Liao, Enqi, Syeda N. Zehra, and Stephen D. Wong. 2024. "Travel Behavior during the 2021 British Columbia Floods Using De-Identified Network Mobility Data." *Findings*, May. https://doi.org/10.32866/001c.117422.

RESILIENCE FINDINGS

Travel Behavior during the 2021 British Columbia Floods Using De-identified Network Mobility Data

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Keywords: transportation resilience, flood, network mobility data, travel behavior

https://doi.org/10.32866/001c.117422

Findings

This study investigates residents' emergent travel behavior before, during, and after the 2021 British Columbia Floods. Using de-identified network mobility data, we analyze travel patterns centered around the municipality of Hope in British Columbia, Canada. Our findings reveal significant drops in travel during the peak of the floods, corresponding with major transportation infrastructure failure. The slow recovery process and dispersed residents highlight the insufficient resilience of key transportation corridors. Furthermore, the results underscore the importance of network mobility data being: 1) privacy-protected, 2) efficient and easy to examine, and 3) adaptable.

1. QUESTIONS

Disasters are increasing in intensity, frequency, and scope due to the continuing effects of climate change (IPCC 2023). During these disasters, transportation systems are essential to ensuring that people can evacuate safely and recovery supplies are distributed efficiently. However, gaps remain in understanding how people travel before, during, and after disasters, especially flooding events (Hamilton et al. 2020). An assessment of travel behaviour can help officials improve their overall transportation response, meet the needs of travelers, and improve evacuation planning. Moreover, current methods to assess disaster behavior, such as surveys and interviews, often fail to generalize results beyond the survey participants (Wong 2020) due to relatively small sample sizes (Wong et al. 2022; Kuligowski et al. 2022). Mobile phone data can solve this issue (e.g., Yabe and Ukkusuri 2020; Zhao et al. 2022), but some concerns remain about privacy controls and anonymization of individual traces (De Montjoye et al. 2018). Anonymized traffic count data have also been used (e.g., Staes, Menon, and Bertini 2021; Parr et al. 2022), but data are usually limited to highways and major roadways without clear origins and destinations. Consequently, our question for this research was: what emergent travel behavior for a flooding event can be determined using de-identified, aggregated, network mobility data? We answer our question using the 2021 British Columbia (BC) Floods in Canada as a proof-of-concept.

2. METHODS

The data used for this study was gathered through the TELUS Data for Good program. TELUS is a large telecommunications company in Canada that provides wireless coverage across the country. The program offers access via an application programming interface (API) to de-identified, privacy-protected network mobility data for researchers focusing on projects that can produce societal benefits. Importantly, the API platform provides secure, de-identified, and aggregated data. This negates privacy issues, while still providing sufficient detail to understand large-scale urban travel behavior. Rather than displaying individual mobile phone traces, the data provides the total number of mobile phone devices that use any cell towers within and between user-defined geographic locations (e.g., cell tower zone, census tract, city, province, etc.). For example, the API can determine the number of devices entering a city from another city. For increased temporal detail, aggregated counts were collected for one-hour segments.

For our case example, we analyzed the number of people traveling between highly impacted cities before, during, and after the 2021 BC Floods using device counts as a proxy. Resulting from an atmospheric river event, the floods severely damaged infrastructure, closed multiple highways and rail lines, and led to evacuations of several areas (British Columbia 2023). We focus our attention on Hope, BC, a small municipality outside of Vancouver that was cut off from the rest of B.C. We first conducted a simple city-to-city analysis between Hope and Merritt, BC (toward the larger city of Kamloops) and between Hope and Chilliwack, BC (toward Vancouver). Using the API, we gathered a device count (i.e., a proxy for trips) starting from Hope and terminating in Merritt and Chilliwack over a two-week span during the 2021 floods. This was matched with 2019 data by weekday to account for day-by-day variations.

