TASK ANALYTIC STUDY OF VARIABILITY IN WHEELED MOBILITY INGRESS ON LOW-FLOOR BUSES

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ABSTRACT

Accessible low-floor public transit buses continue to pose safety and usability barriers for passengers in wheeled mobility devices. Investigative research studies often prioritize individual design features like access ramps. Spatial and temporal conditions during ingress/egress and ramp use that potentially impact safety and efficiency for wheeled mobility users have not been considered.

The study presents a task analytic framework to identify patterns, dependencies and variability in events and sequence of tasks performed by key actors (i.e., wheeled mobility passenger, drivers, and other passengers) in wheeled mobility users' ingress/egress on low-floor buses. Preliminary findings are presented from a video-based task analysis of 15 wheeled mobility ingress observations on in-service ramp-equipped public transit buses. Analysis revealed 28 different task elements and 4 unique sequences of events. The study provides a preliminary framework for analyzing spatial and temporal conditions in ingress-egress of wheeled mobility users, with the goal of identifying constraints on safety and efficiency.

BACKGROUND

Accessible and safe public transportation services are vital for the integration of wheeled mobility device users (WMDUs) in the community. Public transit vehicles, including low-floor buses, the most common mode of urban public transit (NTD, 2012), continue to pose safety and usability barriers for mobility impaired passengers using manual/powered wheelchairs and electric scooters (Cross, 2006; National Council on Disability, 2005; Nelson/Nygaard Consulting Associates, 2008). Steep access ramps and limited space for on-board maneuvering have been documented as key problems that increase the risk of injury among WMDUs under non-impact conditions. Accidents and injuries in ingress/egress occur at a disproportionately higher rate among passengers in wheelchairs compared to their ambulatory counterparts (Frost et al., 2010; Frost et al., 2012). A report by the National Highway Transportation Safety Administration (NHTSA) indicated that 25 percent of overall injuries or deaths that occurred between 1990-1995 in motor vehicles involving wheelchair users were attributed to malfunctions of platform lifts or falling on/off a ramp during vehicle ingress/egress (NHTSA 1997).

More recently, Frost and Bertocci (2010) performed retrospective reviews of WMDU-related adverse incident reports from a six-year period in one metropolitan transit agency. The study revealed that a majority of adverse incidents (42.6%) occurred during ingress/egress when the vehicle was stopped. Furthermore, injuries were 1.8 times more likely to happen during ingress/egress than while at the wheeled mobility securement location (either during transit or when LFB was stopped) (Frost and Bertocci, 2010).

Prior ergonomics and safety-related studies have often resorted to isolating and analyzing user interactions with individual design elements, such as wheelchair securement misuse, steep, access ramp gradients (e.g., studies by Frost et al, 2010, 2012; Frost and Bertocci, 2010). However, multiple factors during the ingress and egress process contribute directly or indirectly to adverse incidents.

A systems-level understanding of potential causal factors and conditions leading to adverse events is largely lacking. Further, time pressure resulting from operational constraints on dwell times and service schedules are often not considered. The purpose of this research is to investigate effects of spatial and temporal factors that influence both safety and inefficiency during the ingress/egress process by WMDU's while acknowledging multiple actors and objectives within the system.

This study develops a task analytic approach to identify patterns, variability and dependencies in events and sequence of tasks performed by key actors (i.e., wheeled mobility passenger, drivers, and other passengers) in wheeled mobility users' ingress/egress on transit vehicles.

METHOD

The study methodology uses information extracted from on-board surveillance video acquired from in-service ramp-equipped public transit buses to identify, analyze and model wheeled mobility ingress/egress tasks and events. Only the ingress phase is presented here for reasons of brevity.

Data Collection

This study was done in collaboration with the Ann Arbor Area Transportation Authority (AAATA or TheRide), a public transport agency operates a fleet of 80 ramp-equipped low-floor buses to serve Washtenaw County in Michigan.

Initial analysis focused on a set of three routes that were served by two buses alternating throughout the day. Six days of on-board video surveillance data was obtained from the transit agency taken from one of the two buses. The data yielded a total of 15 ingress observations by WMDUs forming the primary dataset in this study.

