Tracking Drayage Truck Driver Productivity with an Electronic On-Board Recorder

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ABSTRACT

Port drayage is a subsector of the trucking industry that deals with moving containers relatively short distances (100 miles or less) with origin or destination at a marine terminal inside a port complex. Inefficient port drayage not only leads to high costs for goods movements, but also results in negative externalities of pollution and congestion. We describe in this paper an electronic on-board recording device that can log all relevant activities during a drayage journey. Detailed analysis of the collected data can help identify trouble areas, the understanding of which will be key to developing strategies and/or policy changes for improvement.

Keywords: port drayage efficiency, electronic on-board recorder, mobile technology, GPS

INTRODUCTION

Port drayage is a subsector of the trucking industry that deals with moving containers relatively short distances (100 miles or less) with origin or destination at a marine terminal inside a port complex. While the port drayage journey is typically short, it is responsible for a disproportionately high portion of the total cost to ship the container from its origin to its destination [1]. The drivers and firms involved in moving goods in and out of the ports are a vital link in the nation's supply chain, as a great deal of manufacturing now takes place overseas resulting in imports of finished or semi-finished products to the U.S. Efficient port drayage, then, is key to an efficient supply chain, resulting in lower prices to the consumer at the point of purchase.

The need for efficiency extends beyond the direct participants in the supply chain to the public. Inefficient use of drayage trucks results in negative externalities of pollution and congestion. Given that all port drayage trucks call at the port complex, it is a very visible segment of freight transportation and is often used to illustrate these negative externalities. In recent years, the Ports of Los Angeles and Long Beach have focused on this industry segment, with the Clean Trucks Program as the cornerstone of the Clean Air Action Plan. The Clean Trucks Program (CTP) has phased-in requirements for all trucks to meet EPA emissions standards (by 2012 all trucks will be required to meet 2007 standards). This will result in the port reducing truck-related emissions considerably.

The increased costs of compliance with the CTP puts even more pressure on drayage trucks to operate efficiently. However, port drayage is still perceived as being relatively inefficient with firms and drivers not taking full advantage of routing and scheduling technology and the existing terminal appointment system at the Ports [2]. In contrast, PierPass, a firm that collects fees placed on trucks that enter/leave the Ports during "peak" hours, alleges that these trucks are fairly efficient, making approximately 4 trips in and out of the ports daily. To help provide a full measure of the current state of drayage efficiency and future changes as trade volume grows, we believe a properly designed electronic on-board recorder (EOBR) will be of great value. The goal of such a device is to allow us to track truck flows and obtain detailed information on truck drivers' waiting time and driving time, with maximum accuracy and minimum effort on the part of the driver. In doing so, we will be able to identify sources of inefficiency in drayage, quantify the impacts of these inefficiencies, and propose solutions.

Technology had been used in monitoring the arrival, entry, and exit of trucks at a terminal of the Port of Los Angeles, producing accurate measures of truck turn time and wait time statistics [3]. This work however required humans to station around the terminal under study and capture each truck with a digital camera as it passed various vantage points. The methodology is therefore applicable only to the monitoring of a known sequence of activities within a specific and small area. METRIS, short for Metropolitan Transportation Information System, a tool developed by Digital Geographic Research Corporation using GPS and GIS, has been applied in a study of drayage trucking around the ports of Los Angeles and Long Beach [4]. To track truck movements for more diverse activities in a wide geographical area, we need devices to be placed in the truck that, with the help of the driver, can accurately log every relevant activity with a timestamp and location-stamp. The purpose of this research is to investigate and test the feasibility of such devices to determine whether they are reliable tools for measuring driver time. Once verified, we will make a larger-scale proposal to granting organizations for more widespread use of these devices to gather data on driver time.

Recent advances in tablet computers, computer networking, and GPS technologies have allowed us to extend powerful computational capabilities anywhere where they are needed. Using these technologies we have developed an EOBR that can be mounted in a truck that can, in effect, track its state, processes data and communicate with other machines in an effort to mine the gathered data for information that can both grease the supply chain and also contribute to sustainable urban development. With the gathered data, drayage operations can be analyzed for inefficiencies that increase cost and lead to higher than normal levels of air pollution. While other studies have focused strictly on port terminal efficiency, this study seeks to look at drayage operations holistically and seeks to improve efficiency not only inside the port terminals, but also throughout the entire drayage journey. The requirements of the tracking device will show the different categories of work-related data that we wish to capture and give the reader a better understanding of how this study will be different from previous ones.

