



# OHIO PORTABLE DRIVER SIMULATOR SYSTEM PILOT

Implementation of a Virtual Driving Test  
Within Ohio's Driver Licensing Workflow

A Research Brief From the Center for Injury Research and Prevention

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# EXECUTIVE SUMMARY



This research brief provides a detailed report on progress and findings for the first 14 months of the Ohio Portable Driver Simulator System (PDSS) pilot. In the pilot, the Ohio Department of Public Safety (ODPS) and the Ohio Bureau of Motor Vehicles (OBMV) implemented a previously validated virtual driving test at five Ohio licensing centers as a screener for the driver's license on-road exam.

As background, the OMBV administers 490,000 non-commercial road exams each year with a failure rate of approximately 30 percent. The highest lifetime crash risk for new drivers occurs during the first few months after receiving a license. Even during the on-road (licensing) exam, crashes with novice driver applicants occur, putting driving examiners at risk.

With bipartisan support in 2015, the Ohio legislature passed Ohio House Bill 53 to provide funding for the OBMV to use simulated driving assessments as part of the licensing process and as a safety screening.

In 2017, Children's Hospital of Philadelphia (CHOP), Diagnostic Driving, Inc., The Ohio State University, the ODPS and the OBMV collaborated to adapt the virtual driving test (VDT) for Ohio as the PDSS. The pilot evaluated PDSS' ability to meet the following goals: (1) Ease of integration into the workflow and software reliability; (2) Minimal staff management (3) Applicants' experience with it; (4) Identification of underprepared applicants without over-penalizing those who are ready to complete their on-road exam. Following are highlights from the Research Brief:



## Adaptation of a Commercially-Available Virtual Driving Test to Meet the Specifications of the OBMV

- Building on the strong evidence base for simulated assessment from CHOP and product development from Diagnostic Driving, the team supplemented the design specifications with the needs of a large motor vehicle administration; the PDSS was the result.
- The contract for development and deployment of the PDSS was delivered on time and met all specifications set by the OBMV.
- A successful User Acceptance Test allowed for a large-scale pilot to be deployed on schedule starting July 2017.
- The PDSS met the design specifications to be self-administered by license applicants, was completed within 15 minutes and was highly scalable to meet the demands of a busy licensing workflow.
- The PDSS' real-time scoring allowed for post-test results and feedback capability.
- The PDSS met the hardware specifications to be delivered on standard hardware as a Software-as-a-Service, allowing for rapid deployment and cloud-based updating.

## Pilot Design and Workflow Integration

- The PDSS was integrated into the licensing workflow for new license applicants scheduled for their initial, non-commercial on-road examination (ORE) regardless of age at five licensing centers.
- License applicants were administered the PDSS immediately before their scheduled and initial ORE at selected OBMV pilot exam centers.
- To not influence ORE results, all applicants and driving examiners were blinded to the PDSS results.
- All applicants took their ORE after taking the PDSS so that the scoring algorithm could be developed.
- The first 4,643 PDSS tests administered were linked with manually-transcribed ORE score sheets to identify those who would fail in order to develop a reliable scoring algorithm.

## Pilot Results

- The PDSS was highly scalable and easily expanded to a total of five exam facilities during the pilot.
- During the initial 14-month pilot period, approximately 20,000 PDSS tests were administered. Continuation of the pilot period ending in September 2019 resulted in an additional 20,000 PDSS tests completed for a total of 40,000 at the time of this report, and PDSS tests continue to be administered.
- Examiners and license applicants positively rated the PDSS as easy to use and incorporate into the licensing workflow.
- The technology was found to be reliable: <1 non-critical events per 1,000 PDSS tests administered and 0 critical events over nearly 4,500 hours of cumulative service time.
- The PDSS accurately detected underprepared applicants:
  - Those who failed the PDSS were more than four times more likely to fail their ORE than those who passed the PDSS.
  - The PDSS scoring algorithm had an overall accuracy of 80 percent to predict an applicant's initial ORE result (either pass or fail).
  - Among those who failed, accuracy was higher: 90 percent of applicants who failed the PDSS also failed their initial ORE.
  - Less than 1 percent of all applicants failed the PDSS and passed their initial ORE.
- Key PDSS performance errors were identified to be highly predictive of failing the ORE.

## Implications

- Based on the current scoring algorithm results and assuming that the PDSS is operationalized statewide as a pre-screener to identify those who would go on to fail the ORE, the authors project significant positive outcomes for the OBMV in the focus areas of operational efficiency, customer service and examiner safety.
- In addition, applicants would receive personalized and automated feedback on safe driving performance, providing valuable insights to these novice drivers and their families.
- The successful pilot allowed for a plan to be developed with six recommendations for Ohio to follow that other states may want to replicate (See Key Recommendations, page 21.)

A photograph showing the front of a silver car with significant damage to the grille and bumper. A young man with dark hair, wearing a light blue shirt, is seen from the side, holding a black cell phone to his ear. The background is blurred, suggesting an outdoor setting.

