

FIELD SURVEY OF STEEP SWITCHBACKS USING AN UNMANNED AERIAL VEHICLE (UAV)

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Figure 1. View from a UAV of a 5-axle off-highway truck negotiating a tight switchback.

Introduction

In September 2015, FPIinnovations conducted a unique survey of several steep, tight-radius switchbacks on Vancouver Island. The survey utilized an unmanned aerial vehicle (UAV), GoPro®-style video cameras, and a robotic total station to document how log-hauling trucks travelled through steep switchbacks.

Additionally, a detailed aerial photo survey and ground-based survey were conducted of each switchback to better understand switchback construction and how it affects off-tracking and driver safety.

In order to capture the desired information, several log-hauling trucks were tracked with the UAV through a series of switchbacks. Filming of the trucks from directly overhead documented the vehicles' travel paths and provided insight into their unique off-tracking characteristics. Additionally, video cameras were mounted on

the trucks to provide additional perspectives of vehicle off-tracking. Cameras were mounted to look forward from the rear trailer tires, and backwards from the tractor drive tires.

Information and lessons learned from the survey will be used to develop recommended practices for the design and construction of steep switchbacks, as part of the FPIinnovations Steep Slopes Initiative. Videos, off-tracking analyses, as-built drawings, and more information from the field study can be found on the Steep Slopes Initiative website (<http://steepslopeinitiative.fpinnovations.ca/>).

Equipment

- DJI Inspire 1 UAV
- iON Air Pro video camera
- Trimble S7 total station
- Sony HDR-AS15 video camera



Figure 2. DJI Inspire 1 UAV.

Survey Sites

In collaboration with Western Forest Products' Central Island and Port Alberni forest operations, three road sections with tight-radius, steep switchback curves were chosen for this survey. These locations were selected because they were considered challenging to drive, and log hauling was currently active on these roads.

Table 1. Summary of data collected during UAV survey of steep switchbacks on Vancouver Island

	Switchback #1	Switchback #2	Switchback #3
Road identification	WP--2030 (Central Island)	TK-0152 (Central Island)	KM-1454 (Port Alberni)
Latitude/longitude	N 50° 11' 16.55" W 126° 50' 45.99"	N 50° 17' 38.58" W 126° 58' 11.71"	N 48° 46' 07.68" W 124° 50' 10.57"
Curve length (m)	52	34	53 ¹ / 43 ²
Curve radius (m)³	24	15	15 ¹ / 11 ²
Average road width (m)	7	8	9 ¹ / 11 ²
Average grade (%)	-28	-26	-22 ¹ / -13 ²
Maximum grade (%)	-28	-28	-24 ¹ / -22 ²
Truck configuration	Kenworth on-highway 7-axle tridem drive tractor/tridem pole trailer	Kenworth on-highway 7-axle tridem drive tractor/tridem pole trailer	Hayes off-highway tandem drive tractor/tandem pre-load trailer.
Footage type	UAV/trailer camera	UAV/trailer camera/ tractor camera	UAV
Comments	Simple curve, abrupt grade brake (9%) at the beginning of curve	Simple curve, steep curve entrance (24%) and grades throughout	Switchback #3 consists of two switchbacks in succession connected by a 21-m tangent which creates a reverse curve

¹ For switchback #3, this refers to the first switchback in the reverse curve

² For switchback #3, this refers to the second switchback in the reverse curve

³ Curve radii determined using survey data and Softree RoadEng® computer software



Figure 3. View from the UAV of a 5-axle off-highway truck entering the first of two curves in Switchback #3.

Analysis

Based on the UAV photogrammetry survey, three-dimensional (3D) models of each switchback road section were created. These models were used to determine the as-built horizontal and vertical alignments of each road section, create as-built drawings, and perform off-tracking modelling for each vehicle.

3D models of each site were created using photos from the detailed aerial survey. Photos were processed using Photoscan software to create a 3D point cloud similar to a LiDAR point cloud. A 3D surface was then created using Softree RoadEng to determine horizontal and vertical alignments.

Off-tracking modelling of the observed logging trucks was performed using AutoTURN® (Version 9). For this analysis, only the horizontal component of the curve was considered. Truck dimensions were collected in-field, and included both highway and off-highway configuration logging trucks.

Assessments of UAV and truck-mounted videos were also completed. They provided insight into how the drivers handled steep switchbacks, and how the various logging truck configurations performed while navigating tight-radius curves on steep grades. By utilizing several camera angles, it was possible to estimate vehicle off-tracking, speed, and brake use.

Lessons Learned

- Photogrammetry surveys using the UAV took significantly less time and provided more comprehensive data than conventional total station surveys.
- As-built analysis of switchbacks revealed steep grades or abrupt transitions at the (uphill) entrance and steepest grades at the curve apex.
- AutoTURN results indicated that vehicles had more space to navigate steep switchbacks than shown in the video. This may be a result of AutoTURN not accounting for the tendency of the heavy logging trucks' steer tires to "plow" when navigating tight-radius curves with steep grades.
- Both the AutoTURN results and video showed that pre-load truck configurations were unable to navigate an 11-m-radius curve (Switchback #3).
- Video showed that loaded trucks kept to the outside of the switchback curves to allow for trailer off-tracking. Discussions with drivers indicate that road widening along the outside edge, especially at the (downhill) exit, helps with navigating through the curve.
- Adverse weather conditions may reduce road user safety on steep switchbacks where existing road widths are narrow, and

only provide for minimal clearance between logging truck tires and the road edge.

- Drivers were forced to slow to a crawl when approaching and travelling through switchbacks.
- Highway configuration trucks tended to brake at the beginning of curve, and then release the brakes once past the curve apex.



Figure 4. A loaded 7-axle highway configuration logging truck navigates a steep switchback.