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Safety evaluation of amusement rides using accumulated accident data: Accident data framework

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Abstract

Amusement rides and devices are a popular form of recreation and important component of the tourism industry. Injury-producing accidents are rare, and the viability of the industry relies on perceived safety of the activity. Some existing metrics use accumulated accident reports. Several metrics tabulate the number of injuries, but none collect enough information about the context of accidents to analyse the accumulated data to deduce patterns. This paper describes an Accident Data Framework for a minimal set of variables from reports of amusement device accident, and the structure for a useful narrative to aid reporters and recorders to avoid introducing bias. A pilot test with 125 industry practitioners supported the general feasibility of this approach. A review of requirements confirms the framework supports compliance with ASTM F770, a major international standard. Refinements made in response to a pilot test of the Accident Framework were incorporated into the classification rules, provided in an Annex to the paper.

Keywords: amusement rides; safety; accident data.

1. Introduction

Amusement rides and devices are a popular form of recreation and important component of the tourism industry. As an entirely discretionary activity, loss of trust in the safety of amusement rides and devices could lead patrons to abandon an owner-operator perceived to be unsafe, or to abstain from amusement rides altogether. Fortunately, serious injuries involving amusement devices are rare (International Association of Amusement Parks and Attractions, n.d.). Individual owners, trade groups, and regulators monitor accident occurrence as a part of safety evaluation and management as feedback for improvement and to communicate good results to reassure the public.

Safety evaluation is not limited to accident data analysis. Safety may also be evaluated by complementary programs of Design Risk Analysis, such as ISO 17842-1 (International Organisation for Standardisation, 2015) and safety inspection (Woodcock, 2014a). Analysis ensuing from accident reports also includes in-depth investigation of individual occurrences. These alternate approaches to safety evaluation are outside the scope of this paper, which focuses on different forms taken by safety evaluation based on accumulated accident data.

As a form of safety evaluation, analysis of accident data has the distinct disadvantage that it requires some degree of harm to occur before the lack of safety can be measured. Additionally, an operation can be accident-free without being “safe” if the operation is small, the measurement period is short, the risk is low, or more than one of these.

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However, there is a common moral drive to redeem adverse events by learning something from the occurrence, and using accident data as one safety evaluation tool is axiomatic.

In the realm of safety evaluation, the distinction must be made between accidental injuries and accident events. Injuries may draw attention, or even qualify an event as reportable, but the injury alone lacks context. The accident event provides the context, and along with it, potential approaches for prevention.

Two broad types of analyses are performed by those seeking to evaluate the safety of attractions: analysis of incidence (raw counts or incidence in proportion to exposure), and descriptive analysis such as the nature of events, venues or devices involved, characteristics of injured persons, and other variables. The latter will fail if the required information is not captured at the time of primary reporting.

2. Existing attractions safety metrics

There are several types of systems that currently accumulate data related to accidents involving amusement rides and devices, including public data collection, trade association, regional regulators, and commercial communications between owners and manufacturers. Table 1 summarizes examples of the variety of amusement ride accident data collectors globally, including what is collected, and what is reported and accessible from each type of system. Each is briefly described in this section.

Table 1. Existing collections of amusement ride data

Source/ section / Character-istic of metric	CPSC NEISS database 2.1	IAAPA Annual Safety Report 2.2	Florida public quarterly reports 2.3	Ontario Annual Public Safety Report 2.4	Owner's report to Manufacturer 2.5	Internal operator reports 2.6	News media 2.7
Injury count	Extrapolated to national estimate	Yes*	Yes	Yes	Individual cases	Possibly	Individual cases
Exposure measure	No	Yes*	No*	Provincial population	No	Possibly	No
Context of accident	Intended but not actually*	No	Minimal	Minimal	As pertaining the device	Possibly	Possibly
Public access	Yes, searchable	Report	Report	Report	No	No	Media
Region	USA	Global but primarily North America	Florida, USA	Ontario, Canada	Global	Global	Global

Notes.

CPSC (Consumer Product Safety Commission, USA) NEISS (National Electronic Injury Surveillance System) records of amusement ride-related injury provided no context of the accident, often not clearly identifying the ride.

IAAPA (International Association of Amusement Parks and Attractions) Injury count refers to North America, with 90% reporting, with the majority reporting injury and an exposure measure. Lower or no data from the rest of the world at present.

Florida quarterly reports do not collect exposure (attendance) but this is estimated by a third party for most major parks.

2.1 Consumer Product Safety Commission

The U.S. Consumer Product Safety Commission (CPSC) National Electronic Injury Surveillance System (NEISS) collects reports from the emergency departments of a network of about 100 hospitals across the United States, constituting a stratified probability sample representing all hospitals nation-wide. Each emergency department in this network is assigned a weighting factor based on the sample design. Each case treated in the emergency department in these facilities is coded to identify up to two consumer products involved with the injury. The application of the weighting factors enables a national estimate of the number of related injuries in the U.S. population involving specific consumer products (Consumer Product Safety Commission, 2000).

