

HOW TO ESTABLISH BENCHMARKS FOR SIMULATOR-BASED TRAINING

BENCHMARKS

Simulator benchmarks are important whenever we want to measure level of skill, and this can come about in two ways.

When an experienced operator spends time at the controls of a Personal Simulator, sufficient proficiency can serve as a predictor of level of skill at the controls of real heavy equipment, to help an employer qualify the suitability of that individual for hiring.

Alternatively, when a new operator spends time at the controls of a Personal Simulator, we want the simulator-based training to be taken seriously and ensure that the individual masters each Simulation Module before proceeding to the next one. This is especially important for the final Simulation Module, since the new operator would be typically graduating to subsequent training at the controls of real heavy equipment.

In both cases, for new and experienced operators, benchmarks are key to deciding when simulation results are good enough and in this document; we present some Simlog guidelines about establishing such simulator benchmarks using simulation results.

SIMULATION RESULTS

First, recall that our Personal Simulators record, for each simulator session¹, simulation results in the form of a Results Summary presenting average, minimum, and maximum values for each performance indicator for the associated Simulation Module.

For example, here are some partial results taken from the sample Results Summary in the User

Manual for the Truck Loading Simulation Module of Hydraulic Excavator:

Trial Summary	Count
Trials started	48
Trials completed	47

Performance Indicator	Average	Minimum	Maximum
Execution Time (minutes: seconds)	01:38	01:16	02:05
Volume of material transferred to truck (m ³)	3.45	2.50	4.10
Number of collisions between bucket and truck	0.4	0	2
Number of bucket slams	1.9	1	4

In the first table, we see that 47 trials were successfully completed and in the second table, we see the average, minimum, and maximum values for four of the performance indicators for this Simulation Module.

SIMULATOR BENCHMARKS

For each Simlog Personal Simulator, simulator benchmarks are just target values for the performance indicators for each of the Simulation Modules.

Returning to our example, the simulator benchmark for Truck Loading would be target values for Execution Time and all the other performance indicators.

Continuing in this way, we could also establish a simulator benchmark for each of the other Simulation Modules for Hydraulic Excavator (Controls Familiarization, Excavator Positioning, etc.) to obtain a complete set.

¹A session is simply an instance of simulator-based training. The session starts when you launch a Simulation Module, and it stops when you quit that Simulation Module.

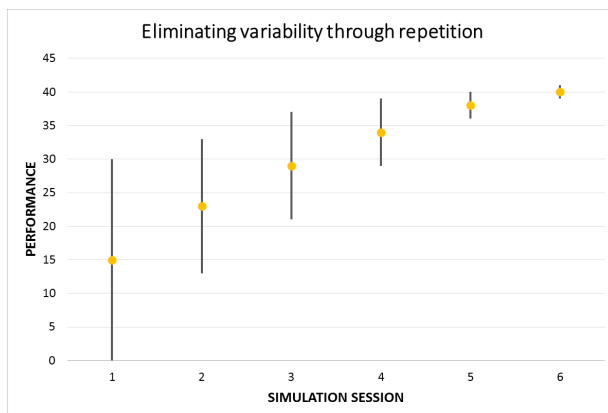
SIMULATION RESULTS AND LEVEL OF SKILL

For any skill-based activity, a beginner and an expert will demonstrate different levels of skill and for our Personal Simulators; those differences appear in two ways for each performance indicator.

For the expert, the average, minimum and maximum values will be better, compared to the beginner. This means that numbers that should be high such as “Volume of material transferred to truck” will be higher, and numbers that should be low such as “Number of collisions between bucket and truck” will be lower.

In addition, for the expert, the difference between the minimum and maximum values will be smaller, compared to the beginner. This comes about because for every trial, the expert consistently performs well, with just small differences between his or her best and worst simulation exercises.

We can therefore conclude that as the beginner improves simulation results will start to look like the expert’s. In other words, as the beginner gains more skill, the values of the various performance indicators will become better and the differences between the minimum and maximum values will become smaller.



CALCULATING SIMULATOR BENCHMARKS USING EXPERTS

The proficiency demonstrated by experts at the controls of our Personal Simulators is, of course, based on the proficiency resulting from many years of work at the controls of real heavy equipment².

