AN AUTOMATED SYSTEM FOR TRACKING THE HAUL OF CONSTRUCTION MATERIALS

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Abstract:

Alberta Transportation is responsible for managing the construction, maintenance and operation activities on approximately 25,000 kilometres of paved highways. On an annual basis over 3 million tonnes of Asphalt Concrete Pavement (ACP) and 4 million tonnes of Granular Base Course (GBC) aggregates are weighed and hauled for highway construction and rehabilitation activities. The construction process is 100% out-sourced with engineering consultants undertaking the design and contract administration duties while the construction activities are awarded to contractors based upon low bid tender.

The present measurement/payment process involves the loading and weighing of gravel trucks at the aggregate pit or asphalt plant by the contractor; manual recording of the haul loads by the consultant's scale person and manual recording by the consultant's road checker upon delivery of the load. The scale sheet is collected by the project manager on a daily basis, totaled and verified against the road checker's book. The same haul data is taken by the contractor and resorted in order to provide payment to the individual truckers. In many cases the consultant and contractor each enters the same data into separate spreadsheet programs. While the present process works adequately there are obvious opportunities for improvement in regards to eliminating contractor/consultant redundancies and with the speed of data collection and reporting.

This paper describes how modern information and communication technologies were used to develop the Automated Truck Haul (ATH) system and the results obtained from a highway paving project where the system was piloted. The ATH system consists of a scale-mounted computer that is used to electronically capture the ACP load data and transmit that data via satellite to a centrally located server. The same data is also transmitted to a GPS equipped PDA computer at the paving site where the road checker automatically captures the time and location of unloading. The unload data is then transmitted to the central server in "near real-time" conditions. Through an internet connection the data is accessible to the project consultant, contractor and the department's regional staff.

Results from the ATH pilot project confirm that cost savings are achievable, mainly through the elimination of the consultant's scale person. Other cost savings and efficiencies were also identified in that the time spend on manual data entry and report generation was greatly reduced.

1.0 Introduction

Alberta Transportation (AT) is responsible for managing the construction, maintenance and operation activities on approximately 25,000 kilometres of paved highways. Prior to 1995 the department used its own staff for the activities related to highway planning, design and construction administration. In 1995 a series of re-engineering initiatives were undertaken looking at the various activities and processes used by the Department. Two of these initiatives were directed to review the process of highway planning and design "Design Projects" and highway construction "Construct Projects". A major outcome from these re-engineering initiatives was the 100% outsourcing of project level design and construction administration duties to pre-qualified engineering consultants (1). No significant changes were made to the procedures used for the actual construction activities. This work continues to be awarded to contractors based upon low bid tender.

Alberta Transportation is proud of its record as an innovative organization. The department is continuously seeking ways to improve its practices and processes. Examples of this are the introduction of an End Product Specification for asphalt concrete pavement approximately 15 years ago, and the introduction of Managed Quality Assurance practices. More recently, the department has established a vision to be "A Centre of Excellence in Transportation in North America". One of the pillars for achieving this vision is by being an early adopter of affordable technology that improves the quality and effectiveness of our services and programs.

Alberta Transportation's success in implementing innovative ideas has been due, in part, to the enviable partnership the department has developed with the Alberta Roadbuilders and Heavy Construction Association (ARHCA) and the Consulting Engineers of Alberta (CEA). It is through this collaborative and consultative tri-party relationship that ideas can be brought to the table; examined, debated and challenged from all perspectives; to ultimately create a situation where the opportunity is maximized to the benefit of all parties. The automated system for tracking the haul of construction materials is a prime example of where all three parties contributed to the concept and trial, and all three parties stand to gain significant ongoing benefits.

1.1 Present Measurement System

On an annual basis over 3 million tonnes of Asphalt Concrete Pavement (ACP) and 4 million tonnes of Granular Base Course (GBC) aggregates are weighed and hauled for highway construction and rehabilitation activities. This work includes both new construction and rehabilitative overlays with and without grade widening. In a typical year 40 to 50 contracts are awarded with over 90% of the work spread among nine main contractors. An average paving project would consist of 60,000 tonnes of ACP material but this varies widely, anywhere from 10,000 to 200,000 tonnes.