## BACKGROUND

Motor vehicle crashes are among the leading causes of death and injury for Ohioans. Of the 299,648 crashes involving 499,169 drivers reported to Ohio law enforcement in 2018, drivers ages 16 to 25 years represented 23 percent of all drivers involved in crashes and 18 percent of the drivers in fatal crashes.<sup>1</sup> Young drivers have less exposure to driving than older drivers and, thus, are overrepresented in these crash data.<sup>2</sup> The cost to Ohio's families and communities is staggering: 136 young drivers killed and 17,237 injured in 2018.<sup>1</sup>

Ohio's statistics reflect those of the nation. For young drivers, crash risk spikes immediately after licensure and then declines over the next 6 to 24 months of licensed driving.<sup>3</sup> The majority of these crashes can be attributed to critical driving errors related to anticipating and avoiding hazards, speed management and distraction, rather than intentional risk-taking.<sup>4,5</sup>

New drivers not only put themselves and others on the road at risk, but also pose a risk to the licensing examiners who evaluate them on the road. In fact, crashes occur during the on-road licensing examination due to the applicants' lack of preparedness.

Whether they pass or fail the on-road examination (ORE), the time before and up to receiving their license is an important period for novice drivers and their families. Practice driving and the driving test are important to families. As such, the licensing examination can be a highly teachable moment in which information about safe driving can be relayed to the applicant. This information becomes all the more impactful if it is customized for the individual applicant and given at the most opportune time— prior to the high risk, early licensure period— and can help to ensure that applicants are truly prepared to drive independently.

The Ohio Bureau of Motor Vehicles (OBMV) administers approximately 490,000 non-commercial OREs for new license applicants each year.<sup>6</sup> Applicants enter the licensing system at different ages: Approximately 28 percent of applicants are under 18 years of age, and they are evenly divided by gender (52 percent male).<sup>7</sup> Approximately 30 percent of OREs are failed for a variety of reasons.

## Current New License Application Requirements in Ohio

In Ohio, new license applicant requirements vary by age.<sup>8</sup> Prior to age 18, new license applicants are required to have a driving permit and receive a minimum of 24 hours of classroom or online instruction and 8 hours of behind-the-wheel instruction at a traditional driving school. These permit holders must complete at least 50 hours of in-car practice (including 10 hours of nighttime driving) with a parent or legal guardian. Finally, they must hold the permit for at least 6 months before applying for a license.

After age 18, novice drivers are not required to progress through the protective Graduated Driver Licensing system and can simply take and pass an ORE to receive a full non-commercial driver's license. If an applicant age 18 or older fails the first attempt at the maneuverability or road portion of the ORE, he or she is required to take an abbreviated adult driver training course before attempting the driving test for a second time.

## New License Applicant Scheduling

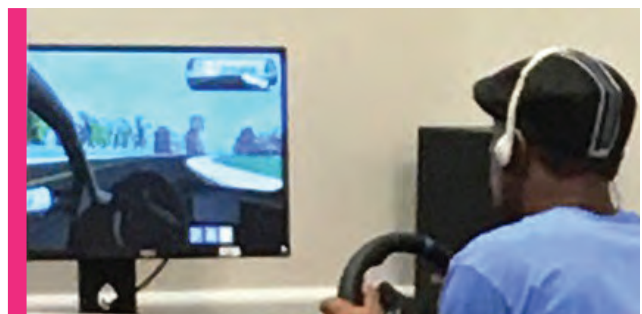
Once the requirements are met, new license applicants can schedule their ORE with an OBMV driving examiner. Each ORE takes approximately 30 minutes to administer and consists of a vehicle inspection, a maneuverability test, and a skill-based road exam.<sup>7</sup> It is important to note that regardless of applicants' preparation prior to scheduling the ORE, all applicants go on to the ORE at the discretion of the evaluator, at times putting the evaluator at risk.

## Evolution of the PDSS Project

Bipartisan House Bill 53 passed in March 2015 to provide funding for the OBMV to prioritize the safety of driver examiners who conduct OREs with novice drivers. This approach included the use of simulated driving assessments, called the Portable Driver Simulator System (PDSS), as part of the licensing process as a pre-screener to identify those who would fail the ORE.

Upon entering office in 2019, Governor DeWine placed a priority to improve the safety of Ohio's young drivers and tasked the Ohio Department of Public Safety (ODPS) to develop and implement an evidence-based program to address this need. Recognizing the value of the data collected since July 2017, the scope of the PDSS project was expanded beyond the initial vision to also provide an evidence base to improve the effectiveness of driver training.

The result of this vision is the Governor's Initiative on Traffic Safety, which has the PDSS pilot research at its core. This initiative involves all OBMV testing sites and selected training schools and will link the PDSS data to driving records to provide a more holistic understanding of the current effectiveness of driver training and illuminate the areas of needed improvement.



## Relevant Research from Children's Hospital of Philadelphia (CHOP)

For more than a decade, traffic safety researchers at CHOP have been working to reduce the frequency and severity of motor vehicle crashes involving young drivers behind the wheel. One key line of research and development has focused on young driver skill acquisition and training.

Young novice drivers go from their lowest lifetime crash risk as supervised learner drivers to their highest lifetime crash risk the day they receive their driver's license. That risk declines steeply over the first year of driving experience.<sup>3</sup> A key objective for CHOP research has been to help newly licensed drivers leave a state licensing agency equipped with the driving skills needed to avoid crashing.

In analyses using the National Motor Vehicle Crash Causation Survey, a federal database, CHOP researchers identified the most common and serious crash scenarios for both young and adult drivers and the errors that contributed to those crashes.

