PRODUCTIVITY STUDY

Conventional vs. Machine-Guided Excavators

ABSTRACT

Positioning technology innovators and construction equipment manufacturers have integrated grade control technology on excavators, dozers, motor graders, skid-steers, milling machines, pavers and other earthmoving equipment. While adoption is steady, many construction professionals are still hesitant to invest in machine control technology unsure of the benefit-to-cost value.

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Overview

In 2019, Trimble facilitated a productivity study to compare the performance of operators of varying skills using conventional vs. machine-guided excavators.

The productivity study showed significant improvement in operator effeciency when using machine guidance.

Test Methods

Over the course of a week, the study evaluators asked 16 operators to perform the simple but common task of digging a 1 m wide x 15 m long by 0.5 m deep trench to an accuracy of ± 3 cm using Komatsu PC228-10 and Hyundai HX220-L excavators.

One trial was performed using conventional excavation techniques (no external grade control), and one using the guidance-only function of the Trimble Earthworks Grade Control Platform. Measurements were taken with a Trimble TSC7 Controller and the Trimble SPS986 GNSS Smart Antenna.

Operators were shown the following information in advance of trials:

- The location and function of the excavator controls
- The Trimble Earthworks interface and the location of the study design
- The SPS986 receiver system that was used in measuring during their conventional excavation demo. This included a conversation describing how the moderator would communicate cut/fill values to them while they were operating. If they had a personal preference in this case, it could be adopted, otherwise communication was dictated by the moderator.

Before each trial, participants were given a five minute warm-up period to familiarize themselves with the machine (e.g. practicing with the controls, digging in a test trench, interacting with the Trimble Earthworks interface).

Trial 1 Conventional

During this trial, participants excavated a 1 m wide x 15 m long by 0.5 m deep trench using conventional excavation methods—no design or external grade control.

At intervals of the operator's choosing, the moderator checked excavated elevations using an SPS986 receiver, providing indications of the required cut and fill values at certain locations. The trench was considered complete when a participant indicated that they had finished excavating.

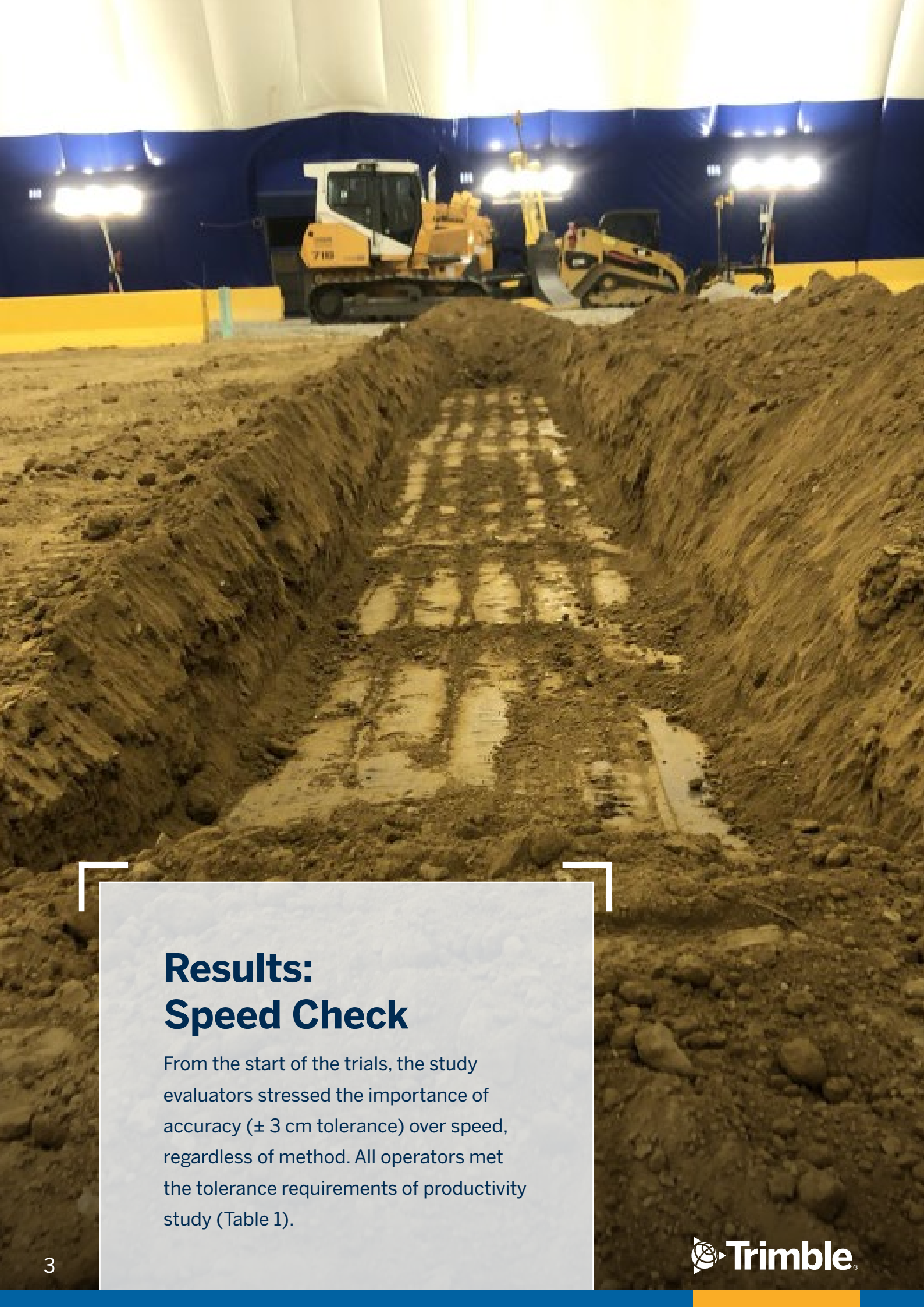
When complete, the trial timer stopped and participants turned off the machine. The moderator then took measurements along the length of the trench to verify the accuracy of the excavation according to the design.