Notionally, the collection of data from emergency departments serves as a filter to focus the national estimate on injuries serious enough to require that level of treatment, although less severe exposures may be included if the injured person or her parent seeks the reassurance of emergency department professionals or the park operator chooses referral to hospital as a conservative response. For descriptive analysis, the CPSC NEISS dataset collects information on the injured person's age, gender, and race, and descriptions of the nature of injury and body parts injured, and a narrative. Amusement rides and devices (product code 1293) are included among the consumer products; waterpark waterslides are included as a separate product (product code 3295).

Records are publicly searchable. Data coded as product code 1293 may include other products that the general public would not consider "amusement rides". Past analysis identified records associated with laser tag, a ball pit, trapeze, obstacle course, playground equipment, haunted house, coin-operated figure (e.g., supermarket horse), pitching cage, or game, for example, as well as waterslides erroneously classified as 1293. While perhaps amusing recreational activities involving some type of apparatus, an extrapolation including these reports overstates national prevalence of carnival and theme park ride injuries by 63% (Woodcock, 2014b). CPSC weighting models used to extrapolate to national estimates may be less valid for amusement rides that widely vary on a regional basis than for household consumer products found more homogeneously around the country (Levenson, 2003).

The NEISS Coding Manual (2019) specifies "*Every case must include a descriptive comment. Start each comment with the patient's age and sex, and include details about the product(s) and sequence of events, as well as the associated diagnoses, affected body part(s), and alcohol/drug involvement. … The Comments should include a description of what the patient was doing when the incident occurred (i.e., the sequence of events), the product(s) involved, and the locale.*" Nevertheless, narratives generally duplicated the age, sex, diagnosis and body part captured in separate variables, but failed to document the type of ride or the event that produced the injury (Woodcock, 2014b). For amusement devices, NEISS is essentially an injury database rather than an accident database.

2.2 International Association of Amusement Parks and Attractions

Members of the international trade association International Association of Amusement Parks and Attractions (IAAPA) are expected to report the annual total number of serious injuries and their annual attendance or ridership or both (National Safety Council, 2020). These reports are aggregated by the National Safety Council (for North America) and international contractors at arm's length from IAAPA, so no individual operators are privy to business metrics of their competitors. Reporting is obligatory for U.S. members, with 61% response in 2019 (National Safety Council, 2020). This initiative is at different stages of maturity in Europe, Middle East, and Africa, and Asia-Pacific regions.

The aggregated data are used to report total occurrences and derive proportions of injuries per admission and injuries per ride overall, which IAAPA uses in public communications. The report provides subtotals for roller coasters, family rides, and children's rides, and for load/unload versus ride motion phases, and serious versus other severity. The database neither collects nor reports information about either the specific injuries or accident events, just the count.

2.3 Theme park quarterly reports to Florida Department of Agriculture

Many internationally prominent theme parks operate in Florida. Six of the world's top 12 theme parks are located in the state, accounting for over 80 million gate admissions in 2019 (Themed Entertainment Association, 2019). Under Florida Statutes (2018) Title XXXVI, chapter 616 § 242 (10) (a), the Department of Agriculture and Consumer Services performs amusement ride safety inspection, but operators with over 1000 employees are exempt from state inspection if they maintain full-time in-house safety inspectors on staff and file annual affidavits of the inspections in the prescribed form. Florida collects quarterly reports from major operators Walt Disney Parks & Resorts, Universal Parks & Resorts, SeaWorld, and Merlin, operators of LEGOLAND, on the nature of serious injuries occurring in each facility (Pedicini, 2016). These reports are accessible online (Florida DACS, n.d.), and also widely published in news media.

Quarterly reports usually identify the park, the ride, the general nature of the event and injury, along with the age and gender of the injured person, and if applicable, whether the person had a pre-existing condition (e.g., a report

might state, "55-year-old woman with pre-existing condition tripped while exiting ride X"). Reports have been described as vague (Pedicini, 2016). Some reported injuries are not patently serious in nature and suggest any hospital transfer may have been precautionary, but were included for transparency. Reporting is qualitative, as the number of serious injuries per park per quarter is too few to tabulate. However, a measure of exposure, attendance is estimated for most major theme parks in the annual Theme Index (Themed Entertainment Association, 2019), although attendance does not necessarily entail exposure to rides.

2.4 Incident reports and annual Public Safety Report in Ontario, Canada

Under the Technical Standards and Safety Act in the province of Ontario, Canada, specific amusement devices must be licensed by the regulator, Technical Standards and Safety Authority (TSSA), whether they are operated at a fixed site or as mobile rides. Licensed operators of amusement devices must report a wide range of occurrences to TSSA, with differing degree of immediacy, including fatal injury, injury requiring medical care, and other occurrences whereby a hazard is exposed resulting in an adverse consequence to a person or property, and conditions that constitute "an immediate hazard to the safety of a person or property" (O. Reg 221/01 § 17.5). Operators report to TSSA the nature of the event, which is recorded in an institutional database. Information about the ride and the owner are known from cross-referenced license databases. Reports of events are reviewed to determine which require in-depth investigation or further inspection of the device. The report is abstracted in multiple variables including parts of body, event category, and Disability Adjusted Life Years rating used to monitor the provincial burden of injury from each regulated technology (Technical Standards and Safety Authority, n.d.).