Most of AT paving projects are completed using mobile drum mixing plants that are set up in the gravel pit or occasionally at an interim stockpile site. In all cases the contractor is responsible for supplying the certified scale and loading the haul trucks. The loading is done by either the plant operator or in some cases the contractor hires a scale person whose duties are separate from that of the plant operator and the scale person hired by the consultant (who verifies that net weight is correct and manually records). In this report the contractor's employee responsible for loading the haul trucks will be referred to as the load operator. In most cases the platform scale is situated directly under the loading silo, however on some projects the contractor elects to set the scale up at some other location within the pit. A variety of scale

types from different manufacturers are in use, but all use load cell technology versus the mechanical beam style of older systems.

Once the truck is loaded a scale person that is hired by the consultant manually records the load information onto both the scale summary sheet and a truck haul card that is given to the driver. In this report, unless otherwise stated, the term scale person will refer to the person hired by the consultant to record for payment purposes the net haul information. Upon arrival to the road the truck driver radios the load weight to the road checker (hired by the consultant) who then records the information into a checker's book. Note, for safety reasons, the department stipulates that the road checker is to remain off the road surface and not approach the haul trucks or construction equipment.

The scale sheet is collected by the consultant's project manager on a daily basis, totaled and verified against the road checker's book. Payment is then provided to the contractor, usually on a per tonne measurement basis, i.e. no separate payment for haul. The contractor takes the same data and provides payments to the individual truckers, either on a per tonne or tonne·km basis. In some cases the consultant and contractor each enters the same data into separate spreadsheet programs. The present system, with only minor changes, has worked adequately for decades however there are obvious opportunities for improvement in regards to eliminating contractor/consultant redundancies and with the speed of data collection and reporting.

2.0 Past Investigations

2.1 Automated System using Radio Frequency Identification Technology

In 1993 the Research and Development Branch of Alberta Transportation coordinated a trial project (2) using Radio Frequency Identification (RFID) technology as a basis to automate the collection and storage of truck haul data on a paving project. On this project an electronic tag, also known as a transponder, was installed onto each truck. Each tag was assigned a unique identification number and was able to transmit, receive and store up to 8 kilobytes of information. The haul data was semi-automatically captured at the weight scale and stored onto the hard drive of a PC computer. It was not a completely automated system as a scale person was still required to monitor the loading process and made several manual entries and checks. A handheld portable reader was used by the checker on the road to communicate with the individual electronic tags. The kilometre station for unloading was manually entered by the road checker into the portable reader. The data from the handheld unit and the data from the scale house PC (copied onto a floppy disk) were then transferred to a field office computer.

While this system was able to collect data as designed a number of technical problems and limitations resulted in no further system development. Some of these problems and limitations included:

- No reduction in engineering staff costs. A scale checker and road checker was still required to enter data.

- Data capture at the scale was not always accurate. Problems were encountered with wind affecting the capture of tare weights. Also there were instances where the weigh data on the electronic tags was not updated properly and entries from the previous day continued to be used.

- Concerns were expressed about the security of the haul data as it was believed that the data could be potentially altered between leaving the scale house and being received on the road.

2.2 Feasibility Study for Developing an Automated Truck Haul System

In 2000 the Technical Standards Branch of Alberta Transportation hired Stantec Consulting Ltd. to undertake a feasibility study (3) on the use of information technology for automating the collection of truck haul data. The objectives of the study were:

- Canvas other highway agencies and report on the current state-of-practice in regards to using such technology.

- Undertake a technology scan and outline different information technologies or system approaches for the potential development of an automated truck haul system. A summary of costs and issues associated with implementing each alternative was also to be provided.

The survey results from other agencies indicated that no other agency was using a completely automated system where the truck haul data was automatically captured both at the mixing plant and at the road site. A few agencies reported using an automatic truck scale where the weigh data is electronically captured and weight tickets are automatically generated.

The feasibility study provided a general description of various communication and information technologies including, RFID, Global Satellite Positioning (GPS), smart cards, wireless communication, bar coding, automated ticket printers and hand held personal computers. While a number of different technologies were described as being feasible, no one integrated system was recommended for further evaluation.