Task Analysis

A task analysis was performed to identify functions, tasks and the sequence of tasks performed by different actors in the system. Task analysis involves the process of documenting how a certain task is completed by breaking the task into steps; each step being a segment of the operation necessary to advance in completing the work (Shepherd and Stammers, 2005). Worksheet templates were created to capture task information and factors impacting ingress performance. Job Safety Analysis guidelines (CCOHS, 2015) were incorporated to identify associated hazards. The result of a task analysis is essentially a set of documents containing figures and tables to describe the human-system interaction.

Task analysis in this study was performed in four phases: (1) identify actors, (2) determine the goals, tasks and functions of each actor independently, (3) normalize and compare tasks different actors, and (4) identify patterns (similarities and differences), constraints, and dependencies across multiple ingress observations. The outputs from each phase are summarized next.

RESULTS

Phase 1: Identify actors

Three categories of actors in the system were identified and studied separately in the observed WMDU ingress cases, namely, the WMDU, the bus driver, and the other passengers boarding and disembarking.

Phase 2: Goals, tasks and functions for actors

An elemental task analysis wherein tasks performed by key actors (viz., the WMDU, the bus driver and the other passengers) are divided into simple elements defined by goals and start-end events. Highlights of the WMDU and bus driver are provided.

Task Analysis: Wheeled Device User

Ingress start event: When the bus has reached a stop and the door has been opened

Ingress end event: Instant when securement of the wheeled mobility device is complete

Table 1 illustrates the task elements and associated events that occur during ingress tasks performed by WMDU. Operationalized start and end event definitions were associated with each task element.

Task Analysis: Bus Driver

Starting event: When the bus has reached a stop and the door has been opened

Ending event: Instant when door closes to leave the stop

Table 2 illustrates the different events that occur during ingress performed by the bus driver.

Table 1: Task elements performed by the WMDU during ingress

Step Number	Task Group / Element
	1 Ramp Ascent
1	1.1 Wait for the ramp to unfold and passengers in front of the wheeled device if any, to board the bus
2	1.2 Align the wheeled device to the ramp
3	1.3 Ascend the ramp to reach the fare-payment station (with either powered or manual propulsion)
4	1.4 Turn the wheeled device towards the bus seating space
	2 Maneuvering and Positioning in the securement location
5	2.1 Wait for the securement station to be setup
6	2.2 Maneuver to the wheel chair securement station
7	2.3 Turn the wheel chair to align to face the front of the bus with the intention of aligning it to the securement station
8	2.4 Maneuver the wheel chair towards the station to position it in the securement station

Table 2: Task elements performed by the bus driver in wheeled mobility ingress

Step Number	Group/Element
	1 Ramp Deployment and Securement Set-up
1	1.1 Waiting for the ramp area to be cleared
2	1.2 Pressing the button to initiate ramp deployment
3	1.3 Rising from the driver's seat
4	1.4 Walking to the securement station
5	1.5 Requesting any passengers occupying the fold-up seats to clear the securement location
6	1.6 Folding up the seats
7	1.7 Moving the device tie-down straps aside in the securement location
8	1.8 Stepping out of the securement location
	2 Securing the Wheeled device
9	2.1 Bending down to retrieve the lap-belt and secure the WMDU
10	2.2 Retrieve the rear securement belt, (distal, proximal)
11	2.3 Securing the rear of the mobility device
12	2.4 Moving to the front of the wheeled device
13	2.5 Reaching for the front securement belt
14	2.5 Securing the front of the mobility device
15	2.6 Standing to return to the driver's seat
16	2.7 Sit and situate on the driver's seat
17	2.8 Wait for the ramp envelope to be clear
18	2.9 Pressing the button to fold the ramp
19	2.10 Waiting for all the passengers to board the bus, if any
20	2.11 Pressing the button to close the door

Phase 3: Excel Data Extraction and Normalization

Decomposing processes into simple elements gives way to comparing and differentiating the different ingress observations. Durations for key task elements (i.e., Task times) performed by the WMDU and bus driver were extracted by observation over three video passes. Each pass, one set of times are recorded.