Annually, TSSA produces a report on occurrences with regulated technologies that reports the raw count of amusement device occurrences in total, and broken down by device type (e.g., waterslide, zipline, coaster, circular rides) (Technical Standards and Safety Authority, n.d.). The report also presents a breakdown of causal type. TSSA noted that 95% of reports for the past 11 years had been ascribed to factors external to the regulatory environment, and 99% of these were ascribed to human factors, such as the rider's own actions (Technical Standards and Safety Authority, n.d.) The narrative detail collected in individual reports is not publicly reported or accessible, but may be used for internal analysis. TSSA does not have access to ridership or attendance data. Therefore, relative risk is not included in the annual report. Instead, TSSA reports risk burden on the Ontario population. This practice is valid for risks of home heating equipment, used by virtually everyone in Ontario; the risk of exposure to amusement devices is diluted by a large but unknown number of non-exposed residents. Changes in compliance with reporting obligation is suspected to account for much year-to-year variation (R. Wiersma, personal communication).

2.5 Owners' reports to ride manufacturers

Under the international "Standard Practice for Ownership, Operation, Maintenance, and Inspection of Amusement Rides and Devices" ASTM F770-21 (ASTM, 2021), amusement device owners must report to ride manufacturers "an incident, failure, or malfunction which, in the owner/ operator's judgment, affects the continued proper operation of the amusement ride or device and is information of which the manufacturer should be aware." The standard does not specify what is to be reported. Standards are not obligatory unless adopted under legal authority although operators may comply voluntarily as a best practice, and this standard has been adopted in many jurisdictions around the world. Each manufacturer would receive reports only for their own rides, even when similar rides are manufactured by other manufacturers.

There is no public access to incidents reported in this manner. The manufacturer determines who to notify. Even regulators may receive this information only through owner/ operators licensed in their jurisdiction.

2.6 Internal operator reports

ASTM F770-21 also prescribes that operators shall collect reports on first-aid incidents including date, name and contact information of the injured person, age, ride manufacturer's name, description of the injury or illness and events related to the incident, description of treatments and classification of degree of injury. Individual operators may comply or deviate from this standard practice, or go beyond it voluntarily or under regulations or codes within their jurisdiction. However, internal operator reports are not accessible to the public.

2.7 News media

News media including local news and global networks are an accessible source of information for forming public opinions. A reporter may become aware of an occurrence in a variety of ways including noting an event trending on social media, being contacted directly by the public, or monitoring emergency radio calls. All amusement ride accidents will not be captured and reported in the media. Media reports are not an indicator of relative prevalence across regions because newsworthiness criteria may vary between regions. However, media reports can reflect a safety level relevant to public decisions about consumption of attractions.

In addition to a count of occurrences, the analyst may take a content-analysis approach and classify each such record by broad ride type, event type, operation type, or region, enabling cross-tabulation among the variables (Woodcock, 2019), or the analyst may examine only cases involving a specific phenomenon, such as rider ejections (Stenzler, 2016). Beyond the issue of possible omission, or absence of coverage of a relevant case, analysis of media reports is inherently limited by the source: news coverage is not written to meet a standard of comprehensiveness for accident reporting. Published reports may lack some detail, in some cases impeding a full understanding of the event. Construction of media reports to a minimum standard of detail would have been advantageous.

2.8 Summary of existing metrics

As was summarized in Table 1, none of the current forms of data collection provide insight into mechanisms of the accidents occurring. Some existing metrics and data sources provide total incidence or population proportions of incidence. Some collect information about injuries, but not about the injury event. None of the sources systematically capture information about accidents in relation to controllable contributing factors. Some capture a narrative. Natural-language analysis of narratives contains the promise of richer insights than can be anticipated in a scheme constructed around variables. However, this promise relies on accurate and comprehensive narratives. Variation in the substance of narratives, as well as the limited availability of narratives in some systems, limits public or researchers' use of narratives to extract necessary variables. Hence, a new accident data framework is proposed.

3. Amusement ride Accident Data Framework

The goal of a new Accident Data Framework (ADF) is to acquire data that will support both risk quantification and formative evaluation. Due to low incidence of amusement ride accidents, risk quantification will only be valid at the population level but formative evaluation will be informative at both population and operation levels. The framework must:

- Retain meaning when identifying details of individual cases are detached, compatible with separately collected metrics of exposure for calculation and comparison of risk levels;
- Manage threats to validity, particularly biases about causation, by collecting objective descriptions and provide classification rules for consistent treatment of ambiguous or boundary cases when used by typical reporters and recorders;
- Be feasible to implement in practice;
- Enable its users to comply with standards such as ASTM F770-21.