In crashes involving drivers 16 to 19 years old, five scenarios accounted for 37 percent of all serious crashes:

- 1 Going straight, other vehicle stopped, rear end
- 2 Stopped in traffic lane, turning left at an intersection, turn into path of other vehicle (e.g., cross traffic)
- 3 Negotiating curve, off the right edge of the road, right roadside departure
- 4 Going straight off the right edge of the road, right roadside departure
- 5 Stopped in lane, turning left at an intersection, turn across path of other vehicle (e.g., opposing traffic)<sup>4,9</sup>

The contributing errors made immediately prior to serious crashes were identified: Rear-end and left turn intersection crashes were primarily due to recognition errors, which include poor scanning, hazard detection and distraction, as well as decision errors, which include following too closely and traveling too fast for road conditions. The majority of run-off-road crashes were caused by decision errors (speeding) or poor driver performance (overcompensating).<sup>4</sup>

The research team at CHOP used these findings to develop and validate a laboratory-based simulated driving assessment that safely exposed drivers to crash scenarios and measured their skill in avoiding crashes. The researchers validated the technology to differentiate drivers according to skill and experience.<sup>10,11,12,13,14</sup>

## Technology from Diagnostic Driving, Inc.

Diagnostic Driving, Inc., a spin-out company from CHOP, was founded by several members of the research team to develop the virtual driving test (VDT) technology as a commercial-grade mobile delivery system that does not require expensive fixed-based driving simulators. The commercial product, Ready Assess™, makes the VDT available for broad deployment in research and non-research settings.

Building on the original intellectual property developed by CHOP, the VDT workflow is self-guided, typically completed in 15 minutes or less, and delivered as a cloud-based application that runs on standard hardware.

Data from the VDT are collected in real-time as time series data which are ultimately reduced by the Ready-Assess™ analytics engine into standard driving performance metrics that have been validated to differentiate drivers by skills and experience.<sup>11,12,14</sup>

In Ohio, the Ready-Assess™ VDT is internally referred to as the PDSS.





# OHIO PDSS DEVELOPMENT: READY-ASSESS™ CUSTOMIZED FOR OHIO

The ODPS, CHOP, Diagnostic Driving, Inc., and The Ohio State University collaborated on the development and implementation of the PDSS.

During the PDSS development phase (January 1- June 30, 2017), the commercial virtual driving test (VDT) software was adapted for the OBMV in collaboration with its subject matter experts, such as IT and driving examiner staff.

Objectives for development of a customized PDSS were to: (1) Adapt the existing VDT software to specifications provided by the ODPS; (2) Conduct a user acceptance test with ODPS staff (driving examiners and IT) to verify its readiness to be deployed in the licensing workflow with actual license applicants; and (3) Integrate the PDSS in the OBMV licensing workflow under a pilot setting by July 1, 2017.

The PDSS is standardized and validated to test performance in common and serious crash scenarios so that the OBMV can assess preparedness for the road test. In less than 15 minutes, the PDSS automatically assesses presence of common errors in vehicle operation and traffic management (as defined by subject matter experts within the ODPS) and the most common serious crash scenarios (as defined from research). The PDSS automatically measures more than 100 skill metrics.

To meet ODPS' specifications, 10 variations of simulated driving routes within the VDT were created to be deployed at random. Each incorporates variations of nationally-recognized common and serious crash scenarios, as well as supplementary tasks defined by the OBMV.

Additional key features of the PDSS software include a self-directed workflow for the customer, plug-and-play technology for the OBMV staff workflow and a simple Software-as-a-Service and subscription-based pricing model.

As designed, new driver license applicants can interact with the PDSS with little interruption to the current workflow because it is inserted into an existing process that they already need to complete in order to get a valid driver's license:

- 1 Applicants scheduled for their ORE are asked to independently complete the PDSS immediately before taking the ORE in the OBMV exam center.
- 2 Applicants report to a PDSS workstation installed at a OBMV exam center just prior to taking the ORE and sign into the workstation using a unique identification number.
- 3 After signing into the PDSS workstation, applicants complete a self-directed VDT workflow lasting approximately 15 minutes. Once completed, applicants are asked to return to the waiting area to be called for their scheduled ORE.

For the duration of the pilot only (i.e., not during full implementation or production): (1) All applicants are able to complete their scheduled ORE regardless of how they perform in the PDSS; (2) Both examiners and applicants are not provided with individualized PDSS results in order to mitigate any additional bias or ORE test anxiety.

Through its internal procurement procedures, the OBMV purchased all hardware required to run the latest version of the Ready-Assess™ software to support workstations at exam centers. The hardware consisted of a standard PC with a monitor, mouse, keyboard, headphones, and an off-the-shelf USB-based steering wheel and pedals (supplied by Logitech). Each PDSS workstation requires a chair and internet connection. ODPS IT was able to image each workstation with the latest Ready-Assess™ software (via remote downloading), and periodic updates to the software were delivered remotely by Diagnostic Driving, Inc.