Apart from task times, information like use of handrails to assist in ramp ascent, type of surface that the ramp deploys on, etc., is also recorded during a fourth pass, though not reported here.

Phase 4: Sequence, Constraints and Dependencies

Tasks times were then normalized (i.e., expressed in percent of total dwell time) in Excel to identify the sequence of tasks performed by the WMDU and driver and also those tasks that overlapped between them. The normalized times of the different occurrences were represented graphically on a timeline to facilitate comparisons. Figure 1 shows a WMDU ingress occurrence that is represented in a normalized bar graph. The first bar represents the activities occurring on the ramp, the second represents the WMDU tasks and the third represents the bus driver tasks.

The task sequence for the 15 ingress observations were graphically visualized with the intention of identifying trends. The sequence differs based on the actual events occurring, driver behavior, and additional passengers boarding and disembarking.

It was observed that when the boarding of other passengers was considered as a varying event and not accounted during classifying the sequences, the 15 ingresses could be categorized into one of four sequence types. The four sequences differed from each other due to either the order in which the tasks occurred or the overlapping of tasks of the WMDU and bus driver. The four sequences are described in Figures 2 along with the sample size of each sequence type

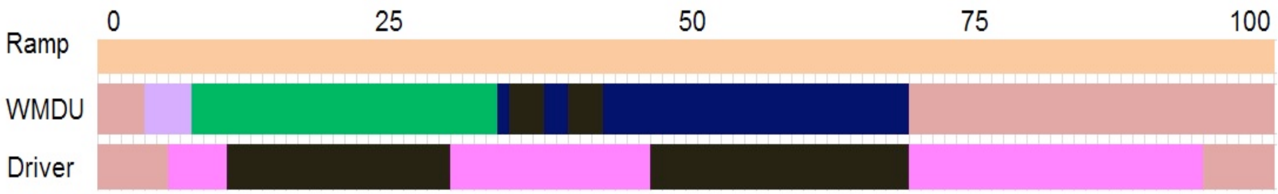

Figure 1: Normalized timeline of ingress task elements performed by the WMDU and Driver for one sample ingress observation from ramp deployment (0%) to ramp closing (100%)