3.1 Structure of the proposed ADF

The ADF is based on an approach used to record and analyse narratives found in media reports (Woodcock, 2019). It consists of four key "event variables" and three "person variables" (Table 2).

The event variables describe the accident event to which records containing person variables may be attached, one record per affected person. Separating the casualties from the event report avoids duplication when multiple patrons are injured in the same accident event. The primary novelty of the ADF is the use of the event variables. Information about casualties is often collected, but event information may not be collected systematically in existing schemes, other than in some narratives.

Table 2: Key variables

Event variables	**Person variables**
Ride type	Severity of harm
Operation type	Age
Operational stage	Gender
Event type	

Original taxonomies for Ride type, Operation type, Operational stage, Event type, and Severity of harm are included in the Annex and discussed in Section 3.3. **Ride types** group similar rides together based on type of ride action and experience. Definitions provide disambiguation rules. "**Operation type** refers to fixed-site, mobile, or waterpark operation. This only needs to be reported when more than one operation is collected by the reporting system. **Operational stage** refers to when the event occurred during the person's interaction with the amusement device: queue, load, ride in motion, ride paused, normal unload, or evacuation. **Event type** includes types of failure events, grouped in categories such as malfunction or hazard of the ride, misoperation, patron reaction or action, and submersion in water. Event type is discussed further in the next section. Event type and Operational stage both give examples of exclusion criteria.

Severity is recorded by the degree of treatment required by the injury, not coincidental higher level of provider. For instance, first aid performed by a person with MD qualification is first aid, not "medical care". Fatal injury would be recorded as such, regardless of treatment rendered prior to fatality. Non-fatal severity includes hospitalization at least overnight other than for observation (consistent with ASTM F770-21), medical care required (such as emergency department, diagnostic imaging, sutures, prescription medication, fracture clinic), first aid required (such as cleaning and dressing a wound), comfort (care that did not require qualified first aid provider such as over-the-counter pain relief, ice, cool water, a shady place to rest), and no-injury.

Age and **gender** may be recorded in any generally accepted manner. For children under the age of two, it can be useful to record years and months of age, consistent with NEISS.

Contact information of the injured person and date of occurrence are presumed to be collected in an administrative preamble to the ADF itself, or by complementary systems as needed. Complementary information about the injury may be recorded as well. Nature of injury, part of body, and object inflicting injury may be recorded using existing injury recording standards and taxonomies such as *Coding of Work Injury or Disease Information* (CSA Z795-03) and its international counterparts. These complementary and administrative variables are not further discussed.

3.2 Retaining meaning

This minimal set of key variables addresses the first objective of the ADF. Operational stage and event type capture meaningful information about the accident context that survive the removal of identifying details. Severity of harm can be reported as a breakdown and used for grouping. Ride type, operation type, age, and gender can be used for grouping in overall reporting, and also potentially to select cases to include in a numerator when a corresponding exposure denominator is available.

The Annex presents the working taxonomy for four key variables: Ride type, Operational stage, Event type, and Severity. For Operational stage and Severity, the taxonomy includes decision rules for classifying occurrences on or near boundaries between classifications. For Ride type and Event type, the taxonomy identifies category groupings for aggregating data to facilitate analysis of smaller datasets.

3.3 Classify consistently while managing threats to validity

The second objective relates to the transition from the "story" of the event to recorded data in the database. While the ADF is a framework of variables, a narrative is a prerequisite. The validity of the aggregated data depends on collection of a valid narrative, and a valid transition from the narrative to classified variables.

The event is typically recorded by a designated person based on a description provided by the injured person, witnesses, and others having information about the reportable event. In some cases, the narrative description is recorded, followed by the same person or another person parsing the narrative description to extract the information required to document each variable. In other cases, the recorder hears the description and proceeds directly to recording the narrative.

In some cases, the primary reporter (injured person or guardian of injured child) will report directly into a form on which they select values of the variables while recalling their experience. However, the ADF is based on recording a narrative as the first step of practice, prior to classification, as it has at least two valuable uses.

If certain patterns of occurrences were noted, all corresponding narratives could be extracted for review, and the nuance in the narrative may be informative. If the classification taxonomy is later revised to break a classification into parts, previous narratives may be retrieved to reclassify those cases so that past and current metrics are comparable.

As previously noted, analyses of aggregated amusement device injuries consistently classify over 95% of events as "human factors", whereas analyses based on narratives interpreted with a human factors lens has reported different findings. Among media reports from a 12-month period, only 6% involved deliberate actions such as self-extraction or hazardous positioning. A further 6% were adverse reaction to the ride (including known and unknown pre-existing conditions) and 6.6% were failures of appropriate actions, while over 36% were malfunctions and 8.8% ejections (Woodcock, 2019). In a study of 100 consecutive reports, there were six mentions of attempts to exit or stand on the ride and 10 references to rider characteristics (age, height, medical reaction, or cognitive disability) while 45% of 84 rider injuries or exposures mentioned contributing facts related to the machine, material, or tools (Woodcock, 2008). The ADF aims to integrate a human-factors lens into the construction of the narrative and thereby to avoid biased causal inferences.