## User Acceptance Testing (UAT)

In June of 2017, UAT was conducted with OBMV subject matter experts and driving examiners to ensure that the PDSS met all the operational goals before deploying it with the public in a pilot setting. They evaluated whether the PDSS met all OBMV specifications (including driving tasks and software reliability), and the driving examiners also considered the acceptable average time to complete the PDSS. Upon completion of UAT, it was determined that the PDSS was ultimately ready for full deployment with applicants as a pilot starting in July 2017.

### SIMPLE WORKSTATION SET-UP

Ready-Assess™ software does not require expensive or proprietary equipment in order to operate.



- 1 STANDARD MONITOR
- 2 STANDARD COMPUTER
- 3 INEXPENSIVE USB STEERING WHEEL AND PEDALS



# PILOT STUDY DESIGN

## Workflow and Scoring Algorithm

In order to optimize the workflow and have a validated scoring algorithm, the PDSS pilot was designed to evaluate implementation metrics for four broad objectives important to the ODPS and the OBMV: (1) Ease of integrating the PDSS into the workflow and software reliability; (2) Minimal staff management; (3) Applicants' experience with the PDSS; and (4) The ability of the PDSS to identify underprepared applicants without over-penalizing those applicants who are ready to complete their ORE.

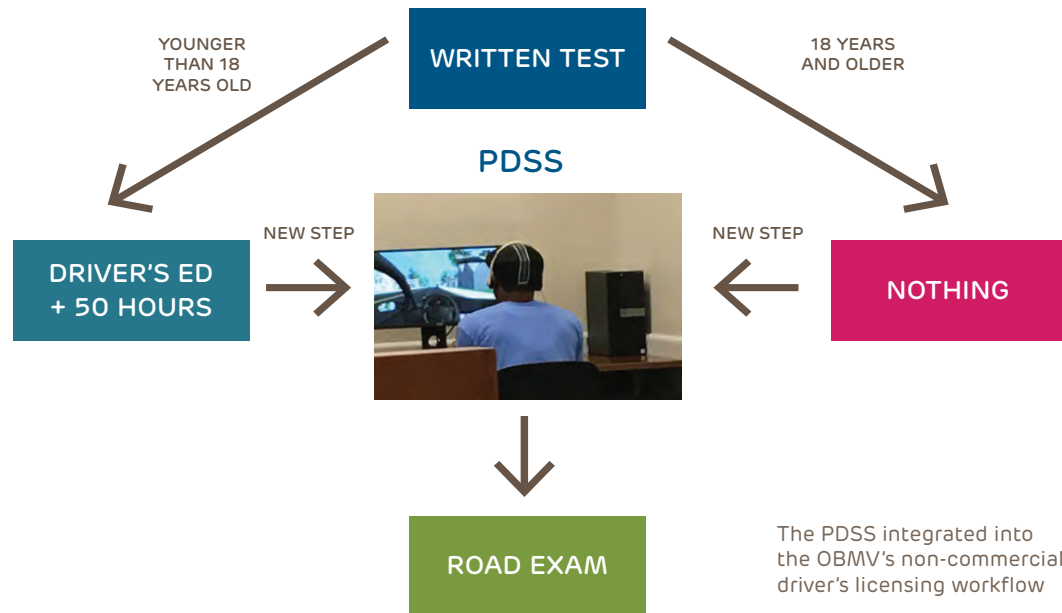
## General Pilot Design

The general implementation design was to integrate the PDSS into the licensing workflow as a pre-screening test to identify those new license applicants who would go on to fail the ORE regardless of age. However, in the pilot phase, the results of the PDSS and the ORE were collected on all applicants. Applicants were asked to complete the PDSS immediately before their scheduled ORE at the OBMV exam center, and the PDSS results had no impact on any applicants completing their scheduled ORE. In addition, all applicants and examiners were blinded from any PDSS results or performance data in order to mitigate any additional bias or ORE test anxiety.

The OBMV provided scanned copies of the ORE scoresheets to the research team so that they could be manually transcribed and linked with the applicants' PDSS results for analyses and scoring algorithm development.

The pilot was designed to be implemented in phases so that workflow issues and software bugs could be addressed early while minimizing their negative impact on the licensing workflow. As such, the PDSS is set up to continuously collect data in real time, while also having the ability to continuously validate the implementation goals for the pilot.





### PHASE 1: Optimize Ease of Workflow and IT Processes

Starting in July 2017, the pilot team tested the PDSS workflow with real “customers” (applicants scheduled for their initial ORE) in one high-traffic licensing center based in Columbus, Ohio (Morse Road). The pilot team members from the ODPS, with remote participation from Diagnostic Driving and CHOP, were able to have the PDSS up and running within one week, with minimal OBMV staff involvement and minimal technical support calls. In this phase we were able to confirm that the PDSS could function as designed and, thus, be ready to scale to multiple licensing centers.

### PHASE 2: Scale for Multiple Locations

Over the course of less than one year, the PDSS was set up and running in three OBMV testing centers located in or near Columbus, OH, as well as in Zanesville and Springfield. These locations represent high-volume licensing centers in diverse urban and suburban environments.

