EVALUATION OF PACKAGE DELIVERY TRUCK DRIVERS: TASK ANALYSIS AND DEVELOPMENT/VALIDATION OF AN OBJECTIVE VISUAL BEHAVIOR MEASURE TO ASSESS PERFORMANCE

by

Kevin Grove

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Dr. John G. Casali, Co-Chair
Dr. Jeff Lancaster, Co-Chair
Dr. Tonya Smith-Jackson

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Co-chairman Dr. John G. Casali

Co-chairman: Dr. Jeff A. Lancaster

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(ABSTRACT)

The job of a package delivery driver (PDD) is complex and demanding. These drivers must possess many skills in order to succeed in their work, including physical stamina, appropriate decision-making, positive customer interaction, and most importantly, operational safety. Companies must use significant resources, not only to provide insurance for existing drivers, but also to train new drivers to use their visual attention effectively while driving, and companies have a vested interest in ensuring that the most capable trainees are selected for jobs. Currently, subjective assessments of supervisors or managers are typically used to make these determinations. While these are valuable methods for assessing drivers, an objective measure of how well the driver is using his/her visual attention would both assist evaluators in making judgments, as well as make those judgments more accurate. The purpose of the study described herein was to 1) conduct a task analysis of the driving component of the PDD job responsibilities, and 2) create and test an objective measure that a package delivery company could use to evaluate the performance of its drivers.

A detailed task analysis based on numerous observations of drivers in their normal work routines was conducted for this research in order to understand these complex tasks. A framework was created for understanding this system of tasks, which was then used to organize all tasks that drivers were observed to perform into more general, goal-oriented activities. Using this task analysis, incidents were identified that were observed while drivers were behind the wheel. This information demonstrated that breakdowns were occurring within the tasks drivers were performing and that improved methods of training and evaluations may be needed as a result.

A construct of visual behavior called Head Down Time (HTD) was then created and tested. An individual HDT is defined as the sum of time of all eye gazes away from the primary display (i.e. windshield) between two distinct eye gazes at the primary display while the vehicle is in motion. HDT was evaluated for its ability to differentiate levels of experience between drivers, its relationship to types of route on which drivers delivered, and its relationship to the driving-related incidents that were observed. HDTs were shown to be differed significantly between drivers of low and high experience, with experienced drivers displaying shorter durations of HDT when compared to inexperienced drivers. HDTs also differed in duration when analyzed by the type of route upon which drivers operated. Commercial and urban routes, while not significantly different with respect to HDT, were shown to have increased HDT durations when compared to rural routes and, in turn, residential routes were found to have significantly longer HDTs than did rural routes and may have significantly shorter durations compared to commercial and urban. Finally, HDTs that were associated with observed driving incidents in terms of chronological proximity were shown to be of significantly longer duration than were HDTs that were not associated with incidents. All tests were conducted using appropriate statistical measures, including t-tests at a level of $\alpha = 0.05$ for each dataset.

Applications of this research include: 1) improvement of PDD training and evaluation methods through use of a detailed task analysis, 2) improvement in how package delivery companies define incidents and train PDD toward the prevention of incidents based on task analysis and observations as to incident frequency, and 3) the further development of HDT as a possible objective measure to supplement the training and evaluation of PDD.

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INTRODUCTION

The job of a package delivery driver (PDD) is complex and demanding. As the companies that provide package delivery services continue to grow with the aid of improved technology and efficiency, so too does the number of drivers that companies need to employ to provide their services. These drivers must possess many skills in order to succeed in their work, including physical stamina, appropriate decision-making, positive customer interaction, and most importantly, operational safety. In an era in which both package delivery companies and the people and businesses that they serve are expanding rapidly, new PDDs face challenges that present a unique set of problems. New drivers must have good memories, and must also be quick to learn new environments. They must be excellent planners, but also flexible to changes. Most importantly, they must be able to multi-task with their visual attention efficiently while performing their responsibilities safely.

Visual attention is defined as the process by which one item, the *target*, is selected for analysis from among several competing items, the *distracters* (American Psychological Association, 2007). Companies must use significant resources, not only to provide insurance for existing drivers, but also to train new drivers to use their visual attention effectively while driving, and companies have a vested interest in ensuring that the most capable trainees are selected for jobs. Currently, subjective assessments on the part of supervisors or managers are used to make these determinations. While these are valuable methods for assessing drivers, an objective measure of how well the driver is using his/her visual attention would both assist evaluators in making judgments, would make those judgments more accurate, and would provide a means with which to standardize PDD selection.

BACKGROUND

Task Analysis

Task analysis is an important tool for understanding a complex system. Task analysis is defined as a method for producing an ordered list of all the things people will do in a system, with details on information requirements, decisions, times, actions, and environmental conditions (Chapanis, 1996). For PDDs, it would be easy to state that they simply have the tasks of pressing pedals and turning steering wheels, but these are neither accurate nor are they comprehensive. A task analysis must also include any additional activities that could be performed over and above the primary task (Wickens, Lee, Liu, & Becker, 2004). These additional activities may well be a key focus, as PDDs often must perform numerous secondary tasks in order to successfully complete their responsibilities.

Task analysis has already been applied successfully to drivers in past research. Barbera, Horst, Schlenoff, & Aha (2004) used a task analysis approach known as the Real-time Control System to study the driver-vehicle system. This study was very thorough, including not only all physical tasks the driver-vehicle must undertake but also the knowledge base required by the driver to perform tasks. For example, the authors identified the action of passing another vehicle as including not only the tasks required to maneuver the car into another lane and back, but also the knowledge of environmental conditions which make it legal and/or safe to pass. When considering professional drivers, this idea can be broken down even further. What tasks must a driver perform in order to attain the necessary knowledge of environmental conditions? The answer to this question is a very important factor that must be accounted for in the task analysis.

Technically speaking, for a PDD to bring the vehicle to a stop, the hands must be used to maintain the bearing of the vehicle and the foot must apply pressure to the brake pedal. However, these are the operations from the machine's perspective. From the driver's perspective, the reason for the stop must be attended (e.g., the delivery site), the appropriate location to stop must be decided upon (e.g., curbside), the speed and distance of cars in front must be judged (e.g., judging when to switch lanes), pedestrians and other vehicles may need to be visually attended (e.g., is turning vehicle yielding, is a pedestrian on a corner intending to cross or wait), and many other factors. This dictates that an approach that centers on <u>all</u> functions of the driver must be used in order to fully capture the required PDD tasks.

The solution to this need is a Cognitive Task Analysis (CTA), which includes both physical and mental operations one must undertake in order to complete his/her job. CTA can be described as a task analysis which accounts for the mental *processes* and *skills* which are required to perform a task at high proficiency levels, and the changes that occur as skill develops (Ward, Hancock, Ganey, & Szalma, 2003). CTA is considered a valuable tool when analyzing tasks that occur in a complex and dynamic environment where uncertainty is present (O'Hare, Wiggins, Williams, & Wong, 1998). In addition to considering all processes, the possibility of *sequential order of tasks* must be accounted for. Is it appropriate to press the brake before visually determining the appropriate place to stop? Should a pedestrian be visually attended before attending to the vehicle in front of the operator? The answer to these and almost any other combination of actions is that it depends upon the situation. Driving, therefore, is best analyzed using a hierarchical task analysis (HTA), and not a sequential one. This approach was outlined by Ward et *al* (2003) in which the authors identified driving as a common situation wherein drivers may experience cognitive overload from the many information and control systems that must be attended. The authors also identify CTA as essential for research involving driver performance that captures realistic driver behaviors and actions. Clearly, both the driving and the additional tasks required of a PDD demand an operator-focused approach to the task analysis.

While HTA has traditionally not been associated with CTA, recent work has suggested that CTA can be used to enrich HTA with information that an observer may not consider (Shepherd, 1998). For example, by looking closely at a situation in which different actions may be taken by a user, an internal (mental) choice can be inferred as having occurred. These choices can then be further broken down into cognitive skills which may be required for the user to make the choice. CTA may also be used to represent actions in the context of a goal. This allows researchers to work backwards from the goals of the user to the tasks the user is performing, which may reveal tasks as too narrowly defined or too specific to certain users.

Finally, task analysis methods, which were used in previous research involving professional drivers and which were successful in identifying an accurate and comprehensive list of tasks of drivers, has promise for evaluating PDDs. Robinson, Casali, & Lee (1997), citing the work of Drury, Paramore, Van Cott, Grey, & Corlett (1987), used a four-phase approach toward developing a complete and detailed task list of those tasks which are critical to hearing for commercial truck drivers. These phases included: 1) System description and analysis, 2) Task description task list, 3) Descriptive data collection, and 4) Applications Analysis.

Driver Distractions

Once the tasks of PDDs are identified through task analysis, focus can then be on how these tasks break down in the driving environment. One common source of breakdowns while driving results from distractions. As mentioned previously, not only is there a high number of accidents that have resulted from the inattention of the driver, but also the number of occurrences is important. A study by Stutts, Feaganes, Reinfurt, Rodgman, Hamlett, Gish, & Staplin (2005) used naturalistic observations of drivers to record the frequencies of various distractions. The study found that not only distractions such as eating, conversing, or reading were very common, but also that high percentages of events, such as having no hands on the wheel and eyes directed away (from the primary view) were associated with these distractions, and that drivers made little to no effort in performing these actions while the vehicle was not moving. All told, drivers spent 14.5% of their total time while the vehicle was in motion on an activity considered as a distraction. For PDDs, the sources of distraction and possible consequences are even more numerous. The participants observed in the above study were commuting to and from work. Unlike commuters, PDDs not only must attend to addresses, timing issues, and make frequent stops while driving, but may possibly do so while operating on unfamiliar roads. This issue must be addressed in order to ensure that the PDDs on the road are capable of handling their job responsibilities safely.

Distractions in driving are, in fact, a very important topic in recent driving research. One example that has received significant attention in recent years is the use of cell phones while driving. Many local authorities have enacted laws restricting cell phone use while driving, the most common of which prevent the use of hand-held cellular phones. The response has been that researchers are now studying the effects of cellular phone use and why it could be a distraction. One such study (Strayer & Johnston, 2001) looked at the issue in two experiments. The first experiment had participants perform a simulated tracking task while either talking on a cell phone (either hands-free or hand-held) or listening to a radio broadcast of their choosing. Participants were randomly given green and red signals while performing the task, and were instructed to depress a brake button when a red signal appeared. The results showed that the effects of cell phone use were comparable between the single tracking task and the dual tracking task while listening to a radio, and that the dual task of talking on a cell phone significantly increased the reaction time and the probability of missing a signal.

Based on these results, the authors designed a second experiment to test two different kinds of cell phone use. One involved "shadowing," in which the participants repeated what was heard on the other end of the cell phone. The other was "generation," in which participants generated their own responses. Participants also performed the tracking test on an easy and a difficult course. The results showed that the participants performing generation tasks had a significant increase in tracking error, particularly in the difficult course. This study is important for two reasons. First, it demonstrated that word generation was the most likely source of distraction in cell phone use while driving, and second, it showed there may be a positive interaction between this distraction and the difficulty of the primary task. In relation to PDDs, it is true that one particular task they may perform is talking on a cell phone, but the more general effect of generating words and its connection to distraction is of more concern. The results from Strayer & Johnson (2001) imply that it may be the <u>use</u> of information rather than just the “in-flow” of information to the brain which causes distraction. Many tasks performed by a PDD involve storing and using new information, such as memorizing an address or generating a mental itinerary of the next few stops, and further inspection of the literature may reveal methods to utilize these factors in evaluation.

A second study (Strayer, Drews, & Johnston, 2003) to follow up on the results found in the one described above set out to again examine the effects of cell phone use, but this time with participants performing actual driving tasks on a simulator. The first experiment examined a braking task on low and high density roads, with and without the participant talking on a cell phone, and with the participant driving in a simulator. In the low-density condition, the dual task resulted in a longer time to brake onset, and in the high-density condition, the dual task led to both slower time to brake onset and several participant accidents in the simulation. The second and third experiments examined the visual attention and memory of participants while using a driving simulator. The participants were asked to recall billboards that were displayed in the simulation, with participants’ eye movements being recorded for fixations. These experiments again had conditions both with and without a cell phone being used. The results showed that participants were less likely to recall a visual stimulus when using a cell phone, and that even when participants looked directly at visual stimuli, they were less likely to create an explicit memory that they could recall later.

These results have strong implications for PDDs. These operators drive large vehicles that are heavy, making the anticipation timing of braking extremely important. They are also required to visually attend to anything around the vehicle that could cause a problem, and the studies above suggest that a secondary task may disrupt the ability of the driver to adequately process visual information. These results could have two different implications. First, the presence of a secondary task (e.g. scanning street addresses) may disrupt other visual tasks, such as checking mirrors. If we consider checking mirrors to be analogous to the billboards discussed above, this secondary task may disrupt drivers' ability to recall the information in the mirror when they need to use it to make a driving decision. Second, using the mirror example again, a secondary task may cause the driver to check a mirror more often and/or for longer durations of time. Such activity could result in serious safety and performance considerations as the driver's vision and attention are directed away from the forward view (i.e., the driving task).

Another study has attempted to integrate findings such as the ones above into existing theories about cognitive ergonomics. Levy, Pashler, & Boer (2006) studied whether or not the issues of performance breakdowns in driving, resulting from secondary tasks, could be described in terms of the Central Bottleneck theory and Psychological Refractory Periods. Central Bottleneck theory, or Single Channel Theory as it is also called, states that the mind has a single channel for processing incoming stimuli, and that when the mind is processing one particular stimulus, it "captures" this channel, and all other stimuli must wait in order to be processed (Wickens & Hollands, 2000). In the experiment, participants drove a simulator and performed two tasks: a braking task and a choice task. The choice task involved a visual or auditory stimulus which occurred once or twice with a 100ms break. Participants were instructed to make a choice by verbally reporting the number of stimuli or by pressing a button in response to the number of stimuli. The results were analyzed for reaction time in both cases, and correctness in the choice cases. For the choice tasks, there was no significant difference between single-task and dual-task scenarios in terms of correctness or response time. For the braking tasks, however, the dual-task scenario resulted in significantly slower reaction times. The authors attribute this to *stimulus onset asynchrony*, which states that when central processing is underway for one task, the processing for another task must be postponed. For a delivery driver, this poses a critical problem. Based upon the average delay of 174ms in braking during a dual-task, the authors claim that this would translate into 16ft of braking distance for a vehicle traveling at 65mph. Calculations such as these are a practical means of which researchers can show how distractions can translate to real-world conditions.

Aviation research by Lancaster and Casali (2008) with pilots in a flight simulator used similar calculations to project the practical implications of operators having their attention drawn from the "out the windscreen" view. This research found that pilots had their attention focused away from the outside for an average of 13.49 seconds while using a particular text-based communication device. Using an example of a common small aircraft traveling at 110 knots and the simple formula (Distance = Rate x Time), the researchers calculated that during this 13.49 second period of distraction the plane traveled 0.47 miles, a time and distance which could have been used to (for example) avoid a potential air-to-air conflict .

Clearly, in all domains in which operators control moving vehicles, there lies a potential for unfortunate (even dangerous) consequences associated with the amount of time that the operator is not attending to the forward view. In addition, studies have suggested that secondary tasks need not be complex to result in stimulus onset asynchrony. The relatively simple task of reporting one or two stimuli while braking resulted in a significant effect. Finally, the lack of a significant effect in the choice response times while braking, in contrast to the significantly slowed response times in the dual-task of braking while choosing, suggests that only the primary task may be delayed. This suggests the possibility that real world observations of secondary tasks may be able to be simplified such that evaluation tools can focus on the consequences to the primary task.

While cellular phones and binary choices are practical examples of the secondary tasks that may affect PDDs, they represent a small portion of the secondary tasks that could actually be performed. Another study that examined the effects of distractions while driving through an analysis of secondary task performance was conducted by Lansdown (2002). In this study, a driving simulator was used and participants were divided into *novices* and *experts*. Participants were given low, medium, and high complexity tasks to complete, involving manipulation of a radio while driving. Participants were also instructed to make verbal reports on events while they drove. Finally, participants eye behaviors were recorded for foveal glances during the experiments. Results indicated that novice drivers had more lane deviations than did expert drivers. The study also found that novices glanced more often and for longer durations at the interface that they were told to manipulate as secondary tasks. Additionally, expert drivers made more verbal reports, almost twice as much on average, than did novice drivers. These results provide additional, valuable insight into how the many secondary tasks of PDDs may affect operational performance. First, errors in the primary task occurred more frequently in the form of lane deviations for the novice drivers. This suggests that monitoring errors in the primary task when secondary tasks are present may be useful for evaluating the performance of PDDs. Second, recordings of eye movement were demonstrated to be successful in differentiating novice from expert drivers, based on glance frequency and durations. Since these methods were used to differentiate the experience of drivers, it may also be useful in evaluating the performance of drivers in a way that can be generalized to more than just the period of time that they are observed (i.e., their general driving habits and abilities).

Occlusion

As stated previously, it may be possible to generalize secondary tasks in order to simplify the process of observing. One way in which secondary tasks may be simplified is the idea of *occlusion*. Occlusion, in general, is simply defined as an obstruction or blockage (American Psychological Association, 2004). Occlusion in terms of driving research refers to the blocking or removal of visual inputs for a period of time. Occlusion has been used for several decades in driving research, and is still in use today. One of the first empirical studies on this topic (Senders, Kristofferson, Levison, Dietrich, & Ward, 1967) used occlusion to evaluate the mental resources required to operate a vehicle. The basic principles behind occlusion in driving research that were used almost 40 years ago are still in use today in many research domains. The basis for their use is that, when driving in normal conditions, the operator does not focus his/her attention on the main task of maintaining the proper speed and bearing 100% of the time. This suggests that driving does not require <u>all available</u> resources of the operator. A driver may perform necessary secondary tasks such as reading a highway sign, checking gauges, or checking mirrors, all of which are important, but which also distract the driver's attention away from the forward view of the vehicle. A driver may also perform unnecessary tasks, such as adjusting a radio, adjusting air conditioning, or other tasks which also remove the driver's attention from the forward view. However, these tasks often have a minimal effect on the driver's main task of keeping the car driving in the correct direction and at the proper speed.

The aim of this study by Senders et *al* (1967) was to determine exactly how much time a driver could remove visual attention away from the forward view while still performing the driving task correctly. This study was unique (and in many ways still is today) in that it involved testing drivers behind the wheel on two separate actual roads: a highway, and a closed-circuit racetrack. Two methods were used for experimentation on each road. First, the drivers' vision was occluded at a fixed frequency and duration, and the drivers were asked to maintain their maximum possible speed. In the second, speed was fixed and drivers were given control of the occlusion, being asked to occlude vision for as long as possible at a particular speed, while maintaining control. The results of the study indicated that longer durations of occlusion resulted in slower speeds for drivers to maintain control, and likewise, at faster speeds, drivers occluded themselves for shorter durations to maintain control. The study also indicated a significant difference between roadway types with respect to vehicle speeds and occlusion durations. The long, straight highway experiments resulted in faster speeds when participants were subjected to fixed occlusions and resulted in longer occlusions when participants were subjected to faster speeds than did experiments on the racetrack. This has two major implications for PDDs. First, there are many different routes on which PDDs operate. Some are more complex than others, and as suggested by Senders et *al,* this may have an effect on the mental resources of the driver. Secondly, with the emphasis that package delivery companies place on safety, their drivers are trained to attend visually to all possible hazards while driving a vehicle, in addition to attending to job requirements such as checking a house number. Therefore, in general, the job of package delivery driving requires attentional resources to be shifted away from the forward view, making the occlusion paradigm an excellent starting point for evaluating driving techniques.