The person coding the event cannot record information that is not provided in the narrative. Thus, it is essential that the narrative documents information pertaining to the variables in the ADF. To provide the information, the ideal narrative describes: the relevant preceding conditions, hazards, or intentions; the failure event marking a transition from typical to atypical process; an intervening event if any, such as aggravating or mitigating actions, reactions, or conditions; the impact event by which the injury was inflicted; and post-impact information including the type of injury and care required (Figure 1).

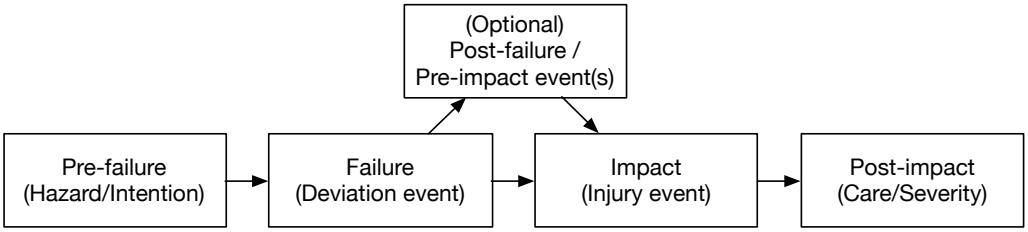

Figure 1. Stages to be included in narrative

Bias is often introduced into investigation by the investigator's inability to isolate knowledge of the outcome and the counterfactuals that would have avoided it, resulting in "bad apple" investigation conclusions (Dekker, 2014). Recording the pre-failure conditions and intentions formalizes the practice of endeavouring to see the event from the perspective of the person in a situation. This practice of documenting antecedents of human performance is not common. Analysis of archival investigation reports of amusement ride accidents previously observed that antecedents of slips (physical execution failures) were documented 53% of the time while mistakes (inappropriate actions) and lapses (failure to act) were investigated less than half as often (Woodcock & Diyaljee, 2010).

Narratives that record little more than the performance of the injured person and outcome may bias classification toward user error because no context or other information is available to classify. For example, the event phrased "*rider hit nose on restraint"* would shape classification toward rider-action-related event categories. Phrasing the same event as *"sudden ride acceleration forced rider's head against restraint"* would shape classifying the event in

terms of irresistible ride forces or uniquely limited postural control. The "*rider hit nose*" narrative would promote interventions related to behaviour, while the "*sudden ride acceleration*" narrative may prompt consideration of the ride's restraint and containment system, along with rider eligibility.

After collecting the information from the sequence of events, the ADF ideal narrative flows in the same sequence: from preceding hazards (if any) to the failure event (deviation from typical process), to successive steps until injury impact and consequences. It requires conscious effort to return to the origin and describe the context before the failure, before the outcome, and not fall back on an easy "rider did something" narrative format.

In addition to collecting fuller information needed to classify the variables, capturing data from the consecutive stages as a narrative on record would also enable use of a modified Haddon Matrix for further analysis of the narratives (Woodcock, 2008).

3.4 Pilot test of feasibility

To evaluate the feasibility of this guidance and provide information needed for its refinement, a small pilot study was conducted with a group of 125 amusement ride inspectors, owner/ operators, and other industry insiders attending an industry professional development and networking event. The exercise was determined by the Ryerson University Research Ethics Board to be a business process-improvement activity and not human-participants research. Groups of five participants received a set of story facts printed on repositionable material (magnetic strips), and a structured format to arrange relevant facts into the narrative structure pre-printed on the magnetic board. Nine scenarios were prepared and groups received the next scenario in the randomly arranged stack. Groups received minimal orientation of less than five minutes, covering the instructions to (1) select story facts and move to the corresponding narrative stage on the board, (2) place magnetic markers indicating three of the key variables (Ride type, Operational stage, and Event type) and Severity, and (3) write freehand narratives, with the goal to avoid "rider did" narratives. Groups then interactively collaborated for 20 minutes to do so.

Overall 84% of groups identified the impact event producing the injury, 72% identified the failure event, 68% identified the preceding event or condition, and 48% identified the intervening event when applicable, despite minimal instruction.

The ADF narrative approach seems practical. Even with this minimal orientation, less than 30% of groups presented incomplete narratives, and 2/3 of reports successfully avoided the "rider did" construction.

Pilot participants classified Severity as intended over 80% of the time. They also classified Operational stage as intended 75% of the time. The decision rules/guidance for Severity and Operational stage was enhanced in response to observed difficulties and the revised version appears in the Annex. As more boundary cases emerge, the guidance can be enhanced to clarify the classification for future users.