### PHASE 3: Optimize the Scoring Algorithm

Diagnostic Driving and CHOP converted the recorded driving performance data (time series of brake, pedal and throttle), as well as positioning within the drive scenarios to develop meaningful metrics of safe driving performance (e.g., complete stop at red lights, following behavior and merging behavior into traffic, etc.). These results were date-matched and linked with the applicants’ transcribed initial ORE results in order to: (1) Generate an analytical dataset of PDSS results linked with the applicants’ initial ORE record; and (2) Develop a range of scoring algorithms that incorporate the metrics to ultimately predict initial ORE results. In partnership with the ODPS and the OBMV subject matter experts, we produced multiple possible algorithms that balanced parameters of interest to the OBMV, including:



- Maximizing examiner safety by reliably identifying in advance underprepared applicants who would go on to fail their ORE
- Maximizing the ability for the PDSS to allow those applicants who are prepared to complete their scheduled ORE (or conversely, minimizing the number of applicants for whom the PDSS predicted to fail but would have gone on to pass their ORE)
- Optimizing the PDSS scoring algorithm to focus on identifying the most seriously underprepared applicants by setting the predicted ‘fail’ threshold within tolerable limits (tolerable for Ohio customers who require licensing services provided by the OBMV)

A combination of machine learning with standard best practices for algorithm development and validation and domain expertise were used to develop the scoring algorithm. (See, p. 17.)

#### PHASE 4: Integrate Personalized and Automated Feedback Into PDSS Workflow

In order to leverage the “teachable moment” of a scheduled ORE, the PDSS was designed to generate an automated report, personalized to the applicant’s PDSS safe driving performance. Diagnostic Driving and CHOP worked with ODPS and OBMV subject matter experts to develop a final reporting template that includes response content in a reading level appropriate for the applicant population who utilize OBMV services. The OBMV-branded template was divided into three general sections:

- 1 A welcome message to the applicant from the OBMV describing the purpose of the PDSS
- 2 Driver’s strengths demonstrated from the PDSS (in bulleted format)
- 3 Driver’s areas for improvement as demonstrated from the PDSS (in bulleted format)

We recognized that providing feedback to applicants upon completing the PDSS could potentially influence the applicants’ ORE performance. To prevent this and to ensure that initial ORE results were not influenced by applicants’ review of their feedback report, the feedback report (delivered via email) was delayed until the end of the business day at 18:00 EST (after the applicants completed their initial ORE). The new feedback feature went into production during the pilot in October 2018. Basic analytics, such as timestamped open rates, linked with the applicants’ PDSS results, were captured. A small focus group with applicants and their families was conducted at each of the five exam centers in order to better understand how the new feedback feature was perceived.

## Minimize Bias in the Pilot Design to Ensure Highly Credible Results

During the pilot phase, the PDSS was not used in licensing decisions. Instead, the workflow was systematic (including all applicants regardless of age, gender or background), and PDSS performance results were neither revealed to applicants nor to OBMV evaluators prior to the ORE. What this allowed for:

- 1 The PDSS scoring algorithms are solely based on driving performance in the PDSS, and no other characteristics of the driver, such as age, gender or other personal characteristics, were used in the scoring algorithms. Therefore, the algorithms remained agnostic and unbiased towards personal characteristics of the applicants being tested.
- 2 The outcome of interest (ORE pass/fail) was independent of the PDSS result: Applicants' on-road performances were not influenced by their PDSS performances, and staff examiners' assessments were not influenced by the PDSS performances. In this way, the PDSS performances and the ORE performances were two independent measurements. Because this was found to be acceptable by all stakeholders, there was no need to change the workflow at new sites.
- 3 A third form of bias was virtually eliminated because there was consistency in the data collection across all sites over time.

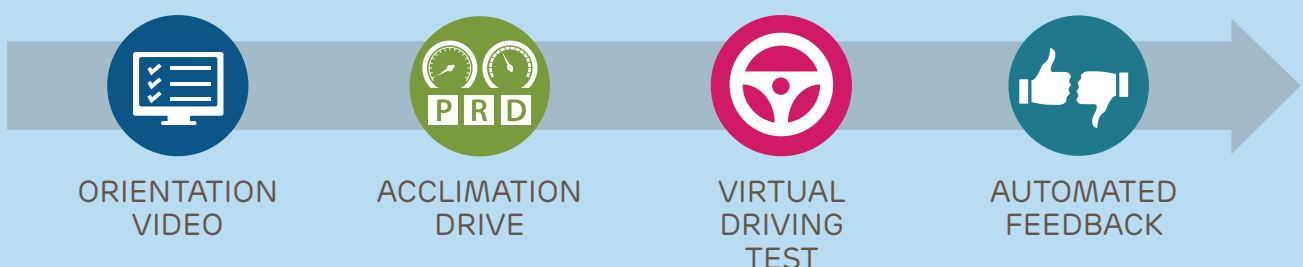
## Final Pilot Workflow Description

OBMV staff directed all applicants to an available PDSS workstation in the testing facility and asked them to put on the headphones and to enter a provided unique identification number. Once applicants entered their unique number into the login screen, the PDSS commenced a self-guided workflow typically lasting less than 15 minutes for applicants to independently complete.

First, a short, CGI-generated orientation video introduced the importance of safe driving and provided applicants with an overview of the stages of the PDSS workflow. This was followed by the acclimation drive, which included a short orientation drive with instructions to orient participants to all of the PDSS controls (e.g., turn signals, transmission, navigation system, etc.) and to allow applicants to test-drive accelerating, stopping and turning on a course without other traffic. This drive ends with a brief "follow instructions" test to assess applicants' ability to manage the controls and follow the instructions covered in it.

