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Transport Telematics as a Tool Supporting the Collection of Used Lead-Acid Batteries in Nepal

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ABSTRACT
In developing countries, the problem of collecting used batteries is a significant environmental problem, especially as: the demand for batteries grows, the system of collection and disposal of used batteries is not appropriate, environmental problems are visible. This problem is particularly important in countries with difficult terrain, an example is Nepal. The subject of the paper is the method of collection of used lead-acid batteries in Nepal with the use of the concept of transport telematics. The scale of the problem in Nepal has been identified, the terrain conditions in which the used batteries are left has also been described, a mobile platform was proposed with a communication system to identify used batteries in the field, and the method of physical collection of batteries dispersed in the field and transport to warehouses was proposed. The technical assumptions of the system for the identification, collection and transport of used lead-acid batteries have been also formulated.

KEYWORDS: telematics, recycling used lead-acid batteries, QR codes, battery recycling in Nepal, used battery collection system

1. Introduction

Major share of battery consumption in the world is occupied by lead acid battery [1]. Lead-acid battery has application in electricity back up, charge storage as well as in automobile for Starting, Lighting and Ignition (SLI). Large quantity of lead acid battery is manufactured globally every year [2]. Improper disposal of Used Lead Acid Battery (ULAB) is hazardous to environment and health [3]. ULAB can be easily recycled with very high recovery rate in Secondary Lead Smelter (SLS) [4].

1.1 Scenario of Nepal in waste battery recycling

Lead acid batteries which are used in solar photovoltaic systems, automobiles, electric vehicles and power battery backup systems are the major sources of ULAB in Nepal. In Nepal the lead-acid battery is replaced in every three to five years. In total there is about 24000 tonnes of ULAB generated each year [5]. ULAB recycling is high priority for Nepal. There are some of the challenges that needs to be addressed while implementing recycling project. One of the challenge is managing ULAB collection system in high Himalayan regions. The challenging geography of Nepal imposes huge difficulty in transportation of materials [6].

1.2 Effects of waste battery and challenge due to geography

In high Himalayan regions of Nepal distribution of electricity through transmission lines is challenging [7]. However they generate and use alternative source of electricity at local level such as micro hydropower and solar photovoltaic system. To store this electrical energy lead-acid batteries are used in large quantities. Collection system of ULAB is difficult to manage in these areas.

So the ULABs are discarded by dumping it in any available land and water sources at mountain region at Himalaya [8]. Around 15% of Nepal is covered by high Himalayan mountains [9]. The means of transportation in mountainous part of Nepal are through truck, airplane and helicopter but they operate in difficult conditions such as dangers of landslides, damaged roads, difficult navigation, high cost of air transport and lack of infrastructure [10]. Planning infrastructure is also difficult due to scattered population throughout the mountains [11]. Improper disposal of ULAB has damaged the vulnerable ecosystem of Himalayas. It has also negatively affected tourism industry of Himalayan regions which is a major source of income to Nepal [12].

1.3 Need to shift towards circular economy

Environment is not a sink for a ULAB. There is a strong relationship between ecological system and economic growth. A holistic view in supply chain of ULAB could lead to creation of new competitive business models [13]. Redesign of supply chain could lead to long-term economic and environmental sustainability as well as innovation. As stated in report from Ellen MacArthur Foundation "Circular economy replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems and business models" [14]

Circular economic model leads to maximizing value creation when considering over the entire lifecycle. Regarding ULAB it is important to consider concept of circular economy. To make ULAB recycling process sustainable it needs to be aligned with the practice of circular economy.

1.4 Collection system and scope of transport telematics

The effectiveness of ULAB recycling system is highly dependent on its collection and distribution especially in country like Nepal. Collection and distribution of ULAB is one of the important aspect of its recycling system. Transportation cost is usually high in mountainous region of Nepal. Also due to unmanaged collection system transportation cost of ULAB in mountainous region will often exceed the scrap value of the ULAB. So the collection rate in these regions are lower. As these area are tourist destinations so the flow of materials exist there even though the supply chain system is weak [15]. The flow of materials indicates that there is possibility of utilizing transport telematics.

Telematics uses information, telecommunication and informatics. It may also includes Global Positioning System (GPS) and navigation system. It has wide applications in vehicular technology such as fleet tracking, transportation management, road safety, vehicle automation and navigation. Investigation on use of transport telematics as a tool for supporting collection of ULAB is the subject of research in his study.