Participants classified 100% of ride types as intended by the taxonomy. Thus, familiar users seem to need little assistance with ride type classification. Use by other reporters may require more assistance, but it is possible that the ride type classification could be made automatically within a regulatory reporting system or owner's inventory. Although a ride may be rethemed and renamed, rides do not change types over their lifetime. The ride type would be retrieved correctly as long as the ride was unambiguously identified and matched in the ride database. The primary role of the taxonomy for ride type is to identify the meta-types for grouping ride types.

In contrast to the other three variables, pilot study participants classified just over 50% event types as intended, using a streamlined form of event classifications. The available classifications consisted of the Event meta-types listed in the Annex, except that unintended body motion was offered as a separate classification from other rider-related classifications. The available meta-events were hazard exposure, misoperation, rider action or characteristic, unintended body motion, clearance failure, ejection, malfunction, or drowning/submersion.

While a strong performance with minimal training, the pilot exercise provides useful guidance for developing training materials and resources that will be useful to some users to enable this scheme to be implemented in the business process. For example, it is also possible that asking users to classify the event type rather than the event

meta-type would have guided the users to more accurate classifications, because this would reduce the abstraction of the classification.

3.5 Standards compliance

Assuming administrative and complementary variables describing the injury are also collected, ADF collects all variables required for compliance with ASTM F770-21, although the reverse is not true. Compliance with ASTM F770-21 would not necessarily ensure the collection of all of the variables of the ADF (Table 3).

Table 3: Comparison of variables ASTM F770-21 vs. Accident Data Framework

F770 §	F770-21 description	Accident Data Framework
11.1.3.1	Date the incident occurred.	N/A May be collected as administrative record
11.1.3.2	Name, address, and telephone number of the person to receive emergency health care service or treatment.	N/A May be collected as administrative record
11.1.3.3	Age of the person to receive emergency health care service or treatment.	Age of injured person
11.1.3.4	Manufacturer's name of the amusement ride or device where or on which the incident occurred.	Ride type
11.1.3.5	Description of the injury or illness. Physical description of the injury or illness. Description of the events causing and related to the incident.	Injury type
		Body part
		Injury event
		Object inflicting injury
		Event type
11.1.3.6	Description of the first-aid service or treatment administered, including medications given.	N/A May be collected as administrative record
11.1.3.7	Incident classification in accordance with 11.2.	(see 11.2.n)
11.1.3.8	Additional information deemed necessary by the owner/operator.	Operation type (when different operation types are collected in the same reporting system)
		Gender of injured person (non-binary, as appropriate)
		Age and gender of person involved in event (e.g., when one person is injured as a result of performance of another person)
		Other specific variables
11.2.1	Severity "injury, illness, serious injury/illness, and minor injury/illness") as determined by the operator	Injury severity categories are defined
11.2.2	Facility-relatedness (related or not related)	Includes option of "general circulation" and "unknown" in Operational stage.
11.2.3	Facility location (on-ride, queue, load/unload, other)	Operational stage, has more location options including spectators, and separate recording of load and unload.

4. Discussion

The ADF extends a researcher-based classification approach (Woodcock, 2019) to a framework that can be practical for users with familiarity with amusement rides and devices. Promising results from minimally trained users suggests possible success and merit of further evaluation of its practicality and reliability. Collection of narratives is an essential element of using the ADF, as collection of preceding conditions or intentions, plus failure, intervening event (if any), and impact event is necessary to properly classify event type. The ADF is compliant with international standards for operators' recording of injuries (ASTM F770-21), but goes beyond to capture lower

levels of severity, stages of operation that standards do not require to be recorded, and separately record load and unload stages as their different nature might bear on preventive interventions. The ADF also goes beyond other approaches in current use.

Collection of the ADF variables enables preparation of descriptive reports of single variables, filtering data to include only reports above a minimum severity, and cross-tabulating variables to identify "black spots" worth additional study. Consistent data recording and classification approaches would benefit the comparison of relative risk when incidence is expressed in relation to exposure.

Refinement of taxonomies could be necessary through further evaluation and use. The ease of use by non-researchers and the ability to extract the necessary subtotals are legitimate reasons to reconsider the definitions/descriptions of classifications and the need to add new classifications. Additionally, finding a consistently large proportion of occurrence in one type may suggest value of dividing the type further; finding a consistently small proportion of occurrence in two or more similar types may suggest value of merging them.

The ADF treats trespassing, worker injuries, and snack-bar mishaps as excluded, out of scope, but users can use it within a reporting system that goes beyond accidents involving patrons experiencing amusement rides by adopting supplementary types in their local taxonomy.

Sophisticated approaches to data mining do not rely on taxonomy-based classification, analysing free-text narratives using natural-language analysis. This approach enables discovery of phenomena that have not been anticipated in pre-determined coding taxonomies. However, even analysis of narrative text requires that the collected narratives are comprehensive, and in many data sources, the narratives are not comprehensive. The ADF promotes development of comprehensive narratives, since a narrative must be clear and complete enough to contain description that enables all of the variables to be populated from the taxonomy. The inability to code the case using the taxonomy provides prompt feedback that more narrative information is required. Improved narratives increase the feasibility of data mining.

