identification of the specifications of the design solution); (4) systems implementation and operation (i.e., transforming the IS design solution into an operational working version); and (5) systems maintenance (i.e., the repair, improvement, and updating of the operational system solution) [1].

The socio-technical approach (STS) has its beginnings from both organization change practice [18] and social psychology [19]. It seeks the resolution of the main concerns of the social system (i.e., organizational design, reward systems, communication patterns) and the technical system (i.e., process, technology, tools, machines, and methods) in pursuing the implementation of an IT innovation in an organization [5].

Tornatzky and Fleischer [5] presented their "systems design perspective," which is a synthesis of the following approaches: technocentric, sociocentric, conflic/bargaining, systems life cycle, and socio-technical systems.

(a) Understand the Characteristics of the Innovation

The technocentric approach espouses the notion that technological factors dominate the implementation experience, thus, leading to the following consequences: (a) there should be a detailed technical plan for implementation; (b) methods engineering should help in the redesign of business processes and jobs; (c) the innovation should be able to be integrated with the existing technical system; and (d) technical criteria should be used in measuring implementation effectiveness [20]. The "systems design perspective" also calls for a technology-organization match. The technology innovation also influences how different parts of a firm need to coordinate. Implementation of information systems supporting environmental goals extends the level of coordination needed from internal integration to interorganizational integration within the supply chain context.

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(b) Develop Measures of Implementation Effectiveness

A wholistic approach to measuring implementation effectiveness would include metrics that are relevant to the technocentric, systems development life cycle, sociocentric, and conflict/bargaining approaches.

(c) Plan and Pace Implementation

Pacing technology implementation refers to the speed at which changes are unfolded, which could range anywhere from gradual to radical [21].

(d) Design or Redesign the Organization

The sociocentric approach focuses on making the organization more flexible, humanistic, and open to changes brought about by the innovation [5].

(e) Modify Human Resources Policies

Human resource policies involving employee selection, compensation, appraisal, and training --- all of which have important implications for innovation implementation have to be modified to fit the innovation [22].

(f)Design or Redesign Jobs

The design and/or redesign of jobs are needed to ensure that the affected workers and the work system required by the innovation are linked [5].

(g) Install the Innovation and Integrate with the Existing System

The systems design approach prescribes the following: (a) incorporating end user needs into the requirements definition phase; (b) designing the new system so that it can integrate with the larger IT system that encompasses the firm; and (c) ensuring the provision of resources for reliable system maintenance and providing for both incremental and radical system changes if called for.

## IV. Research Methodology

This paper uses a single case study approach in aligning the concepts and guidelines prescribed by the TOE framework to the two brief case studies featured here: Kentfa Advanced Technology (i.e. use of electric scooter in Taiwan) and PALPA/Lassila & Tikanoja (i.e., use of RFID-enabled glass recycling centers). The case study approach is an appropriate methodology in testing the application of a conceptual framework to a real firm. This study used the qualitative research method of content analysis in analyzing secondary sources such as video transcripts, journal articles, case study materials, trade publication articles, etc. Most of these materials are freely available on the web. The following are accepted definitions of the content analysis method:

> "Content analysis is any research technique for making inferences by systematically and objectively identifying specified characteristics within text." [23, p. 5].

> "Content analysis is a research technique for making replicable and valid inferences from data to their context." [24, p. 21].

> "Content analysis is a research method that uses a set of procedures to make valid inferences from text." [25, p. 9].

In this study, the concepts used for conducting content analysis were derived from the TOE framework. This framework forms the "context" of the content analysis method as applied to secondary sources of research materials used for the two case studies.

> "A context is always someone's construction, the conceptual environment of a text, the situation in which it plays a role. In a content analysis, the context explains what the analyst does with the texts; it could be considered the analyst's best hypothesis for how the texts came to be, what they mean, what they can tell or do. In the course of a content analysis, the context embraces all the knowledge that the analyst applies to given texts, whether in the form of scientific theories, plausibly argued propositions, empirical evidence, grounded intuitions, or knowledge of reading habits…. The context specifies the world in which texts can be related to the analyst's research questions." [26, p. 33].

TOE concepts were used in analyzing the secondary materials within the context provided by the different theoretical frameworks or "prior theory."