While the study by Senders et *al* (1967) demonstrated the usefulness of occlusion techniques, its results reflect the uncertainty preferences of the driver, instead of objective evaluations that can realistically be applied and used on the road. While previous work utilizing occlusion towards performance measurement is scarce, it has been used to this end successfully. A study by Godthelp, Milgram, & Blaauw (1984) used occlusion methods while driving to measure what was called Time-to-Line-Crossing (TLC). The idea of TLC is that by taking measurements of the car's instantaneous position, bearing angle, and steering wheel position, it can be predicted when the car will pass one of the two lane markings on the road if the values remain constant. In this study, TLC values were obtained during trials in which occlusion was introduced to drivers. The purpose of these experiments was to validate TLC as a performance measurement tool which could describe driving strategy. While TLC was effectively evaluated with occlusion by the authors, this study using PDD would aim to create and validate an *evaluation* tool that would be of use to package delivery companies, and not a *predictive* tool which would be of limited operational use. It would be difficult at best to convince a PDD that his/her actions are inappropriate based upon where the vehicle would be in a certain number of seconds if the driver did not make adjustments. More importantly however, is that the occlusion paradigm successfully evaluated a method for driving assessment, and should result in similar success using PDD.

Occlusion techniques may also provide some insight into *why* the secondary tasks of PDD could be problematic. A study by Noy, Lemoine, Klachan, & Burns (2004) used occlusion techniques to examine driver performance from the perspective of *task interruptibility*. Task interruptibility, as it relates to driving distractions, says that the more easily a task may be interrupted, the less distracting it is to drivers, because it allows drivers greater control over the task sharing conditions (Noy et *al*, 2004). The participants in the study drove vehicles in a simulator while performing secondary tasks in both occluded and unoccluded conditions. The tasks involved radio tuning and simulated visual searches. Through analysis of driving performance, the study found that participants had a decrease in lane-keeping performance when any of the three secondary tasks were introduced. Through analysis of subjective workload, the study found that the visual tasks, particularly the scrolling visual tasks, were more frustrating, required more effort, and had a large effect on mental demand. The authors believe that this shows the low interruptability of visual tasks and explains why many visual tasks are particularly distracting to drivers. For PDDs, this paints a dangerous picture. With so many of their inputs being visual in nature, the need for methods to evaluate the ability of drivers to safely perform many visual tasks is even greater.

A Proposed Objective Measure for the Research

Based upon the literature presented above, it is believed that an effective evaluation tool can be based on the premises of occlusion. First, a method of objective observation for such a tool must be established. Critical incident technique (Flanagan, 1954) provides an outline for such a method of observation. Critical incidents, according to the author, are observable human activities in which the purpose and consequence of actions is clear. The author also states that for such observations to be acceptable as objective and unbiased, two conditions must be adhered to when using the technique.

The first condition is the establishment of a standardized system of classification, one in which the need for inferences and interpretations by the observer is minimized. In the case of PDDs, traffic laws provide an objective starting point for such classification. In addition, drivers are subject to numerous additional rules imposed by their employers, such as completely stopping before crossing railroad tracks and backing into all perpendicular parking spaces, who have an interest in minimizing accidents and actions which may cause them. Modern technology also assists in the creation of such a classification system. The ability of researchers to easily record participants in an unobtrusive manner allows observation of incidents that restrictions (such as riding passenger in a delivery vehicle) would not allow, and also allows observers to put increased emphasis on context, which helps ensure the ability to infer the intent of the participant, while the cameras capture visual cues. The classification system for "driver critical incidents" could incorporate all of the above in such a way that incidents are clearly defined from one another, and are easily recognizable. Recordings also allow researchers to review their observations for completeness and accuracy under the same classification system. The second condition is that results are studied in the context of established principles of human behavior. Research results in the subjects of task analysis, distraction, and visual occlusion have been established for a significant period of time, and new research in the areas of distraction and visual occlusion will provide a basis for techniques described below for analyzing observations.

Another important point to discuss in establishing an objective measure for PDD evaluation is differentiating between distraction and occlusion. In the occlusion situations presented here, the driver has had his/her visual inputs completely cut off, but mentally they are not presented with other tasks to process. Under occlusion, the driver is theoretically still paying attention to the road, or more accurately what is remembered of it, even though he/she is unable to see it. In the distraction situations presented above, the driver not only had his/her vision occluded (the foveal vision away from the forward path of the vehicle), but is, additionally, visually attending to another task. As mentioned previously, it would be beneficial for an evaluation tool to simplify secondary tasks and focus on the consequences of primary task interruption. A reasonable way to do this would be to take a conservative approach and model both distractions and occlusions as occlusions alone. In equal situations, these conditions can only degrade performance more, and perhaps unsafely so, if a driver has a second task to mentally attend to in addition to having his/her vision occluded. Therefore, a reasonable approach would be to evaluate drivers based upon their eye movements; more specifically, whether their foveal vision is on the road ahead or is in another location, and to treat all instances wherein the driver is looking away from the primary out-the-window scene as occlusions, even if the driver is actually distracted. Through this methodology, a conservative estimate of driver visual patterns that can lead to problems can be established. It is suggested to refer these periods (modeled as occlusions) as “Head Down Time,” since they are only “modeled” as occlusions and it would be misleading to call them as such. In short, if an analysis shows that a particular period modeled as occlusion results in significant driver incidents, the inclusion of distraction in addition to occlusion would likely result in equal or worse results. In this manner, a simple tool could be created that measures durations and frequencies of occlusions in drivers which can then be compared to validated standards of what driving behaviors lead to problems and unsafe conditions.

Another area to consider is the existence of a working definition of HDT based upon the results of previous studies using occlusion. Senders et *al* studied occlusion periods of 1.5s, 2.0s, 2.5s, 3.0s, 4.0s, 6.0s, 7.5s, and 9.0s (1967). The more complete data set of the two testing speeds that were published showed performance decreases across all intervals, with the largest decrease occurring between 2.5s and 3.0s. This, however, is not enough to make any strong conclusions.

Another study that used occlusion through a different means may provide a better estimate. Hildreth, Beusmans, Boer, & Royden (2000) used a driving simulator and occlusion techniques to test drivers in making corrective maneuvers while occluded. The experimenters used a constant occlusion period of 1.5s in the first three experiments, and for the fourth set up trials with three durations of occlusion, 1.0s, 2.0s, and 4.0s, in order to test its effects separately. The results showed that while there were individual differences among drivers, there was little difference between the 1.0s and 2.0s durations.

The 4.0s duration, however, showed a significant decrease in performance. Only two of the six drivers tested were able to maintain a sinusoidal pattern of steering correction during the 4.0s occlusion and, in general, there was more variability during occlusion periods than in the 1.0s and 2.0s trials. Because decreases in performance are expected with increases in occlusion time, it may be better to look at the variability of results as an indicator of when an occlusion goes beyond the natural durations of inattention while driving and then does have an effect. In the experiment above, standard deviations were calculated for both *steering angle* and *lateral position* during the maneuvers. As deviations increased, there was an indication of poorer lane-keeping ability. Variability in steering angle was higher with occlusion introduced, and increased with occlusion duration increases up to 2s, after which it leveled off. Variability in lateral position increased when occlusion was introduced, with huge increases after long periods due to the early variability in steering wheel angle. Based on these measurements, the authors concluded that after approximately 1.5s of occlusion, the participants as a whole were unable to successfully complete the task due to their increase in response variability. Based on the measurements of Senders et *al* (1967), differences were noted with occlusions as short at 1.5s. Based on the work of Hildreth et *al* (2000), significant effects were noticed after only 2.0s, with the variability increasing even earlier and the authors concluding that 1.5s was the approximate limit for participants in general. These previous studies provide valuable information with which to compare the results of this research toward face validity.

A final point of discussion regarding occlusion is that there are still questions about its effectiveness. While researchers have attempted to use occlusion to evaluate secondary tasks while driving, such as the study by Baumann, Keinath, Krems, & Bengler (2004) which attempted to evaluate in-vehicle navigation devices, there are those who question this approach. Occlusion techniques have been shown to be empirically robust with respect to primary task evaluation (Lansdown, Burns, & Parkes, 2004), but its use for evaluating secondary tasks usually results in disruptions. These results suggest that research using PDDs should be in line with this assessment, and should only evaluate the primary task of operating the vehicle. Observations of any secondary task errors (i.e., a PDD checks a rear view mirror before changing lanes but cannot correctly assess the speed and distance of the car the in other lane) should thus not be considered for analysis and should be equally treated to a similar situation which does not involve the error. Both cases should be treated as an occlusion, with the problem being factored into the analysis in terms of extra time associated with the error, and not the error itself. While it would be ideal to have drivers who do not commit errors, this is unreasonable to expect and it is beneficial for the analysis to include some way for drivers who deal with mistakes better than others to be differentiated.

RESEARCH NEEDS AND OBJECTIVES

This research is a part of a larger project for a package delivery company to improve the safety of work and quality of performance of PDDs. This research addresses a need of the company, which is to have objective measures and data that can be used to accurately and precisely evaluate PDDs (particularly trainees) based on their driving performance. This research addresses the need in two steps. First, a detailed task analysis that is specific to the tasks relating to operating a delivery vehicle has been performed. This task analysis began with the cooperating company's documentation of driver responsibilities and was supplemented by observational data, questionnaire data, and interview data from PDDs. Second, a method for collecting objective, observational data was designed, and was tested with current PDDs performing their jobs in company vehicles. Based on the literature review above, a tool and methodology that could observe drivers for distractions and eye glances would provide objective data that can enable evaluators to evaluate the skill of PDDs beyond their ability to perform correctly under ideal conditions, and would be able to correctly identify poor patterns of behavior without necessarily observing negative consequences. This methodology involved videotaping PDDs' eye movements, with their knowledge, while they operated their vehicles during the course of a normal workday. The data have been analyzed for incidents of HDT which, as a composite measure of distractions and occlusion, has been well-established in previous research as reducing the operator's capabilities in performing driving tasks.

The objectives of this research were: 1) to identify a method of collecting objective data based on driving performance, and 2) to identify a method to evaluate the data for statistically meaningful relationships between HDT and errors of commission or omission while performing tasks identified within the task analysis. These findings could be applied to not only the evaluation of PDD trainees, but also to the training of new and experienced PDDs. The research may benefit the supervisors who train and evaluate new PDDs, as they would have an objective tool to supplement their evaluations, and data that can supplement their training efforts. The research may benefit package delivery companies, because the driving tasks are some of the most important and most frequently performed activities of PDDs, and objective measures can help to determine which driver applicants can and cannot perform them well in a fair and unbiased manner, as well as which experienced drivers are meeting expectations.

HYPOTHESES AND ANALYSES

As stated before, the objective of the study was to develop and test an objective measure of driving performance for delivery drivers. Based upon the research literature, the following hypotheses were proposed regarding relationships among participants, environments, HDT, and driver incidents.

H1: Experienced PDDs have significantly fewer incidents and shorter duration of HDTs when compared to inexperienced PDDs.

H2: PDDs that are experienced on a particular route have significantly fewer incidents and shorter duration of HDTs than PDDs that are inexperienced on a particular route.

H3: Different kinds of routes show significant differences in the number of incidents and the duration of HDTs. These differences are as yet unknown but are believed to exist.

H4: HDTs associated with observed driving incidents will show significant differences in their durations when compared to HDTs that are not associated with observed driving incidents.

In addition to the hypotheses above, there were two hypotheses for which the capabilities to address in this study were uncertain:

H5: Weather conditions will have a significant impact on the number of incidents, number of HDTs, and duration of HDTs.

H6: Data from various telemetrics-outfitted delivery vehicles show significant relationships between specific driver behaviors and the number and durations of HDTs.

T-tests were conducted to ascertain any relationships between the stratifications above within the data observed. These tests were conducted at a level of $\alpha = 0.05$ for each *dataset*. Where multiple t-tests were performed on a given dataset (i.e. to test each of the different stratifications), a Bonferroni correction was applied in order to achieve a total $\alpha = 0.05$ across all independent tests on the dataset. These t-tests were conducted with the null hypothesis in each case that there was no difference between the driver stratifications. Hypotheses were supported or rejected based upon the probabilities calculated in the t-tests that the data observed in this research would be achieved if the null hypothesis were true.

METHODOLOGY

This research consisted of a task analysis of PDD actions while driving and experimentation to address the following goals:

1) Collect objective data on PDD actions and behaviors during delivery vehicle operation;
2) Determine if any relationships exist between Head Down Time and stratifications of PDD in terms of experience and route types
3) Determine if any relationships exist between Head Down Time and errors of commission or omission in the tasks

Participants

There were a total of 34 male PDDs who participated in this research effort. Each driver participated in at least one of the following elements of the study: non-videotaped observations (pilot study), focus group interviews (pilot study), or videotaped observations. Several drivers participated in more than one of the elements above. All participants had a valid driver's license and were employed as a full time or a part-time driver for the cooperating package delivery company at the time of the study. The potential participants were selected by the company assisting the research effort; however, participation was completely voluntary for all drivers. All participants who volunteered were informed that they could refuse participation or discontinue participation at any time during the study without penalty and signed a consent form (Appendix A) before participating in the study. Participants who were observed with or without cameras were accompanied by the researcher for the entire duration of the day (i.e. until all packages had been delivered), while focus groups were conducted prior to the start of work for participants.

Experimental Apparatus

Delivery Truck

Observations were collected on delivery trucks currently in use with the cooperation of a package delivery company. The trucks used were the ones normally driven by participating employees. The trucks varied in size, but all utilized a 4-cylinder engine and usually received daily maintenance for any possible mechanical problems. Any experimental equipment for observation (see below) was installed in the truck cab prior to the participating driver beginning work and was removed immediately after completion of the day's observation to avoid conflicts with the participant's and company's use of the truck outside of the observation. The in-cab instrumentation was selected and configured for ease and efficiency of mounting/dismounting.

Cameras

The cameras used in this study were "bullet cameras" designed to be small, unobtrusive, and mountable in a variety of locations and positions. The cameras chosen were model APC-6CB3N01D by Apec (Figure 1). These were color cameras that are 1/3" in diameter, 5.5" in length, scan at a resolution of 512x492 pixels, and sample at a rate of 30 frames per second. The cameras also feature a 0.01 Lux sensitivity to light, and automatically adjust to black and white for low light conditions. A total of four cameras were used in the study, each mounted in a specific location to capture information about the participant, the vehicle, or the vehicle's surroundings. The first camera (see Figure 2, top image) was located in front of the participant and was positioned so as to see the participant's face and upper body movements. The second camera (see Figure 2, top image) was located on the dashboard facing out the windshield, so as to capture what the participant could see in front of him/her. The third and fourth cameras (see Figure 2, bottom left and bottom right images) were mounted inside the cab, and facing each side rear-view mirror to allow rearward views on each side of the vehicle. This assisted in gathering data about the external environment to the sides and to the front of the vehicle, in addition to aiding the analysis of head and eye movements. The cameras were firmly attached to the vehicle with industrial strength Velcro™ in locations which did not interfere with the driver's job responsibilities.

Figure 1. Apec APC-6CB3N01D video cameras used to observe drivers.

Figure 2. Camera positions within the cab of the package delivery vehicle.

Digital Video Recorder

The data from the cameras were sent to a Digital Video Recorder (DVR) box which was also shock mounted within the vehicle in an unobtrusive location (Figure 2, top image). The DVR chosen for this study was Model ADR-411U by Apec (Figure 3). This DVR performed several functions with the data. First, the DVR received the input from all four of the cameras, each camera recording at 30 frames per second. The DVR then performed the function of a “quad splitter”, taking each of the four camera inputs and combining their signals into one composite picture. The DVR sampled all four signals at once at 30 frames per second. Finally, the DVR performed the function of recording the data onto an Integrated Drive Electronics (IDE) hard drive that was placed within the DVR. A 250 gigabyte Seagate IDE hard drive was purchased and mounted for this task. Finally, after the recording of a participant was finished, a Universal Serial Bus (USB) port on the DVR was used to extract the data on to a computer for subsequent reduction and analysis. The DVR was shock mounted with foam to prevent hard drive issues and secured in place with industrial-strength Velcro.

Figure 3. DVR which records video camera inputs.

Battery

In order to power the electrical equipment used for observational purposes, a sealed, portable battery was used. A Sears Marine Battery (Figure 4) was outfitted for this task. These batteries are designed for continuous low-level usage, and are deep-cycle so that power can be drained and recharged without damage. A custom bus was designed and built so that components could simply plug in to receive the correct power.

Figure 4. Marine battery used to power in-vehicle surveillance equipment.

Video Editing Software

Video editing software was used to view, reduce, interpret, and analyze observational data collected with the video cameras. The software used for this was VirtualDub, a freeware video editing tool for the PC. This software was not as powerful as other popular professional video editing suites, but handled all research needs of compressing video, editing video, and stepping through video frame by frame for eye movement analysis. The software was run on a personal computer and a Samsung SyncMaster 205BW LCD computer monitor was used to display the video.

<u>Procedure</u>

Documentation Review

The company cooperating with the research provided copious documentation for review. These documents included PDD training methods and requirements, safety methods and requirements, standard operating procedures, and evaluation procedures. These documents were read and studied in order to understand what the company requires of the drivers while behind the wheel of the package car, both from a driving and from a job-related task standpoint. This information was used to generate an initial checklist of possible incidents that could occur while a PDD is behind the wheel (Appendix B). This checklist included both driving and non-driving related incidents.

Pilot Study 1 – In-Vehicle Observations (No video)

In order to build upon and revise the initial checklist, observational rides were scheduled with 10 PDD. Each of these observations took place over the course of the entire work day of the driver, and involved a researcher with the incident checklist (Appendix B) riding as a passenger and taking notes. In following the definition set forth previously, these were all observable activities in which the purpose and consequence were clear to an observer (Flanagan, 1954). However, these particular incidents were all “negative” in the context of safe and effective driving performance. All of the participating drivers did so on a voluntary basis, and all drivers signed informed consent forms (Appendix A) prior to participating. The checklist used by the researcher during this pilot study evolved with each new observation, as the researcher added, clarified, and removed items from the list. Some items were found to be redundant (e.g., *driving through an intersection with a yellow light* and *driving through an intersection with a red light* were separate incidents but actually addressed the same issue – the PDD incorrectly judging the stop point of the intersection), some needed additional clarification (e.g., *eye gaze while driving* was separated into incidents for specific places the PDD's eyes could gaze), and some were added as the researchers gained valuable information from their observations (e.g., *4-way flashers not used where appropriate* was not included in the original checklist because it was believed they were used when the vehicle was not in motion, but were added after PDDs were observed using them in a variety of situations. One of the purposes of these pilot study rides was to correct any issues that manifested before video data was collected. In addition to collecting checklist data, the researcher would ask questions while the PDD was out of the vehicle (i.e. not driving). The questions related to driving and job tasks that the researcher observed, such as the driver visibly planning his/her route while driving, what the driver thought of a particular situation he/she had just navigated, or other questions which could assist in further developing the task analysis and incident list. The checklist data from these observations were not used in any statistical analysis because the list was iterated with each observation and there were no objective data with which to confirm the incidents. The checklist was used, however, to enrich the initial framework of the task analysis toward finalizing it for use in future data collection. The researcher also subjectively observed enough incidents using the checklists to merit studying them further with objective observational data. Being professional drivers, at this point it was unclear if there would be too few incidents to observe on a daily basis with which to conduct an analysis.

Pilot Study 2 – Focus Group Interviews

Based on the information gathered in the documentation review and the initial in-vehicle observations, focus group interviews were conducted in order to glean additional insight into the decision making processes of PDDs and any known or unknown habits that they might have regarding priority of tasks. These interviews were a qualitative method for the researchers to identify important issues. There were two interviews sessions conducted, one consisting of 4 and the other consisting of 5 PDDs and each taking place in a meeting room provided by the company prior to the start of work that day. Also, drivers who volunteered were presented with an informed consent form prior to participation (Appendix C), and were reminded verbally that they were free to leave answers blank on the survey, not participate in the discussion, or leave the group at any time. One of the two groups agreed unanimously to allow the researcher to record the verbal discussion onto tape.

Videotaped In-vehicle Observations

With a finalized, comprehensive incident checklist, the researcher scheduled another series of in-vehicle observations with PDD. A total of 11 observations were scheduled for this purpose. As in all other phases of this research, participation was voluntary on the part of drivers, and all drivers were given and signed informed consent forms (Appendix A) prior to participating. Drivers were also verbally notified that if they ever felt uncomfortable with the observations, they could opt out at any time without penalty and all data particular to that PDD would be destroyed. One participant chose to opt out and the data for this participant was subsequently destroyed. These observations were similar to the pilot study observations, with a researcher riding as a passenger on the vehicle with the finalized incident checklist (Figure 5). Additionally, these observations included a closed circuit video capture system to provide objective data with which to supplement the researcher's incident checklist. The video data provided a means with which to review the researcher's observed incidents for confirmation at a later date, as well to identify and include in the analysis any incidents the researcher failed to record.