Next, applicants began the PDSS assessment drive, a simulated driving route which incorporated variations of nationally-recognized common and serious crash scenarios and provided basic navigational directions to the drivers. This drive was randomly chosen from a bank of 10 possible assessment drive variants. Finally, participants completed an on-screen debriefing survey consisting of three questions to assess their ability to understand the PDSS directions and their comfort with the PDSS controls.

### THE READY-ASSESS™ SELF-GUIDED WORKFLOW





# PILOT STUDY RESULTS

Researchers analyzed a de-identified dataset containing PDSS results of approximately 20,000 applicants from five OBMV licensing centers during a 14-month pilot period (July 1, 2017 - August 31, 2018). Among the approximately 20,000 applicants who attempted the PDSS, the researchers linked the first 4,643 PDSS results with the initial corresponding and manually transcribed ORE results. Due to the manual nature and staff-intensive effort required to transcribe ORE score sheets into an electronic format (double entered to verify integrity), it was not cost-feasible to transcribe the PDSS' ORE results for every applicant who completed it. The sample that was ultimately linked with ORE results was verified by OBMV subject matter experts to be proportionally representative of the exam facilities from which the results came and to the overall ORE fail rate. Researchers found:

## **1. Nearly All Applicants Could Complete the PDSS as Part of the Entire Licensing Workflow**

Among the N=4,643 analytical sample of applicants who attempted the PDSS, 94 percent (N=4,349) completed the entire workflow and 6 percent (N=294) did not.

## **2. Operations and Feasibility Metrics Were Met**

Because the PDSS is self-directed by applicants, staff were only required to direct applicants to a PDSS workstation. No additional time was needed to explain or supervise its use. They reported that the PDSS seamlessly incorporated into the licensing workflow. With more than 20,000 PDSS completed, there were no schedule backlogs. The PDSS was easily administered to applicants already waiting for their scheduled ORE appointments. After the initial launch, expansion to additional sites required minimal training, most of which was included in a simple instruction manual.

### 3. OBMV Staff Appreciate Minimal Onsite Management

When the ODPS is ready, OBMV staff reported that they are willing to use the PDSS to assess new license applicant preparedness and to protect the safety of examiners by requiring those that fail the PDSS to reschedule their ORE after more supervised driving practice. Staff continue to see the value after an additional 20,000 completed administrations of the test.

Information Technology (IT) staff reported that the PDSS is reliable technology with very few and minor technical issues (<1 non-critical events reported per 1,000 PDSS tests administered; 0 critical events). They reported an efficient help desk support infrastructure provided by Diagnostic Driving, Inc. with fast turnarounds (within two hours).

IT staff felt that there was minimal management required because the PDSS software has automatic remote updates that minimize time spent managing the PDSS software. They appreciated the “easy delivery model” that requires no large vertical integrations with OBMV internal IT systems. Applicants were able to independently complete the entire PDSS workflow in an average time of 13 minutes or less.

### 4. OBMV Customers Report Easy-to-Use and Realistic

Based on data collected from more than 20,000 PDSS tests administered over the 14-month period, new license applicants reported that the PDSS was easy-to-use and follow (avg. rating: 4.2 using a Likert scale of 1.0 to 5.0), was realistic and a reasonable representation of what they typically see on the road (avg. rating: 4.3). They were also generally comfortable with the PDSS control inputs provided by Logitech G29. Feedback from OBMV staff indicated that less than 1 percent of applicants who attempted the PDSS reported symptoms of simulator-based motion sickness.

### 5. PDSS' Analytics Can Predict Failure of the ORE

Data from the first 4,643 applicants (PDSS results linked with ORE results) comprised the analytical dataset (representing 23 percent of the 20,000 PDSS tests administered during the 14-month pilot period). Within this sample, 3,397 applicants (73 percent) passed the ORE and 1,246 (27 percent) failed the ORE on their initial attempt. These rates were consistent across all five testing locations and consistent with the statewide ORE fail rate.

Compared to those applicants who passed the PDSS, applicants who failed the PDSS were 4.17 times more likely to fail their ORE (95% CI: 3.89-4.47). Less than 1 percent of all applicants were considered as ‘false alarms’— those applicants who failed the PDSS and ultimately passed their ORE.

Among the entire analytical sample (N=4,643), a smaller subset of drivers committed serious errors in the PDSS. A higher frequency of workflow and driving errors occurred among those who went on to fail the ORE versus those who passed the ORE.

**Examiners and administrative staff reported that the PDSS required minimal staff time.**



## Algorithm Met Success Criteria

Using a combination of (1) Machine learning with standard best-practices for algorithm development and validation; and (2) Domain expertise (novice driver expertise from CHOP and ODPS subject matter experts), scoring algorithms were developed based on key parameters of interest defined by the ODPS and the OBMV. The table below summarizes the algorithm that best optimized all of the parameters.