2. Methodology and Purposed Solution

The research problem is finding efficient method by which transport telematics could be utilized as a tool for supporting the collection of used lead acid batteries in Nepal at mountainous region. From this study cloud connected dynamic Quick Response (QR) code system has been purposed as a tool of transport telematic to support collection of ULAB in Nepal.

Although population density is low in these areas there is a significant movement of people and materials due to tourism. There is land and air transportation system. Also with hiking, use of porters and use of animals is significant part of transport [16]. In such situation tracking and matching system could be beneficial for controlling movement of ULAB towards the collection centre. The tracking system with loc1ation indication could be attached in ULAB.

The transport telematics needs to be synchronized with analytics which are generated by movements of ULAB. Thus any vehicle which runs through that specific location could be able to collect ULABs based on that analytics. This way tracking of ULAB and matching it with vehicle transporting in that area can be done. Nepal is one of the least developed country with poor infrastructure [17]. In such situation research needs to be done to investigate appropriate telematic tool that supports collection of ULAB in Nepal in low cost. For this some of the telematic tools are reviewed. In context of Nepal the effective solution was seen in use of dynamic Quick Response (QR) codes. Not only dynamic QR code used to track the geo-location but also on each time it is scanned the details of the scan and user can be retrieved. This is very useful for generating analytics. The system is connected to cloud based platform and integrated with the central system of ULAB collection and recycling. The advantage of using cloud based platform are cost saving, flexibility in operation, better security of data, increase in manageability and quality control, ease in collaboration, and increased efficiency [18].

3. Results

3.1 Review of existing technology for tracking geo-location

There are several technologies available which can be used in tracking. Each technology has its limitations in terms of range, cost, accuracy and adaptability. For the purpose of tracking, we review following Global Positioning System (GPS) enabled/linked systems: dynamic QR Codes, passive Radio Frequency Identification (RFID) / Near Field Communication (NFC), active RFID, Bluetooth Low Energy (BLE), SMS/Global System for mobile (GSM) Real-Time GPS [19]. RFID and NFC is deployed for tracking in short range. It cannot provide geospatial data of moving item. Also it is expensive. Thus, it is unsuitable for tracing ULAB. Due to limited range of NFC it could not be used either. Bluetooth technology is restricted to limited range so it will not be useful as well. GPS and geospatial

information of item at real time can be traced by using a cellular network using GSM. It has high accuracy and high range. But its components are relatively heavy, power consuming and expensive. So it is not suitable for tracking ULAB [19].

3.2 Use of QR code as a tool for telematics system

QR code can be seen as less expensive and effective option for tracing ULAB to supporting its collection. QR codes is form of two-dimensional barcode containing coded information [20]. QR codes can be easily scanned with a smartphone to get information [20]. QR codes can be used in consumer products, advertisement, money transaction, and URL redirection [21]. It may contain maps, website and digital resources [22].

3.3 Operating principle of dynamic QR code for tracking geo-location

Dynamic QR code can be tagged with ULAB. In dynamic QR code location history and other necessary information related to ULAB can be encoded [23]. When a smartphone scans that dynamic QR code it reads previous location history of the ULAB, stores it, transfers it to another storage device and then encodes current location into that dynamic QR code [24]. The scanning confirms status of ULAB at collection point. Now this smartphone sends location history of ULAB in real time to cloud connected dynamic supply chain system which is in turn connected to central system of ULAB collection and recycling. In this way an integrated system with feedback and control is achieved.

3.4 Working mechanism of telematics system using QR code

When you create a QR Code in your account you can activate the GPS tracing function [25]. QR code itself does not have built-in GPS tracking capability however smartphone has GPS enabled system [25]. Dynamic QR codes can also encode process parameters and other necessary information to support the recycling process as well. The lead acid battery might go to secondary collection system or tertiary collection system, however the location and information can be easily identified in successive scanning by smartphone and processed by cloud connected dynamic system in real time. All the data base generated is send to central system which is connected to relevant stakeholders. This increases accuracy of decision making. Furthermore, it can be processed as a big data. Thus generated database and IT infrastructure can be easily spread to other countries through technology transfer.