Incidents	Count														
Speeding															
Taking a turn too fast															
Hard decelleration															
Following too close to a vehicle															
Stop distance too close to a vehicle															
Failure to stop where appropriate															
Exceeding lane															
Exceeding intersection															
Improper clearance while changing lane															
Unnessesarily harsh adjustments															
Seat belt off while vehicle in motion															
Cargo door open while vehicle in motion															
Parking break not engaged at an appropriate stop															
4-way flashers not used where appropriate															
Turn signal not used where appropriate															
Horn not used where appropriate															
DIAD used while in motion															
Cell Phone used while in motion															
Other device or object used while in motion															
Package(s) left in cab while in motion															
Other Traffic Law Violation															
Missed turn															
Missed stop															
Stopped at incorrect address															
Fixation on Left Rear View															
Fixation on Right Rear View															
Fixation on Camera Monitor															
Fixation on Front View															
Fixation on Object in Front View															

Figure 5. Finalized Incident Checklist.

For this series of observations, the researcher arrived at the company facility approximately 90 minutes before the drivers were scheduled to leave. Upon arriving at the vehicle of the PDD scheduled to be observed, the researcher began by mounting the battery in the package section of the car on the floor with industrial strength Velcro. The researcher then mounted the DVR and power bus onto foam placed on the dashboard of the vehicle. These were then secured into place with industrial strength Velcro. The power connection of the bus was then routed along the corners of the vehicle and up to the ceiling with tape so as to be unobtrusive. The wire was then taken through a small gap in the wall separating the cab from the package section of the vehicle, taped into the corners to as to be unobtrusive, and connected to the battery. Next the four cameras were mounted inside the cab of the vehicle using the industrial strength Velcro. The power and signal wires for each camera were then connected to the bus and DVR, respectively. This completed the system functionally.

After the system was setup, a video cable was connected from the DVR to a monitor outside the vehicle in order to position the cameras correctly. The PDD being observed or a nearby supervisor would sit in the driver's seat while the researcher oriented the cameras appropriately. After the cameras were correctly positioned, the researcher routed all wires into corners and bundled all excess wire length into a space under the dashboard. Finally, the researcher checked to make sure all equipment was secure, extra tape and Velcro™ were placed in the back of the truck, all extra equipment was moved to a storage room at the facility, and the PDD was presented with the informed consent form. Due to scheduling constraints (observations were scheduled by the company the day before) and time constraints (installation and removal of the equipment required approximately 90 minutes, PDDs generally arrived 30-45 minutes before work began), the researcher could not present the PDD with the informed consent from before installing equipment in the vehicle. The PDD was assured upon arrival that no data would be collected, or any data already collected would be destroyed if at any time the PDD did not want to participate; however, they were informed that both the researcher and equipment would be present in-vehicle for the duration of the day. One PDD exercised this option and all data collected from this PDD was destroyed while the PDD was present. The researcher observed the driver until he/she was finished work at the end of the day are returned to the company's facility. At this point, the researcher thanked the drivers for their participation and proceeded to remove all video equipment from the truck, returning the truck to its original condition at the start of the day.

Data Reduction

Video Data Reduction

After all videotaped observations were completed, the data were compressed into Audio Video Interleave (AVI) format using the XviD codec, an open source video compression/decompression library. Utilizing the checklists and any other notes recorded by the researcher while in the vehicle, the researcher began to catalog all driving incidents within each video. To complete this, the video was played via VirtualDub, an open source video editing tool. This program allowed the researcher to step through the videos frame by frame where needed in order to carefully view each possible incident and record the exact frame where they occurred. The video was recorded at 30 frames per second, meaning incidents could be checked and re-checked very carefully and with high resolution, and their times were therefore recorded with precision. The researcher successfully reviewed all video data from all 11 observations where the PDD was behind the wheel and the package car was in motion, with the exception of late evenings when a lack of light created visibility issues. The incidents were recorded into a spreadsheet in a Microsoft Excel file.

In addition to the driving incidents, noteworthy events in the video were also entered into the respective spreadsheets for later reference if needed. These included unusual situations, such as a driver encountering a 5-way stop intersection, or a driver performing a task in a poor or in an exemplary fashion, such as negotiating a turn with an obstructed view where a pedestrian is walking around the bend. This was requested by the participating company for possible internal use and was not used for research purposes.

A second, separate analysis of the video was conducted toward testing the hypotheses relating to HDT. This analysis involved the researcher coding <u>all</u> eye gazes of the PDDs from video into an Excel spreadsheet. This coding recorded the frame at which each eye gaze began and ended, where the eye gaze was directed (e.g., forward, left, right), and the type of road where the gaze occurred (e.g., highway, 2-lane, parking lot). The analysis of each video began when the package car left the facility and ended when ambient outdoor light was low enough to cause the cameras to switch from color to black and white. Once the video cameras switched to black and white, clarity became an issue in distinguishing eye movements. While clarity was sufficient to continue when recording incidents, it was generally not sufficient for analyzing eye movements.

Again only periods where the driver was behind the wheel of the vehicle and the vehicle was in motion were coded.

Using this eye movement analysis, a program was written in order to extract all HDTs from the Excel spreadsheet. For this extraction, two operational definitions of head down were used. First, while the vehicle was moving forward, a head down was defined as the summation of a single or group of consecutive eye gazes away from the forward view. Second, while the vehicle was in reverse, a head down was defined as the summation of a single or group of eye gazes away from the left mirror, right mirror, or rear camera monitor. As an example, if the vehicle was moving forward while the PDD was looking forward, then the PDD looked left for 1 second and then looked in the left mirror for 2 seconds before returning to the forward view, it was recorded as a 3 second HDT. Because of clarity issues (such as glare from glasses) and time constraints, 6 of the videos were analyzed for eye movements out of the total 11. The elimination of these videos from HDT analysis are discussed within the statistical analysis of HDT section.

RESULTS AND DISCUSSION

As stated earlier, the task analysis was performed in four phases: 1) System description and analysis, 2) Task description task list, 3) Descriptive data collection, and 4) Applications Analysis. The results will be discussed in terms of these four steps. This will be followed by the results of hypothesis testing related to HDT.

System Description and Analysis

The system of interest for this task analysis was the package delivery vehicle and the PDD. It is limited in scope to what happens while the driver is operating the vehicle, and does not include activities outside the vehicle or while the vehicle is not in operation. From studying the documentation provided by the participating company, it was determined early in the research process that a sequential task analysis would be a poor framework for describing this system, as discussed previously. This was due to the many decisions PDDs must make throughout a given day. These decisions may or may not have "correct" answers. For example, according to the documentation received, the company trains PDDs to look "Left, Right, Left" when approaching an intersection. In this situation the actions of the PDD could be considered incorrect if performed in a different order (e.g., Right, Left, Right). Another example from the company's documentation states that drivers should check their left and right rear view mirrors periodically to be aware of their surroundings. Whether a driver checks the left mirror or right mirror first is a matter of personal preference; in general both are appropriate. However, if either of the actions were not performed, the omission would certainly be considered inappropriate. Because these seemingly minor decisions, which PDDs may not even be aware they make, are so prevalent in their operations, Hierarchical Task Analysis (HTA) was determined to be the most appropriate method of PDD Task Analysis. HTA would also allow the research team to elicit how PDDs make both important and inconsequential decisions while they are behind the wheel.

Additionally, many of the safety and job-related tasks required by the company of their PDDs are distinct from the physical operation of the vehicle. The physical tasks of PDDs behind the wheel that could be elicited from the company's documentation were straightforward and could be generalized to the operation of almost any vehicle (e.g., proper shifting with a manual transmission, how often to check mirrors). The cognitive safety and job-related tasks however were unique to the package delivery job and often had a direct influence on the physical tasks that the driver performs by way of a decision. For example, the company's documentation states that it trains PDDs to make eye contact with other drivers at intersections that have stop signs. The purpose of this requirement is for the package delivery driver to attempt to ascertain the intentions of the other drivers before proceeding through an intersection. This process results in the driver making a decision as to whether it is safe to proceed, and subsequent decisions are then made as the PDD continues to observe the environment as the action is carried out.

Another example illustrates that these decisions can be completely internal and do not require external stimulus. According to the documentation provided by the company, PDDs are trained to make planning and logistics decisions for their next handful of deliveries while they are out of the vehicle making their current delivery. These decisions are assisted by an electronic device, a type of handheld computer which PDDs keep with them, which maintains a preplanned route for their day and delivery information for all of their work. During in-vehicle observation by the researcher in the first pilot study, the drivers were observed to frequently use this device for planning purposes while behind the wheel and the vehicle is not in motion (such as while stopped at a signal light) and occasionally it was observed that PDDs would use the device for planning purposes while the vehicle was in motion.

In both of these examples, the drivers were using their attentional resources to gather external information, which is used in a decision making process, and which results in either the status quo (i.e. continue as planned), or in a change of the physical tasks being performed. In an effort to confirm the relationship described above, the second pilot study, consisting of short surveys and short interviews with PDDs, was conducted with small groups of drivers. These two qualitative methods were used to help address this assumption about PDD behavior. In the interview portion of these meetings, the researcher attempted to discover if the external information that PDDs observed was the main factor affecting the decisions that are made behind the wheel. Essentially, the researcher wanted to confirm that task sequencing was not a factor in how PDDs performed behind the wheel. If task sequencing was an issue, something other than personal preference and the external environment could have contributed to decision making, and the above framework for how drivers operate behind the wheel would be incomplete. During each group interview, the researcher presented the drivers with a situation that was believed to be "complex" based on the documentation review performed earlier. These included multi-lane roads with external "threats" such as pedestrians, bicyclists, signal lights, or stop signs. The PDDs were told what they were required to do, such as approach the intersection and make a left turn while yielding to oncoming traffic. The PDDs were then asked questions such as how they would approach the situation, what they would likely look at first, and which "threat" they thought most likely could result in negative consequences. The PDDs answered these questions definitively by stating that they scan everything while approaching the intersections, that they would either look at the first "threat" that came into view of wherever they were looking at the time, and that no threat was "bigger" than any other. When pressed by the researcher to try to differentiate the threats from one another, the PDDs resisted, saying that doing so means making assumptions about the situation, and that making assumptions is dangerous when approaching any situation.

The survey portion of the SME interviews (Appendix D) was used to elicit whether and to what degree the PDDs had retained their training and used it while operating the vehicle. While the documentation provided by the package delivery company was thorough and comprehensive, the researcher decided to use the opportunity to survey PDDs to discover if the drivers actually retained the methods espoused in the documentation based on self-reporting. All participating drivers responded that they were familiar with the practices they were trained on, and many responded that they felt they knew them well enough to train other drivers on them. In addition to these questions, the surveys queried drivers on possible sources of distraction or stress while driving. The survey results were not used in the task analysis but was gathered at the time in case enough interviews for quantitative analysis could be conducted, however, the opportunity for additional interviews and quantitative analysis did not present itself.

Task Description Task List

Having performed a complete documentation review, conducted 10 in-vehicle observations, and conducted two SME interview sessions, the next step of the task analysis began: the creation of a task description task list (Table 1). Using all knowledge gained at that point, a list of all task-level operations that the PDD could perform within the scope of the system was created. This list was made with respect to the framework of environmental observation, decision-making, and physical task execution in mind. At this point in the research, effort was placed into making the list comprehensive, so that the checklist for video-taped observations would be as complete as possible. Focus was not shifted to organizing the tasks within a framework until after video data were collected and analyzed. This was done so that tasks could be observed by the researcher multiple times, and frame-by-frame if necessary, so as to determine how they interacted.

Table 1. Task Description Task List (prior to video analysis for incidents)

TASK DESCRIPTION TASK LIST	
Cognitive – Driving Tasks	**Psychomotor – Driving Tasks**
Judge follow distance of own vehicle	Accelerate
Scan for threats at proper eye lead distance	Decelerate
Check speedometer	Maintain speed
Evaluate traffic density	Maintain bearing in center of lane
Evaluate traffic speed	Switch lanes left
Check left mirror	Switch lanes right
Check right mirror	Turn left
Check camera screen (reverse only)	Turn right
Judge distance to right curb	Alert others to intentions (turn signal, horn)
Judge distance to left curb	
Check left curb for pedestrians	**Physical Sub-Tasks**
Check left curb for motorist	Look forward
Check right curb for pedestrians	Look left
Check right curb for motorist	Look right
Check left intersection for pedestrians	Look at left mirror
Check left intersection for motorists	Look at right mirror
Check right intersection for pedestrians	Look at monitor
Check right intersection for motorists	Look over left shoulder
Check forward intersection for pedestrians	Manipulate gas pedal
Check forward intersection for motorists	Manipulate brake pedal
Evaluate signal light	Manipulate parking brake
Judge decision point for a stop at a signal light	Manipulate clutch
	Manipulate gear shift
Cognitive – Job Tasks	Manipulate steering wheel
Know location of next stop	Manipulate turn signal
Know location of future stops	Manipulate horn

During this phase of the research, the critical incident checklist was finalized (Figure 5). This sheet was used while on-vehicle to record driving incidents that were observed by the researcher. This data was subsequently used to assist in the incident analysis where video data was analyzed for critical incidents.

Descriptive Data Collection

With a finalized list of driver incidents (Figure 5), the second phase of in-vehicle observations began. Each of these observations consisted of a researcher riding as a passenger with the PDD, and with the video recording equipment collecting video data. While participation in these observations was completely optional on the part of the PDDs, the researcher did make an effort to cover all stratifications put forth in the hypotheses. There were a total of 11 observations with video cameras, and how they fell into the stratifications is shown in Table 2. Each package delivery driver fell into exactly one of the overall experience and on-route experience categories, while each driver may have fallen into multiple route type categories. This is because some drivers had very specific divisions within their workday, conducting deliveries that occurred within one or more route type categories in a given day (e.g., commercial in the morning, residential in the afternoon), and it would not be appropriate to generalize each driver into one category.

TABLE 2. Experience, Experience on Route, and Type of Route levels for participants in video data collection.

Participant #	Experience	Experience on Current Route	Type of Route
304	> 5 Years	> 6 Months	Commercial, Residential
305	≤ 5 Years	≤ 6 Months	Commercial, Industrial, and Residential
306	≤ 5 Years	> 6 Months	Rural
307	≤ 5 Years	≤ 6 Months	Commercial, Residential
308	> 5 Years	> 6 Months	Rural
309	≤ 5 Years	≤ 6 Months	Rural
310	≤ 5 Years	≤ 6 Months	Industrial, Commercial, Residential
311	> 5 Years	> 6 Months	Commercial, Residential
312	> 5 Years	> 6 Months	Urban
313	> 5 Years	> 6 Months	Urban
314	≤ 5 Years	≤ 6 Months	Commercial, Residential

After the video data were collected on a given day, they were transferred to a personal computer and compressed for analysis. The incident analysis consisted of a review of all video footage from all 11 PDDs while behind the wheel and with the written checklist in hand. A second researcher assisted with this analysis, working concurrently with the primary researcher. The primary researcher analyzed six videos in this manner, while the second researcher assisted by analyzing the remaining five. The researchers stopped the video and recorded the frame number and type of all incidents observed into a spreadsheet, and used the written checklist for each PDD strictly as a guide for potential incidents. The incidents observed via video were considered final and differed in several cases from what was recorded by the primary researcher on the actual ride-along checklist (e.g., because of missed or false-positive incidents). This was the only portion of data analysis involving a second researcher, and the subsequent analysis of video involving HDT was conducted only by the primary researcher.

After all videos had been completely reviewed for incidents, examination of the data commenced. Individual incidents were reviewed toward trying to learn the circumstances of the occurrence. Did the PDD follow the procedures as trained? If not, what did they omit? If so, did the PDD perform a task incorrectly? Was there something beyond the training the PDD could have done to prevent the incident? By asking these questions while observing video footage of PDDs performing tasks with and without incident, the task description task list could be improved and made comprehensive such that all observed actions had been included. This process led to the creation of the finalized task list (Table 3), which was a comprehensive look at all tasks that PDDs were observed to perform.

Table 3. Finalized Task List (after video analysis for incidents)

Final List of Tasks and Physical Subtasks Performed by Drivers

Cognitive – Driving Tasks

Judge follow distance of own vehicle
Judge follow distance of vehicle in front
Scan for threats at proper eye lead distance
Check speedometer
Evaluate traffic density
Evaluate traffic speed
Check left mirror
Check right mirror
Check camera screen (reverse only)
Read and comprehend road signs
Judge distance to right curb
Judge distance to left curb
Check left curb for pedestrians
Check left curb for motorist
Check left curb for animals
Check right curb for pedestrians
Check right curb for animals
Check right curb for motorist
Check left intersection for pedestrians
Check left intersection for motorists
Check right intersection for pedestrians
Check right intersection for motorists
Check forward intersection for pedestrians
Check forward intersection for motorists
Evaluate signal light
Judge decision point for a stop at a signal light

Cognitive – Job Tasks

Know approximate time
Know location of next stop
Know location of future stops

Psychomotor – Driving Tasks

Accelerate
Decelerate
Maintain speed
Maintain bearing in center of lane
Counter environmental conditions
Switch lanes left
Switch lanes right
Turn left
Turn right
Alert others to intentions (turn signal, horn)

Physical Sub-Tasks

Look forward
Look left
Look right
Look at left mirror
Look at right mirror
Look at monitor
Look over left shoulder
Manipulate gas pedal
Manipulate brake pedal
Manipulate parking brake
Manipulate clutch
Manipulate gear shift
Manipulate steering wheel
Manipulate turn signal
Manipulate horn
Manipulate heat
Switch headlights on/off
Switch high beams on/off
Switch windshield wipers on/off
Switch flashers on/off
Check addresses of current location
Check handheld device
Check time
Check map

Next, the researcher fleshed out the final framework (Figure 6) for how tasks were performed. It was noted that tasks fell into three different categories. First, the relationship between the physical and cognitive tasks PDDs performed was identified. Through the data analysis, it was discovered that PDDs used physical tasks (referred to as *sub-tasks* in the final framework) in order to complete cognitive tasks. For example, if a PDD had the cognitive task of maintaining a proper follow distance on the highway from the vehicle in front of the package car, he/she performed physical subtasks such as manipulating the gas pedal and manipulating the brake pedal.