3. FINDINGS

Our analysis of city-to-city flow found a clear change in device counts during the 2021 BC Floods (compared to 2019 data), which indicates a significant deviation in travel behavior. While percentage change varies between years, likely due to seasonal effects (from winter storms) and small population changes, a spike occurs on November 14 (Table 1, Figure 1) between Hope and Merritt, likely corresponding to a small evacuation before the worst of the storm. A clear reduction occurs on the second day of the floods (November 15) and continues through our dataset (Table 1), arising from damaged infrastructure and severe flooding in Merritt. Travel appears to briefly recover at time points for several following days (Figure 1), likely due to temporary access for evacuation purposes. More consistent travel begins on November 20 due to alternative routes, though there is still a daily reduction of devices by over 65%. Continued reduction may be a result of the evacuation order in Merritt on November 15 (Global News 2021), parts

Table 1. City-to-City Flow from Hope to Merritt in BC in 2019 & 2021

Hope to Merritt					
Device Counts in 2021		Day of Week	Device Counts in 2019		Percentage Change
11/11/2021	10670	Thursday	5020	11/7/2019	112.5%
11/12/2021	7300	Friday	10600	11/8/2019	-31.1%
11/13/2021	6410	Saturday	7140	11/9/2019	-10.2%
11/14/2021	7750	Sunday	5940	11/10/2019	30.5%
11/15/2021	190	Monday*	9520	11/11/2019	-98.0%
11/16/2021	60	Tuesday	5370	11/12/2019	-98.9%
11/17/2021	150	Wednesday	5120	11/13/2019	-97.1%
11/18/2021	100	Thursday	5390	11/14/2019	-98.1%
11/19/2021	230	Friday	7340	11/15/2019	-96.9%
11/20/2021	1230	Saturday	5070	11/16/2019	-75.7%
11/21/2021	1200	Sunday	6960	11/17/2019	-82.8%
11/22/2021	1150	Monday	5340	11/18/2019	-78.5%
11/23/2021	1480	Tuesday	4970	11/19/2019	-70.2%
11/24/2021	1710	Wednesday	5100	11/20/2019	-66.5%
11/25/2021	1920	Thursday	6150	11/21/2019	-68.8%

*Remembrance Day (statutory holiday in Canada)

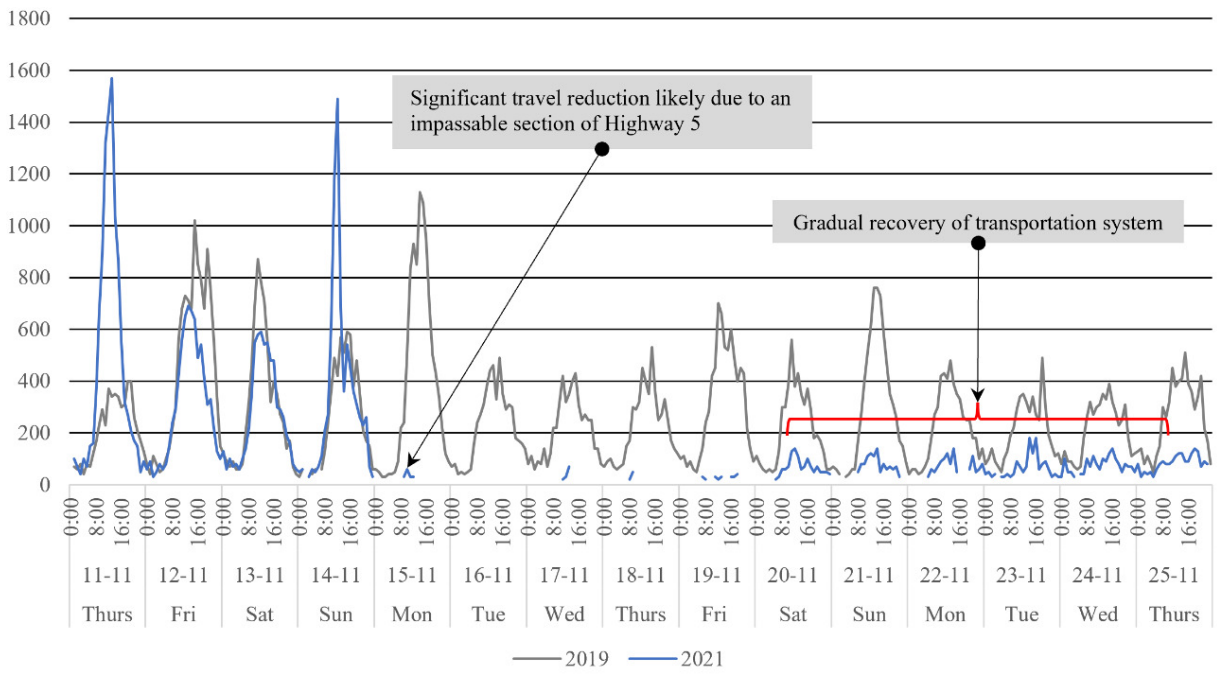

Figure 1. Hourly device counts from Hope to Merritt in 2019 (Nov 7 – Nov 21) and 2021 (Nov 11 – Nov 25). Data matched by weekday to account for day-to-day variation (dates in 2021).