> "Analytical constructs operationalize what the content analyst knows about the context, specifically the network of correlations that are assumed to explain how available text are connected to the possible answers to the analyst's questions and the conditions under which these correlations could change….analytical constructs ensure that an analysis of given texts models the texts' context of use…" [26, p. 34].

The following key conceptual elements of the content analysis method as stipulated by [26] were used in this study: (1) body of text selected for the analysis; (2) research question that needed to be addressed; (3) a context of analysis within which interpretations will be made; (4) analytical constructs that operationalize what the analyst knows about the context; and (5) inferences that will be arrived at to address the research question.

## V. Findings

### *A. Case Study 1: PALPA and Lassila & Tikanoja: Glass Recycling*

1. Environmental Context

The European Union (EU) is one of the more advanced continents when it comes to setting recovery targets for packaging materials used for physical goods. Collection and recycling rates for glass, however, are much higher in Finland than its counterpart EU requirements [27]. Reusable glass bottles have been recycled in Finland since way back in the 1950s; recyclable bottles are washed and reused about 33 times during their product life cycle [28]. In 1952, the Finnish government introduced the predecessor of the current deposit system for glass bottles to be deployed at the consumer level [29].

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Suomen Palautuspakkaus Oy (PALPA), a not for profit organization was created in 1996 to oversee the organizations and firms involved in bottle recycling in Finland [28]. Since PALPA was created, bottle recycling reached about 60 percent, but by 2011, it came close to 100 percent, compared with recycling of metallic cans at 94 percent and plastic bottles at 92 percent. Finnish law has greatly supported glass bottle recycling and this law determines the minimum deposit amount that can be used per bottle.

There is still a need to improve the collection rates and logistical infrastructure involved in glass recycling to make municipal level collections more efficient. Deposits and refunds may be applied for two types of bottle product packaging: refillable bottles and the so-called one-way packaging [30]. This case study is about glass bottles using one-way packaging or single-use bottles that are melted down after one use during the recycling process in order to produce new bottles, food containers, or other glass-based products. To optimize its energy savings, smelters use a combination of virgin materials and recycled glass in their business operations. In contrast, refillable glass bottles are collected after use, washed, and then, refilled with the product by the producer or bottler [30].

2. Organizational Context

The matter of glass bottle recycling in Finland involves a complex network of institutions and stakeholders that comprise the organizational, or more appropriately, the inter-organizational context of this brief case study. In order to ensure the success of the glass bottle recycling initiative, these multiple entities need to collaborate so that appropriate changes in business operations and consumer-level individual behavior relevant to glass bottle recycling are permanently installed in this society.

In 1952, the Finnish government introduced the predecessor of the current deposit system for glass bottles to be deployed at the consumer level [29]. As of late, however, the Finnish government passed the Waste Act of 2011, which empowers the national government to control the operations of container return systems, the imposition of deposit fees, and the other obligations of the parties involved in the container return system. Through the passage of this act and the previous legislations before that, the Finnish government has communicated a determined vision of making its society environmentally aware and respectful of the physical resources involved in the production of glass bottles and related products.

Right around 2012, PALPA was affected by new regulations passed by the government that enabled consumers to return one-way glass bottles to any collection point that have been designated for collecting cans and bottles [31]. This regulation resulted in the increase of one-way glass bottle collection points from 350 to about 5,000 just within the retail sales network alone, and doubled the number of plastic bins/containers used to collect and transport the glass bottles from these collection points to waste processing centers. Thus, L&T was tasked with both supplying and tracking these plastic bins/containers as they were used throughout the recycling system.

Regulations governing the disposition of containers are overseen by the Finnish Ministry of the Environment. The Ministry of Finance, on the other hand, governs revenue collection from the affected entities and ensuring low administrative costs for the Finnish government. PALPA, the organization that oversees bottle recycling, operates and develops deposit-based recycling systems, and is owned by large beverage firms and major retailers. PALPA reports to the Ministry of the Environment, while all importers and breweries must register new packaging with PALPA before these products could be made available in the market. PALPA must approve these products before information about them can be logged in the recycling system and registered in the database, which is linked to the reverse vending machines that monitor all items sold. Producers must pay PALPA deposit and recycling fees which are evaluated based on their monthly sales revenues [29].