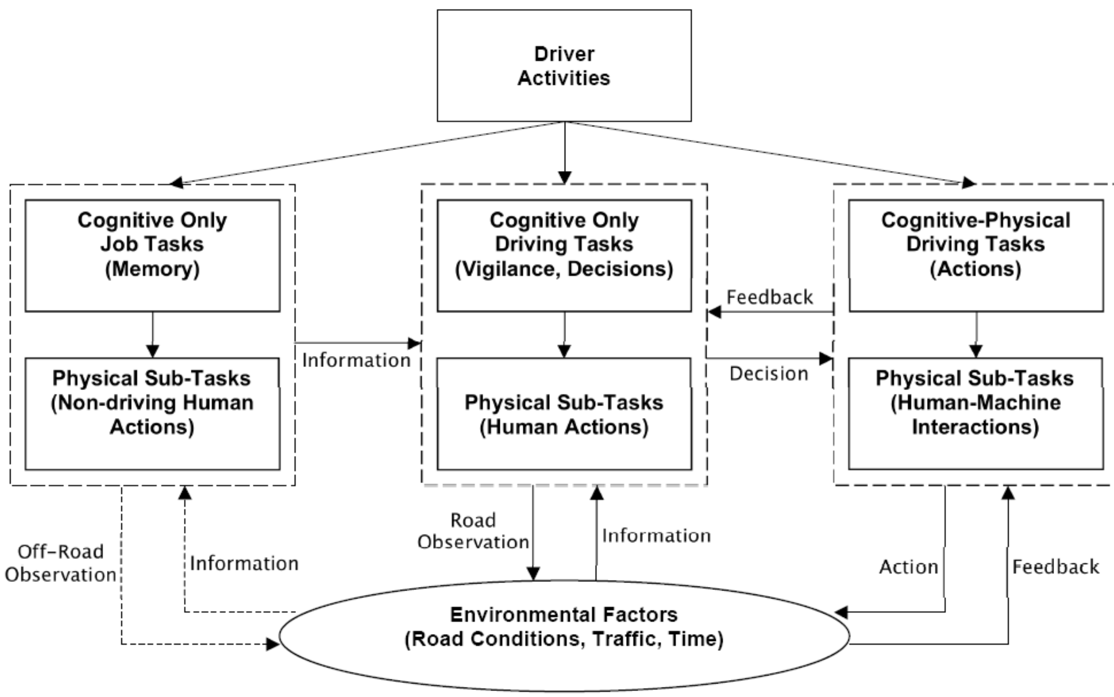

Figure 6. Framework for PDD task performance

In addition to this distinction, interactions between cognitive tasks and physical subtasks were divided into three groups. These groups were 1) job-related tasks, 2) driving tasks that did not require interaction with the vehicle, and 3) driving tasks that required interaction with the vehicle (psychomotor interaction). The first group of sub-tasks, job-related tasks, was those that were performed because of the delivery responsibilities of the PDD, and as such may have been unique to a task analysis performed on that type of driver. For example, a PDD needed to know the location of his/her next stop and, additionally, needed to know the location of future stops for planning purposes. These tasks were strictly related to the job the PDD was trying to perform. The PDD could safely and effectively perform driving activities without performing these job-related tasks; however, these tasks were what satisfied his/her job responsibilities, usually toward the result of keeping the PDD on schedule.

The second group, driving tasks which do not require interaction with the vehicle, were tasks considered as integral to safely and effectively performing driving activities, but any physical actions associated with them only involved the driver. These tasks were related to eliciting information from the environment, such as checking a rear view mirror or reading a road sign. In these examples the physical sub-tasks associated with these operations involved looking in a particular direction.

Finally, the last group, driving tasks that required interaction with the vehicle were tasks that involved using the controls of the vehicle toward some goal. These were *action-feedback interactions* with the external environment. An example of this would be decelerating the vehicle at a stop light. The cognitive tasks of judging the speed and distance of the vehicle in front of the package car were performed concomitant with the physical sub-task of pressing the brake pedal. Feedback from the pressing of the brake pedal (e.g., while on a wet road surface) was used in a kind of *information loop* until the action was completed.

Finally, it should be noted that the physical sub-tasks associated with job-related cognitive tasks were *not necessary*. In fact, the physical sub-tasks were only performed if the cognitive task was not done correctly; for example, if the PDD forgot the address of the next stop. In this case, the driver needed to check the address using a hand-held device at the appropriate time (i.e., when the package delivery vehicle is not in motion).

In general, all three groups of subtasks were used by the PDDs to gather information from the environment in a different manner. The information from one group of actions may be used in another group's tasks. For example, a PDD may decide to switch lanes. This will entail several tasks which do not expressly involve physical interaction with the vehicle, such as checking mirrors, judging speeds of other vehicles, and judging distances of other vehicles. The PDD would then perform a series of tasks that did involve physical interaction with the vehicle, such as accelerating/decelerating by manipulating the pedals, shifting gears, manipulating the turn signal, and turning the steering wheel. In this example there is clearly a relationship between the first and second group of tasks (e.g. the judgment of other vehicles' speeds affects how the PDD manipulates the pedals to accelerate/decelerate), and therefore how the three groups interact needs to be explored.

The first interaction, between job-related tasks and cognitive tasks without physical interaction with the vehicle, is a passing of information. The information that resulted from successfully performing the job tasks (e.g., recalling the street address of the next stop) is subsequently used to the cognitive tasks (e.g., turning the vehicle where appropriate), and is done so without physical interactions with the vehicle. No aspect of the cognitive tasks, however, were used by the job tasks. Cognitive job tasks were essentially independent of the other tasks, and existed as a control mechanism by which other tasks abide. The second interaction, between cognitive tasks which do not use physical interactions with the vehicle and psychomotor tasks which do interact with the vehicle, was modeled as a decision feedback loop. Decisions were made by the PDDs based on information elicited from cognitive job tasks and cognitive driving, such as recalling a delivery address or checking a rear view mirror. Once the decision was made, psychomotor tasks were carried out, such as accelerating the vehicle. This resulted in feedback, which becomes an information input used in subsequent decisions.

Another point to discuss regarding the framework is the environmental information which the tasks described above elicit. The environment is very important in how this framework was set up. Much of "driving" using this framework can be broken down into *use of current knowledge* about the environment (e.g., time of day), *acquisition of new information about the environment* (e.g., making eye contact with a pedestrian), and *decisions based on the environment*, (e.g., decelerate because pedestrian is crossing street). In this manner the environment interacted directly with the physical subtasks that were associated with all three groups of tasks. Additionally, there were some tasks designed specifically to combat or mitigate environmental conditions. Examples of such tasks would be turning on/off the windshield wipers and turning on/off the headlights. Finally, the environment can be a source of stress for PDDs while behind the wheel. While stress and its effects are not dealt with in this study, it should be noted that its effects were observed in the video data. For example, PDDs were observed as becoming visibly distraught or angry after checking their watches (i.e., a delivery being late). Other examples included PDDs becoming angry or frustrated because of the actions of another driver on the road, PDDs becoming visibly confused when the environment did not match their expectations (e.g., a driver unfamiliar with an area expecting one road name but coming across another), or PDDs having to lean or shift their positions significantly because of a visibility issue in the environment (i.e., an obstruction of view).

The final part of the framework is the PDD activities. To this point the tasks PDDs performed and how they related to each other have not been discussed, but in order to complete the task analysis the tasks needed to be organized such in a way as to be meaningful when discussed within the broader activities that PDDs perform. An activity in terms of this framework was a group of tasks that comprised a larger goal, such as “turn right at stop sign.” Such an activity would require many individual tasks that worked toward completing this overall goal. The PDD would need to check for traffic and pedestrians on both sides of the road, turning his/her head in both directions. The PDD would then need to decelerate before the turn and then accelerate through the apex, operating the brake and gas pedals toward that end. The PDD would need to alert others to his/her intentions by operating the turn signal. The PDD would need to attend to the distance from his/her package car to the right curb, as these vehicles were large and required larger than normal turning radii. This would require a PDD to be looking to the right and looking into the right rear-view mirror as well. These operations are all *standard* tasks that would need to be performed in the context of “turning right at stop sign" and there could be many more depending on the individual circumstances of a given situation. The video data were used to identify all observed activities PDDs performed while behind the wheel (Table 4).

Table 4. List of PDD Activities.

Final List of DSP Driving Related Activities
Merging / Lane Shift
Turn Right
Turn Left on 1-way Road
Turn Left on 2-way Road
Turn Right at Stop Sign
Turn Left at Stop Sign on 1-way Road or "T" intersection
Turn Left at Stop Sign on 2-way Road
Proceed Straight at Stop Sign
Turn Right at 4-way Stop
Turn Left at 4-way Stop
Proceed Straight at 4-way Stop
Turn Right at Signal Light
Turn Left at Signal Light on 1-way Road
Turn Left at Signal Light on 2-way Road
Proceed Straight at Signal Light
Parking Lot Navigation
Residential and Urban Maintenance
Rural Maintenance
Commercial and Industrial Maintenance
Highway Maintenance
Residential, Rural, and Urban Deliveries (No Reverse)
Commercial and Industrial Deliveries (No Reverse)
Reverse
Wait Time

With the framework complete, a list of all tasks observed to be used in the completion of each activity was created. These tasks were organized according to the types of tasks outlined in the framework (Figure 6). This constituted the final work of the task analysis: a comprehensive list of observed high-level activities, the observed tasks that were performed to complete these activities, and a framework toward understanding how these tasks interacted while they were being performed by PDDs.

Applications Analysis

There are many practical applications of the above analysis, both for the company the cooperated with the research and for any company which utilizes delivery drivers in large or small roles. The above task analysis was applied to two procedures of the company that sponsored the research: 1) a training procedure and 2) an evaluation procedure. These two applications were based on two documents provided by the company regarding how it trains and evaluates new drivers. The first document outlined a series of specific situations that new drivers would encounter during package car driving training. Within these situations, there were actions that the driver was expected to perform correctly, as well as critical incidents that might occur if he/she did not. Using the task analysis above, the document was reviewed, resulting in recommendations on how to improve it. For example, the document used *stopping the vehicle at a delivery location* as one of these situations. The document lists critical incidents of *stopping at the incorrect location*, *not positioning the vehicle to move forward on restart*, and *failure to check around the vehicle before leaving*. Using the task analysis, suggestions were made to add two additional critical incidents to the doccument: *failure* *to engage parking brake* and *failure to use 4-way flashers*. Another example situation involved traversing straight through a 4-way stop, or through a 2-way stop. This situation had no critical incidents listed, only actions for the driver to perform correctly. Based on the task analysis, a recommendation was made that the situations be separated into two separate ones, as they differed in the tasks required of the driver. Next, a recommendation was made that critical incidents be included specific to *failing to make eye contact with other motorists stopped at the intersection* and *failing to make eye contact with pedestrians at the intersection*.

The second document provided by the sponsoring company regarding how it trains and evaluates new PDDs included a checklist that is used by supervisors when testing a PDD. The supervisor would ride as a passenger with the driver for a portion of the day, and would note any incidents on the list that occurred. These incidents were then transformed into a "score" with which to grade the driver. Recommendations were again made toward improving the document resulting from the task analysis. One example was an entry where the supervisor would note whether the driver changed lanes "dangerously." It was suggested that the term "dangerously" could be replaced with more specific danger indicators such as *changing lanes without proper clearance*, *improper speed while changing lanes* (such as an excessive acceleration), *failure to check mirrors while changing lanes*, or *failure to look over left should when changing lanes* (specifically, merging left). By removing the subjective and ambiguous term "dangerously" from the evaluation, it was believed that not only will supervisors have a more reliable evaluation method with which to identify and catalogue 'danger' through the use of more objective critical incident indicators, but also that PDDs will learn more from the evaluations by receiving more specific feedback as to what it was that was considered 'dangerous.' These are two practical examples of the many training and evaluation uses of the task analysis performed for package delivery companies.

Statistical Analyses

In addition to recording incidents for use in the task analysis, the incidents were compiled for use in statistical analysis as well. The participating company was provided with information about incident occurrences that were broken down by the driver stratifications identified. The results of the identified critical incidents across all drivers are shown in Table 5. A total of 720 critical incidents were recorded after reviewing the video tapes of all collected data. Across all PDDs, the critical incident of *using a handheld device while the vehicle is in motion* was the most common incident, occurring 185 times and accounting for 25.7% of all observed critical incidents. The next most common critical incident was *failing to use the horn where appropriate*, which occurred 105 times and accounted for 14.6% of all observed critical incidents. The third most common critical incident was *use of food or beverage while the vehicle was in motion*, which occurred 75 times and accounted for 10.4% of all observed critical incidents. These were the most notable recurring incidents over the course of all observations.

TABLE 5. Incidents observed across all participants in videotaped observations.

Incident	Number	Percent of Total
4-way flashers not used where appropriate	3	0.4%
Cargo door open while in motion	3	0.4%
Cell phone used while in motion	29	4.0%
Package delivery device used while in motion	185	25.7%
Exceeding intersection	13	1.8%
Failure to stop where appropriate	70	9.7%
Fixation on an object in the front view	4	0.6%
Fixation on left rear view	1	0.1%
Food while in motion	75	10.4%
Harsh adjustments	1	0.1%
Harsh braking	5	0.7%
Horn not used where appropriate	105	14.6%
Improper clearance while changing lane	1	0.1%
Lane Exceedance	34	4.7%
Missed stop	4	0.6%
Missed turn	1	0.1%
Other device used while in motion	28	3.9%
Parking brake not used where appropriate	70	9.7%
Seatbelt not used where appropriate	34	4.7%
Speeding	18	2.5%
Stop distance too close to a vehicle	9	1.3%
Stopped at incorrect address	2	0.3%
Turn signal not used where appropriate	25	3.5%

Two statistical analysis were performed on this dataset of incidents. First, incidents were then broken down by the participant's overall experience driving a package car for the company. Six of the 11 observed PDDs had ≤ five years' overall experience, and a total of 48.90 observed hours within this stratification. This represents the total time the PDD was working, including periods in and out of the vehicle. This time was used because some critical incidents, such as failure to engage the parking brake and stop distance too close to a vehicle, necessarily occur when the vehicle is not in motion. The remaining five drivers with > 5 years' experience a total of

58.18 observed hours between them. The incident totals for PDDs within each stratification were divided by the number of observed hours in order to obtain ratios for statistical analysis. These ratios represent the number of incidents of a particular type per hour of observation. The period of observation for each PDD began when the vehicle left the companies facility and ended when the vehicle returned to the company's facility at the end of the day. The ratios of incidents per observed hour for PDDs with ≤ five years' overall experience and > five years' overall experience can be seen in Table 6 and Table 7, respectively.

TABLE 6. Incidents observed across PDDs with ≤ five years overall experience.

Incident Name	Total	Incidents / Observed Hour
4-way flashers not used where appropriate	3	0.05
Cargo door open while in motion	2	0.03
Cell phone used while in motion	9	0.15
Package delivery device used while in motion	144	2.48
Exceeding intersection	6	0.10
Failure to stop where appropriate	51	0.88
Fixation on an object in the front view	2	0.03
Fixation on left rear view	1	0.02
Food while in motion	6	0.10
Harsh adjustments	1	0.02
Harsh braking	2	0.03
Horn not used where appropriate	90	1.55
Improper clearance while changing lane	1	0.02
Lane Exceedance	24	0.41
Missed stop	1	0.02
Missed turn	1	0.02
Other device used while in motion	21	0.36
Parking brake not used where appropriate	37	0.64
Seatbelt not used where appropriate	3	0.05
Speeding	13	0.22
Stop distance too close to a vehicle	1	0.02
Stopped at incorrect address	2	0.03
Turn signal not used where appropriate	22	0.38

TABLE 7. Incidents observed across PDDs with > five years' experience.

Incident Name	Total	Incidents / Observed Hour
4-way flashers not used where appropriate	0	0.00
Cargo door open while in motion	1	0.02
Cell phone used while in motion	20	0.41
Package delivery device used while in motion	41	0.84
Exceeding intersection	7	0.14
Failure to stop where appropriate	19	0.39
Fixation on an object in the front view	2	0.04
Fixation on left rear view	0	0.00
Food while in motion	69	1.41
Harsh adjustments	0	0.00
Harsh braking	3	0.06
Horn not used where appropriate	15	0.31
Improper clearance while changing lane	0	0.00
Lane Exceedance	10	0.20
Missed stop	3	0.06
Missed turn	0	0.00
Other device used while in motion	7	0.14
Parking brake not used where appropriate	33	0.67
Seatbelt not used where appropriate	31	0.63
Speeding	5	0.10
Stop distance too close to a vehicle	8	0.16
Stopped at incorrect address	0	0.00
Turn signal not used where appropriate	3	0.06

In order to ascertain if these two stratifications were significantly different, a t-test was performed. Because this is the first of two analyses done on this dataset, it was conducted at a level of $\alpha = 0.025$ in order to maintain an overall $\alpha = 0.05$ across the dataset. The descriptive statistics, an interval plot of the data, and the results of the t-test can be seen in Table 8, Figure 7, and Table 9, respectively. While the average of the ratios within each group differed by .09 incidents per observed hour, the t-test resulted in a p-value of $p = 0.559$. This did not allow for the rejection of the null hypothesis that the two levels of overall experience are not significantly different.

Table 8. Descriptive statistics of incidents per hour of observation stratified by PDDs with "High" and Low" experience.

Descriptive Statistics - Incidents per Observed Hour Ratios Stratified by Levels of Overall Experience				
	N	Mean	StDev	SE Mean
High Overall Experience Ratios	23	0.246	0.35	0.073
Low Overall Experience Ratios	23	0.331	0.592	0.12

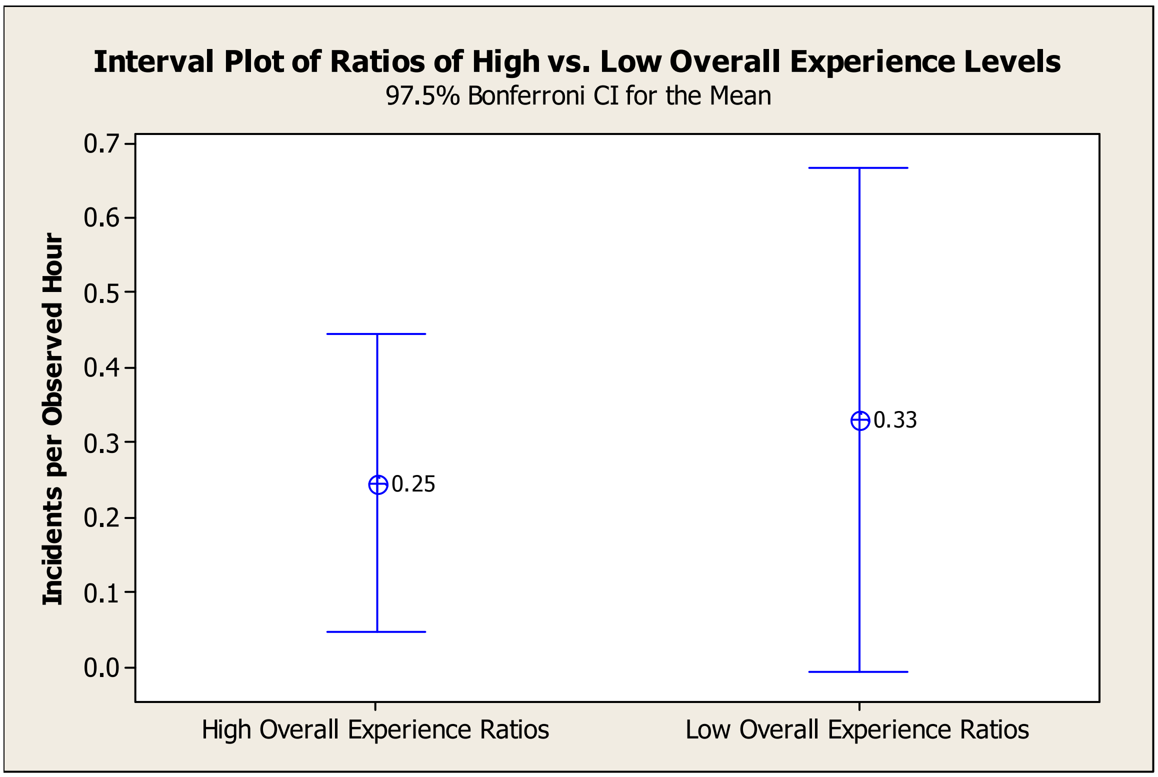

Figure 7. Interval plot of incidents per observed hour for "High" and "Low" levels of overall experience.

Table 9. T-test of incidents per hour of observation ratios between PDDs of "High" and "Low" experience levels at $\alpha = 0.025$.

Difference = mu (High Overall Experience Ratios) - mu (Low Overall Experience Ratios)			
Estimate for difference:	-0.085		
97.5% CI for difference:	(-0.421, 0.251)		
T-Test of difference = 0 (vs not =):	T-Value = -0.59	P-Value = 0.559	DF = 35

The second analyses on the incident data involved stratifying participants according to the on-route experience (i.e. experience driving on the particular route on which they were observed), with one group constituting ≤ six months' experience and the other > six months' experience. Often, experienced PDDs stay on the same route for a long period of time and, as a result, there were only minor differences between on-route experience and overall experience in terms of where participants fell in the stratification. Five of the participating drivers had ≤ six months' experience on-route, while the remaining six drivers had > six months' experience on-route. The ratios of incidents per observed hour for PDDs with ≤ six months' on-route experience and > six months' on-route experience can be seen in Table 10 and Table 11, respectively.