of which were lifted on December 3 (Little 2021a), or the continued closure of HW5. This highway reopens later to commercial traffic on Dec. 20 and all traffic on Jan. 19 (B.C. Ministry of Transportation and Infrastructure 2023).

Table 2. City-to-City Flow from Hope, BC to Chilliwack, BC in 2019 & 2021

Hope to Chilliwack					
Device Counts in 2021		Day of Week	Device Counts in 2019		Percentage Change
11/11/2021	21600	Thursday	13560	11/7/2019	59.3%
11/12/2021	18620	Friday	19090	11/8/2019	-2.5%
11/13/2021	19590	Saturday	15050	11/9/2019	30.2%
11/14/2021	20640	Sunday	17540	11/10/2019	17.7%
11/15/2021	810	Monday*	31200	11/11/2019	-97.4%
11/16/2021	1750	Tuesday	14960	11/12/2019	-88.3%
11/17/2021	6690	Wednesday	14270	11/13/2019	-53.1%
11/18/2021	3160	Thursday	14310	11/14/2019	-77.9%
11/19/2021	3590	Friday	16070	11/15/2019	-77.7%
11/20/2021	5730	Saturday	12840	11/16/2019	-55.4%
11/21/2021	6700	Sunday	17530	11/17/2019	-61.8%
11/22/2021	6840	Monday	13530	11/18/2019	-49.4%
11/23/2021	7840	Tuesday	12380	11/19/2019	-36.7%
11/24/2021	8410	Wednesday	12950	11/20/2019	-35.1%
11/25/2021	7890	Thursday	14340	11/21/2019	-45.0%

*Remembrance Day (statutory holiday in Canada)

Similar results were found for Hope to Chilliwack (Table 2), with a large drop on November 15 and 16 in 2021. The increase at the beginning of the storms may indicate a small evacuation of Hope away from potential flood risks or early Remembrance Day travel to avoid the storms. In Figure 2, device counts increased for the next weeks at a faster rate than for Hope-Merritt, likely due to lower infrastructure damage. Chilliwack is also connected to Hope through several additional routes, which would indicate flexibility in infrastructure for travelers.

Our takeaways focus on both methodology and empirical analysis. First, de-identified network mobility data can approximate hourly travel in disasters at a reasonable level of granularity. Second, our analysis largely matched with route closures across BC (British Columbia, 2021; Serebrin 2021), indicating the relatively strong ability of this proxy method to show general behavioural trends. Third, device counts indicate a rapid movement of people away from the Hope area to other destinations on the first day of major rainfall. Finally, travel patterns suggest a slow recovery and poor resilience of some B.C. highways, routes, and infrastructure. With repair costs expected to reach over $1 billion CAD (Garrett 2023), lessons from this study indicate a need for more adaptive infrastructure for maintaining travel during major flooding events. This research also points to the feasibility of collecting de-identified network mobility data to approximate travel patterns before, during, and after disasters. With its strict privacy protections, simple interface, and zero cost structure, the TELUS data and associated API open a new methodological avenue for timely and big datasets for transportation resilience.