3.0 Development of Automated Truck Haul System

In order to develop a prototype system an Edmonton based company, Truckbase Corporation, was invited to review the department's business needs and submit a proposal on automating the collection of truck haul data. This company has done previous work for the department (4) in developing a web based system for monitoring the location and actions of snow plow trucks using GPS technology. When preparing their proposal Truckbase was encouraged to interview a number of local paving contractors to review in detail their operating procedures and type of equipment used (mixing plant, weigh scale, haul trucks, pavers, etc.). The department was interested in receiving a proposal where Truckbase had received concurrence from a paving company to partner on an existing contract towards evaluating a prototype system.

On this trial project the department would be responsible for all costs associated with developing the automated system while the volunteer contractor would be willing to let Truckbase do the necessary equipment modifications and installations without requesting any extra work charges.

3.1 Trial Project Location

The chosen trial project was a combined grade widening and pavement overlay on Highway 18, west of Westlock, which is approximately 90 km north of Edmonton. The project was 18.8 km in length and consisted of 35,195 tonnes of a Type 2 asphalt concrete mix. A separate bid item

was also included for 500 tonnes of Type 2 mix to be supplied as Asphalt Mix for Others, i.e. material that is picked up at the mixing plant by the local maintenance area contractor. Granular base course aggregate was also to be supplied as part of the grade widening activities however automating the measurement and tracking of this material was not included as part of this evaluation. The contractor for this project was E Construction Ltd. while the consultant was Al-Terra Engineering, both are based in Edmonton.

On this project the contractor's drum mixing plant was situated at the gravel source located near Fort Assiniboine resulting in a dead haul of approximately 60 kilometres. Loading of the haul trucks was done by the load operator (in this case a scale person hired by the contractor) while a second scale person, hired by the consultant, was responsible for recording the time, truck number and net load. The contractor used an above ground platform scale containing a DS 1000 electronic scale head manufactured by Western Scales Inc. On a typical day the contractor would use 20 haul trucks that consisted of either bottom dump trailers (net load of approximately 30 tonnes) or bottom dump combination units consisting of a trailer and pup trailer (net loads of approximately 40 tonnes). The asphalt mix was dumped and windrowed onto the road surface where a pick-up unit would pick-up and transfer the mix to the hopper of the paver. A road checker that was hired by the consultant was recording the load deliveries. Paving of the road intersections and entrances was done using a smaller paving unit.

For this trial project no changes were made to the regular measurement procedures, i.e. the consultant still used scale summary sheets, haul cards and a road checker's book. The Automated Truck Haul (ATH) system was only used on a shadow or demonstration basis. The system developer supplied three engineering staff members (not all three used continuously) to setup, troubleshoot and operate the system. In the case of data entry at the scale house the load operator was able to operate the computer after a brief training period. The data collection on the road for the system was handled by one of the Truckbase employees (referred to as ATH road checker in the remainder of this report).

4.0 Description of Pilot System

The system developed for this pilot project consisted of the following equipment:

- Computer with satellite communication ability and auxiliary equipment at the scale house.
- Two hand held personal digital assistant (PDA) units. One was GPS equipped and the other was equipped for satellite communication.
- Off-site server located at the Truckbase office in Edmonton.

The equipment installation was done by Truckbase personnel while the contractor was mobilizing the plant and equipment to the project. No problems were encountered while installing this equipment.

A more complete description of the equipment used and how it operated is contained in the final report submitted by Truckbase (5) and further summarized as follows.

4.1 Scale House

A standard desk top computer with a 15 inch LCD monitor was connected to the scale head by means of serial port communications. The computer was a Pentium III running at 500 MHz with 128 of RAM and used the Windows 98SE operating system. The computer was pre-

programmed at the beginning of the project to contain the identification and tare weight information for each truck to be used. New trucks that were brought on during the project could be easily entered into the system by the load operator. As the truck drove on the scale the load operator would enter the truck identification number and would select the type of weight information to be recorded, either *Gross* (default) or *Tare* if a new tare weight was desired. Once the truck was finishing loading the load operator would enter *Yes* and the truck number, net load weight, material type and time would be stored onto the hard drive. A load receipt would be printed for the truck driver using a small dot matrix printer.