The Finnish government displays features of the “organic” organizational system and there are strong vertical and lateral linkages among the government institutions involved in enforcing glass container recycling in the country. Each government institution described in this network fulfills its part in the complex network that needs to support this societal endeavor. The Finnish government has clearly designated PALPA as the “hub” of this complex network that needs to both craft and manifest the vision for glass recycling by virtue of its governance powers over the institutions, firms, and citizens affected in this effort.

Other organizations involved in this effort are the RFID-related information technology vendors, especially Lassila & Tikanoja (L&T), the lead vendor and firm chosen by PALPA to be responsible for supplying the plastic containers for collecting the glass bottles and for developing and maintaining the RFID-enabled system used to track these assets [31]. Based in Helsinki, Finland, L&T provides services related to environmental protection include waste management and recycling, property and sewer maintenance, and environmental construction [31]. L&T operates in a number of European countries outside of Finland --- Sweden and Russia and has about 8,000 employees.

Other RFID-related vendors include: Vilant, a Finnish provider of RFID solutions; Impinj, an American RFID vendor that provided the Speedway Revolution R420 RFID readers; (4) AdhTech, a Swedish firm that provided the ultra-high frequency RFID tags; Beneli AB, another Swedish firm that provided rugged RFID inlays; and Nordic ID, a Finnish firm that provided the Merlin handheld RFID readers.

3. Technological Context

(a) Understand the Characteristics of the Innovation

After concluding the consideration of various RFID vendors, L&T decided to work with Vilant, a Finnish vendor that offers RFID solutions, from the systems design stage all throughout the selection of appropriate hardware and software and finally, up to the deployment of the initiative,

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which has unfolded in three phases [31]. In the first phase (also the pilot phase), the RFID project team tested both RFID tags and readers at a waste processing centers before arriving at the final decision on which hardware products to use. A specific technical concern that needed to be addressed was the requirement for RFID tag "hardiness" in order to withstand the rugged physical conditions such as hot water washing sprays in the waste processing centers.

(b) Develop Measures of Implementation Effectiveness

Marko Turunen, L&T's Project Leader, shared an important success indicator as a result of the PALPA RFID initiative: "One important general quantity indicator can be found from PALPA's statistics which indicate that the return rate of glass bottles in Finland is around 91 percent, which is top-class internationally." [31, p. 4]. Finland outperforms Denmark which posted 89 percent and Estonia, 86 percent for glass bottle returns. The all-important environmental benefits from glass bottle recycling are articulated by Turunen as well: "Recycled material is fully re-used and thereby decreases the need for new glass manufacturing….[in addition] …efficient logistics processes decrease the needed transportation volumes, and in that way decrease carbon dioxide emissions." [31, p. 4].

(c) Plan and Pace Implementation

The complete RFID system solution consists of the following components: (1) ultra-high frequency (UHF) tags from Adh Tech, a Swedish vendor; (2) hard laminated RFID inlays from Beneli AB, another Swedish vendor; (3) Speedway Revolution R420 RFID readers from Impinj, a U.S. RFID vendor; (4) RFID software such as the Visibility Manager from Vilant; (5) the Merlin handheld RFID readers from Nordic ID, a Finnish RFID vendor.

The RFID project developed through three phases [31]. In phase one, L&T tagged about 25,000 plastic containers within a four-month period in the first half of 2012, which were monitored by RFID readers installed at all locations. The RFID data was captured by the readers and processed using Vilant's client and server software during that testing period.

Phase two involved the change in PALPA's business model as a result of using the RFID system. From simply collecting and washing used glass bottles, PALPA was now able to actually undertake the recycling of glass bottles --- which has become a significant source of other income.

Phase three kicked in right around the end of 2013 after small RFID system adjustments were made. The much improved RFID tracking capability was now monitoring about 50,000 plastic containers and about 1,000 to 1,500 events are captured and reported daily by the system.

(d) Design or Redesign Jobs

The change in business model for PALPA in phase two of the RFID system initiative from generating income from strictly collecting and washing used glass bottles to actually recycling these bottles would require a redesign of the jobs of the workers in the plants.