Trial 2 Guidance Only

Machine Technology: Trimble Earthworks Guidance-Only

During this trial, participants excavated a 1 m wide x 15 m long by 0.5 m deep trench using the guidance only function of Trimble Earthworks. Participants had access to the trench design and Earthworks interface but did not have any automatic machine control.

As with Trial 1, when complete, the trial timer stopped and participants turned off the machine. The moderator then took measurements along the length of the trench to verify the accuracy of the excavation according to the design.



Results: Speed Check

From the start of the trials, the study evaluators stressed the importance of accuracy (± 3 cm tolerance) over speed, regardless of method. All operators met the tolerance requirements of productivity study (Table 1).

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TABLE 1: **AVERAGE ERROR** (M)		
	Conventional	Guidance
Novice	.032	.038
Intermediate	.024	.028
Expert	.016	.022

Of note, all operators met the required performance specifications for both methods.

The performance difference became clearly visible in performance time at all experience levels.

The average of all operators—novice to expert—showed an almost 43% improvement with guided grade control across the board.

Inside the Numbers

An important element of the productivity study was to provide some realistic performance (time and accuracy) values for conventional versus machine operated excavation.

A common assumption is that machine automation will help novice operators improve speed and quality. Unsurprising to most, the productivity study results confirmed that assumption. On average, novice operators were almost 50% faster with guidance-only than conventional methods (Table 2 and 3). Simply put, on average, novice operators were able to complete the job in 1/3 the time of conventional practices (8:25 versus 24:57) while staying well within required error tolerance. Expert operators, on average, completed the project, in 9 minutes and 56 seconds with conventional methods.

TABLE 2: **TIMES BY OPERATOR SKILLS**		
	Conventional	Guidance
Novice	24:57	11:26
Intermediate	11:02	8:04
Expert	9:56	6:03

> **“A common assumption is that machine automation will help novice operators improve speed and quality. The productivity study results confirmed that assumption.”**

TABLE 3: **PERFORMANCE BY OPERATOR**

Performance Deltas (%)	
Operator	Conventional vs. Guidance
1	-36.36%
2	-49.96%
3	-53.53%
4	-44.19%
5	-32.68%
6	-65.42%
7	-32.00%
8	-51.93%
9	-49.00%
10	-38.40%
11	-27.10%
12	-23.70%
13	-2.56%
14	-56.91%
15	-71.14%
16	-49.72%
Average	-42.79%
Std. Dev.	17.06%

■ Denotes a performance **increase** between Trial 1 and Trial 2

■ Denotes a performance **decrease** between Trial 1 and Trial 2

The study shows that while a novice operator does not have the experience to handle a machine with the same skill as an experienced operator, guidance, can significantly improve their ability to get jobs done faster with accuracy (Table 4).

One of the novice operators noted that he was able to "concentrate on smoothing out the trench because his focus was on staying in alignment rather than worrying about fine motions."

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TABLE 4: **NOVICE OPERATORS**

Performance Deltas (%)

Operator	Conventional vs. Guidance
2	-49.96%
3	-53.53%
4	-44.19%
6	-65.42%
10	-38.40%
14	-56.91%
15	-71.14%
16	-49.72%
Average	-53.66%
Std. Dev.	10.73%

TABLE 5: **INTERMEDIATE OPERATORS***

Performance Deltas (%)

Operator	Conventional vs. Guidance
7	-32.00%
9	-49.00%
11	-27.10%
12	-23.70%
13	-2.56%
Average	-26.87%
Std. Dev.	16.71%

■ Denotes a performance **increase** between Trial 1 and Trial 2

■ Denotes a performance **decrease** between Trial 1 and Trial 2

■ Denotes a performance **increase** between Trial 1 and Trial 2

■ Denotes a performance **decrease** between Trial 1 and Trial 2

On average, intermediate operators were around 27% faster with guidance-only than conventional methods as compared to conventional methods (Table 5).