The computer was linked to the Globalstar communications satellite network. After either a predetermined number of loads or set amount of time the stored data was transmitted to the satellite and then onwards via the internet to both the Truckbase home server and the PDA unit located on the paver. The upload interval used on this project was ten minutes. More frequent transmissions could be done however satellite transmission costs would be higher. All load transactions were stored on the scale house computer and could be transmitted at a later time if there were any satellite communication problems. An UPS (uninterrupted power supply) device was used to protect against power fluctuations and outages. A screen capture of the computer input screen is shown in Figure 1.

4.2 Paving Site

Located on the paver was a Panasonic Toughbook PDA unit which was also connected to the Globalstar communications satellite network. The unit was mounted inside a protective plastic case that was magnetically mounted to the paver. A simple plug-in connection allowed the unit to be powered from the paver. This unit served as a communications relay to both the checker's PDA via an 802.11b wireless connection and the Truckbase server via a Globalstar data modem.

A second Toughbook PDA was carried by the ATH road checker and featured an internal GPS module plus 802.11b wireless communications capability. Data entry could be performed through either a pen stylus or keyboard entry. A photo of the Panasonic Toughbook unit is shown in Figure 2.

Custom software was written for the PDA units and the user interface employs intuitive menu selection options. Well in advance of the loaded truck's arrival, the ATH road checker could view a list of incoming loads. Once a truck arrived the checker would select that truck using the pen stylus. The checker would mark the location of the load using either GPS coordinated that were automatically generated by the attached GPS receiver in the PDA unit. In cases where the load was delivered to some other location other than the paver, i.e. for mix placed on approaches or used as preliminary levelling, the checker could manually input the kilometre station with accompanying remarks. Information for lane direction, lift number and mat would default to previously entered values but could also be manually changed if required. The system was also programmed to provide on-going tonnage spread rate calculations in a separate report to the checker.

The load and unload data would be transmitted to the satellite and home base server at pre-determined intervals (usually every 10 minutes) or at any time the checker wanted an update. An example of the input screens for the portable PDA is shown in Figure 3.

4.3 Data Storage and Access

Both the load and unload haul data was sent to the Truckbase server through the Globalstar communications satellite network and the internet. The GPS coordinates were converted at the server to highway kilometres values corresponding to the linear referencing methodology used by Alberta Transportation. Access to the data was available via the internet to the contractor, consultant and the department. The security of the data was protected though a high security website using password protection and encryption technology. Physical protection of the data was also maintained through daily back ups to a secure off-site location.

Various administration rights were granted to the individual parties. The department was only given read access while the contractor was given read access for all data and update access to the truck management information. The consultant was given full access to all data.

Access to the data base was obtained by logging onto the Truckbase website and entering the appropriate username and password. A screen capture of the truck haul data as accessed through the internet is shown in Figure 4. On this screen the viewer could click on any of the column heading to sort the data in ascending or descending order. Also available from this screen is an "*Export to Excel*" button which would download the column headings and haul data for the selected contract into an Excel format file. The consultant and contractor could then take the data and resort or summarize to meet their needs.

5.0 Trial Project Findings

Paving on Hwy 18 started on September 23, 2003 and was finishing on October 6, 2003 for a total of 14 working days. The prototype ATH system was in operation for the full period. In general the ATH system did perform as expected however a number of problems, enhancements and outstanding issues were identified which need to be addressed prior to any further implementation.

Collection of weight data at the scale house worked well with only minor complications. The load operator was able to quickly learn how to enter data into the computer and all loads were successfully collected and transmitted to the home base server. For the first two days of production the haul data was stored on the server but was not accessible through the internet. This was rectified and was not a problem for the remainder of the project. A small problem was identified in instances where the truck was almost, but not fully, loaded and the load operator would enter *Yes* to capture the load. The load operator would then give a small top-up amount of mix to complete the load and enter *Yes* for the second time. In those instances the ATH road checker would observe that the same truck would have two loads marked as being loaded within minutes of each other. The ATH road checker would then mark the second load as being delivered and later bring the situation to the project manager's attention. The project manager would then delete the first load from the data base through the web-site access. System revisions to handle this situation will be looked at in future versions.

No other problems occurred with the collection of the load data. Based upon this project it does appear feasible to remove the consultant hired scale person and collect the load haul data through automated means.