(e) Install the Innovation and Integrate with the Existing System

*Components of the RFID System:*

The complete RFID system solution consists of the following components: (1) ultra-high frequency (UHF) tags from Adh Tech, a Swedish vendor; (2) hard laminated RFID inlays from Beneli AB, another Swedish vendor; (3) Speedway Revolution R420 RFID readers from Impinj, a U.S. RFID vendor; (4) RFID software such as the Visibility Manager from Vilant; (5) the Merlin handheld RFID readers from Nordic ID, a Finnish RFID vendor.

Plastic containers were tagged with the UHF RFID tags after they were received from suppliers and prior to their use at L&T's largest waste processing center in southern Finland in the small town of Kerava. The large size of the Kerava waste processing plant required the use of RFID gate reader enclosures for its dock doors. Thus, L&T installed three Vilant Smart Gates each equipped with an Impinj Speedway Revolution R420 RFID reader, four circular antennas, and a touch-screen personal computer (PC) running Vilant's client software. This software performs the following functions: (1) manage communications between the RFID readers and the PC; (2) enable RFID data processing; (3) support graphical user interface (GUI) features for checking tag reading accuracy; and (4) monitor system status and data communications. These three Smart Gates are used mainly for tracking the plastic containers passing through them. However, when the unloading and loading processes for the glass bottles are done, the workers use Nordic ID's Merlin handheld readers for backup data capture and processing. These readers are activated using Vilant's software. L&T also has seven other satellite waste processing centers that are smaller in size and thus, only require use of the handheld RFID readers.

Both gate and handheld RFID readers are located and used in the areas of the waste processing centers designated for receiving and washing the glass bottles. They are also used for tracking empty plastic containers that are eventually sent back to delivery terminals and collection points such as shops, restaurants, and alcohol stores.

There are generally two kinds of software used to support the RFID system. The functions of the Vilant client software running on the PC have been previously described. There is also the Vilant server software called Visibility Manager that does the following: (1) support GUI features for data receiving and communications with the client software; (2) support GUI features for generating customized data reports; (3) support asset and even data listings; and (4) support system administration functions.

Both L&T and PALPA jointly provided end user training for workers in the plants in the following: (1) use of Vilant client software; (2) use of Vilant server software, Visibility Manager; (3) use of the different devices; and (4) how to manage exception handling cases.

The only major technical issue with the RFID system was the incidence of redundant RFID tag reads as a result of

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having extra plastic containers standing by that were not part of the asset pool being tracked. PALPA quickly solved this problem by both adjusting RFID reader parameters and designating separate physical areas in the processing plants for container receiving, washing, and sending locations.

*RFID Information Processing Tasks:*

The RFID data captured from the tags helped L&T process important standard business documents and reports for effective asset management. L&T's customers, in this case, would be firms like brewers (e.g., Hartwall, Meira Nova, Olvi, and Sinebrychoff), major retailers (e.g., Kesko, Tuko, and Inex), among others, could send their orders for containers via the Internet directly from their enterprise resource planning (ERP) systems as EDI messages or PDF attachments. L&T's system would automatically respond to these order requests with an email specifying the exact number of plastic containers that could be provided at that point in time. At this time, though, asset and event data is not yet integrated with the external systems of PALPA's customers.

L&T based their customer invoicing on completed container orders and asset and service quantity data supported by the captured RFID system data represented by asset and event data. Turunen shared this: "Customized data reports on server user interfaces provide the key data for servicing invoicing and thereby enable the business [interaction] between PALPA, its owner and customer companies, and Lassila & Tikanoja as service provider." [31, p. 4].

Accurate invoicing was enabled also by the fact that this captured RFID data also supported L&T's inventory system, which showed the most current, real time available container inventory levels, thus, avoiding the problem of "overbooking" containers.

The captured RFID data also improved business processes in the waste processing centers in major ways. Turunen further explained: "Quick scanning and data collection of asset data in different transactions made it possible to organize this business efficiently at the processing center floor level….The logistics chain enables more efficient processes and thereby makes it possible to increase the return rate of glass bottles, as accurate statistics about the asset inventories at different locations is available all the time and we are able to deliver sufficient asset volumes to every system location." [31, p. 4].

Perhaps the most notable development in this RFID system initiative is the emergence of a new business model for PALPA --- now, the organization can not only collect and wash used glass bottles, but also undertake actual glass bottle recycling. As Jarmo Sallinen, Vilant's Project Manager, put it: "This system data forms a significant part of the whole business model for efficient recycling of glass bottle material." [31, p. 4].