The following figures demonstrates working of the purposed system:

Fig.1. QR code is scanned to retrieve previous geo-location where URL was encoded [own study]

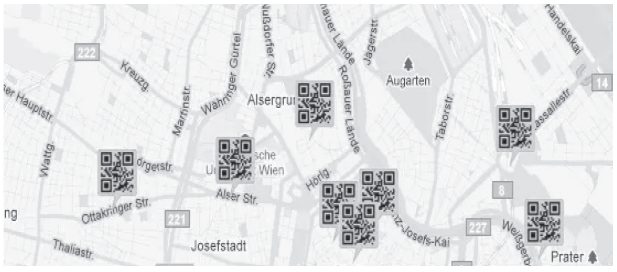

Fig. 2. Geo location where the QR code has been scanned could be transmitted and plotted in map with identification and analytics [own study]

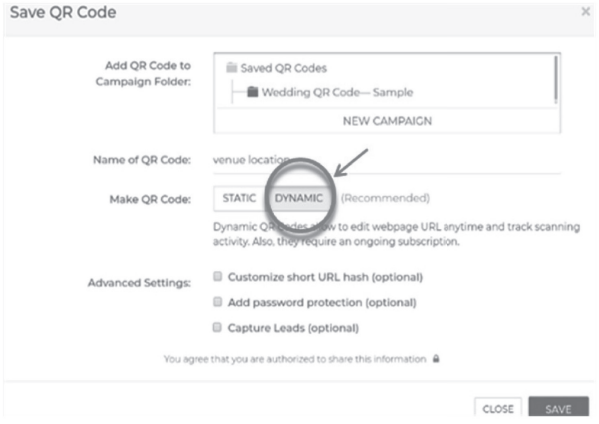

Fig. 3. QR code if dynamic allows to change geo-location linked with it [own study]

3.5 Advantage of using dynamic QR code

QR codes can be easily generated in low cost. Using QR code also saves necessary space. QR codes is maintenance free. Unlike other telematics devices QR code does not need to be manufactured and neither it needs maintenance. This makes QR code great option from sustainability point of view. Applications for generation and reading QR code is easily available. In QR code information can be encoded as well as decoded. Important information such as safety procedures, date of manufacturing, operations procedure, supplier, collection point can be encoded into QR code.

3.6 Scope of using blockchain technology in this system

It would be great advantage to incorporate blockchain into this system. Blockchains can act as virtual ledgers which are transparent and accountable. It is beneficial to record information in blockchain in such a decentralized system. It would be more reliable because it is impossible to tamper the information contained in these blocks which has been secured by cryptographic hash. Incorporating blockchain to manage plastic waste has already been initiated [26]. This initiation uses concept of plastic bank. Blockchain secured digital token is given to people who bring plastic waste to the plastic bank. This token is used for purchasing necessary items and food

through plastic bank app. Also smartphone could be charged with this token. One of the biggest advantage of using blockchain is that it facilitates transaction and recycling business. Transparency of blockchain allows investors to see movement of their investment. Also it helps to increase accountability for a person or company that generated waste. Blockchain helps to shift towards circular economy.

3.7 System for decision support from stakeholders

The central system is connected with relevant stakeholders as illustrated in above figure. The analytics and database is send to relevant stakeholders. With the analytics and database the stakeholders helps in decision making and also sends forecast to prepare system for future operations.

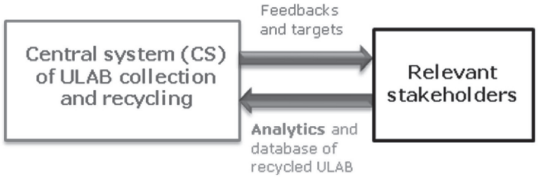

Fig. 4. Interchange of analytics and database between central system and relevant stakeholders [own study]

3.8 Operation procedure of purposed system

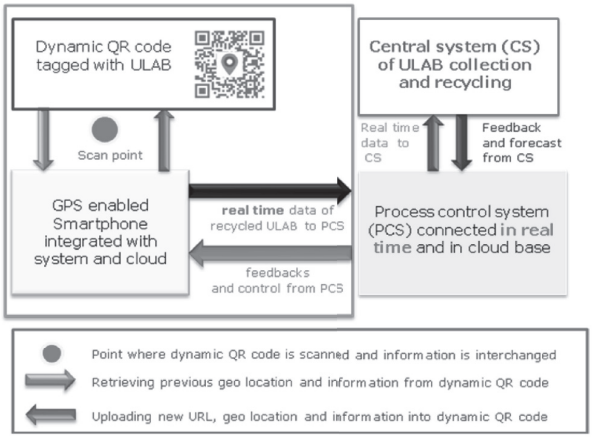

Fig. 5. Schematics of system for tracing geo-location and information interchange in real time [own study]