Most of the glitches observed during this trial project were at the paving site involving the two PDA units. The maximum range in communication between hand held and paver mounted PDA units was originally expected to be between 50 and 90 metres. In practice the maximum

operating distance was between 10 and 20 metres and at times the ATH road checker operating the hand held unit would have to physically access the unit mounted on the paver. Changes would be required to improve the range and reliability of the wireless communication prior to any further implementation. The system developer is currently looking at alternative hardwire devices for wireless communication.

The battery life of the hand held unit was shorter than expected, often less than a day's production. In an attempt to conserve power the unit was sometimes turned off resulting in a few loads being entered without the GPS coordinates. The kilometre station for these loads would have to be updated later by the project manager via the web-site access. Carrying extra batteries and reducing power consumption by not using the screen's backlight feature would help in this regard.

The main conclusion was that, with equipment modifications as previously discussed, an automated system could be used to collect the unload haul data and transmit it to a central data base. The system as used on this project would still require a road checker to perform these duties except instead of using pencil and paper the checker would use a hand held PDA unit with GPS and wireless communication capabilities.

The internet access feature allowing the viewing and downloading of updated haul data was tried by all three parties. Each organization had a different opinion on the usefulness of this feature. Alberta Transportation staff are not directly involved in the day-to-day project management activities but instead rely upon the consultant to monitor and summarize the truck haul data. Accordingly, while it was convenient to click onto the internet and access this data they did not see it as being particularly useful for their particular needs. The consultant and contractor on the other hand found this feature to be very useful and time saving. Haul data that was once entered by hand into spreadsheet programs could now be quickly downloaded off the internet. The contractor's head office staff found the instant access to the near real-time data to be useful. They could easily check on the status of the project without having to contact their field staff.

Comparisons were made between the data collected using the regular manual methods and that collected using the ATH system. For the load data there were no discrepancies other than the duplicate loads previously discussed. With the unload information two discrepancies were noted involving errant loads not delivered to the paver (one load was not delivered due to mechanical breakdown of the truck and the other was delivered at a field entrance). In each case the information entered into the ATH system was determined to be correct.

A number of other data base enhancements, not here discussed, were suggested by all three parties for incorporation into future system versions.

6.0 Benefit/Cost Considerations

Costs

The estimated capital costs for a contractor to outfit one plant and paver using the same equipment used on this project is estimated to be:

Site	Equipment	Costs
Plant	PC computer, UPS backup, monitor, printer and Truckbase license fee	$5,800
Paver	Two PDA units, one with GPS, one with satellite modem, each with wireless communication	$7,900
	Estimated Total	$13,700

These equipment costs do not account for any hardware upgrades or enhancements to address the wireless communication and battery power issues that were previously discussed, however those are not expected to be substantial.

Satellite transmission costs for this trial project were under $1.50 per load but would likely be lower with higher volume usage, i.e. full scale implementation. Assuming an average asphalt plant produces 200,000 tonnes per year, the average annual costs using satellite communications for one plant would be approximately $8,000. One remaining cost that has not yet been estimated is that associated with the data base management activities through web hosting. This cost is largely dependant on economics of scale and the actual business model used to setup and operate the ATH system. This needs to be assessed prior to full scale implementation.

Benefits

The annual cost savings associated with converting one paving operation can be summarized as follows:

- Eliminating the need for a consultant hired scale person would result in an annual savings to the department of approximately $29,000.

- The cost savings associated with automating the input of haul data into a spreadsheet or data base program and generating standard reports and invoices would be realized by the consultants and contractors. Actual costs saving would vary from company to company. Based upon discussions with the contractor and consultant that worked on this project it is estimated that a reduction in administration activities would be from 1 to 4 man-hours per day. This would roughly translate to $5,000 to $20,000 per year.

These numbers indicate that the payback period to industry (primarily Alberta Transportation but also contractors and to a lesser extent consultants) is less than one year. The savings alone by not requiring a scale person ($29,000 per year) is greater than the estimated capital costs plus one year worth of satellite transmission costs - combined total of approximately $22,000.

The ATH system also offers other intangible benefits such as:

- Consultants, contractors and the department would have the ability from their office to monitor the near real-time progress of a project located anywhere in the province.