TABLE 10. Incidents observed across PDDs with ≤ six months of on-route experience.

Incident Name	Total	Incidents / Observed Hour
4-way flashers not used where appropriate	1	0.02
Cargo door open while in motion	2	0.04
Cell phone used while in motion	5	0.11
Package delivery device used while in motion	101	2.12
Exceeding intersection	6	0.13
Failure to stop where appropriate	31	0.65
Fixation on an object in the front view	1	0.02
Fixation on left rear view	0	0.00
Food while in motion	6	0.13
Harsh adjustments	1	0.02
Harsh braking	2	0.04
Horn not used where appropriate	34	0.71
Improper clearance while changing lane	1	0.02
Lane Exceedance	11	0.23
Missed stop	1	0.02
Missed turn	1	0.02
Other device used while in motion	15	0.32
Parking brake not used where appropriate	31	0.65
Seatbelt not used where appropriate	1	0.02
Speeding	13	0.27
Stop distance too close to a vehicle	1	0.02
Stopped at incorrect address	2	0.04
Turn signal not used where appropriate	6	0.13

TABLE 11. Incidents observed across drivers with > six months of on-route experience.

Incident Name	Total	Incidents / Observed Hour
4-way flashers not used where appropriate	2	0.03
Cargo door open while in motion	1	0.02
Cell phone used while in motion	24	0.40
Package delivery device used while in motion	84	1.41
Exceeding intersection	7	0.12
Failure to stop where appropriate	39	0.66
Fixation on an object in the front view	3	0.05
Fixation on left rear view	1	0.02
Food while in motion	69	1.16
Harsh adjustments	0	0.00
Harsh braking	3	0.05
Horn not used where appropriate	71	1.19
Improper clearance while changing lane	0	0.00
Lane Exceedance	23	0.39
Missed stop	3	0.05
Missed turn	0	0.00
Other device used while in motion	13	0.22
Parking brake not used where appropriate	39	0.66
Seatbelt not used where appropriate	33	0.56
Speeding	5	0.08
Stop distance too close to a vehicle	8	0.13
Stopped at incorrect address	0	0.00
Turn signal not used where appropriate	19	0.32

In order to ascertain if these two stratifications were significantly different, a t-test was performed. Because this is the second of two independent analyses on the incident dataset, the test was conducted at a level of $\alpha = 0.025$ in order to maintain an overall $\alpha = 0.05$ across the data. The descriptive statistics, interval plot of the data, and the results of the t-test can be seen in Table 12, Figure 8, and Table 13, respectively. Again, a small different was calculated in the averages of the ratios, but with a p-value of 0.558 the data was not sufficient to reject the hypothesis that there is no significant difference.

Table 12. Descriptive statistics of incidents per hour of observation stratified by PDDs with "High" and Low" on-route experience.

Descriptive Statics - Incidents per Observed Hour Ratios Stratified by Levels of Experience On-route				
	N	Mean	StDev	SE Mean
High On-route Experience Ratios	23	0.327	0.426	0.089
Low On-route Experience Ratios	23	0.249	0.463	0.097

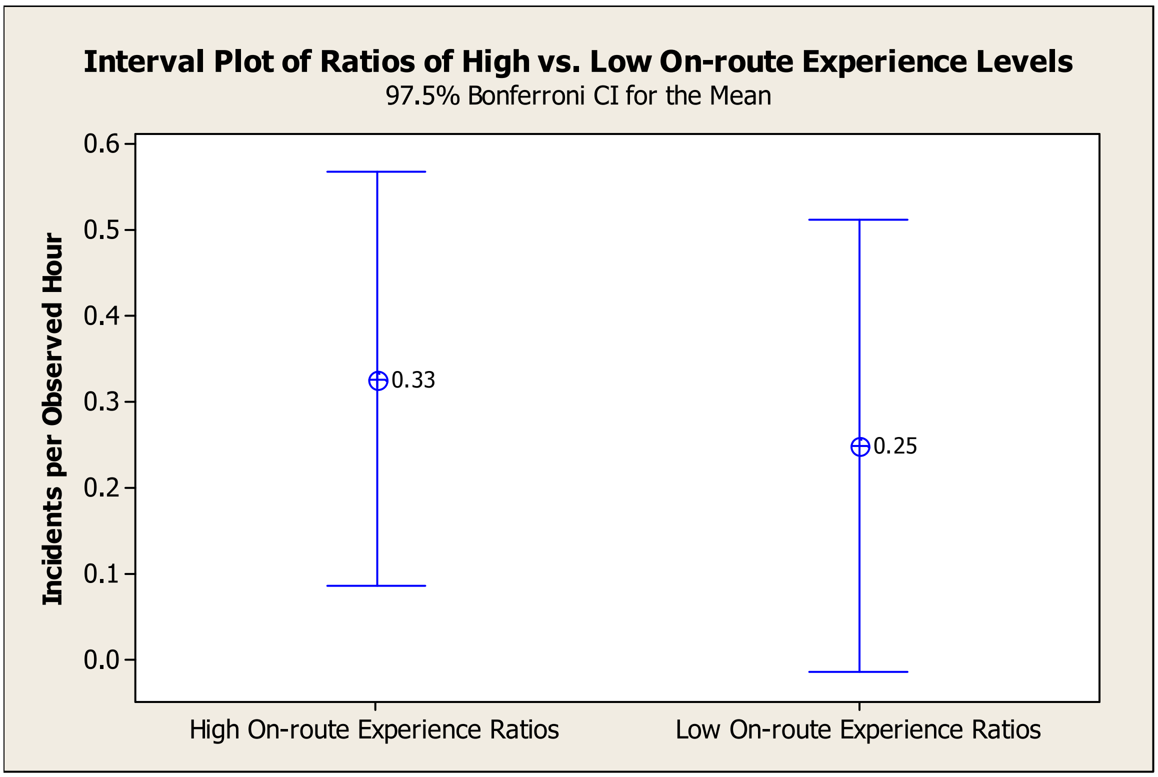

Figure 8. Interval plot of incidents per observed hour for "High" and "Low" levels of on-route experience.

Table 13. T-test of incidents per hour of observation ratios between PDDs of "High" and "Low" experience levels at $\alpha = 0.025$.

Difference = mu (High On-route Experience Ratios) - mu (Low On-route Experience Ratios)			
Estimate for difference:	0.078		
97.5% CI for difference:	(-0.227, 0.382)		
T-Test of difference = 0 (vs not =):	T-Value = 0.59	P-Value = 0.558	DF = 43

A third stratification, route type, was planned but could not be carried out because of the small sample size. The number and types of incidents for Residential, Urban, Commercial, Industrial, and Rural routes are shown in Table 14, Table 15, Table 16, Table 17, and Table 18, respectively.

TABLE 14. Incidents observed across PDDs within residential route.

Incident	Number
Cell phone used while in motion	4
Handheld device used while in motion	70
Exceeding intersection	1
Failure to stop where appropriate	4
Food while in motion	8
Harsh adjustments	1
Harsh braking	1
Lane exceedance	3
Other device used while in motion	7
Parking brake not used where appropriate	6
Stopped at incorrect address	1

TABLE 15. Incidents observed across PDDs within urban route.

Incident	Number
Cargo door open while in motion	1
Cell phone used while in motion	15
Package delivery device used while in motion	32
Exceeding intersection	1
Failure to stop where appropriate	14
Food while in motion	32
Harsh braking	1
Horn not used where appropriate	14
Other device used while in motion	6
Parking brake not used where appropriate	27
Seatbelt not used where appropriate	31
Speeding	1
Stop distance too close to a vehicle	8
Turn signal not used where appropriate	3

TABLE 16. Incidents observed across PDDs within commercial route.

Incident	Number
Cargo door open while in motion	2
Cell phone used while in motion	4
Handheld device used while in motion	7
Exceeding intersection	11
Failure to stop where appropriate	13
Fixation on an object in the front view	2
Food while in motion	31
Horn not used where appropriate	32
Improper clearance while changing lane	1
Lane exceedance	12
Missed stop	1
Missed turn	1
Other device used while in motion	4
Parking brake not used where appropriate	23
Speeding	5
Stop distance too close to a vehicle	1
Stopped at incorrect address	1

TABLE 17. Incidents observed across PDDs within industrial route.

Incident	Number
Package delivery device used while in motion	24
Food while in motion	3
Other device used while in motion	1
Parking brake not used where appropriate	7
Seatbelt not used where appropriate	1

TABLE 18. Incidents observed across PDDs within rural route.

Incident	Number
4-way flashers not used where appropriate	3
Cell phone used while in motion	6
Package delivery device used while in motion	52
Failure to stop where appropriate	39
Fixation on an object in the front view	2
Fixation on left rearview	1
Food while in motion	1
Harsh braking	3
Horn not used where appropriate	59
Lane exceedance	19
Missed stop	3
Other device used while in motion	10
Parking brake not used where appropriate	7
Seatbelt not used where appropriate	2
Speeding	12
Turn signal not used where appropriate	22

Residential routes were characterized by deliveries to private residences, driveways, parallel parking, frequent stop signs, and low traffic density. Urban routes were characterized by deliveries to both private residences and businesses, narrow roads with parallel parking, frequent stop signs and signal lights, and high traffic density. Commercial routes were characterized by nearly exclusive business deliveries, included high traffic density from customers to those businesses, and included frequent stops and signal lights. Industrial routes were characterized by nearly exclusive business deliveries, low traffic density (these businesses typically did not deal directly with individual customers), few stops and signal lights, frequent use of loading docks, and some usage of unpaved roads. Rural routes were characterized by both private residences and business deliveries, low traffic density and narrow roads, few stops and signal lights, long periods of time between deliveries, and the use of roads that were not state-maintained.

The large differences in time PDDs spent delivering within each route type, as well as the smaller number of drivers realized within each route type did not allow for meaningful direct comparisons. No conclusions were drawn from the route-type stratification, but the data may still provide useful anecdotal information for future work.

In order to test the hypotheses regarding HDT, the HDTs needed to be extracted from the video data (i.e., video data reduction). First, the videos were examined to determine which of them had maintained clear views of the drivers' eyes, and had no other issues that would make recording eye movements problematic. Six of the 11 videos were determined to be acceptable for eye coding. One video was eliminated due to the driver's use of sunglasses (thereby disallowing eye-gaze determinations), two videos were eliminated due to severe glare from eye glasses, one video was eliminated due to the two side cameras falling down during the observation (these two cameras were important in differentiating looks toward the left and left rear view and right and right rear view, but did not affect incident coding); finally, one video was eliminated because the camera positioned and aiming at the driver's face was oriented improperly (the other cameras were oriented correctly and incident coding was not affected). Time constraints, including the availability of PDDs based on the company's schedule, did not allow for the collection of additional video data.

In order to acquire these HDTs, each video was stepped through frame-by-frame, and every eye gaze was recorded into a MS Excel spreadsheet. The records included the frame number at which a given eye gaze began and ended, where the eye gaze was directed, and on what type of road the eye gaze took place. All periods wherein the package car was in motion were coded in this manner, ending at the point where the video cameras switched from color to black and white due to low ambient light conditions. This point was consistently close to where the experimenter would have difficulty in determining eye movements, resulting in indeterminate HDT periods would have had to have been coded. Through this procedure, a voluminous data set resulted that represented a continuous 'mapping' of where the PDD directed his/her gaze all times when the vehicle was in motion for each of the six drivers. In order to extract HDTs from the eye data, a program was written using Python (a general purpose, high-level programming language) per the definitions set forth above, and for when the vehicle is moving forward and in reverse.

The number of drivers used in the video data reduction portion of the analysis was fewer than those in the incident analysis, and some parts of the hypotheses cannot be addressed due to this. Hypotheses H1, H2, and H3 specified three types of stratification for which to analyze for significant differences in HDTs. These three types of stratification were overall experience, on-route experience, and type of route. In each of these hypotheses, there are statements about the number of critical incidents (addressed above), the number of HDTs, and the duration of HDTs. The claims about number of number of HDTs need to be compared between groups of drivers, resulting in a dataset of six observations stratified as per the particular hypothesis, while the claims about HDT durations compare a dataset of over 12,000 HDT observations stratified as per the particular hypothesis . It was therefore deemed inappropriate to make any comparisons or draw conclusions regarding *number* of HDTs.

How the six drivers whose data could be analyzed fell into each stratification can be seen in Table 19. Some drivers had fewer route types listed for the HDT analysis compared to the critical incident analysis. This was because more ambient light was required for discerning eye movements, resulting in HDT analysis ending earlier in the day on most videos. Additionally, hypotheses H5 and H6 were set forth as conditional based on the ability to collect specific kinds of data. Objective, continuous data specific to weather conditions could not be collected in a practical manner within the context of this research effort, and therefore hypothesis H5 was not addressed in this research and as a result no conclusions were drawn regarding it. The telemetric data that would have been required to address hypothesis H6 was not made available to the research effort, and therefore H6 was not addressed in this research and as a result no conclusions were drawn regarding it. The hypotheses that were addressed by this research were the incident and HDT duration portions of hypotheses H1, H2, and H3, as well as H4 in its entirety. Hypotheses H1, H2, and H3 dealt with comparing critical incident numbers and durations of HDTs within the *overall experience*, *on-route experience*, and *route type* stratifications, respectively. The hypothesis H4 dealt with comparing durations of those HDTs that were associated with critical incidents to those HDTs that were not associated with critical incidents. A total of 1,713,003 frames of video were coded in the research effort, resulting in 30,863 eye movements that comprised a total of 12,630 HDTs of varying durations. These HDTs were stratified as outlined in each hypothesis for analysis.

TABLE 19. PDD experience levels and route types for HDT analysis.

Participant #	Experience	Experience on Route	Type of Route
304	> 5 Years	> 6 Months	Commercial
305	≤ 5 Years	≤ 6 Months	Commercial
308	> 5 Years	> 6 Months	Rural
311	> 5 Years	> 6 Months	Commercial, Residential
312	≤ 5 Years	≤ 6 Months	Urban
313	> 5 Years	> 6 Months	Urban

When the six drivers coded for video were separated into groups by overall experience and by on-route experience, the groups within each stratification were identical. Participants 305 and 312 were classified into the 'inexperienced' group of stratifications and participants 304, 308, 311, and 313 were classified into the 'experienced' group of both stratifications. As a result, the data that was used to test hypotheses H1 and H2, which stated HDTs of PDDs with more overall experience would be shorter in duration than HDTs of PDDs with less overall experience and HDTs of PDDs with more on-route experience would be shorter in duration than HDTs of PDDs with less on-route experience, respectively, were identical and the hypotheses were thus combined.

After combining these hypotheses, the inexperienced group represented PDDs with ≤ six months' experience on-route <u>and</u> ≤ five years' experience overall. The experienced group represented PDDs with > six months' experience on-route and > five years' experience overall. As with the previous incident dataset, the HDT dataset had multiple independent analyses conducted on it. To compensate for this a correction was applied in order to maintain an $\alpha = 0.05$ across the entire dataset. A total of seven independent tests were conducted (one experience analysis and six comparisons of route types), and therefore a level of $\alpha = 0.0071$ was used in each individual test. To test the hypothesis that the inexperienced and experienced groups as stated above had different durations of HDTs, a t-test at a level of $\alpha = 0.0071$ was conducted with a null hypothesis that the two experience levels were not significantly different. The descriptive statistics, interval plot of the data, and the results of the t-test can be seen in Table 20, Figure 9, and Table 21, respectively. PDDs classified as "High" experience averaged approximately .07s shorter HDT durations. The t-test subsequently calculated a p-value of 0.000. This allows the null hypothesis that the two levels of experience are not significantly different to be rejected.

Table 20. Descriptive statistics of HDT duration in seconds stratified by PDDs with "High" and "Low" experience.

Descriptive Statistics - HDT Durations (sec) Stratified by Experience			
	Mean	SE Mean	StDev
High Experience	1.1806	0.0111	1.4479
Low Experience	1.2538	0.0156	1.4294

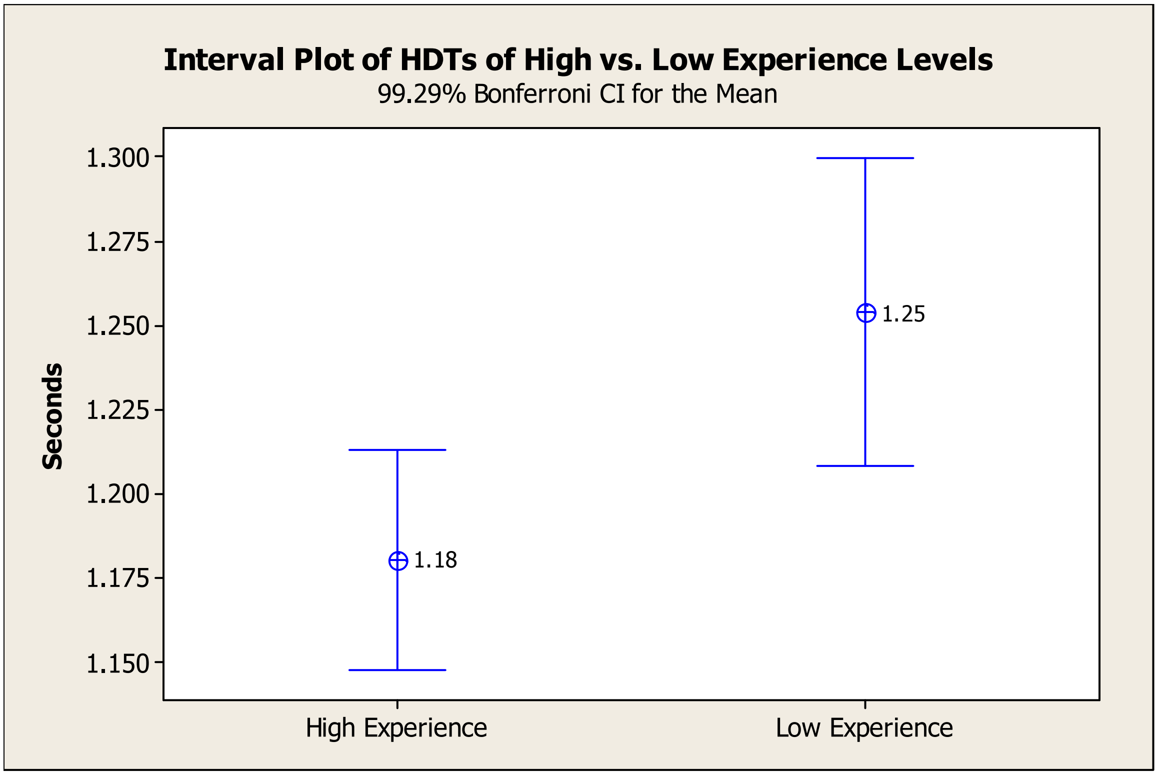

Figure 9. Interval plot of durations of HDTs across "High" and "Low" levels of levels of PDD experience.

Table 21. T-test of HDT durations between PDDs of "High" and "Low" experience levels at α = 0.0071.

Difference = mu (High Experience) - mu (Low Experience)			
Estimate for difference:	-0.0731		
99.29% CI for difference:	(-0.1248, -0.0215)		
T-Test of difference = 0 (vs not =):	T-Value = -3.81	P-Value = 0.000	DF = 16884

There are two major issues with this HDT/experience result that must also be addressed. The first issue is external validity, because even though the researcher was able to extract a large body of HDTs from the videos, only six drivers were used in this analysis. Further research across a wide variety of drivers is required in order to generalize the results to all package delivery drivers. Additionally, this methodology recorded drivers for an entire day, which may be impractical for a package delivery company. While it was felt important to collect as much data on each driver as was possible (due to the limited number of PDDs participating and subsequently used in HDT analysis), a package delivery company would likely need a method of collecting smaller samples of HDTs that would still retain external validity in terms of generalizing the behaviors of that particular driver. This leads to the second issue, which is the small difference in the times of inexperienced and experienced drivers' HDTs. While significantly different, the real practicality of this difference may not be useful. From a data collection perspective, if the true difference between population means is as small as the sample means in this study suggest, the samples sizes necessary to detect this difference may be too large to be practical for use within a package delivery company. Additionally, the difference in sample population means may not be indicative of the future potential of a driver. For example, one PDD in training may exhibit longer HDTs but show significant improvement over time (perhaps owing to inexperience with the type of work), while another PDD in training may exhibit shorter HDTs while not improving over time (perhaps owing to previous experience as a delivery driver or familiarity with the area). Finally, the observed difference must be put into the context of real world performance. In other words, does an average difference of 0.07s have any meaning in the context of job performance? The final hypothesis (comparing HDTs associated with incidents with those that were not) assisted in addressing this final question. The implications of these issues will be discussed in the following section.