In this system dynamic QR code is tagged with lead acid battery. The geo-location and necessary information is encoded and retrieved in dynamic QR code in several scan points along the supply chain. This QR code could serve as user manual for lead acid battery during its use. As the QR code is dynamic, the same QR code can be encoded with its consumption history, geo location and other relevant information after consumption of the battery. This will help in collection of used lead acid battery (ULAB) and to generate analytics. The information and geo-location can be retrieved by using smartphone or a reader. The geo-location and relevant information is send to the database system which can be cloud based. New geo-location and information can be encoded in dynamic QR code by simply changing the URL tagged into it. Analytics can also be generated from it. In this way new geo-location is tagged on every successive scan which will in turn indicate the changing position of the ULAB and the process it has undergone. The process is connected with Central System which provides feedback. In this manner real time data of recycled ULAB is send to Process Control System (PCS) and eventually to Central System (CS).

3.9 Circular supply chain integrated with QR code based telematics system

The ULAB recycling facility is integrated with network of supply chain in a closed loop considering reverse logistics into the system as illustrated in figure below:

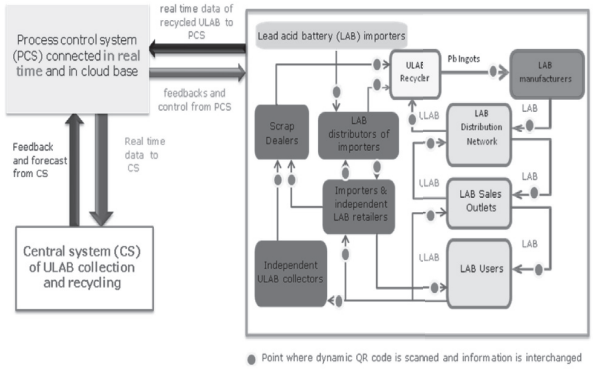

Fig. 6. Schematics of ULAB recycling supply chain integrated with telematics system

In ULAB recycling supply chain at several points there is scanning of dynamic QR code. The overall system is well integrated into a real time. The advantages of being connected and performing process in real time are: errors are known instantaneously, efficiency of service increases due to better forecast and quick decision, unnecessary cost is saved due to flexibility in system to changes [27].

3.10 Future works

This system can be divided into subsystem. The modular design of the system allows transfer of this technology easy. This system can be replicated to other developing countries as well. Most importantly the telematics tools used in this system can also be utilized in supply chain of other materials such as food and medicine. In countries such as Nepal where there is severe difficulty in supply of food and essential medicine this tool would be highly useful. This tool can also be incorporated in health care, telemedicine as well as in education. It is a new concept in Nepal to implement dynamic QR code as telematics tool for recycling used lead-acid batteries so technical infrastructure needs to be developed for it. For successful implementation of this project it is most important to increase technology awareness. In Nepal use of smartphone is widespread among common people but still people are not much acquainted with utilizing new technology such as

telematics, informatics, cloud computing. Thus it is important to provide training and demonstration.

4. Conclusion

The advantage of using dynamic QR code is that the same QR code can be used for encoding several locations on successive scans without rewriting or reprinting the code [28]. This saves time, money and energy. It is significantly inexpensive [22]. It also helps to identify the process which the battery has undergone. In this manner the information database can be created and managed and the process can be controlled as well. Other advantages of dynamic QR code is that it can be activated and deactivated at any time [24]. Design of QR code can be customized to match with corporate/business identity [28]. QR codes can be created and printed in any size [28]. The information in QR code can be transferred as text file formats [28]. The analytics such as identity of scanner, number of times scanned, date and time of scan etc can be generated when QR code is scanned [29]. Also notification can be generated each time when QR code is scanned [28]. It can be connected to cloud [30]. Safety instructions, date of manufacturing, date of installation and other relevant details can also be encoded with QR code of lead-acid battery. This helps in recycling process, monitoring condition of the battery as well as in decision making. Dynamic QR code technology has wide application. It is easy to implement and has high accuracy.

In least developed country such as Nepal there is high priority for cost effective system. In Nepal number of mobile phone user is 34% higher than the its population [31]. Thus use of dynamic QR codes as a transport telematic tool seems to be effective, adoptable and reliable for Nepal to support collection and recycling of used lead-acid batteries.

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