For that reason, doing as well as the expert at the simulator is the best way of deciding when simulator-based training should stop and subsequent training at the controls of heavy equipment should begin.

How then to calculate simulator benchmarks from the simulation results of such experts?

Recall from the previous discussion that for an expert, the differences between the minimum and maximum values for each performance indicator will be small. For that reason, Simlog recommends that the expert’s average value be used as the target value for benchmarking.

Of course, this means having at least one expert available, to generate simulation results and then benchmarks and in many cases, experts are either members of your training staff or simply your most experienced operators. (Refer to the section “Help from Simlog” later in this document for the situation where no such expert is available.)

After that, it is important to review those benchmarks in light of other considerations.

OTHER BENCHMARK CONSIDERATIONS

When establishing benchmarks from simulation results, one kind of other consideration refers to safety. Returning to our example, it would be appropriate to require that the “Number of collisions” should always be zero. In other words, to help promote safety, you may choose to oblige your students to work so carefully that there will be, on average, no collisions for the Truck Loading Simulation Module.

²We now know that on average, it takes at least 10,000 hours of deliberative practice to become expert at skill-based activities such as playing sports and operating heavy equipment at a professional level. One leading reference to the scientific research is [The Cambridge Handbook of Expertise and Expert Performance](#), Cambridge University Press, 2006.

³For Hydraulic Excavator, a “bucket slam” is counted when the bucket is either completely opened or completely closed, causing the bucket cylinder to reach the hydraulic limit of its range of motion in either direction.

A second kind of other consideration refers to the recommended practices proposed by the Original Equipment Manufacturer (OEM), primarily related to avoiding unwarranted wear-and-tear on real heavy equipment. Once again returning to our example, the OEM would suggest that there should never be a bucket slam³ because this causes the hinge pin that attaches the bucket to the end of the boom to wear prematurely.

By taking both groups of considerations into account, you will establish new benchmarks that not only reflect expert proficiency at the controls of your Personal Simulator, but also important considerations related to safety and OEM recommendations. As it turns out, they typically go hand in hand, since the OEM recommendations are also meant to promote safety.

HELP FROM SIMLOG

It sometimes happens that no expert is available to generate simulation results, to establish target values. In such cases, Simlog can provide a starting point in the form of benchmarks developed by other Simlog customers, from whom we have obtained permission to pass them along.

Whether you have developed your own simulator benchmarks or you are using such a starting point from Simlog, it is important they be subject to some fine-tuning to better fit your own population of simulator users, as described in the next section.

FINE-TUNING SIMULATOR BENCHMARKS USING STUDENTS

When using benchmarks developed by experts, or perhaps passed along by Simlog, you may discover that your students cannot develop sufficient mastery in the time available for simulator-based training, to meet those benchmarks.

It is therefore important to use the simulation results of your own students in order to

modulate your expert's target values or the starting point provided by Simlog.

To proceed, begin by reviewing just the last simulator session for each student. If the differences between the minimum and maximum values for the various performance indicators are mostly small, this suggests that the student has demonstrated sufficient proficiency for this Simulation Module and for that reason, his or her average values are suitable for our calculation. When the differences are not small, this suggests that the student should continue the simulator-based training for this Simulation Module.

Then using such average values for those students demonstrating sufficient proficiency in this way, calculate the average of those average values, and then round up or down to obtain a simpler number to be used as a target value. For performance indicators associated with numbers e.g. "Execution Time", target values with just one or two decimal places will be sufficiently precise.

In this way, the target values for all performance indicators for that Simulation Module constitute a preliminary simulator benchmark for that Simulation Module.

When reviewing the expert's target values, remember to take into account the considerations related to safety and OEM recommendations previously described.

EVALUATING SKILL USING THE SIMULATOR BENCHMARKS

Now you and your students, can evaluate level of skill by simply comparing the average values of your students with the simulator benchmark for that Simulation Module, as they complete each simulator session.

But doing well enough means more than meeting (or exceeding) the benchmarks "now and then". It means meeting the benchmarks

“all the time”, i.e. consistency in performance. And that’s why, in order to ensure that the student has obtained enough skill to consistently do well, many Simlog customers rely on a “five trials in a row” evaluation.