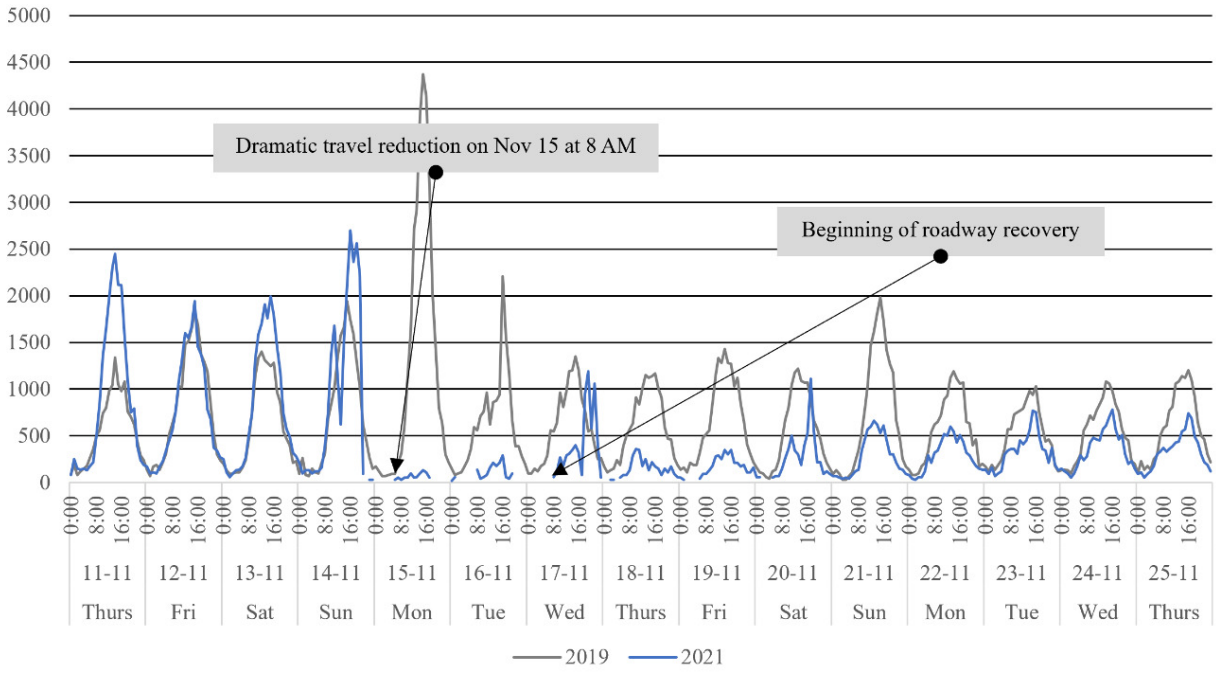

Figure 2. Hourly device counts from Hope to Chilliwack in 2019 (Nov 7 – Nov 21) and 2021 (Nov 11 – Nov 25). Data matched by weekday to account for day-to-day variation (dates in 2021).

ACKNOWLEDGMENTS

We thank the TELUS Data for Good team, especially Kendal Burtch and Jesslyn Dymond, for their commitment to the research and providing the data. The research was supported by the Dean's Research Award at the University of Alberta. We also thank the anonymous reviewers for their insightful and helpful feedback.

Submitted: November 07, 2023 AEST, Accepted: April 27, 2024 AEST

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SUPPLEMENTAL INFORMATION

TELUS Insight data incorporates approximately 9.8 million cellular devices across Canada. A new timestamped record is created when a device:

a) Makes or receives a phone call;

b) Sends or receives an SMS/MMS message;

c) Sends or receives data;

d) Is dormant for over 30 minutes; or

e) Moves/connects to a new cell tower.

At a minimum, a non-moving device that is not actively used will generate 48 timestamped records per day, and an average device generates 300 timestamped records per day. Since the data results in 3 billion records per day, TELUS Insight data (de-identified network mobility data) provides absolute results for all TELUS customers.

For this research, the TELUS Insight team confirmed that there were no anomalies in the number of records each day since 2019 (inception of the de-identified network mobility data). However, some changes may exist in the number of customers as people switch carriers. The inability to determine this change is a limitation of the study. Moreover, the number of TELUS customers in a specific area is not available externally due to TELUS Privacy by Design guidelines. However, research by the Government of Canada has determined that TELUS accounts for about 28% of the Canadian market (Canadian Radio-television and Telecommunication Commission 2022). Within British Columbia, TELUS accounted for 40.6% of subscribers in 2019 and 43.0% of subscribers in 2021 (CRTC 2023). The following population changes also occurred between 2016 and 2021 (when a census was conducted in the area (Statistics Canada 2024))

- Hope: 6,181 to 6,686
- Chilliwack: 83,788 to 93,203
- Merritt: 7,139 to 7,051

These population differences do not account for changes in the number of travellers passing through Hope, Chilliwack, and Merritt, who would also be counted in the methodology based on the requirements of the timestamped records above.