- Increased safety as one less employer would be required at the mixing plant.

- Increased accuracy of haul data as the current system involves multiple manual entries of the same data.

- Potential for better monitoring and enforcement of overweight loads.

- Ability of the road checker to track down errant loads. Under the current system the road checker has no information on which trucks have been loaded until they show up at the paver. With the ATH system the road checker knows which trucks have been loaded and can be more proactive in tracking down loads that were not delivered to the paver, i.e. were they legitimately used elsewhere on the project or are they missing?

7.0 Future Work

Based upon the encouraging results from this trial project the department plans to further investigate this technology on a limited number of projects in 2004. The ATH system to be used on these projects will be updated to include the previously discussed equipment and data base modifications. For at least a portion of these projects it is intended to have the system fully tested without the presence of the scale person and have the consultant hired road checker operate the PDA unit at the paving site.

Other outstanding issues or items to be addressed prior to full scale implementation include:

- Testing the ability of the system to handle multiple contracts.

- Testing the ability of the system to handle multiple bid items, material types, pavers and projects within a single contract.

- Assessing the ability of the system to be integrated into other mixing plants and scale heads.

- Determine the reliability of the system. Will system breakdowns stop production or do other back up measures need to be put into place?

- What business model is to be used to purchase the equipment for other contractors and plants and how are the ongoing operation costs to be financed?

- Does the system provide the department a sufficient amount of protection against receiving fraudulent weighs?

Although the discussions in this report have focused on asphalt paving work, the department also intends to investigate the future use of this system on granular base course projects. While the process is similar – haul trucks are loaded in the pit and unloaded on the road – there are also significant differences, i.e. no asphalt plant or paver, which will likely require further system modifications.

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Truckbase Corporation - Mike Malychuk, Rob Farquharson and Troy Arnestad
E Construction Ltd. - Harold Orom
Al-Terra Engineering - Sean Snowden