REQUIREMENTS OF THE TRACKING DEVICE

To encourage the driver to enter data for each activity as it occurs, the logging must be doable in one or two hand motions. Therefore, an EOBR for drayage operations must be a hand-held device with a touch screen and be simple and intuitive to use by someone familiar with drayage operations. The user-interface must group related operations together and separate out unrelated operations. The design must provide simple, meaningful shortcuts in the operator's language and be consistent with the lexicon of drayage transportation. Finally, the device must be able to sit in the user's periphery until such time as the user needs to focus on it and then be returned to the periphery. The simplicity of the interface will allow the driver to concentrate on driving and relate to the device as just another piece of dashboard hardware. The interface will provide feedback to the user on changes of state, error conditions, (etc). The design will be tolerant and allow the user to undo and redo operations when necessary and internal and external components will be reused for consistency. The specifications reveal that the device will both accomplish these tasks and be easy to use.

Specifications

Each trip needs to be uniquely identified, either by a unique name that the user enters, or a unique number generated by the device. At the same time, the system will generate a unique key-value for each trip allowing the user to then initiate a time stamp and logging process. Once the process is started, the user will indicate the origin type and destination type of the trip to be a rail yard, transload/storage facility, a warehouse/distribution center, or other location. At the time the trip begins, the user must also specify whether the trip is a pickup empty, pickup full, deliver empty or deliver full. The software will log and timestamp the location of the truck at regular intervals throughout its journey. The driver will interact with the recorder only if relevant details about the trip need to be recorded, such as delays. Upon arriving at the destination, the driver will initiate a timestamp and location log for the end of the trip. Finally, the device must have sufficient storage for large datasets that may be the result of long trips. The device we chose was the Android-based Samsung Galaxy Tab [5] that was programmed in Java using the Eclipse IDE [6]. We also chose Google Earth (GE) for our mapping software and SQLite [7] as our Relational Database Management System (RDBMS).

Software Design Environment

Android supports component-based software development. Each Android application is made up of one or more software components that typically run in a single thread. The components used for the Drayage Recorder are the activity and the service.

Android activities are windows presented to the user that hold the user interface (UI). Each time a new activity is launched a new screen is presented to the user. Because memory is often limited on small devices, activities have lifecycle states specifically designed to preserve the state and the data of the currently running activity while at the same time ensuring resources are available for other programs.

The Android service is a persistent background process that runs in the main thread, timestamping and logging vehicle locations. To accommodate fault tolerant behavior, the service was programmed to run in its own worker thread so that data would continue to be gathered in the event of a crash.

User Interface

The Drayage Recorder UI is simple and easy to use. It consists of four screens that lead the user in wizard-like fashion allowing him to focus on the higher-level problem-solving task of driving. The LoginActivity screen presents the user with a text box and two buttons, one for On Duty and one for Off Duty. Before On Duty can be pressed, the user has to enter a trip name into the text box, by tapping on the box to reveal a keyboard. The algorithms and data structures will provide both an active and a static model of the system for a clearer operational view of the device.

ALGORITHMS AND DATA STRUCTURES

The Drayage Recorder has five states: *LoginActivity*, *MainService*, *OriginDestinationAcivity*, *TripInformationActivity* and *NotesActivity*. The LoginActivity allows the user to enter the trip name and stop and start the MainService, which is a persistent background process that logs and timestamps vehicle locations. The OriginDestinationActivity allows the user to input details about the origin, destination, and type of the trip. The TripInformationActivity allow the user to enter information about trip delays and time stamp those details by acquiring a binder to the MainService; a binder is an interface for an inter process remote procedure call. Finally, the NotesActivity is a text entry screen for adding additional information to the trip record. Figure 1 shows a simplified Drayage Recorder state diagram.

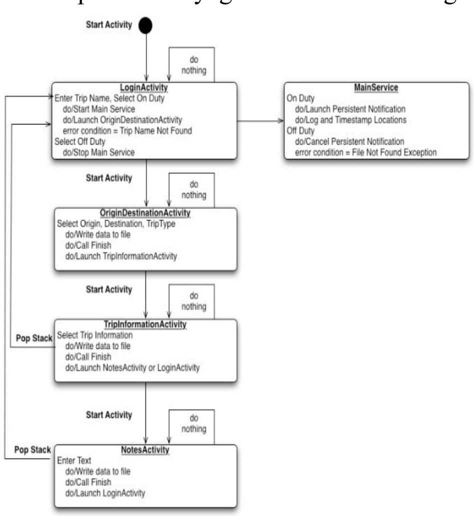

FIGURE 1. Drayage recorder UML state diagram.