The next hypothesis (H3) was that different types of routes would result in significantly different durations of HDTs. The six drivers for which HDTs were acquired represented four of the five types of route. Residential, commercial, urban, and rural route types were represented within the sample of HDTs; however, none of the six PDDs spent any time on an industrial route. Therefore, industrial route data could not be included in this analysis, resulting in testing of only the other four route types for significant differences in HDT durations.

The descriptive statistics table and interval plot of the data can be seen in Table 22 and Figure 10, respectively. Mean time spent 'head down' was 1.72s, 1.55s, 1.31s, and 1.70s for commercial, residential, rural, and urban route types, respectively.

Table 22. Descriptive statistics of HDT duration in seconds stratified by Commercial, Residential, Rural, and Industrial route types.

Descriptive Statistics - HDT Durations (sec.) Stratified by Route Type			
	Mean	SE Mean	StDev
Commercial	1.7203	0.0322	1.8082
Residential	1.5529	0.0634	1.6423
Rural	1.3067	0.026	1.4189
Urban	1.6985	0.0283	1.8082

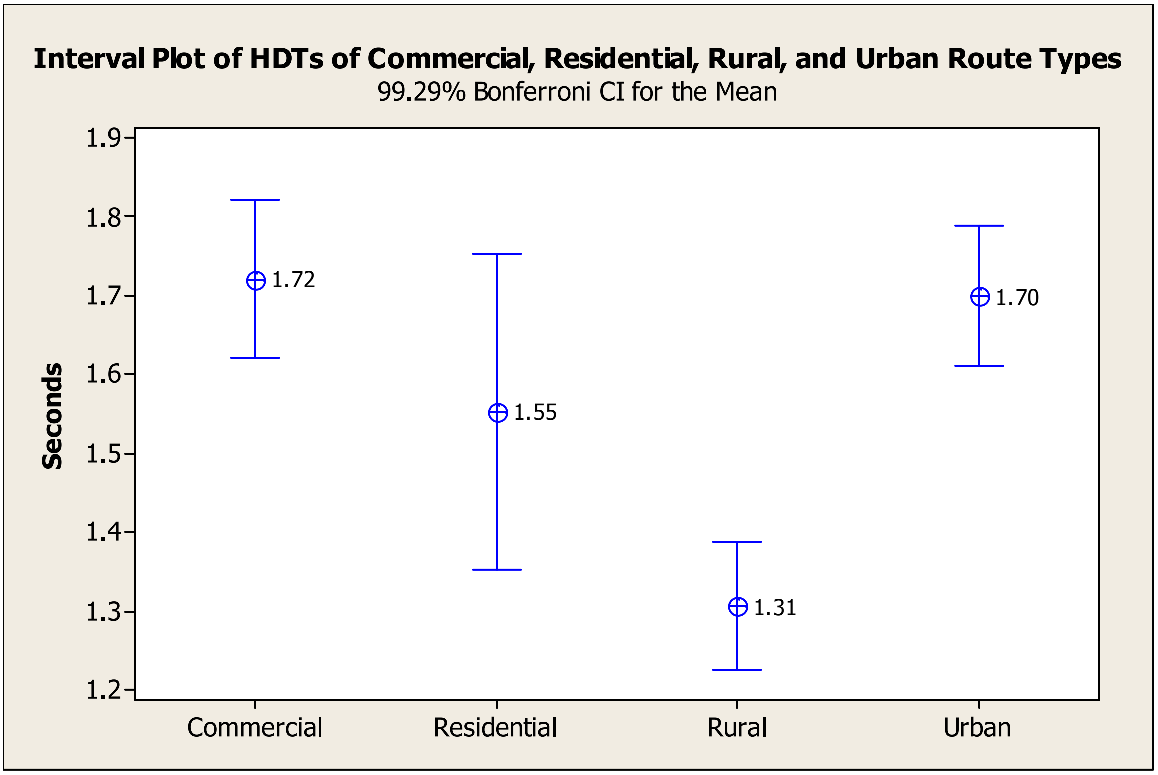

Figure 10. Interval plot of durations of HDTs stratified by Commercial, Residential, Rural, and Urban route types.

T-tests comparing each possible pair of route types were conducted in order to test for differences between the types. As stated previously, these tests were conducted at a level of $\alpha = .0071$ in order to maintain an overall $\alpha = .05$ for the dataset. As there were four route types, six t-tests were conducted in order to evaluate each possible comparison between two types. The results of these six t-tests are given in Table 23, Table 24, Table 25, Table 26, Table 27, and Table 28. The first important result was that even at a level of .0071, the rural route type was significantly different from <u>each</u> other route type. In all three t-tests involving the rural route type, a p-value of 0.000 was calculated. The second important result was that in the t-tests between commercial/residential and urban/residential, the p-values calculated were below 0.05 but were not significant at the 0.0071 level. Therefore, because of the number independent tests run on this dataset the hypotheses that residential is not significantly different from the other types cannot be rejected. However, because of the values are below 0.05 (0.019 and 0.036 for commercial and urban respectively), it should be stressed that this conclusion is conservative and the results should be interpreted as an indicator that additional research may allow a more definitive conclusion. Finally, the t-test between commercial an urban resulted in a p-value of 0.610, which clearly did not allow rejection of the null hypothesis that the two route types are not significantly different.

Table 23. T-test of HDT durations between Commercial and Residential route types at α = 0.0071.

Difference = mu (Commercial) - mu (Residential)			
Estimate for difference:	0.1674		
99.29% CI for difference:	(-0.0245, 0.3593)		
T-Test of difference = 0 (vs not =):	T-Value = 2.35	P-Value = 0.019	DF = 1042

Table 24. T-test of HDT durations between Commercial and Rural route types at α = 0.0071.

Difference = mu (Commercial) - mu (Rural)			
Estimate for difference:	0.4136		
99.29% CI for difference:	(0.3022, 0.5250)		
T-Test of difference = 0 (vs not =):	T-Value = 10.00	P-Value = 0.000	DF = 5945

Table 25. T-test of HDT durations between Commercial and Urban route types at α = 0.0071.

Difference = mu (Commercial) - mu (Urban)			
Estimate for difference:	0.0218		
99.29% CI for difference:	(-0.0935, 0.1372)		
T-Test of difference = 0 (vs not =):	T-Value = 0.51	P-Value = 0.610	DF = 6796

Table 26. T-test of HDT durations between Residential and Rural route types at α = 0.0071.

Difference = mu (Residential) - mu (Rural)			
Estimate for difference:	0.2462		
99.29% CI for difference:	(0.0612, 0.4313)		
T-Test of difference = 0 (vs not =):	T-Value = 3.59	P-Value = 0.000	DF = 907

Table 27. T-test of HDT durations between Residential and Urban route types at α = 0.0071.

Difference = mu (Residential) - mu (Urban)			
Estimate for difference:	-0.1455		
99.29% CI for difference:	(-0.3330, 0.0419)		
T-Test of difference = 0 (vs not =):	T-Value = -2.09	P-Value = 0.036	DF = 955

Table 28. T-test of HDT durations between Rural and Urban route types at α = 0.0071.

Difference = mu (Rural) - mu (Urban)			
Estimate for difference:	-0.3918		
99.29% CI for difference:	(-0.4953, -0.2883)		
T-Test of difference = 0 (vs not =):	T-Value = -10.19	P-Value = 0.000	DF = 7016

The results of the HDT by route analysis suggest that visual behaviors may differ depending on the type of route on which a PDD operates. The results suggest that on rural routes, PDDs have the shortest duration of looks away from the forward view. This is followed by residential routes, which were significantly longer than the rural route type in terms of HDT duration, and may be significantly shorter than commercial and urban. Finally, the results suggest that commercial and urban routes are not significantly different from each other in terms of HDT duration, that both are significantly longer than rural routes, and that both may be longer than residential routes. These results may be due to the inherent increase in vehicle/pedestrian/other activity to which a PDD must attend on commercial and urban route types. The implications of these results could be important for training purposes at a package delivery company. The differences observed above may indicate that PDD operations on rural routes, and possibly to a lesser extent on residential routes, requires less visual attention away from the forward view, which may in turn be less demanding on a PDD in terms of mental workload and stress. Likewise, these differences may indicate that urban and commercial routes require more visual attention away from the forward view, which may in turn be more demanding on a PDD in terms of mental workload and stress.

As with the previous analysis, there are three major issues to discuss with this result. Again, large amounts of HDT data were collected from a limited sample of PDDs. In order to address external validity in this respect, a much broader base of drivers must be studied across all route types. Secondly, the route type classifications used in this analysis were based on discussions with managers who were subject matter experts within the package delivery company. It should be stressed that the package delivery company did not have official route classifications. Each observation used in this analysis was categorized within the route-classification system according to the assessments of the supervisor and PDD responsible for the route being observed. Other package delivery companies may classify routes differently from this research effort. Finally, the results above must again be put into the context of real world performance. If the true means across routes are equal to the sample means observed in this study, would these differences have any real implications for job performance? The final hypothesis (comparing HDTs associated with incidents with those not associated with incidents) again assisted in addressing this issue. The implications of these issues will be discussed in the following section.

The final hypothesis tested was for a difference between HDTs associated with critical incidents and HDTs *not* associated with critical incidents. For this hypothesis, the critical incidents identified above were used as the starting point. Critical incident types related to driving were identified, and those not related to driving were removed from this analysis. The list of critical incident types which were identified as driving-related is provided in Table 29. Each critical incident was scrutinized to determine whether it occurred during an HDT and, if it did not, the HDT that occurred directly prior to the critical incident. These HDT were then considered as associated with a critical incident for analysis. T-tests at $\alpha = 0.05$ with unbalanced samples and a null hypothesis that there was no significant difference between the two populations was used. The descriptive statistics, interval plot for the data, and t-test results can be seen in Table 30, Figure 11, and Table 31, respectively.

TABLE 29. Critical incidents used in HDT Analysis for Hypothesis 4.

Incidents For HDT Analysis
Speeding
Taking a turn too fast
Hard deceleration
Following too close to a vehicle
Failure to stop where appropriate
Exceeding lane
Exceeding intersection
Improper clearance while changing lane
Harsh adjustments
Other traffic law violation
Missed turn
Missed stop
Stopped at incorrect address

Table 30. Descriptive statistics of HDT duration in seconds stratified by HDTs associated with incidents and HDTs not associated with incidents

Descriptive Statistics - HDT Durations Stratified by Incident Association			
	Mean	SE Mean	StDev
HDTs Associated with Incidents	3.499	0.412	2.968
HDTs Not Associated with Incidents	1.5987	0.0155	1.7411

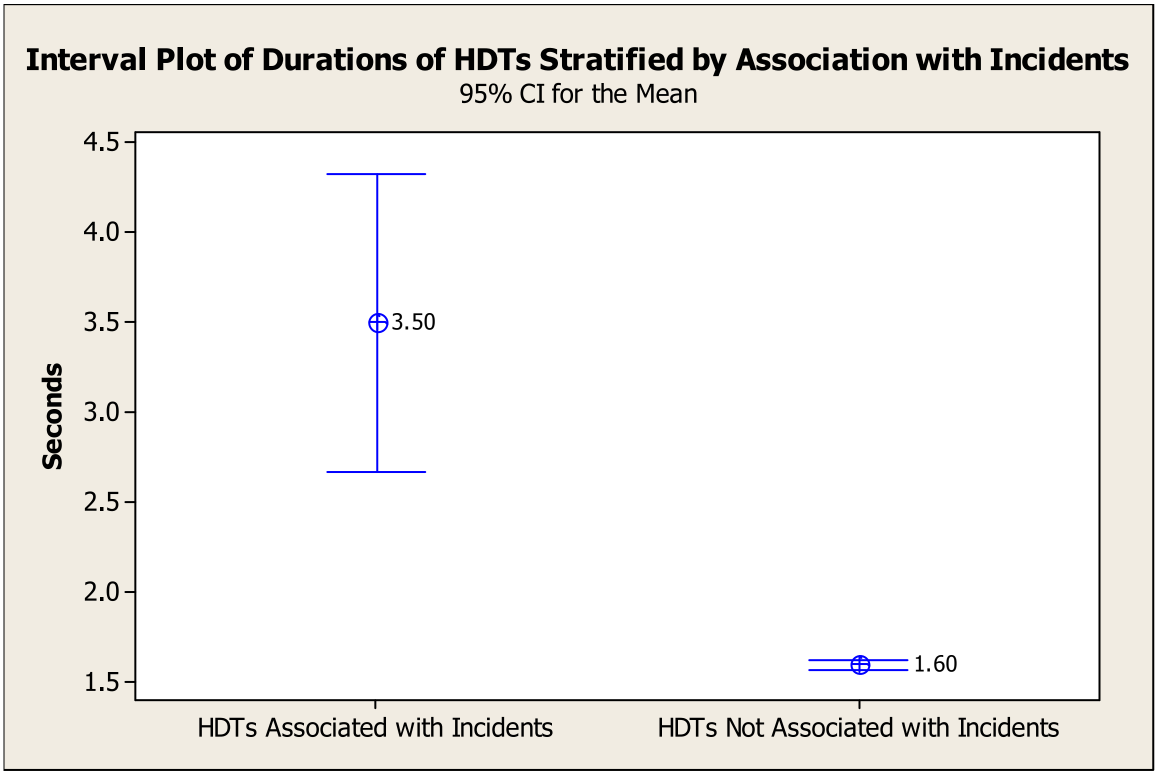

Figure 11. Interval plot of durations of those HDTs associated with incidents compared to those HDTs not associated with incidents.

Table 31. T-test of durations of HDTs associated with incidents and durations of HDTs not associated with incidents.

Difference = mu (HDTs Associated with Incidents) - mu (HDTs Not Associated with Incidents)			
Estimate for difference:	1.901		
95% CI for difference:	(1.074, 2.728)		
T-Test of difference = 0 (vs not =):	T-Value = 4.61	P-Value = 0.000	DF = 51

These results suggest that HDT durations may have a strong relationship with observed critical incidents. The large difference between the means of HDTs associated with incidents compared to those that were not also suggests HDTs may have a practical use to a package delivery company. If further research can establish long HDTs as a predictor of negative critical incidents, long durations of HDTs may be able to be integrated into training and evaluation programs at a low cost of money and time. The result from this test is also subject to the issue of external validity discussed in the above results. While the six drivers included in this analysis displayed a large difference between HDTs associated with critical incidents and HDTs not associated with incidents, the true population means may not be as profound. This means it may be more difficult to find a predictive value of HDT for incidents that can be generalized to all package delivery drivers due to the smaller sample size used in this analysis.

Additionally, the method of associating HDTs with incidents can be improved. This research took each incident and associated it with the closest subsequent HDT that was observed. This research used a conservative approach to associating HDTs with incidents, however it may be the case that multiple HDTs can be associated with an incident, and methods of improving how HDTs are associated with incidents would in turn improve the precision of this analysis.

CONCLUSION

This research has demonstrated that PDDs face a far more complex set of tasks when behind the wheel than would be expected for normal driving. PDDs face a complex set of observations and decisions that must be made quickly in order to comply with company policies for safety and productivity. In order to prepare trainees for performing these tasks and evaluate them for performance under time constrained and possibly high stress situations, package delivery companies have instituted rigorous training and evaluation programs for their drivers. These programs are very specific in the techniques PDDs are trained to use and evaluated on. The goal of this research was to create an objective measure that could assist in these training and evaluation procedures by contributing an unbiased, quantitative measure to the subjective assessments currently used by the package delivery company participating in the research.

This research conducted a detailed task analysis based on observations of PDDs in their normal work routines in order to understand these complex tasks. All tasks which PDDs were observed to perform were recorded, and a framework was created toward understanding this system of tasks based on the three types of tasks that drivers were observed to perform. These three types were job-related tasks, driving tasks without physical interaction with the vehicle, and driving tasks requiring physical interaction with the vehicle. The framework was then used to organize all tasks that PDDs were observed to perform into more general activities, which were goal-oriented sets of actions drivers undertake (e.g., *Turn left at 4-way stop*, *Turn right at signal light*). Using these goal oriented sets of actions, it was then demonstrated how these detailed activities could be used in designing training modules for new PDDs. This framework and series of activities were applied to a group of driving situations that together were designed as a training module for new drivers. It was demonstrated that these situations could be clarified and enriched through application of the framework and activities generated by the task analysis by providing information on exactly what activities, tasks, subtasks, and interactions between them are required to be performed in a given situation. Additionally, it was demonstrated that the framework and activities could be used to clarify and enrich the evaluation procedures for new and existing drivers. The framework and activities were applied to an evaluation checklist which described items for which a PDD could be graded based on a point system. By applying the framework and activities generated from the task analysis performed in this study, suggestions were made to clarify items identified as unclear so as to improve the precision of the evaluations.

Beyond these examples, the framework and activities are directly applicable in other manners as well. Rather than scripting larger, more complex situations for training purposes, package delivery companies may be able to script the activities directly and piece them together as necessary to form the larger, job-oriented situations. Additionally, the framework may be useful to PDDs, supervisors or managers who want to better understand a unique situation that is present on a current route. Driving is a very complex task and there are many situations where a PDD or evaluator, even an experienced one, may be presented with circumstances that have never been encountered before. The framework may provide a means with which to systematically analyze the situation and understand tasks that which are appropriate for the circumstances.

Information was gathered on all of the critical incidents that were observed while PDDs were behind the wheel of a package car. This information demonstrated that breakdowns were occurring within the tasks PDDs performed, and that improved methods of training and evaluations may be needed as a result. The incidents were stratified according to experience and type of route, and a statistical analysis was performed in order to evaluate overall experience of PDDs and on-route experience of PDDs for possible differences in observed incidents. These results of these tests did not show a significant difference between these two stratifications. However, as stated previously a relatively small sample size was used in this research, and a broader sample of PDDs may provide more insight into the issue. If a broader sample of PDDs can demonstrate a significant difference between experience levels, it may be possible for a package delivery company to customize training techniques for new PDD and evaluation techniques for all PDD. For example, if particular incidents could be shown as more frequently observed in inexperienced PDDs when compared to experienced PDDs, training programs could put extra emphasis on training to prevent them. Likewise, if particular incidents could be shown as more frequently observed in a particular experience level of PDD or a particular route type, evaluation procedures (such as point values on a grading sheet) could be customized to fit the experience level and type of route in the evaluation, respectively.

The construct of HDT was evaluated for its ability to differentiate levels of experience within PDDs, its relationship to types of route on which PDDs deliver, and its relationship to the driving related critical incidents that were observed. HDTs were shown to be statistically different across levels of experience, but as mentioned above this difference must be put in the proper context. While HDT was shown through statistical analysis to differentiate between inexperienced and experienced PDDs, that difference may not be significant in the context of actual performance. Inexperienced PDDs averaged 1.18s duration for HDTs, while experienced PDDs averaged 1.25s duration for HDTs; a difference of only .07s. When analysis was done across HDTs associated with and without incidents, those associated with incidents averaged 3.50s while those not associated with incidents averaged 1.60s, a difference of 1.90s. Despite the statistically significance between inexperienced and experienced PDDs in this analysis, when compared to the averages in the incident analysis (which could be considered one measure of performance) the difference of .07s does not seem to be meaningful as an indicator of incidents. Given the large amounts of data that may be needed in order to conclude which group a PDD belongs to, that comparing incidents across experience levels did not provide evidence for a difference between the groups, and that the .07s difference does not appear to indicate increased incidents, the difference between inexperienced and experienced PDDs' HDT durations may have limited practical implications for a package delivery company. While .07s is certainly significant in terms of signal detection and reaction in a moving vehicle (e.g. improved stop distance), this is a statement about HDT's effect on a PDD's reaction *given* an incident occurs, not its effect on the occurrences of incidents in the first place. It is therefore recommended that future research focus on the effects of HDT duration on other factors *given* an incident. This could be done with a simulator in which the incident is controlled, or using telemetrics to capture data in a similar field study where an incident is observed. From a system safety perspective it is most desirable to prevent incidents, however driver experience seems not to have an effect on the occurrence of incidents, and the difference in HDT duration seems most applicable in the possible mitigation of incidents by experienced PDDs.