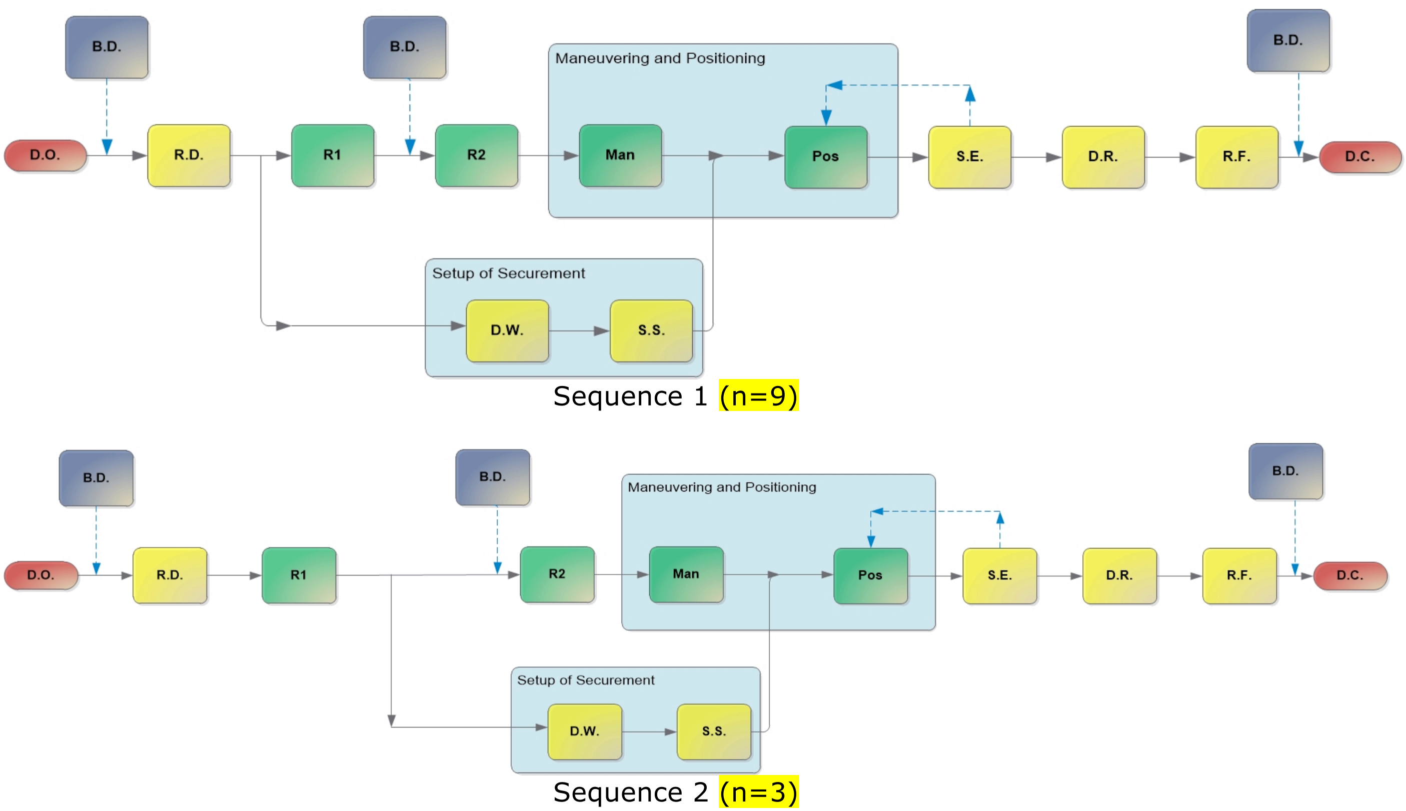

Figure 2: Graphical representation of two of the four observed task sequences identified in WMDU ingress from Door Opening (D.O.) to Door Closing (D.C.). The tasks differed in the sequence of tasks performed by the driver (shown in yellow), WMDU (in green) and opportunities for other ambulatory passengers to board or disembark (B.D.).

DISCUSSION

Multiple factors during the ingress and egress process on buses, including psychosocial, spatial and temporal considerations, contribute to adverse incidents involving WMDU. This study is a preliminary effort in a task analytic approach to identify differences in the ingress process. Four unique sequences of events were observed across 15 ingress observations based on the sequence of task elements.

Findings from this work can help identify potentially hazardous conditions and subsequent preventative strategies. For instance ramp ascent often occurred unsupervised by the WMDU (e.g., Figure 1-top: Sequence 1) when the driver has already moved to bus interior compartment to initiate set-up. Driver feedback to the WMDU such as in misalignment with the ramp can prevent or minimize potential risks.

From an operational perspective, results from this study help identify events and task sequences performed by the bus driver that lead to safer and more efficient dwell time based on the scenario present at that particular bus stop. Transit agencies and policy-makers could use this approach to identify unsafe practices, evaluate driver performance, and develop best practice guidelines when serving passengers using wheeled mobility devices.

The systematic decomposition of task demands in transit vehicle ingress/egress and potential variance in tasks provide rehabilitation engineering and occupational therapists to evaluate consumer needs in terms of wheeled mobility equipment and skills or travel training necessary for safe public transportation use. The variability in wheeled mobility user abilities, travel conditions, and differences across transit agencies only highlight the need for research to understand these relationships.

The tasks identified in this preliminary study also depend on operational policies like having the driver set-up the securement location and perform device securement. Often these are optional tasks performed by the driver in an attempt to reduce dwell time or difficulty for the user.

Ingress task sequences presented here are based on a limited set of 15 observations. Other conditions and sequences may exist that have not been identified yet. Additional analysis is on-going.

CONCLUSION

The results of this study provides a systematic approach to describing tasks, constraints and dependencies in wheeled mobility ingress on transit vehicles, with the goal of identifying and mitigating conditions that impede safety and efficiency.

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