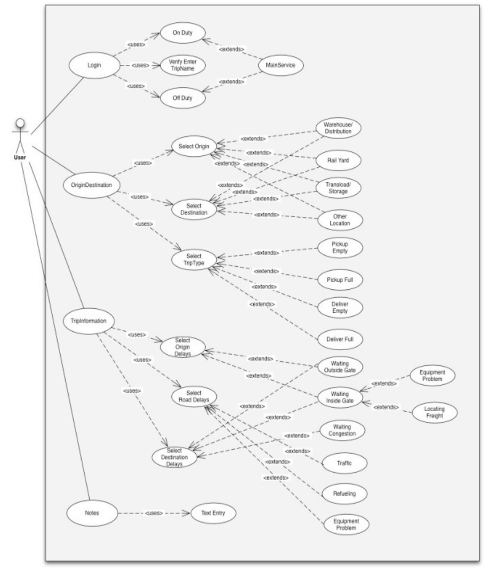

FIGURE 2. Drayage recorder UML use case diagram.

The user activity is straightforward; there is as little opportunity as possible to allow the user to make choices. The reason for this is two-fold: to increase the reliability of the data and to also encourage driving safety. If the user is tempted to stay focused on the device for longer than is absolutely necessary, then the public's safety becomes a concern and productivity goes down. Figure 2 shows the use case, which reflects the user's interaction with the system.

The Drayage Recorder is based on simple algorithms. It does not seek to do everything but rather seeks to do a limited set of things well. By keeping its design simple, the user can be safe and accurate and is more likely to accept the idea of having a digital device on-board the vehicle; this simplicity also extends to the processes of data collection and analysis.

DATA COLLECTION AND EXTRACTION

Drayage Recorder data is written to SQLlite flat files, one file written by the OriginDestinationActivity and one file written by the MainService. The GPS location data is also written to a Keystone Markup Language (KML) file that can be viewed in GE. We have performed a limited amount of experimentation with the recorder to test its usability and robustness, collect data during the trial run, and complete the experiment with statistical analysis on the collected data. What follows is the data collection methodology used to verify the software and its data logging capabilities.

Data Collection

The recorder was mounted to the windshield of Driver X's truck using the Samsung Galaxy Tab navigation mount for the experimentation. Before the test run, the driver was given a tutorial on the operation of the device including instructions on how to reboot the device in the event of a failure and how to interpret and log different types of delays that may be encountered during each move. The device was synchronized to one researcher's phone and home computer using SugarSync Back Up Software that enabled us to monitor the progress of the tests hourly and intervene if the device was not working properly. Driver X performed test runs with the recorder between February 5th and February 10th, 2012, logging a total of 18 trips. The software correctly wrote an OriginDestination file, a Log file and a KML file for each trip. The logged data were imported to a SQLite RDBMS for statistical analysis.

Besides the collected data, the test runs provided us with valuable feedbacks on deficiencies of our design and led to the following improvements:

1. While an initial version of the software allowed the user to enter a name for each trip, we replaced that functionality with a method that assigns a pseudo random integer as the unique id for each trip, and is written when the user selects On Duty.
2. The initial version of the software also had a notes activity allowing the driver to enter a holistic text record about the trip. Both features were eliminated because data from Monaco and Grobar reveal that approximately 68% of drivers have a high school education or less [2], potentially limiting the usefulness of such records.
3. A major concern that most companies had, when evaluating whether or not to test the device was the level of interaction required on the part of the driver. We have thence simplified the UI and reduced the amount of driver actions/interactions.
4. A Spanish translation of the original interface was used in anticipation that many drivers would be Hispanic [2]; though Driver X was fluent in both Spanish and English making it possible for us to seek feedback from him on the translation.
5. The warehouse/distribution center category from the TripInformationActivity was split into two upon the recommendation of a driver who said they were generally separate locations.

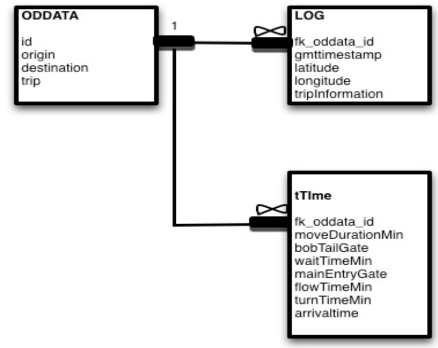

FIGURE 3. SQLite database used for trip information storage.