### *B. Case Study 2: Kentfa Advanced Technology and Electric Scooters in Taiwan*

1. Environmental Context

Taiwan's Ministry of Transportation & Communications reported that there are about 13.5 million scooters and motorcycles used in Taiwan thus far [32]. Only about 122,500 scooters or motorcycles out of this total are petrol free or electric --- a miniscule portion of the total vehicles in use. This means there are about 375 scooters or motorcycles per square kilometer mostly in the densely populated cities of this nation.

Through the years, the Taiwanese government implemented programs in a number of phases to support the use and adoption of electric scooters by its citizens in place of petroleum-based or petrol scooters widely in use. In addition, the government sought to enhance the energy efficiency of its petrol scooters and eventually shift to the use of zero-emission scooters.

The Taiwanese government has put in place emission standards for scooters since 1988. Recently, it is also put into effect the Phase 5 Emission Standard which is considered close to the Euro 3 emission standards through a two-stage approach [33]. During the first stage put into effect last 2003, the government required the use of more energy efficient scooter engines and during the second stage which started in 2006, emissions of new Taiwanese scooters were expected to match those stipulated by the current Euro Standards that apply to new scooters. The Taiwanese government also sponsored programs to promote the use of electric vehicles through the years. In the seventies, the government launched its first program to encourage the use of light-duty electric vehicles, such as those using lead-acid batteries. Subsequently, the Environment Protection Administration (EPA) adopted a program called "Action Plan for Developing Electric Scooters" to subsidize the purchase of two-wheel electric scooters to replace the 50cc petrol scooters [33]. The technology behind the two-wheel electric scooter at that time was still limited - Taiwanese consumers were discouraged by the inconsistent quality and inadequate maintenance of the vehicles. In 2003, however, the subsidy program was canceled as the 26,000 total electric scooters sold as of that year did not significantly reduce air pollution in a way that would justify the cost of the subsidy program.

To assist the Taiwanese government in improving its future promotional efforts for the electric scooter, the Industrial Development Bureau (IDB) of the Ministry of Economic Affairs (MOEA) surveyed Taiwanese scouter users to understand reasons for the failure of the previous promotional campaign. The survey results provided empirical evidence for the gaps between scooter user expectations and the actual performance of the electric scooter at that time across a number of dimensions: price of the scooter; maximum speed; acceleration capability; climbing capability; curb weight; time it takes to charge the battery; cruise range; and running costs. The following are key findings of the study [33].

The price of the scooter and the time it takes to charge emerged to be of great concern to the scooter users. Other consumer issues include: (1) inadequate battery charging infrastructure - too few charging stations for a certain geographic coverage; (2) inadequate cruise range of the electric scooter; (3) long charging time - lead-acid batteries take about 6 to 8 hours to charge that delivers only a 20-kilometer ride; (4) poor durability of the battery - the VRLA

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battery, for instance, could be charged up to 200 times in its lifetime but delivers only 4000 kilometers in total driving distance; and (5) high battery price.

As will be explained in the technology context section, the use of RFID for asset tracking batteries in the battery exchange stations could help tremendously in both enabling the setting up of additional battery exchange stations and cutting the time it takes for a consumer to obtain a fully charged battery. Both improvements could potentially overcome a considerable amount of hesitation on the part of Taiwanese scooter riders to adopt electric scooters.

2. Organizational Context

The Taiwanese government has communicated a clear vision of the country being more energy efficient in the use of ubiquitous transportation in the form of the scooter for some decades now [34]. In this case study, the Taiwanese government demonstrates its renewed and persistent effort to support the use of petrol-free scooters in the form of electric scooters using RFID-enabled battery exchange stations.

The proposed adoption of the electric scooter in Taiwan involves a number of stakeholders with their unique roles in Taiwanese society. The "organizational context" theoretical concept in past research involving information technology adoption has been more frequently associated with a single or a number of corporate entities involved in the adoption of a technological innovation. In this particular case study, it is the institutional layer of Taiwanese society, the different companies that would be manufacturing and supporting energy efficient scooters that would be used to substitute petrol-based scooters, and its individual end user scooter riders who are involved.