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Figures

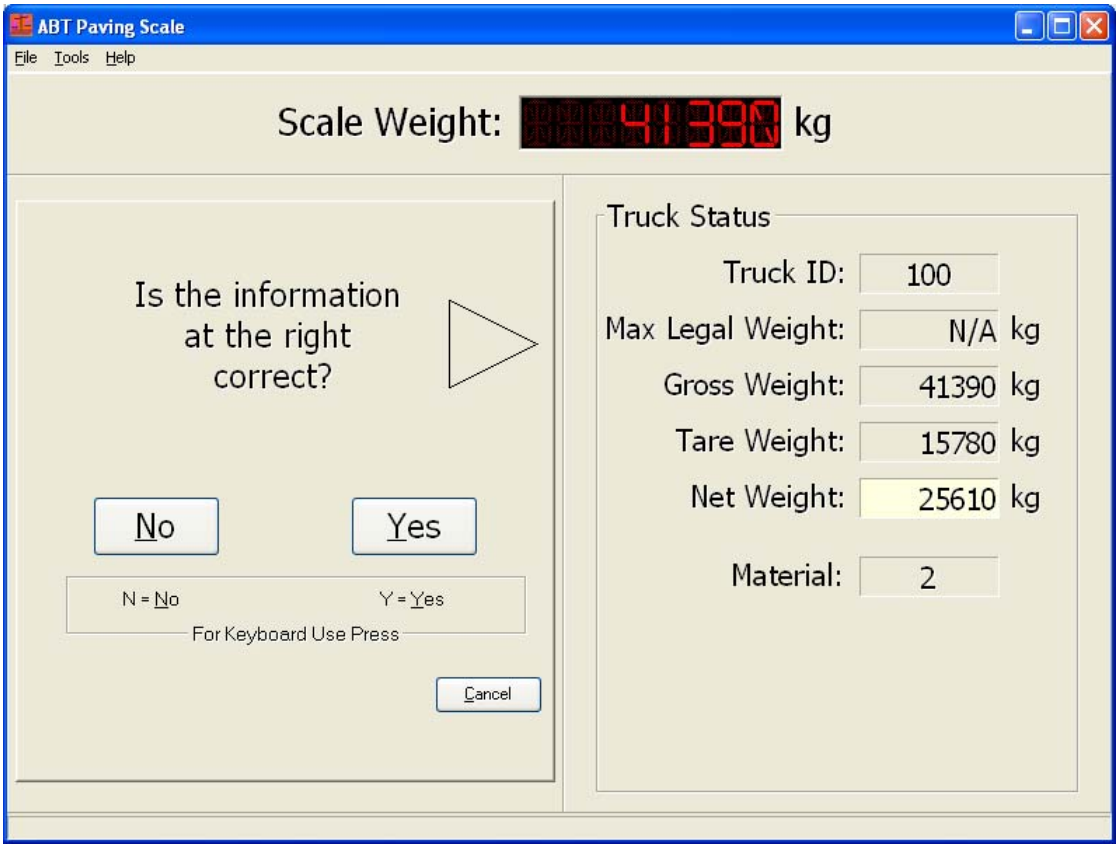


Figure 1 Input Screen of Scale House Computer

Figure 2 Panasonic Toughbook Unit for Road Checker

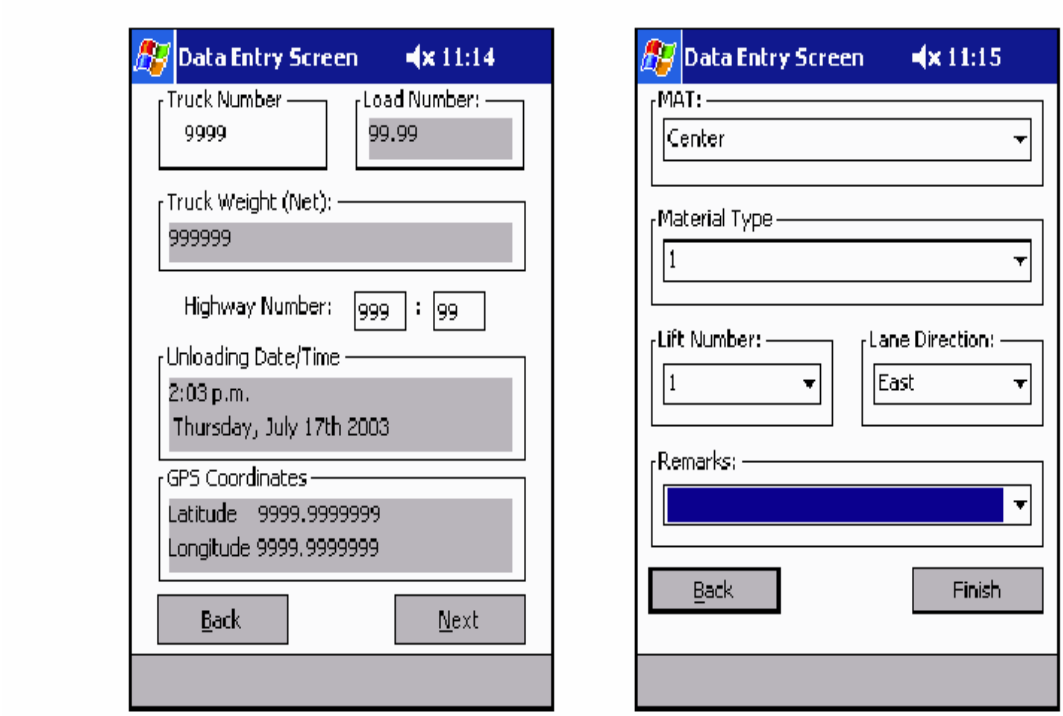
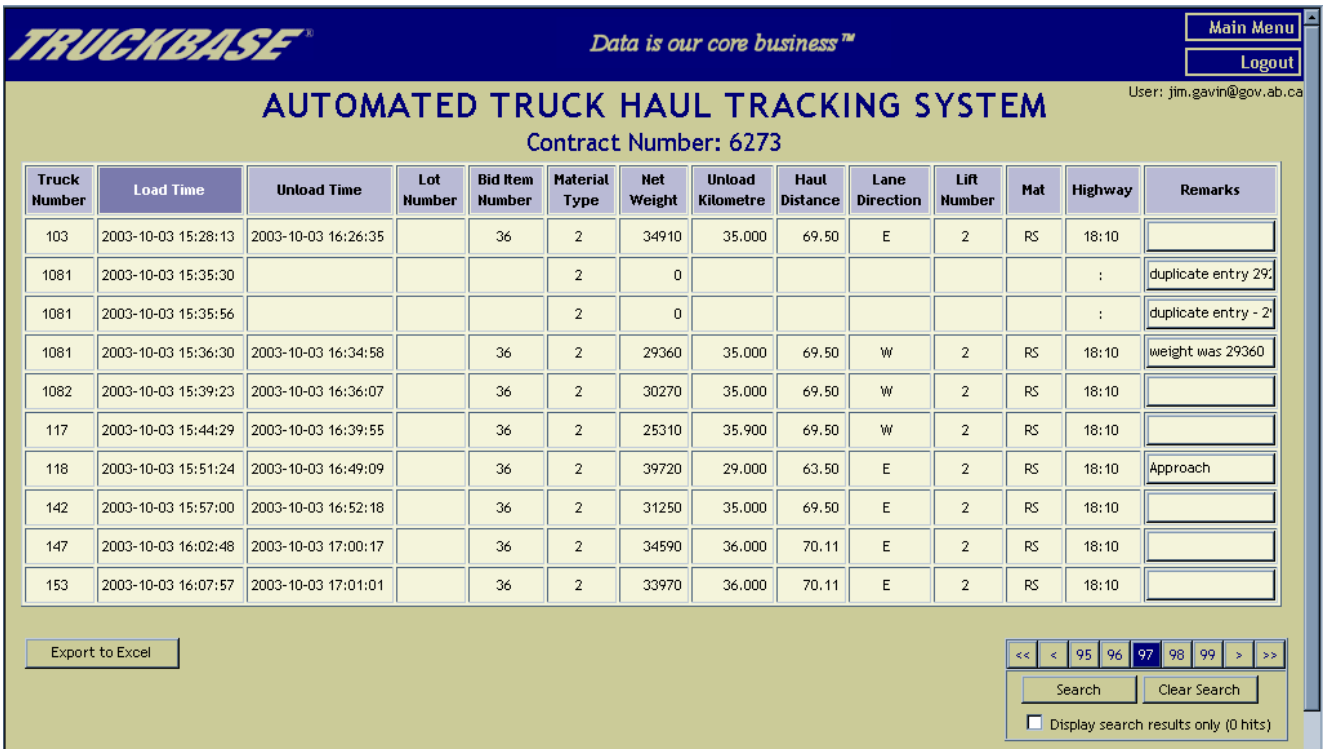