The next analysis involved comparing HDT durations across the types of route observed in this research. The average durations of HDTs were 1.72s, 1.55, 1.31s, and 1.70s for commercial, residential, rural, and urban route types, respectively. Statistical analysis showed the rural route type to be significantly different from all other types. Additionally, it indicated that the residential route type may be significantly different from the commercial and urban types as well. Finally, it showed no significant difference between urban and commercial route types. Again, when compared to an average of 1.60s for HDTs not associated with incidents and 3.50s for HDTs associated with incidents, these results do not seem to indicate particular route types will have increased incidents. However, the fact that routes were significantly different from each other may still be of use to package delivery companies. The differences in HDT duration between route types may be indicative of how much visual attention they require away from the forward view. In this light, the differences between route types may be useful to package delivery companies in deciding where to conduct training and evaluations. For example, if a package delivery company wishes to train a new PDD on a route that requires the least visual attention away from the primary tasks (perhaps for a brand new trainee), these results suggest that a rural or possibly residential route may accomplish this goal. On the other hand, if an evaluator wants to evaluate a PDD on the route type with the most visual attention away from the forward view (perhaps to evaluate the PDD in the circumstances with the most possible sources of error and/or stress), these results suggest that an urban or commercial route may accomplish this goal.

The final analysis involved comparing the durations of HDTs associated with incidents to those not associated with incidents. This analysis found a statistically significant difference between them, with HDTs not associated with incidents averaging 1.60s and HDTs associated with incidents averaging 3.50s. The magnitude of this difference may allow for useful, practical applications of the result. Further research is required in order to better establish the durations of HDTs associated with incidents and be allow these durations to be generalized to all PDDs. However, if the actual difference is as profound as the results of this study, it could be directly applied to the training and evaluation techniques of package delivery companies. A package delivery company could use a value of HDT in which research shows the chance of an incident is greatly increased and insert it directly into the evaluation forms with a point value. This would provide an objective basis for evaluating the basic visual strategies of the PDD to supplement the subjective assessments of the evaluators. Additionally, new trainees could be taught during training how such long durations of HDT are associated with incidents and instruction on HDT durations can be integrated into training that occurs behind the wheel.

There are many aspects of this research that have the potential to improve training and evaluation methods of package delivery companies. However, the limitations of this research must again be made clear. This research collected data from one workday among a small sample of PDDs. While further research must be done in order to corroborate these results and generalize them to larger populations of PDDs, and possibly even other types of delivery driver, the results indicate that there may be important practical benefits to exploring the construct of HDT and how it can be implemented within training and evaluation procedures.

FUTURE RESEARCH

Additional study of the HDT construct and the behaviors of package delivery drivers could prove invaluable to companies that employ professional drivers. If HDTs prove useful in the area of package delivery, it may also prove useful in other professional driving arenas such as freight drivers, public transportation drivers, or even professional race drivers. The important distinction is that HDT is not a measure of time spent away from the forward view in general, but of time spent away from the forward view each time the driver moves his/her eyes away. In this regard, HDT may be useful both with respect to evaluating a driver for how long he/she spends on individual saccades away from the forward view gathering information, but also for evaluating environments for how much information they contain away from the forward view.

Additional research in this area must focus first on addressing the issues of external validity in testing HDTs addressed in previous sections. A wider study involving a large number and greater variety of drivers in terms of age, experience, route type, ethnicity, gender, and safety record within the company is required to be able to truly examine the relationships this study suggests. Additionally, objective criteria to differentiate routes would be better able to assess HDTs across different types. These criteria could include the total number of stops per period of time, the distance traveled per period of time, the number of packages per stop, or other measures.

The method of associating HDTs with incidents can also be refined in future research. Additional research may be able to determine methods of objectively eliminating HDTs that are not associated with incidents from analysis. Such research may be able to determine an upper limit, a period of time after an HDT in which if no incident was observed, it should not be associated with any incidents (i.e. if enough time passes after an HDT, it wouldn't be reasonable to associate it with an incident). Such research may also be able to integrate the time between an HDT and subsequent incident into the analysis. For example, an HDT associated with an incident could be recorded as 4 seconds in duration with 2 seconds until incident onset. This would allow both the time until onset and the interaction of HDT duration and time to onset to be analyzed.

As mentioned above there are other ways in which HDT may be applied to package delivery driving. This research focused on looking at the occurrence of incidents, but future research can explore the effects of HDT *given* and incident. These effects could be reaction time, stopping distance, follow distance, angle of the steering wheel, or any other metric which allows conclusions about the situation before the incident and how the driver reacted to the incident. The results of the experience analysis support this approach to HDT, as the significant difference in HDT durations between levels of experience may contribute to these metrics of how drivers react.

Another area where further study is merited is the duration of HDTs associated with incidents. As described above, if a particular duration of HDT can be demonstrated as a point where the occurrence of incidents begins to increase sharply, this duration would have immense value to a package delivery company. In order to get such a value a broad study of HDTs and incidents must be conducted with the ability to generalize the results to all PDDs. Additionally, the types of incidents could be separated for individual analysis. If an HDT duration exists which indicates an increased chance of incident occurrence, it may be different for each particular type of incident. In this manner the most conservative of the values across all incident types could be used by a company for training and evaluation purposes.

Additional research can also focus on applying the task analysis and concept of HDT to other aspects of package delivery driving or other driving professions entirely. One possibility is applying the concept of HDT to evaluate head-up displays (HUD) for vehicles. These displays integrate additional information into the forward view, and with more precise tools for measuring eye movements (such as those realizable with eye-tracking devices), HDT may be a useful means with which to evaluate such devices. Another possibility is the applicability of the task analysis to other professional drivers. Freight drivers and many public and private transportation drivers (i.e. taxi drivers, bus drivers) may share many aspects of their work with PDDs. For example, they likely have detailed safety procedures, they may have timing and scheduling concerns that must be considered concurrently with the driving task, and they may encounter unfamiliar environments in which they need to continue performing secondary tasks while they are uncertain about the primary task of driving. Further research could use the task analysis presented here as a starting point for analyzing the jobs of these other professional drivers.

Finally, the concept of HDTs may be useful outside of the realm of driving altogether. There are many other jobs in which an operator must gather and use information from a primary display and a secondary display, and use this information in the operation of controls. Examples include flying an airplane, multi-display safety and security systems that require human observation (e.g., nuclear power stations), and the interfaces of portable devices such as cell phones. HDT analysis may provide a useful method of evaluation in these fields when there is a context of a primary task and secondary tasks.

REFERENCES

American Psychological Association. (2004). *APA Dictionary of Psychology* (Van den Bos, G. R. Ed.). Washington DC.

Barbera, T., Horst, J., Schlenoff, C., Aha, D. (2004). Task Analysis of Autonomous On-road Driving. In *Proceedings of SPIE Vol. 5609*, pp. 61-72.

Baumann, M., Keinath, A., Krems, J., Bengler, K. (2004). Evaluation of in-vehicle HMI using occlusion techniques: experimental results and practical implications. *Applied Ergonomics* 35, pp. 197-205.

Chapanis, A. (1996). *Human Factors in Systems Engineering*. New York: John Wiley & Sons Inc.

Drury, C., Paramore, B., Van Cott, H., Grey, S., and Corlett, E. (1987). Task Analysis. In G. Salvendy (ed.), *Handbook of human factors*. New York: Wiley.

Godthelp, H., Milgram, P., Blaauw, G. (1984). The Development of a Time-Related Measure to Describe Driving Strategy. *Human Factors* 26(3), pp. 257-268.

Flanagan, J. (1954). The Critical Incident Technique. *Psychological Bulletin* 51(4), pp. 327-358.

Hildreth, E., Beusmans, J., Boer, E., Royden, C. (2000). From Vision to Action: Experiments and Models of Steering Control During Driving. *Journal of Experimental Psychology* 26(3), pp. 1106-1132.

Lancaster, J. (2004). Investigating Pilot Performance Using Mixed Modality Simulated Data Link. Unpublished doctoral dissertation, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Lansdown, T. (2002). Individual differences during driver secondary task performance: verbal protocol and visual allocation findings. *Accident Analysis and Prevention* 34, 655-662.

Lansdown, T., Burns, P., Parkes, A. (2004). Perspectives on occlusion and requirements for validation. *Applied Ergonomics* 35, pp. 225-232.

Levy, J., Pashler, H., Boer, E. (2006). Central Interference in Driving: Is There Any Stopping the Psychological Refractory Period? *Psychological Science* 17(3), pp. 228-235.

O'Hare, D., Wiggins, M., Williams, A., Wong, W. (1998) Cognitive task analyses for decision centered design and training. *Ergonomics* 41(11), pp. 1698-1718.

Noy, Y.I., Lemoine, T., Klachan, C., Burns, P. (2004). Task interruptability and duration as measures of visual distraction. *Applied Ergonomics* 35, pp. 207-213.

Robinson, G. S., Casali, J. G., and Lee, S. E., Role of driver hearing in commercial motor vehicle operations: An evaluation of the FHWA hearing requirement. Final Report. Virginia Polytechnic Institute and State University, Department of Industrial and Systems Engineering, Technical Report Number 9703 (Audio Lab Number 9/1/97-5-HP), September, 1997. (278 pgs) (FHWA contractor's final report)

Senders, J.W., Kristofferson, A.B., Levison, W.H., Dietrich, C.W., Ward, J.L. (1967). The Attentional Demand of Automobile Driving. In *46th Annual Meeting of Committee on Highway Safety*, pp. 15-33.

Shepherd, A. (1998). HTA as a framework for task analysis. *Ergonomics* 41(11), pp. 1537 - 1552

Strayer, D., Johnston, W. (2001) Driven to Distraction: Dual-Task Studies of Simulated Driving and Conversing on a Cellular Phone. *Psychological Science* 12(6), pp. 462-466.

Strayer, D., Drews, F., Johnston, W. (2003). Cell Phone-Induced Failures of Visual Attention During Simulated Driving. *Journal of Experimental Psychology* 9(1), pp. 23-32.

Stutts, J., Feaganes, J., Reinfurt, D., Rodgman, E., Hamlett, C., Gish, K., Staplin, L. (2005). Driver's exposure to distractions in their natural driving environment. *Accident Analysis and Prevention* 37, pp. 1093-1101.

Van der Horst, R. (2004). Occlusion as a measure for visual workload: and overview of TNO occlusion research in car driving. *Applied Ergonomics* 35, pp. 189-196.

Ward, P., Hancock, P.A., Ganey, H.C.N., Szalma, J.L. (2003). Naturalistic Driving: User and Task Analysis. In *Proceedings of the Second International Driving Symposium on Human Factors in Driving Assessment, Training, and Vehicle Design*, pp. 70-72.

Wickens, C., Hollands, J.G. (2000). *Engineering Psychology and Human Performance*. New Jersey: Prentice-Hall Inc.

Wickens, C., Lee, J., Liu, Y., Becker, S. (2004). *An Introduction to Human Factors Engineering Second Edition*. New Jersey: Pearson Education, Inc.

APPENDIX A

Informed Consent Form

Informed Consent Form
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed consent form for participants of Research Project Involving Human Subject

Title of the Project: Driver Service Provider (DSP) Training System: Ride-Alongs

Investigators: Drs. Tonya Smith-Jackson, Thurmon Lockhart, Brian Kleiner, Maury Nussbaum, Woodrow Winchester, John Casali, Jeff Lancaster
Graduate Research Assistants: Yoon Suk Lee, Will Lee, Kevin Grove, Prakriti Parijat, Jung Yong Lee

I. The Purpose of this Research/Project
The purpose of this study is to acquire information on package delivery and pick-up behaviors of DSPs. We are not evaluating you, but are only interested in observing how you do your work each day. We are not here to report you or provide direct data on your specific behavior by name to your employer. All data we share with UPS will be summarized so that no one person is identifiable.

II. Procedures
If you choose to participate in this study, we will ask you to complete one informed consent document. We will ride along with you through most or all of your day today, and will interrupt once in awhile to ask questions to understand what you are doing and why. We will be videotaping at different points in time to capture some of your behaviors. This data will be used for our research purposes, that is, to improve the design of training systems for UPS drivers.

III. Risks
Risks to you for participating in this study are minimal. The only identifiable loss is related to the inconvenience that may be introduced by our presence in the vehicle. We will make every effort to avoid interfering with your work. Actual participation in this study will not likely cause any harm.

IV. Benefits of the Project
You will probably not gain any direct benefits as a result of your participation, but you have the knowledge of having benefited DSPs at UPS.

V. Extent of Anonymity and Confidentiality
We assure confidentiality to all participants of the study. However, anonymity can not be guarantee, because we will need to have your signatures on the Informed Consent document. However, this document will be kept in a locked cabinet for 5 years and your name will not be associated with the content of this observation, but you will be assigned a three-digit number to protect your privacy. Your number is _____.

All data will be collected by the researchers only. No one other than the researchers will have access to the data. All responses will be coded so as not to include the name of the participant. The information you provide will have your name removed and only a three-digit participant number will identify you during analyses and any written reports of the research.

This study is being conducted solely for educational purposes and the resulting data and interpretations will also be the part of the researcher's academic work. Consistent with these academic processes, any results would be freely publishable after review by UPS. However, to protect your identity, neither personal nor institutional names nor UPS site names or distinguishing information will be used in any published works. We are willing to share drafts of reports with you before submitting them for publication.

VI. Compensation
There is no compensation for participating in this study.

VII. Freedom to Withdraw
Participation in the study is voluntary and the decision about whether you wish to participate is strictly your own. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled. Withdrawal from the study will not result in any adverse effects.

VIII. Approval of Research
This research project has been approved by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University and by the Department of Industrial and Systems Engineering (College of Engineering).

____________________ ____________________
IRB Approval Date IRB Expiration Date

IX. Participant's Responsibilities
Upon signing this form below, I voluntarily agree to participate in this study. I have no restriction to my participation in this study.

X. Participant's Permission

I have read and understood the Informed Consent and conditions of this study. All of my questions have been answered. I agree to participate in this project.

____________________________ ____________________
Participant's Signature Date

Should I have any questions about the research or its conduct, I may contact:

Dr. Tonya Smith-Jackson Email: smithjack@vt.edu Phone: (540) 231-4991

Dr. David Moore, Email: moored@vt.edu Phone: (540) 231-4991
Chair, IRB

APPENDIX B

Initial Task List for Observation

Traffic Incidents	Count														
Improper or lack of seatbelt use															
Incorrect shifting of gears															
Failed to make eye contact with driver on road where needed															
Collision with curb while turning vehicle															
Improper use of turn signal															
Turn signal not used where required															
Driving through an intersection with a yellow light															
Driving through an intersection with a red light															
Failure to stop at a stop sign															
Failure to stop at a railroad crossing															
Exceeding speed limit															
Exceeding lane while moving															
Exceeding lane at a stop															
Exceeding intersection at a stop															
Failure to use parking break when stopped on a steep hill															
Forgetting to disengage parking break															
Forgetting to hold down break while disengaging parking break															
Changing lane without proper clearance															
Driving too close to behind a vehicle															
Using diad while in motion															
Using phone while in motion															
Improperly using other device while in motion															
Package left in cab while in motion															
Cargo door left open while in motion															
Incorrect turn was made															
Appropriate mirrors not checked while driving															
Sign of fatigue while driving															
Eye gaze while driving															
Noticable distraction while driving															

Stopping Incidents	Count														
Improper or lack of seatbelt use															
Incorrect shifting of gears															
Horn not used where required															
Failed to make eye contact with driver in parking lot															
Failed to make eye contact with pedestrian in parking lot															
Failed to make eye contact with driver while parallel parking															
Failed to make eye contact with pedestrian while parallel parking															
Collision with curb while turning vehicle															
Camera not used when backing up															
Appropriate mirrors not checked when backing up															
Appropriate mirrors not checked when parallel parking															
Unsafe speed in parking lot															
Unsafe clearance in parking lot															
Collision with object in parking lot															
Stopped at unsafe distance when parallel parking for delivery															
Stopped at unsafe speed when parallel parking for delivery															
Stopped at incorrect address															
Using diad while in motion															
Using phone while in motion															
Improperly using other device while in motion															
Package left in cab while in motion															
Cargo door left open while in motion															
Improper or lack of turn signal use															
Sign of fatigue while parking															
Sign of fatigue while leaving															
Eye gaze while parking															
Eye gaze while leaving															
Noticeable distraction while parking															
Noticeable distraction while leaving															

Truck Incidents	Count														
Improper or lack of seatbelt use															
Cargo door left open while driver out of vehicle															
Engine left running at a delivery															
Parking break not engaged at a delivery															
Keys left in ignition at a business delivery															
Keys left in ignition at a residential delivery															
Keys left in ignition at an apartment delivery															
Keys left in cargo door at a business delivery															
Keys left in cargo door at a residential delivery															
Keys left in cargo door at an apartment delivery															
Keys left in other unacceptable location at a delivery															
Proper contact not used when exiting vehicle															
Forgetting to disengage parking break															
Forgetting to hold down break while disengaging parking break															
Four way flashers not engaged where appropriate															

APPENDIX C

Survey and Interview Informed Consent Form

Informed Consent

Informed consent form
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed consent form for participants of Research Project Involving Human Subject

Title of the Project: Driver Service Provider (DSP) Training System: Focus Groups

Investigators: Dr. John Casali, Dr. Jeff Lancaster
Graduate Research Assistant: Kevin Grove

I. **The Purpose of this Research/Project**

The purpose of this study is to acquire information on your thoughts about training for DSPs. We are not evaluating you, but are only interested in understanding your thoughts about the training you received and getting additional information on ways to improve the training. We are not here to report you or provide direct data on your specific behavior by name to your employer. All data we share with UPS will be summarized so that no one person is identifiable.

II. **Procedures**

If you choose to participate in this study, we will ask you to sign one informed consent document (this document). You will keep a copy for yourself. We will then ask you to complete a demographic form, which helps us to categorize our data to make comparisons as needed. We will audiotape this session, so please do not refer to each other by name. You will be given a participant number on a card to be placed in front of you for the other members of this focus group to see. We will refer to you by that number. This data will be used for our research purposes, that is, to improve the design of training systems for UPS drivers. We will then ask you to review some of the ideas we have regarding a new way to train DSPs. We would like to get your honest and direct feedback about what will or will not work. This entire meeting will last no more than 25 minutes.

III. **Risks**

Risks to you for participating in this study are minimal. The only identifiable loss is related to the inconvenience that may be introduced by taking time out of your schedule to participate. We will make every effort to avoid interfering with your work, and will stick to the agreed-upon time schedule. Actual participation in this study is not likely to cause any harm.

IV. **Benefits of the Project**

You will probably not gain any direct benefits as a result of your participation, but you have the knowledge of having benefited DSPs at UPS.

V. **Extent of Anonymity and Confidentiality**
We assure confidentiality to all participants of the study. However, anonymity can not be guaranteed, because we will need to have your signatures on the Informed Consent document. However, this document will be kept in a locked cabinet for 5 years and your name will not be released. At the end of the 5-year period, we will destroy the documents. Your name will not be associated with the content of this observation, but you will be assigned a three- digit number to protect your privacy. Your number is ____. Your employer will not be given any information that matches your name to what is reported in this focus group.

All data will be collected by the researchers only. No one other than the researchers will have access to the data, unless it is aggregated first. We will use digital audio recorders so we can analyze your feedback later. This is important so we don't miss critical information. You will be given a card with a 3-digit number. We ask that you refer to yourself by this 3-digit number and please do not refer to any other participants by name. All responses will be coded so as not to include the name of the participant. The information you provide will have your name removed and only a three- digit participant number will identify you during analyses and any written reports of the research.