Success Criteria	Definition	Current and Best Result
Overall Accuracy of Algorithm	How often the algorithm is correct in predicting ORE results (Pass or Fail)	PDSS correctly predicts <b>8 out of 10</b> applicants' ORE results
False Alarm Rate	How often the algorithm would incorrectly predict failing the ORE	Of all applicants, less than <b>1 in 100</b> fail the PDSS but go on to pass the ORE
Positive Predictive Value	Among the applicants who failed the PDSS, the proportion of these applicants who failed their ORE	<b>9 in 10</b> applicants who failed the PDSS actually failed their ORE
Algorithm Fail Rate	How often the algorithm would fail the applicant in the PDSS	<b>10 out of 100</b> applicants failed the PDSS
Algorithm Risk Ratio	Relative risk of failing the ORE if the PDSS predicted "fail" vs, "pass"	Compared with applicants who passed the PDSS, applicants who failed the PDSS were <b>&gt;4x likely</b> to fail their ORE

With this algorithm, researchers could look at individual-level performance errors and found that specific PDSS-scored errors predicted failure of the ORE.

Anecdotally, OBMV subject matter experts identified three primary reasons why some applicants could not finish the entire workflow: (1) Applicant struggled with the controls or did not understand the instructions; (2) Applicant chose not to complete the PDSS; or (3) Applicant was called for the ORE earlier than expected. Although uncommon (6%), we identified that not completing the PDSS in its entirety was highly associated with failing the ORE: When compared to those who did complete the workflow, those who did not were nearly two times more likely to fail the ORE. (See the first table on page 18.)

Among the 94 percent who did complete the entire PDSS workflow, the research team examined specific driving performance errors made during the assessment drive to determine if any of these errors were individually associated with failing the ORE. The second table on page 18 summarizes the critical PDSS errors that were most associated with failing the ORE. (Note: All associations were statistically significant.)

## OPERATIONAL ERRORS PREDICT FAILURE OF THE ON-ROAD EXAM (ORE)

Condition	% Overall	% Within ORE=Fail	% Within / ORE=Pass	Risk of Failing ORE (95% CI)
Did not complete the acclimation drive	1%	3%	1%	208% (164-264%)
Did not complete the entire PDSS workflow	6%	11%	4%	189% (166-215%)
Failed the "follow instructions" test at end of acclimation drive	5%	11%	2%	265% (237-297%)

## SERIOUS DRIVING ERRORS PREDICT FAILURE OF THE ON-ROAD EXAM (ORE)

PDSS Metric	% Within ORE=Fail	% Within ORE=Pass	Risk of Failing ORE If Error Was Made	95% CI
Driving dangerously slowly	38%	6%	593%	458-768%
Improper steering, erratic / weaving	11%	2%	470%	324-680%
Failing to yield to traffic	13%	2%	441%	308-630%
Jerky braking	12%	3%	336%	228-494%
Violating speed limits	6%	1%	334%	197-568%
Failing to scan in all directions	15%	5%	263%	183-378%
Driving in the wrong direction after receiving a navigational prompt	22%	10%	220%	188-254%
Not coming to a complete stop at a stop sign	22%	14%	157%	135-180%
Driving through a red traffic light without coming to a complete stop	26%	17%	153%	135-174%
Colliding with a vehicle or a pedestrian	40%	32%	125%	115-137%



## Applicants Receptive to Feedback

Initial results of integrating automated and personalized feedback suggest that applicants and their families are receptive to reviewing this information. Upon releasing the feedback feature into production in October 2018, nearly 40 percent of all applicants opted to supply their email address to receive feedback within the PDSS workflow. Of the applicants who supplied their email address, nearly 25 percent opened their feedback email within 24 hours of receiving it, and approximately 30 percent opened their feedback email within a week of receiving it.

Focus groups with applicants and their families (25 applicants and their families, if available) conducted after completing their initial ORE while reviewing their personalized feedback on a laptop screen revealed the following: (1) The feedback was easy to understand and follow; (2) The feedback was useful to help guide their learning-to-drive experience; and (3) They were pleased that their OBMV exam center provided this as a free service.

The focus groups also provided additional insight on how the feedback could be improved, such as: (1) Providing an overall summary grade; (2) Linking the provided areas for improvement to credible educational content that the applicants could access and practice; and (3) Using additional modalities to deliver the feedback, such as text messaging or printing out a physical copy after completing the PDSS.

# IMPLICATIONS

After implementing the PDSS pilot in a real world setting over a 14-month period in the OBMV licensing workflow, we determined that the PDSS worked as designed, was feasible, and was acceptable to both OBMV staff and their customers.

Importantly, the PDSS was able to predict with accuracy which new license applicants were likely to fail their ORE. (See page 16.)

The PDSS could specify what driving errors in the PDSS were associated with failing the ORE, which can help with provision of feedback and improved driver training. The PDSS also linked test operational errors to increased risk of failing the ORE. (See tables on pages 17-18.)