Figure 3 Example of Data Entry Screen for Road Checker's PDA



Truck Number	Load Time	Unload Time	Lot Number	Bid Item Number	Material Type	Net Weight	Unload Kilometre	Haul Distance	Lane Direction	Lift Number	Mat	Highway	Remarks
103	2003-10-03 15:28:13	2003-10-03 16:26:35		36	2	34910	35.000	69.50	E	2	RS	18:10	
1081	2003-10-03 15:35:30				2	0						:	duplicate entry 29
1081	2003-10-03 15:35:56				2	0						:	duplicate entry - 2
1081	2003-10-03 15:36:30	2003-10-03 16:34:58		36	2	29360	35.000	69.50	W	2	RS	18:10	weight was 29360
1082	2003-10-03 15:39:23	2003-10-03 16:36:07		36	2	30270	35.000	69.50	W	2	RS	18:10	
117	2003-10-03 15:44:29	2003-10-03 16:39:55		36	2	25310	35.900	69.50	W	2	RS	18:10	
118	2003-10-03 15:51:24	2003-10-03 16:49:09		36	2	39720	29.000	63.50	E	2	RS	18:10	Approach
142	2003-10-03 15:57:00	2003-10-03 16:52:18		36	2	31250	35.000	69.50	E	2	RS	18:10	
147	2003-10-03 16:02:48	2003-10-03 17:00:17		36	2	34590	36.000	70.11	E	2	RS	18:10	
153	2003-10-03 16:07:57	2003-10-03 17:01:01		36	2	33970	36.000	70.11	E	2	RS	18:10	

Figure 4 Online Screen View of the Automated Truck Haul System