Data Extraction and Preliminary Analysis

Of the 18 trips logged by Driver X, five originated or terminated in a port terminal. Those port terminal statistics, along with all of the OriginDestination files and Log files, were imported into a SQLite RDBMS that relates each specific trip to its respective GPS log data and also the turn time information for each port-related trip. Figure 3 shows the database definition. The turn time statistics were gathered by animating each of the KML files associated with the port related trips.

The KML files clearly show the driver's progress over the duration of each move and produce time stamped place marks at key areas throughout the port terminals visited. Recall that Lam et al. defined wait time as the amount of time from arrival to admittance with ticket issued, flow time as the amount of time from when the ticket is issued at the pedestal to when the truck clears the exit gate, and turn time as the sum of both the wait time and the flow time [3]. The KML files from the five port terminal trips were analyzed for wait times, flow times and turn times at each terminal by graphically matching the truck's location with satellite images of each terminal. While there is not a large enough sample of data from which to derive meaningful statistics, the evidence nonetheless shows that if the devices were more widely distributed over a longer period, enough data could be gathered to get an almost perfect picture of traffic inside the ports. Note that GPS introduces a high degree of identity precision and for the purpose of this study is said to be 100%, therefore the data gathering and processing focuses on accuracy. Table1 shows the data gathered from the KML analysis of the five port-centered trips: times are in minutes.

TABLE 1. Move durations, gate types, wait times, flow times and turn times for port-centered moves. All times are in minutes

id	move Durat-ion	bob Tail Gate	wait Time Min	main Entry Gate	flow Time Min	turn Time Min
-938717670	123	0	31	1	46	77
-530500372	206	0	47	1	126	173
1675412033	76	0	4	1	57	61
1425786168	61	0	20	1	20	40
1697570061	74	0	50	1	15	65

From the data in Table 1 we can calculate the mean, median and standard deviation of the wait time, flow time and turn time from the five trips. The results are presented in Table 2, where the times are represented in minutes. Note that due to the small sample size, the confidence interval for the standard deviation is wide. Nevertheless the data is precise and in volume would produce a very accurate picture of wait times, turn times and flow times.

TABLE 2. Wait time, flow time and turn time statistics for port-centered moves. All times are in minutes

Statistic	Wait Time	Flow Time	Turn Time
Mean	30.4	52.8	83.2
Median	31	46	65
Standard Deviation	19.1	44.5	51.9

Looking at all eighteen Origin Destination files from the test, we can get a sense of the frequency of individual origin and destination types logged by Driver X; Table 3 shows that frequency.

TABLE 3. Frequency of origin and destination types

Origin/Destination Types	Number	Percentage
Transload/Storage	11	61%
Port Terminal	9	50%
Warehouse	9	50%
Rail Yard	4	22%
Other Destination	2	11%

The data reveals that 61% of moves either originate or terminate at a transload/storage yard, 50% of moves originate or terminate at a warehouse, 22% of moves originate or terminate at a rail yard and 11% of moves originate or terminate at some other destination. Across all of these moves, 55% are moves of empty containers.

From the content of the KML files and a post interview with the driver, we determined that all of the trip type data was entered accurately by the driver and recorded accurately by the software. Across a large sample of drivers we can gather OriginDestination data that is both high in accuracy and precision. While the possibility exists that a driver may enter data incorrectly, the tests show that the driver was able to enter the correct data and that the interface enabled his experience. Table 4 shows all of the OriginDestination records from the test. The test yielded 18 TripInformation records each logging the GPS locations of the truck during each move. Each file was compared with its KML counterpart and all of the GPS coordinates are matching. The driver, however, did not log any delay information during the test even though the KML files show areas of delay, most notably inside the port terminals. When asked to account for the discrepancy between the delays in the KML files and those not recorded in the TripInformation files, the driver said that all of the delays that he encountered were inside port terminals and due to customs holds on the cargo for which he was waiting; the TripInformationActivity does not account for customs delays. Moreover, it is apparent from the post mortem that without a time delay clock, each driver would interpret delays independently providing a very raw dataset.