While analogous approaches could be offered for other technologies, the ADF taxonomies were specifically designed for amusement rides and devices. Use in other domains has not been considered in this paper.

5. Conclusion

While pilot use was promising, further study is needed to examine both the efficacy of training on production of efficient narratives and the reliability and accuracy of recording and classifying the ADF variables by typical users who receive and document adverse occurrence reports. Evaluation of the ADF continues using archival reports and further trial with new reports is intended.

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Annex: Taxonomies for Accident Data Framework Variables

The following tables describe inclusion criteria for each classification. Two taxonomies (event type and ride type) also describe how the types are grouped into categories. Operational stage and Event also show definition of "excluded" events. ADF users may opt not to exclude these, capturing them as additional data points as part of a broader accident data system.

Severity

Severity	Definition
No known injury	No injury, or it is unknown whether there was an injury and injury is unlikely given the available information.
Comfort on site	Required or requested comfort such as cool drinking water, shade, blanket, place to rest, over-the-counter remedy such as for headache or nausea, ice packs, liniment. Includes bandages, wraps, antiseptic wipes given to guest for self-treatment. May have included consultation with first aid provider but did not require trained professional diagnostic or treatment service.
First aid	Required treatment to cleanse wounds, remove splinters, eyewash treatment, apply dressings, sling or splint applied / administered by first aid / EMT.
Medical care	Required treatment by physician, emergency department, clinic, X-ray for diagnosis and treatment consisting of more than capacity of first aid, including concussion protocol, diagnostic imaging, cardiogram, suture of laceration, setting fractures, casts and slings. Report of backboard, cervical collar or departure by ambulance presumed to indicate subsequent medical exam. Includes reference to fracture, dislocation, concussion, "may need stitches" or other severe conditions clearly exceeding first aid, but no requirement for hospitalization other than for observation.
Hospitalization	Required admission to hospital overnight or longer, such as for surgery, tests, etc., not including admission merely for observation.
Fatal injury	One or more fatal injuries resulted from the event.
Not stated	An injury or impact event was described but the narrative did not use any of the established terms used to identify severity.

Operational stage

Operational stage	Definition
Queue	Spectator, bystander, and events involving fence, gate other than during load, unload, ride, evacuation.
Platform/loading	Transition from standing on platform to seat or riding position. Steps to ride (if part of ride)
Ride in motion	During ride cycle while ride is moving up to the point when the ride vehicle or accelerated body movement is stopped and restraints are open, or unlocked for self-opening, or rider has approval to exit, except when paused due to planned or atypical pauses of the ride cycle. This includes deceleration while under the ride control or momentum of riding.
Ride pause	During ride cycle of automated rides, when paused, e.g., when loading/unloading other seats or waiting for ride vehicle to reach unload platform, reversing direction, during automation stop, pending directions for evacuation. This stage includes stoppage prior to being instructed to exit, during which some patrons may self-evacuate without authorization. This stage includes the moment of resumption of motion, affecting patrons still in vehicle or fully or partially out of vehicle.
Normal unload	After accelerated motion of ride cycle has stopped and any restraints have been opened, this stage includes rising from or leaving the riding position, stepping off the device, transiting the platform and exiting toward gate. If multiple attractions within same enclosure (no new queue), includes transition to next loading stage.
Evacuation unload	Exiting from the ride other than at the normal unload position, including use of lifting devices, catwalks, other alternate exit paths, with or without assistance by emergency responders.
Unknown	Injury or illness was reported after ride and rider did not notice or cannot recall when occurred but has described a credibly ride-related occurrence.
(Excluded)	Patron injury or illness not associated with riding, spectating, queuing for a ride, e.g., at food or retail concession, show, ticketing. Occurrence during maintenance or servicing affecting employee or contractor. Trespassing at a ride by any person unauthorized.