Within Taiwanese society, we observe an "organic" rather than "mechanistic" inter-organizational system that binds the different institutions under the leadership of the central government. In many ways, technological diffusion and adoption is facilitated by this type of arrangement --- a centralized tone in a society with a strong cultural respect for top down mandates makes passing government laws supporting technological diffusion much easier.

The strong formal lateral linkages and boundary spanning mechanisms among the different government agencies have been involved through time in the promotion of energy efficient scooters. For instance, the development of the earlier form of electric scooter supported by lead-acid batteries was made possible through the joint efforts of a number of Taiwanese institutions. The National Tsing-Hua University (Taiwan), Tanyon Iron Works, and Yuasa Battery Company jointly produced a 200-vehicle fleet for mail service delivery, which were powered by lead-acid batteries [33]. Subsequently, the Environment Protection Administration (EPA) adopted a program called "Action Plan for Developing Electric Scooters" to subsidize the purchase of two-wheel electric scooters to replace the 50cc petrol scooters [33]. Then, sometime even later, to assist the Taiwanese government in improving its future promotional efforts for the electric scooter, the Industrial Development Bureau (IDB) of the Ministry of Economic Affairs (MOEA) surveyed Taiwanese scooter users to understand reasons for the failure of the previous promotional campaign.

The Taiwanese government also used slack resources in the form of monies to support a subsidy program to encourage electric scooter use. The Taiwanese government sponsored a three-tiered subsidy program put into effect in November 2009 that released anywhere from NTD6,500 (i.e., New Taiwan Dollar) to NTD 11,000 per scooter to the individual scooter user, depending on the size of the engine. Electric scooter manufacturers, in turn, received up to NTD16 million from the government if they could sell more than 8,000 scooter units in the first year of the subsidy program, 14,000 scooter units in 1020, and 16,000 scooter units in 2011-2012. Operators of battery charging stations, as well, received subsidies of up to NTD100,000 per charging station [33].

3. Technological Context

(a) Understand the Characteristics of the Innovation

After many years of encouraging the use of more environmentally friendly scooters, the Taiwanese government launched its first program to encourage the use of light-duty electric vehicles, such as those using lead-acid batteries. In 2012, however, the Taiwan Environmental Protection Administration (EPA) spearheaded a project involving the use of battery exchange stations that would use RFID for tracking the batteries that are both surrendered from these stations and the fully charged batteries that are subsequently purchased by scooter riders [32].

(b) Develop Measures of Implementation Effectiveness

There is no data as yet as to the increase in the use of electric scooters in Taiwan as a result of installing these battery exchange stations. However, there were plans to install an additional 500 such stations by the end of 2014, since they have become popular with the scooter riders, according to T.H. Liu, director of EPC Solutions Taiwan, the firm hired by EPA to provide consulting services for this RFID project [32].

(c) Plan and Pace Implementation

The Taiwanese Environmental Protection Administration (EPA) implemented this RFID deployment in phases [32]. In 2012, the first battery exchange stations were set up in the industrial town of Kaohsiung in phase one. The pilot project that was first implemented in Kaohsiung was the result of the collaboration of the local governments, EPA, and Kentfa. About 30 BES were set up and located in places like the MRT stations, public bike rental sites, and tourist attractions [35]. Thereafter, additional stations were built in Taipei in phase two. Thus far, there are a total of 60 such stations all over the country, and the plan is to install another 500 stations by the end of 2014.

(d) Install the Innovation and Integrate with the Existing System

The scooter riders' experience is expected to improve significantly as they interact with the BES. Previously, these riders would have had to charge their scooter batteries at home

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for a long period of time before leaving for work, and then, do so again, before leaving their workplace at the end of the day [32]. Even if about 8,000 battery recharging stations were available for use, scooter riders were greatly inconvenienced by the couple of hours needed to recharge and claim their batteries at these stations. The new and improved BESs are expected to change this experience by allowing scooter riders to merely swap used up batteries for fully charged ones at a fraction of the time it used to take to charge them the old way. Moreover, the new BES are to be positioned ubiquitously throughout the city in popular public venues where major traffic routes are located. In the near future, the plan is to install more BESs next to ATMs, convenient stores, supermarkets, electric vehicle distributor offices, and scooter shops [35].

The use of the new BESs depends on the riders' use of their EasyCard payment card also used to pay for bus and train rides and other transport-related services in Taiwan [32]. More than 30 million such cards have been issued to date. After paying an initial fee using this payment card, the riders are provided with a fully charged battery by the BES. Riders use this card for exchanging a depleted battery for a charged one thereafter.