TABLE 4. SQLite OriginDestination file showing the id number, origin, destination and trip type of each move

id	origin	destination	trip
-1791539385	Port Terminal	Rail Yard	Pickup Empty
-1611836280	Transload/Storage Yard	Warehouse	Deliver Full
-1532100582	Transload/Storage Yard	Port Terminal	Pickup Empty
-1229770573	Rail Yard	Warehouse	Pickup Full
-938717670	Port Terminal	Transload/Storage Yard	Pickup Full
-660782626	Port Terminal	Rail Yard	Pickup Full
-530500372	Transload/Storage Yard	Port Terminal	Deliver Empty
-401423358	Transload/Storage Yard	Warehouse	Deliver Full

1750873	Transload/Storage Yard	Warehouse	Deliver Full
243053625	Transload/Storage Yard	Port Terminal	Deliver Full
344015324	Other Destination	Rail Yard	Deliver Empty
798825168	Transload/Storage Yard	Warehouse	Deliver Full
1390165033	Transload/Storage Yard	Warehouse	Deliver Empty
1425786168	Transload/Storage Yard	Port Terminal	Deliver Empty
1675412033	Warehouse	Port Terminal	Pickup Empty
1697570061	Warehouse	Port Terminal	Deliver Empty
1856014652	Transload/Storage Yard	Other Destination	Deliver Empty
2064137356	Warehouse	Warehouse	Deliver Empty

CONCLUSIONS

The growth in traffic expected at the twin ports over the next twenty years will result in higher over-the - road drayage flows for Southern California and this increase will surely have an effect on urban development, public health, and the overall efficiency of the global supply chain. For this growth to be sustainable, drayage flows need to become more efficient so that the twin ports and surrounding communities can coexist in a way that creates jobs, is good for the consumer, and does not negatively impact public health and well-being. While this is not currently the model in drayage operations, the ubiquity of small computers is making it possible for these trucks to become roving computational devices that can sense the environment around them and report back about their state. Thus port terminal efficiency can be increased, health related problems decreased and logistics zones developed to maximize the already existing road, real estate and container capacity.

To address these issues, we have proposed and reviewed the development and a test of a drayage specific EOBR called Drayage Recorder. It is clear from the limited amount of collected data and the preliminary analysis that the recorder has the necessary functionalities to enable the tracking of activities within a port terminal, providing data for accurate statistics on port-service efficiency. The recorder has been designed to track drayage efficiency at other facilities such as warehouses and distribution centers, as well as delays in traffic during drayage trips.

While the sample of data collected from the tests by Driver X was not large enough to generate reliable statistics, along with functional testing and unit testing, it produced a high degree of confidence in the data-gathering method and its underlying technology. Some of the findings of the data collection are:

1. To ensure that the recorder will be fully utilized in all parts of every drayage journey, drivers need more familiarity with the recorder and more confidence with its operation.
2. The definition of "delay" is largely qualitative. For example, if a driver is in a slow moving line for the pedestal but perceives that to be the norm for that particular port terminal, he may not log it as a delay. Conversely, a driver may regularly log delays anytime he is not the only one in line. We need to come up with a more objective definition of the term for the collected data to be meaningful.
3. When interviewed, Driver X said that it was difficult to remember to use the recorder, that even though it was in front of him, the details of his job made him focus on other things. This again points to the need of more familiarity with the device.
4. While Driver X found the device easy to install and use, it is clear from our discussions with other drayage operators and from the data gathered, that the less a driver has to interact with a device, the better; both for the accuracy of the data collection process and the safety of the drivers and other vehicles on the road.
5. By leveraging more of the capabilities of the Samsung Galaxy tab or similar Android device, it may be possible to gather much of the data we currently gather without requiring as much interaction by the driver. We can for example tether the device to the vehicle's various on-board computer systems via Bluetooth and tie the GPS logging process to the vehicle's ignition. This can provide the device with data about the vehicle's operation, such as torque, revolutions per minute, fuel usage, and weight, which may allow us to determine whether or not the truck is a bobtail, carrying an empty container or carrying a full container. We can also create a database of origins and destinations and build GPS proximity alarms for those locations and areas within those locations.

The data collected from the recorder can be mined for port and transportation efficiency to help create logistics zones, affect transportation planning, and positively impact the air quality in surrounding communities. As traffic increases at the ports over the next twenty years, this data will be crucial in helping governments to plan for that future, allowing businesses to compete and help people in and around the ports coexist with the rapid increase of port traffic.

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