Practically, this means that for each Simulation Module, the student’s final simulator session consists of just five trials. And in this way, if the target value for “Number of collisions” is zero, doing well enough means that the student completes the first trial with no collisions, then the second trial with no collisions, etc. so that the for this Performance Indicator, the “Average”, “Minimum”, and “Maximum” columns in the simulation results are all (exactly) zero.

At some customer sites, the training staff has established multiple benchmarks that set the bar progressively higher, in step with expectations about average student progress, to encourage students to remain motivated and continue to take the simulator-based training seriously.

In either case, it is important that the simulator benchmarks be visible, perhaps printed out and displayed at each Personal Simulator. Alternatively, such customers have prepared wall-sized posters that hang on a wall in the simulator lab, to make it easy for a room full of students to all see the benchmarks from their simulator stations.

ABOUT SCORING SIMULATION RESULTS

Operating real heavy equipment means working carefully and working quickly. Working carefully, because otherwise there will be damage to equipment or worse, injury to the operator or other people on the job site. Working quickly, because there’s always another job waiting. And that is why, at Simlog, our Performance Indicators are designed to “capture” both, making feedback diagnostic instead of just a simple “pass” or “fail”.

As one example, the Performance Indicators of our Forklift Personal Simulator include Execution Time, average and maximum driving speeds (forwards and backwards), measurements about how precisely loads are picked up and put down (errors in orientation, centering, etc.), and counts for many different kinds of collisions (forks with loads, forks with shelves, etc.). In addition, a variety of incorrect operating conditions will trigger “Procedure Errors”, such as driving “out of bounds”. More importantly, conditions related to safety receive special attention: if the forklift is about to overturn, or a load is about to fall down falling from a shelf, a “Fatal Error” will be triggered that stops the simulation immediately.

But how can you “score” the simulation results of your students when they include numbers associated with working carefully and working quickly? At Simlog, we are pleased to provide the following advice, based on what many of our leading customers are already doing.

To begin, because safety always comes first, your students need to learn to do things carefully enough. Returning to the example of our Forklift Personal Simulator, this means

- No “Fatal Error”
- No “Procedure Error”
- No collisions (of any kind)
- Nothing else “bad” e.g. for the “Ramp Driving” simulation module, no driving on the ramp in the wrong direction

Practically, this will necessarily mean working slowly.

But later, with sufficient practice, your students will continue to do things carefully and learn to work more and more quickly. And that’s when it’s time to start “scoring”, based on what you deem to be quick enough, typically measured as a target value for “Execution Time”.

Now it's easy to see that if your student's average "Execution Time" is twice the target value, i.e. two times too slow, then the student's "score" would be 50%. In such a case, the student should be encouraged to continue to practice the same Simulation Module until the "Execution Time" becomes small enough to equal (or surpass) your target value.

Of course, if some/most of your students are unable to equal (or surpass) your target value, then this suggests that the target value is too "difficult" and should be "relaxed", following the Simlog guidance about "fine tuning" in the earlier sections of this document.

ORGANISING SIMULATOR-BASED TRAINING

Just like the simulator-based training for airline pilots and astronauts, Simlog recommends that you instruct your students to train in one hour time intervals.

For every Personal Simulator, the time in hours and minutes since the start of the current session is displayed in the lower right corner of the simulation window, making it easy to keep track of the simulator-based training time.

At many customer sites, simulator-based training is organised in morning and afternoon segments, with half the class in the simulator lab while the other half is busy with lectures or hands on activities related to the maintenance and repair of real equipment.

In that way, the two groups switch at mid-day so each student can obtain about three hours of simulator-based training, i.e. about three simulator sessions of one hour each.

COPING WITH "WEAKER" STUDENTS

For any skill-based activity, people will come up to speed differently, some faster, some slower.

For this reason, you will likely encounter students who do not meet the benchmarks

established for your simulator-based training. For these "weaker" individuals, it's important to make extra simulator-based time available, perhaps early in the morning or late in the afternoon. Otherwise, when they graduate to the controls of real heavy equipment, they will not be as ready as their classmates, leading to increased accidents and more equipment damage due to inexperience.

Of course, if the simulation results of those individuals continue to be poor despite the extra simulator-based training time, then this suggests that they are not sufficiently apt for operating heavy equipment. Indeed, our Personal Simulators are often used to help identify such people before training begins, especially where training programs are oversubscribed, to try to ensure that everyone will develop the necessary skills to graduate and find gainful employment.

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