Upon spotting a BES, scooter riders merely have to take the following simple steps to accomplish the battery exchange procedure. Using their EasyCard designed to support Taiwan's various public transportation systems, the riders register into the system by inserting their cards in a slot that will activate the BES software. Kentfa has installed two RFID readers in each BES - one is the Alien Technology ALR 9650 UHF model RFID reader to read the RFID tags on the batteries, and the second reader, a 13.56 MHz HF reader from EasyCard Corp. to interrogate the RFID tags embedded in the EasyCard payment card [32].

The HF reader for the EasyCard will capture the rider's ID number, which will be sent to the Kentfa software installed in the computer built into the BES machine. The data received from the HF reader will associate the rider's ID to the stored identification data to verify that the rider is a valid customer. The smart touchscreen will also ask for the rider's password, which after verification will allow the rider to select the battery exchange option presented in the onscreen menu. After the system acknowledges this choice, a door in the BES will open and allow the rider to insert the depleted battery in the slot. The Alien UHF reader will capture the information on the battery's RFID tag and verify the battery's information against data stored in the system. The Kentfa software controlling the RFID system records the following data in the BES system: battery's serial number, maintenance record, manufacturer, amperage, frequency and location of battery recharging, and identification information of participating scooter operators [32].

Batteries that have reached the maximum number of recharging allowed will be rejected by the BES. At that point, the BES will instruct the rider to go to another location where a brand new battery can be purchased. The BES' sensory system also automatically measures the remaining electric charge on the battery inserted in the slot, estimates the time needed to recharge it completely, and finally, presents the bill to the rider's EasyCard account. There are two systems in place when it comes to recharging depleted batteries. One set of BESs will automatically recharge depleted batteries after riders have surrendered them. Another set of BESs use a manual system where humans are used to collect depleted batteries from the BES, transfer them to another recharging station, and then, put them back in the BES after the batteries are fully recharged. After the EasyCard payment is completed, another BES door will open that will enable the rider to take a fully charged battery. Then, the BES kiosk screen will then display the cost of the fully charged battery that has just been dispensed and the value of the current balance remaining on the rider's smartcard. The cost of the battery exchanged will be cheaper than purchasing gasoline for the conventional petrol based scooter. Also, the rider is expected to pay only 70 percent of the price of a brand new battery when taking a recharged but previously used battery.

At the moment, Kentfa tags the batteries using Alien Technology's EPC Gen 2 ultra-high frequency (UHF) RFID tag based on the Higgs-3 chip. In the future, Kentfa will practise source tagging and require battery manufacturers to pre-tag the batteries before they are delivered to Kentfa.

## VI. Conclusion

The TOE framework has been very useful in understanding the technological, organizational, and environmental forces that drove the use of RFID for environmentally motivated deployments in Taiwan (electric scooter) and Finland (glass bottle recycling. Both case studies involved the participation of the national governments of both countries and against this backdrop, the multi-stakeholder collaboration involving a number of institutions was critical in enabling their respective initiatives. At this time, the RFID technology has advanced far enough that no really serious technical problems have proven to create barriers to the successful implementation of this tracking technology. Both case studies also involve the issue of using incentives within the power of their respective governments to offer to its citizens so that the adoption of the electric scooter in the case of Taiwan and the more frequent use of glass bottle recycling collection efforts will be more widely accepted. An important aspect of incentivizing the appropriate behavioral modifications would include designing the stations that the citizens or organizations involved need to interact with to facilitate these very much needed behavioral changes. So, for instance, in the case of the battery exchange stations in Taiwan --- they need to be more ubiquitous and the design of the graphical user interface that a scooter rider needs to interact with should be easy to use and the batteries, easy and effortless to dispense. In the case of the glass bottle recycling centers, the number of plastic containers for collecting bottles should be increased and so should the number of collection points. A highly welcome and serendipitous outcome of the PALPA/L&T RFID initiative is the emergence of a new business model for PALPA so that in addition to merely collecting and washing glass bottles, the

organization could now generate new revenues from actually recycling the used glass bottles. Such are the kinds of innovative upshots that firms can look forward to if the appropriate technology is creatively deployed.

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