Based on the PDSS scoring algorithm described on page 17, the estimated annual ORE volume across Ohio, and Governor Mike DeWine's Initiative on Traffic Safety, which has the PDSS pilot research at its core, we project the following positive outcomes if the PDSS is ultimately operationalized and used as a pre-screening tool in the licensing workflow statewide:

## ANNUALIZED PROJECTIONS FOR THE PDSS AS AN ORE PRE-SCREENING TOOL\*

Focus Area	Projected Realization and Benefit to OBMV
Safety	A significant reduction in risk exposure to examiners, the applicants and to the public by having more than 40,000 fewer OREs administered for underprepared applicants annually
Customer Service	All applicants and their families can receive automated and personalized safe driving feedback based on their PDSS results incorporating state-sponsored messaging. Our initial results from the new feedback feature suggest that applicants and their families are receptive to reviewing it and find it a valuable addition to the current services provided by the OBMV.
Operational Efficiency	Savings of approximately 25,000 examiner hours spent on failed OREs annually

\*Assumptions used: (1) 490,000 non-commercial OREs administered by the OBMV in 2018<sup>6</sup>; (2) Statewide ORE fail-rate in Ohio is approximately 30%<sup>6</sup>; (3) The Ohio ORE takes approximately 30 minutes to administer, on average.<sup>7</sup>





KEY

## RECOMMENDATIONS

The PDSS remains under pilot testing in Fiscal Year 2020. With the transition to the new state administration as of January 2019 (led by Governor Mike DeWine), the PDSS is currently being overseen by the Ohio Traffic Safety Office (OTSO) within the ODPS as of July 2019.

With more than 20,000 tests administered during the reporting period (and nearly 40,000 tests administered as of September 2019), the authors make the following set of key recommendations to the OTSO and key state stakeholders in the Governor's Initiative on Traffic Safety:

### 1 PLAN FOR STATEWIDE IMPLEMENTATION.

Expand the pilot to all OBMV exam centers statewide, spreading from Central Ohio. As part of this more wide-scale implementation, the highly portable PDSS could be placed in driving schools and other locations. We expect the results to be consistent with those in the testing centers to be easily integrated with existing OBMV data collection application systems. Ready-Assess™ has an application programming interface (API) to communicate data with external IT systems.

**STATUS:** ✓ Underway FY2020

### 2 TURN ON AUTOMATED FEEDBACK FUNCTIONALITY.

Provide automated performance reports with evidence-based suggestions for improved safe driving performance to all new license applicants. A successful pilot revealed that this could easily be implemented in a busy setting with the results sent directly via email to applicants.

**STATUS:** ✓ Underway FY2020

3

**IMPLEMENT THE PROTECTIVE FEATURE OF PDSS IN THE WORKFLOW.**

Use the PDSS as a safety screener to identify those applicants who would go on to fail the ORE. The current PDSS scoring algorithm is highly sensitive in identifying those applicants not adequately prepared for the ORE and would not over-penalize prepared applicants by preventing them from completing their scheduled ORE. Less than one percent of all applicants failed the PDSS and ultimately passed their ORE.

**STATUS:** 🔍 Exploration FY2020; engage key state stakeholders and legislators

4

**OPTIMIZE THE PDSS AND ITS SCORING ALGORITHM FOR OTHER DRIVING POPULATIONS.**

Identify immediate vertical uses for PDSS beyond new drivers (e.g., evaluation of mature drivers, drivers with medical conditions and drivers with repeat traffic violations, ODPS and ODOT fleet employees) and develop and implement User Acceptance Test protocols to evaluate the application of the PDSS in these domains.

**STATUS:** 🕒 Future Consideration

5

**USE PDSS AS A GENERAL-PURPOSE QUALITY IMPROVEMENT TOOL AND TO ASSURE CONSISTENCY IN TESTING ACROSS A RANGE OF SITES, BEYOND THE OBMV.**

Encourage use of the PDSS by a wide variety of stakeholders who aim to have consistent, objective, evidence-based testing. The OTSO could use the PDSS in driver training schools to guide and evaluate improvements in training, develop standardized curriculum content, and compare outcomes across schools. Other stakeholders might use the PDSS to assess fleets (e.g., state or municipal drivers) or as part of community programming (e.g., incorporating the PDSS into state-sponsored events).

**STATUS:** ✅ Underway FY2020

6

**INTEGRATE PDSS INTO GOVERNOR DEWINE'S INITIATIVE ON TRAFFIC SAFETY.**

Operationalize the PDSS as a pre-screening tool in the OBMV's licensing workflow to improve efficiency and driving safety. The PDSS will save a significant amount of examiner time, and its automated feedback delivery mechanism can be used to incorporate state-specific sponsored messaging towards combating unsafe and distracted driving.

**STATUS:** ✅ Underway FY2020

The PDSS was able to predict with accuracy which new license applicants were likely to fail their ORE.

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## Author Disclosures

Flaura K. Winston, MD, PhD and Venk Kandadai, MPH disclose their intellectual property and financial interest in Diagnostic Driving, Inc. and Children's Hospital of Philadelphia's institutional interest in Diagnostic Driving, Inc. Diagnostic Driving, Inc. developed Ready-Assess™, the software behind the PDSS. Dr. Winston serves as the Chief Scientific Advisor, and Mr. Kandadai serves as the Chief Executive Officer of Diagnostic Driving, Inc. Dr. Winston operates under a Conflict Management Plan from Children's Hospital of Philadelphia and the University of Pennsylvania whereby she has no interaction with participants (all field-data collection procedures were carried out by the Ohio Bureau of Motor Vehicles personnel), and all analyses were reviewed and approved by outside consultants with no intellectual or financial interest in Diagnostic Driving, Inc: (1) John Bolte, PhD, a traffic injury researcher at The Ohio State University; and (2) Nancy Kassam-Adams, PhD, a behavioral researcher at Children's Hospital of Philadelphia and the University of Pennsylvania.



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