Event

Event category	Event type	Description of event
Ride	Malfunction	Loss of structural, mechanical integrity, or automation control during ride or while riders and bystanders are exposed; includes failure of restraint system leading to ejection. Excludes ride cycles stopped by safety related control system or operator intervention pending restart or evacuation.
	Forces caused unintended body motion within seat or vehicle	Body moved by forces of ride in motion, including flailing and sliding of body as allowed by secured restraint and containment system as designed; patron unable to control effect of ride forces on unrestrained body parts.
	Forces produced ejection of rider from seat or vehicle	The rider separated from the ride vehicle due to ride forces from functional restraint and containment system; includes separation from waterslide tube/raft prior to entry to catch pool/ runout due to tube overturned or unable to maintain grip; no intentional self-extraction or malfunction / failure of restraint system.
	Machinery or structures entangled rider hair, clothing or body part	Rider's hair, clothing or a body part inserted into, pinched, or caught in a gap, structure, or mechanism that failed to exclude insertion/ entanglement, or normally free-moving ride part entangled or struck body part (clearance adequate other than due to loose-object movement).
	Hazard exposure of rider	Includes chemical, electrical, foreign object, animal exposure, surface defect, friction; may involve insufficient or failed hazard control, other than malfunction.
Operation	Misoperation	Operation of power, brakes, restraint devices etc. at wrong time, in wrong direction or activation of wrong object; or non-operation when operation is required, or admission of patrons when not appropriate..
Patron	Action failure	Action failure, of appropriate or reasonable action; loss of control of controlled action, such as slip, trip, fall, twist ankle while performing appropriate action.
	Inappropriate action	Intentional self-extraction from moving or paused vehicle, standing or rising up in seat, leaning out, self-propelling or attempting to resist motion; no malfunction or deformation of ride.
	Medical condition/reaction	Atypical health state (such as seizure, loss of consciousness, asthma, panic attack, aneurysm) resulting from known or unknown medical condition, occurring coincidentally or aggravated by ride; not including injuries completely produced by another event.
	Encroachment	Trespassing in restricted area by non-rider; not including passing through restricted area after self-extraction or fall.
	Intentional harm	Intent to produce harm to self, others, or property; may have been intercepted before worst outcome resulted.
Submersion	Submersion	Submersion in water component of the ride, including drowning or near-drowning.
(Excluded)	Excluded events	Violence, assault, or other criminal act Worker injury other than in capacity of rider Devices out of scope, or no event described in narrative.

Ride type

Ride category	Ride type	Ride action
Mechanical rides including vertical translation, full and/or partial rotation around one or more axes, and low elevation / slow speed tracked rides and boats	Horizontally revolving	Partially or fully revolves around one or more axes on sweep(s) or turntable; primary axis is vertical or less than 45° from vertical.
	Flat tracked rides (train, boat)	Follows track or channel along one plane, which may have minimal undulations.
	Dark ride (single level)	Follows track or channel through show building, along one plane, which may have minimal undulations.
	Vertically revolving	Rotates around a horizontal axis at fixed elevation or raised on a boom.
	Vertical drop ride	Translates vertically on tower.
	Skycoaster/slingshot	Propelled by stretched bungee cords or springs, with rider contained in ride vehicle.

Ride category	Ride type	Ride action
cont'd	Simulator/motion base at fixed placement	Up to six degree of freedom movement of ride vehicle, with or without media; single or multiple occupants per motion base.
Roller coaster and path-guided elevated or high-speed tracked rides and boats	Roller coaster	Follows track with significant undulations including lift or launch and descent; includes multi-level dark ride.
	Gondola	Translates horizontally, suspended from significantly elevated path.
	River rapids	Follows undulating water channel and rotates along the path; often a round multi-rider raft.
	Flume ride	Follows water channel with multiple levels with significant undulations including characteristic splash descent; often a log shaped vehicle or boat.
	Dark ride (multilevel)	Follows track or channel through show building, with multiple levels with significant descent.
Patron directed amusement devices	Go kart	Start, stop, and steering by patron, within lateral limitations and traffic of other patrons.
	Bumper cars, bumper boats	Start, stop, and steering by patron, anticipating collisions with similar vehicles, on deck or water.
	Mountain coaster	Follows terrain on descending rail, with maximum speed and stopping under control of rider.
	Trampoline park	Patron's body rebounds from trampoline on impact of patron and others; foam pit absorb impact.
	Inflatable	Surface of inflated device rebounds impact of patron and others; includes obstacle courses and slides.
	Walkthrough (funhouse, dry slide)	Stationary surfaces including steps, sliding surfaces, nets, unstable surfaces (including mechanically assisted) along patron's walking path.
	Bungee-assisted bounce	Trampoline rebound impact of patron contained in restraint device connected to bungee cords.
	Velcro wall	Wall covered with Velcro material sticks on impact of patron wearing Velcro outerwear.
Waterslide conveys rider with water flow through a channel that may be entirely open, entirely enclosed, or combinations of both; applies to attraction path from elevated starting point into catch pool or run-out.	Body slide	Waterslide with no raft, tube, or mat; includes slide paths of multiple kinds.
	Raft/tube slide	One or more riders slide along the slide path while sitting in or on an inflated raft or tube.
	Racing mat slide	Riders slide using a mat.
	Trap-door slide	Rider begins the slide when a trap door is opened, dropping them into the slide path.
Waterpark (attractions other than waterslide)	Pool	Body of water without waves or current other than local water flow of filtration system and water disturbance by other patrons.
	Wave pool	Artificially generated waves move patrons in pool.
	Lazy river	Artificially generated current move patrons along a channel with or without the use of flotation devices.
	Pool deck	Flat surface around pool or lazy river, which may be flush with or above the depth of the water at that point.
Adventure attractions	Zipline	Follows taut wire rope, within body harness, with maximum speed, stopping, and swinging partially or fully controllable by rider.
	Bungee (freefall)	Freefall from fixed point of attachment, rider within body harness, attached to bungee cord.

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