This study is being conducted solely for research and development purposes, and the resulting data and interpretations will also be the part of the researcher's academic work. Consistent with these academic purposes, any results would be freely publishable after review by UPS. However, to protect your identity, neither personal nor institutional names nor UPS site names or distinguishing information will be used in any published works. We are willing to share drafts of reports with you before submitting them for publication.

VI. **Compensation**
There is no compensation for participating in this study.

VII. **Freedom to Withdraw**
Participation in the study is voluntary and the decision about whether you wish to participate is strictly your own. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled. Withdrawal from the study will not result in any adverse effects.

VIII. **Approval of Research**
This research project has been approved by the Institutional Review Board for Research Involving Human Subjects at Virginia Polytechnic Institute and State University and by the Department of Industrial and Systems Engineering (College of Engineering).

____

____
IRB Approval Date
IRB Expiration Date

IX. **Participant's Responsibilities**

Upon signing this form below, I voluntarily agree to participate in this study. I have no restrictions to my participation in this study.

X. **Participant's Permission**

I have read and understand the Informed Consent and conditions of this study. I understand that the discussions will be audiotape to support data recording. All of my questions have been answered. I agree to participate in this project.

_____________________________ _____________________

Participant's Signature Date

Should I have any questions about the research or its conduct, I may contact:

Dr. Tonya Smith- Jackson Email:smithjack@vt.edu Phone: (540) 231-4991

Dr. David M. Moore, Email : moored@vt.edu Phone: (540) 231-4991
Chair, IRB

APPENDIX D

Survey Task Analysis Questions

UPS driver service provider (DSP) questionnaire

For the items below, please mark or fill in your responses to the best of your ability. All responses are kept confidential, and are completely anonymous.

1. Are you familiar with the **Space & Visibility** guidelines?

   a. Yes.
   b. No.

2. Do you feel that you know the **Space and Visibility** guidelines well enough that you could teach them to a trainee?

   a. Yes.
   b. No.

3. Are you familiar with the **HABITS** guidelines?
   a. Yes.
   b. No.

4. Do you feel that you know the **HABITS** guidelines well enough that you could teach them to a trainee?

   a. Yes.
   b. No.

5. On average, how much time do you spend planning your day in the morning before you leave the facility?

   a. None
   b. Less than 5 minutes
   c. 5 – 10 minutes
   d. 10 – 20 minutes
   e. 20 – 30 minutes
   f. More than 30 minutes

6. On average, how many packages per day do you find loaded out of place on your vehicle after you leave?

   a. None
   b. 1-2
   c. 3-4
   d. 5-8
   e. More than 8

7. On average, how many packages per day do you find on your vehicle that should not be on your vehicle or are missing from your vehicle?

   a. None
   b. 1-2
   c. 3-4
   d. 5-8
   e. More than 8

8. In general, do you feel more comfortable driving your vehicle on rural roads or urban roads?

   a. Rural
   b. Urban
   c. Little or no difference

9. Based on your experience, do you believe that there are any guidelines that are **especially important** to your work as a DSP? If so, please describe them below.

   ____
   ____
   ____

10. Based on your experience, do you believe there are any guidelines that are **difficult to remember** in certain situations in your work as a DSP? If so, please describe them below.

   ____
   ____
   ____

11. Name one thing that you have learned in the performance of your duties as a DSP that was <u>not covered in your DSP training</u> (you are free to list as many as you like):

   ____
   ____
   ____

12. If you could change or add one thing to your DSP training to make it <u>more effective or useful</u>, what would it be (please describe)?

   ____
   ____
   ____

On a scale of 1-7, please answer the following based on any training you received when first becoming a DSP.							
	Please mark your answers in the boxes below						
	Not at all 1	2	3	4	5	6	Completely 7
13. How well do you feel training prepared you for using the DIAD in your everyday responsiblities as a DSP?							
14. How well do you feel training prepared you for driving the UPS truck in your everyday responsiblities as a DSP?							
15. How well do you feel training taught you how to use the Space and Visibility techniques in your everyday responsibilities as a DSP?							
16. How well do you feel training prepared you for handling packages in your everyday responsiblities as a DSP?							
17. How well do you feel training taught you to use the HABITS principals in your everyday responsibilities as a DSP?							
18. How much do you feel that your instructor(s) had a personal interest in making you a successful DSP?							
19. How confident do you think you were after training that you could begin the responsibilities of a DSP?							
20. How ready do you think you <u>actually</u> were after training to begin the responsibilities of a DSP?							

On a scale of 1-7, please answer the following based on your personal experience as a DSP.							
	Please mark your answers in the boxes below						
	None 1	2	3	4	5	6	Completely 7
21. To what degree do you feel using the DIAD while driving distracts you as a driver?							
22. To what degree do you feel using a cell phone while driving distracts you as a driver?							
23. To what degree do you feel reading package labels while driving distracts you as a driver?							
24. To what degree do you feel checking building addresses while driving distracts you as a driver?							
25. To what degree do you feel checking street signs while driving distracts you as a driver?							

APPENDIX E

Activities with Associated Tasks and Physical Subtasks

Merging / Lane Shift

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Evaluate traffic density	Look at left mirror
Evaluate traffic speed	Look at right mirror
Check left mirror	Look over left shoulder
Check right mirror	
Read and comprehend road signs	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Maintain speed	Manipulate clutch
Switch lanes left	Manipulate gear shift
Switch lanes right	Manipulate steering wheel
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate turn signal
	Manipulate horn

Turn Right

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Check right mirror	Look at right mirror
Read and comprehend road signs	
Judge distance to right curb	
Check right intersection for pedestrians	
Check right intersection for motorists	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Turn right	Manipulate clutch
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate gear shift
	Manipulate steering wheel
	Manipulate turn signal
	Manipulate horn

Turn Left on 1-way Road

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Check left mirror	Look at left mirror
Read and comprehend road signs	
Judge distance to left curb	
Check left intersection for pedestrians	
Check left intersection for motorists	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Turn left	Manipulate clutch
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate gear shift
	Manipulate steering wheel
	Manipulate turn signal
	Manipulate horn

Turn Left on 2-way Road

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Evaluate traffic density	
Evaluate traffic speed	
Read and comprehend road signs	
Check left intersection for pedestrians	
Check left intersection for motorists	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Turn left	Manipulate clutch
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate gear shift
	Manipulate steering wheel
	Manipulate turn signal
	Manipulate horn

Turn Right at Stop Sign

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Evaluate traffic density	Look at right mirror
Evaluate traffic speed	
Check right mirror	
Read and comprehend road signs	
Judge distance to right curb	
Check left intersection for pedestrians	
Check left intersection for motorists	
Check right intersection for pedestrians	
Check right intersection for motorists	
Check forward intersection for pedestrians	
Check forward intersection for motorists	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Turn right	Manipulate clutch
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate gear shift
	Manipulate steering wheel
	Manipulate turn signal
	Manipulate horn

Turn Left at Stop Sign on 1-way Road or "T" intersection

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Evaluate traffic density	
Evaluate traffic speed	
Read and comprehend road signs	
Judge distance to left curb	
Check left intersection for pedestrians	
Check left intersection for motorists	
Check right intersection for pedestrians	
Check right intersection for motorists	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Turn left	Manipulate clutch
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate gear shift
	Manipulate steering wheel
	Manipulate turn signal
	Manipulate horn

Turn Left at Stop Sign on 2-way Road

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Evaluate traffic density	Look at left mirror
Evaluate traffic speed	
Check left mirror	
Read and comprehend road signs	
Judge distance to left curb	
Check left intersection for pedestrians	
Check left intersection for motorists	
Check right intersection for pedestrians	
Check right intersection for motorists	
Check forward intersection for pedestrians	
Check forward intersection for motorists	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Turn left	Manipulate clutch
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate gear shift
	Manipulate steering wheel
	Manipulate turn signal
	Manipulate horn

Proceed Straight at Stop Sign

<u>Cognitive Only Job Tasks</u>
Know approximate time
Know location of next stop
Know location of future stops

<u>Associated Physical Sub-Tasks</u>
Check addresses of current location
Check DIAD
Check time
Check map

<u>Cognitive Only Driving Tasks</u>
Judge follow distance of own vehicle
Judge follow distance of vehicle in front
Scan for threats at proper eye lead distance
Evaluate traffic density
Evaluate traffic speed
Read and comprehend road signs
Check left intersection for pedestrians
Check left intersection for motorists
Check right intersection for pedestrians
Check right intersection for motorists
Check forward intersection for pedestrians
Check forward intersection for motorists

<u>Associated Physical Sub-Tasks</u>
Look forward
Look left
Look right

<u>Cognitive/Physical Driving Tasks</u>
Accelerate
Decelerate
Maintain bearing in center of lane
Alert others to intentions (turn signal, 4-way, horn, etc)

<u>Associated Physical Sub-Tasks</u>
Manipulate gas pedal
Manipulate brake pedal
Manipulate clutch
Manipulate gear shift
Manipulate steering wheel
Manipulate horn

Turn Right at 4-way Stop

Cognitive Only Job Tasks
Know approximate time
Know location of next stop
Know location of future stops

Associated Physical Sub-Tasks
None

Cognitive Only Driving Tasks
Judge follow distance of own vehicle
Judge follow distance of vehicle in front
Scan for threats at proper eye lead distance
Check right mirror
Read and comprehend road signs
Judge distance to right curb
Check left intersection for pedestrians
Check left intersection for motorists
Check right intersection for pedestrians
Check right intersection for motorists
Check forward intersection for pedestrians
Check forward intersection for motorists

Associated Physical Sub-Tasks
Look forward
Look left
Look right
Look at right mirror

Cognitive/Physical Driving Tasks
Accelerate
Decelerate
Turn right
Alert others to intentions (turn signal, 4-way, horn, etc)

Associated Physical Sub-Tasks
Manipulate gas pedal
Manipulate brake pedal
Manipulate clutch
Manipulate gear shift
Manipulate steering wheel
Manipulate turn signal
Manipulate horn

Turn Left at 4-way Stop

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Read and comprehend road signs	
Check left intersection for pedestrians	
Check left intersection for motorists	
Check right intersection for pedestrians	
Check right intersection for motorists	
Check forward intersection for pedestrians	
Check forward intersection for motorists	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Turn left	Manipulate clutch
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate gear shift
	Manipulate steering wheel
	Manipulate turn signal
	Manipulate horn

Proceed Straight at 4-way Stop

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Read and comprehend road signs	
Check left intersection for pedestrians	
Check left intersection for motorists	
Check right intersection for pedestrians	
Check right intersection for motorists	
Check forward intersection for pedestrians	
Check forward intersection for motorists	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Maintain bearing in center of lane	Manipulate clutch
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate gear shift
	Manipulate steering wheel
	Manipulate horn

Turn Right at Signal Light

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Check right mirror	Look at right mirror
Read and comprehend road signs	
Judge distance to right curb	
Check left intersection for pedestrians	
Check left intersection for motorists	
Check right intersection for pedestrians	
Check right intersection for motorists	
Check forward intersection for pedestrians	
Check forward intersection for motorists	
Evaluate signal light	
Judge decision point for a stop at a signal light	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Turn right	Manipulate clutch
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate gear shift
	Manipulate steering wheel
	Manipulate turn signal
	Manipulate horn

Turn Left at Signal Light on 1-way Road

Cognitive Only Job Tasks
Know approximate time
Know location of next stop
Know location of future stops

Associated Physical Sub-Tasks
None

Cognitive Only Driving Tasks
Judge follow distance of own vehicle
Judge follow distance of vehicle in front
Scan for threats at proper eye lead distance
Check left mirror
Read and comprehend road signs
Check left intersection for pedestrians
Check left intersection for motorists
Check right intersection for pedestrians
Check right intersection for motorists
Check forward intersection for pedestrians
Check forward intersection for motorists
Evaluate signal light
Judge decision point for a stop at a signal light

Associated Physical Sub-Tasks
Look forward
Look left
Look right
Look at left mirror

Cognitive/Physical Driving Tasks
Accelerate
Decelerate
Turn left
Alert others to intentions (turn signal, 4-way, horn, etc)

Associated Physical Sub-Tasks
Manipulate gas pedal
Manipulate brake pedal
Manipulate clutch
Manipulate gear shift
Manipulate steering wheel
Manipulate turn signal
Manipulate horn

Turn Left at Signal Light on 2-way Road

<u>Cognitive Only Job Tasks</u>
Know approximate time
Know location of next stop
Know location of future stops

<u>Associated Physical Sub-Tasks</u>
None

<u>Cognitive Only Driving Tasks</u>
Judge follow distance of own vehicle
Judge follow distance of vehicle in front
Scan for threats at proper eye lead distance
Evaluate traffic density
Evaluate traffic speed
Read and comprehend road signs
Check left intersection for pedestrians
Check left intersection for motorists
Check right intersection for pedestrians
Check right intersection for motorists
Check forward intersection for pedestrians
Check forward intersection for motorists
Evaluate signal light
Judge decision point for a stop at a signal light

<u>Associated Physical Sub-Tasks</u>
Look forward
Look left
Look right

<u>Cognitive/Physical Driving Tasks</u>
Accelerate
Decelerate
Turn left
Alert others to intentions (turn signal, 4-way, horn, etc)

<u>Associated Physical Sub-Tasks</u>
Manipulate gas pedal
Manipulate brake pedal
Manipulate clutch
Manipulate gear shift
Manipulate steering wheel
Manipulate turn signal
Manipulate horn

Proceed Straight at Signal Light

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Read and comprehend road signs	
Check left intersection for pedestrians	
Check left intersection for motorists	
Check right intersection for pedestrians	
Check right intersection for motorists	
Check forward intersection for pedestrians	
Check forward intersection for motorists	
Evaluate signal light	
Judge decision point for a stop at a signal light	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Maintain speed	Manipulate clutch
Maintain bearing in center of lane	Manipulate gear shift
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate steering wheel
	Manipulate horn

Parking Lot Navigation

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	Check addresses of current location
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Evaluate traffic density	Look at left mirror
Evaluate traffic speed	Look at right mirror
Check left mirror	
Check right mirror	
Read and comprehend road signs	
Judge distance to right curb	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Maintain speed	Manipulate clutch
Maintain bearing in center of lane	Manipulate gear shift
Turn left	Manipulate steering wheel
Turn right	Manipulate turn signal
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate horn

Residential and Urban Maintenance

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Check speedometer	Look at left mirror
Evaluate traffic speed	Look at right mirror
Check left mirror	
Check right mirror	
Read and comprehend road signs	
Judge distance to right curb	
Check left curb for pedestrians	
Check left curb for animals	
Check right curb for pedestrians	
Check right curb for animals	
Check left intersection for pedestrians	
Check left intersection for motorists	
Check right intersection for pedestrians	
Check right intersection for motorists	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Maintain speed	Manipulate clutch
Maintain bearing in center of lane	Manipulate gear shift
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate steering wheel
	Manipulate horn

Rural Maintenance

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Check speedometer	Look at left mirror
Evaluate traffic speed	Look at right mirror
Check left mirror	
Check right mirror	
Read and comprehend road signs	
Check left curb for pedestrians	
Check left curb for animals	
Check right curb for pedestrians	
Check right curb for animals	
Check left intersection for pedestrians	
Check left intersection for motorists	
Check right intersection for pedestrians	
Check right intersection for motorists	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Maintain speed	Manipulate clutch
Maintain bearing in center of lane	Manipulate gear shift
Counter environmental conditions (wipers, headlights, etc)	Manipulate steering wheel
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate horn
	Manipulate heat
	Switch headlights on/off
	Switch high beams on/off
	Switch windshield wipers on/off

Commercial and Industrial Maintenance

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Check speedometer	Look at left mirror
Evaluate traffic speed	Look at right mirror
Check left mirror	
Check right mirror	
Read and comprehend road signs	
Check left curb for pedestrians	
Check right curb for pedestrians	
Check left intersection for pedestrians	
Check left intersection for motorists	
Check right intersection for pedestrians	
Check right intersection for motorists	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Maintain speed	Manipulate clutch
Maintain bearing in center of lane	Manipulate gear shift
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate steering wheel
	Manipulate horn

Highway Maintenance

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Check speedometer	Look at left mirror
Evaluate traffic speed	Look at right mirror
Check left mirror	
Check right mirror	
Read and comprehend road signs	
Evaluate signal light	
Judge decision point for a stop at a signal light	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Maintain speed	Manipulate clutch
Maintain bearing in center of lane	Manipulate gear shift
Counter environmental conditions (wipers, headlights, etc)	Manipulate steering wheel
	Manipulate turn signal
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate horn
	Manipulate heat
	Switch headlights on/off
	Switch windshield wipers on/off

Residential, Rural, and Urban Deliveries (No Reverse)

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	Check addresses of current location
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Check left mirror	Look at left mirror
Check right mirror	Look at right mirror
Read and comprehend road signs	
Judge distance to right curb	
Check left curb for pedestrians	
Check left curb for animals	
Check right curb for pedestrians	
Check right curb for animals	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Maintain bearing in center of lane	Manipulate clutch
Switch lanes left	Manipulate gear shift
Switch lanes right	Manipulate steering wheel
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate turn signal
	Manipulate horn
	Switch flashers on/off

Commercial and Industrial Deliveries (No Reverse)

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	Check addresses of current location
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look forward
Judge follow distance of vehicle in front	Look left
Scan for threats at proper eye lead distance	Look right
Check left mirror	Look at left mirror
Check right mirror	Look at right mirror
Read and comprehend road signs	
Judge distance to right curb	
Check left curb for pedestrians	
Check right curb for pedestrians	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Maintain bearing in center of lane	Manipulate clutch
Switch lanes left	Manipulate gear shift
Switch lanes right	Manipulate steering wheel
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate turn signal
	Manipulate horn
	Switch flashers on/off

Reverse

Cognitive Only Job Tasks	Associated Physical Sub-Tasks
Know approximate time	None
Know location of next stop	
Know location of future stops	

Cognitive Only Driving Tasks	Associated Physical Sub-Tasks
Judge follow distance of own vehicle	Look left
Judge follow distance of vehicle in front	Look right
Scan for threats at proper eye lead distance	Look at left mirror
Check left mirror	Look at right mirror
Check right mirror	Look at monitor
Check camera screen	Look over left shoulder
Judge distance to right curb	
Judge distance to left curb	
Check left curb for pedestrians	
Check left curb for animals	
Check right curb for pedestrians	
Check right curb for animals	

Cognitive/Physical Driving Tasks	Associated Physical Sub-Tasks
Accelerate	Manipulate gas pedal
Decelerate	Manipulate brake pedal
Maintain speed	Manipulate clutch
Turn left	Manipulate gear shift
Turn right	Manipulate steering wheel
Alert others to intentions (turn signal, 4-way, horn, etc)	Manipulate turn signal
	Manipulate horn
	Switch flashers on/off

Wait Time

Cognitive Only Job Tasks
Know approximate time
Know location of next stop
Know location of future stops

Associated Physical Sub-Tasks
Check addresses of current location
Check DIAD
Check time
Check map

Cognitive Only Driving Tasks
Scan for threats at proper eye lead distance
Evaluate traffic density
Evaluate traffic speed
Check left mirror
Check right mirror
Read and comprehend road signs
Check left intersection for pedestrians
Check left intersection for motorists
Check right intersection for pedestrians
Check right intersection for motorists
Check forward intersection for pedestrians
Check forward intersection for motorists
Evaluate signal light

Associated Physical Sub-Tasks
Look forward
Look left
Look right
Look at left mirror
Look at right mirror

Cognitive/Physical Driving Tasks
Maintain speed
Counter environmental conditions (wipers, headlights, etc)
Alert others to intentions (turn signal, 4-way, horn, etc)

Associated Physical Sub-Tasks
Manipulate brake pedal
Manipulate parking brake
Manipulate clutch
Manipulate gear shift
Manipulate steering wheel
Manipulate turn signal
Manipulate horn
Manipulate heat
Switch headlights on/off
Switch high beams on/off
Switch windshield wipers on/off
Switch flashers on/off