Regarding resolution, TELUS Insights data is based on the locations of the cellular towers, and their coverage areas. The spatial granularity is dependent on the cellular coverage in the area. Coverage accuracy is typically below 200 meters in urban areas, between 200 meters and one kilometer in suburban

areas, and between one and many kilometers in rural areas (depending on remoteness). The resolution of data for Hope, Merritt, and Chilliwack in the majority of the area is generally within 200 meters to one kilometer, though certain areas might fall within a one to five-kilometer range. In our analysis, we used the entire municipal district (DM) of Hope and the entire cities (CY) for Merritt and Chilliwack. Regarding overall geography, using straight-line distances and measuring from city center-to-center, Hope is approximately 93 kilometers from Meritt and 44 kilometers from Chilliwack.

For timestamps, the device counts were collected in 60-minute buckets, meaning that each device was counted once and only once if it recorded a timestamp in that 60-minute bucket. The trip terminates in that specific bucket. For routes, since a pass-through location was not included, the device counts factor in all available routes to Chilliwack and Merritt from Hope.

Timeline of Key Events – November 12, 2021 to November 20, 2021

Date	Key Events
Nov. 12, 2021	• Environment Canada issues warnings of extreme rainfall and snow due to the atmospheric river (Little 2021b). • No travel advisories are issued at the time for the Remembrance Day long weekend (Schmunk 2021).
Nov. 13, 2021	• Heavy rainfall begins across the Lower Mainland, increasing in intensity over the day (Schmunk 2021).
Nov. 14, 2021	• Mudslides and flooding begin blocking highways and roads (Schmunk 2021), while evacuation alerts begin in Abbotsford (Hopes, 2022). • HW5 between Hope and Merritt is closed due to a mudslide in the afternoon (DriveBC 2021). • Debris fields and mudslides are reported on HW3 and HW7 in the evening (Castanet 2021).
Nov. 15, 2021	• DriveBC reports significant closures of HW1, HW3, HW5 (Hope-Merritt), HW7 (Hope-Chilliwack), and HW11 (Judd and Michaels 2021). • A landslide on HW99 occurs in the morning (Schmunk 2021). • Officials issue mandatory evacuation orders in Merritt due to significant flooding (Global News 2021). • All major highways connecting the Lower Mainland and Interior B.C. are severed in at least one section and have closures (Judd and Michaels 2021).
Nov. 16, 2021	• Evacuation orders are issued for parts of Abbotsford and HW1 is flooded in multiple sections in the Lower Mainland (Hopes, 2022). • Over 1,000 motorists are stranded in Hope, which has become disconnected from the rest of B.C. (Ballard 2021). • A section of HW7 toward Chilliwack opens up in the evening with limited capacity to help evacuate people from Hope (Kotyk 2021).
Nov. 17, 2021	• With some bridges completely collapsed and closed highways, supply chain issues arise (Schmunk 2021). • A provincial state of emergency is declared due to the severe flooding and landslides (B.C. Public Safety and Solicitor General 2021).
Nov. 18, 2021	• Despite ongoing recovery and cleanup, reports suggest that over 17,000 people across B.C. are evacuated from the floods (Schmunk 2021). • HW 7 opens for essential travel (B.C. Ministry of Transportation and Infrastructure 2021b).
Nov. 19, 2021	• Canadian Armed Forces are deployed to aid in the disaster (Schmunk 2021). • HW 3 opens for essential travel only (B.C. Ministry of Transportation and Infrastructure 2021d).
Nov. 20, 2021	• HW1 between Chilliwack and Hope opens to a single lane of traffic in both directions (B.C. Ministry of Transportation and Infrastructure 2021a). • HW99 is reopened, allowing a connection between the Lower Mainland and the Interior B.C. (B.C. Ministry of Transportation and Infrastructure 2021c).
Other Events	• HW1 in Abbotsford is opened on December 2, 2021 (Hopes, 2022). • HW5 reopens for commercial traffic on Dec. 20, 2021, and all traffic on Jan. 19 (2022) (B.C. Ministry of Transportation and Infrastructure 2023).

SUPPLEMENTARY MATERIALS

Supplemental Information

Download: https://findingspress.org/article/117422-travel-behavior-during-the-2021-british-columbia-floods-using-de-identified-network-mobility-data/attachment/226627.pdf