It's no surprise that expert operators performed exceptionally well in all test scenarios. They were the fastest and most accurate (Table 6). Nothing replaces time in the seat!

TABLE 6: **EXPERT OPERATORS***

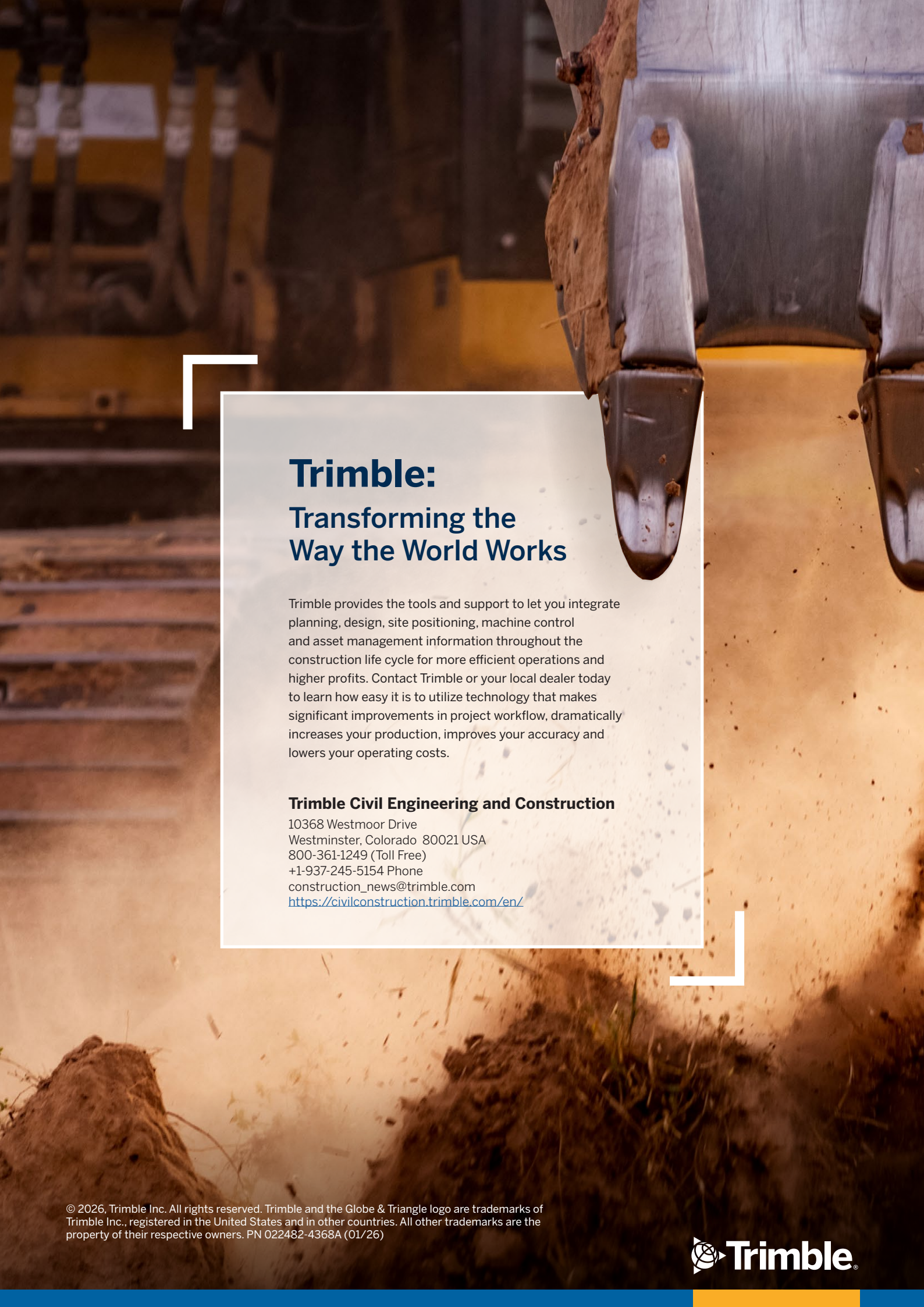
Performance Deltas (%)

Operator	Conventional vs. Guidance
1	-36.36%
5	-32.68%
8	-51.93%
Average	-40.32%
St. Dev.	10.22%

■ Denotes a performance **increase** between Trial 1 and Trial 2

■ Denotes a performance **decrease** between Trial 1 and Trial 2

The study numbers indicate that guidance make a very good operator better and enable less skilled operators to perform close to intermediate and expert operators with comparable accuracy.



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