Measurement, Analysis and Comparison of Drops Experienced by Packages in Inter-State and Intra-State Next Day Shipments in United States

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ABSTRACT: Several past studies have been conducted for the purpose of measuring and analyzing the dynamics of single package shipping environment for the next day delivery services provided by companies including DHL, FedEx, UPS and USPS. Over the past few decades increased shipping hazard evaluations using data recorders has influenced protective package designs to offer optimized product protection due to a better understanding of the distribution environment. This study analyzes the drops sustained by packages during next day shipments within California (intra-state) using two different carriers—FedEx and OnTrac and within United States for shipments to two different regions in east and west (inter-state). This study established that the intra-state drop heights experienced by the packages exceeded the current levels recommended for inter-state distribution by international standards like ISO, ISTA and ASTM.

1.0 INTRODUCTION

THE US small parcel delivery industry typically transports packages small enough to be handled by one individual without the need for special equipment The landscape for this industry has changed significantly over the past decade. With parcel delivery companies branching out from their niche business models into adjacent services, such as UPS into the express air shipment and FedEx into ground deliveries, the competition between such companies has escalated over the past decade. In May of 2008 DHL Express announced the restructuring plans for its US network, which also included terminating its business relationship with

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ABX Air and entering into a contract with competitor UPS for air freight operations. [1].

FedEx and UPS are the leading small parcel corporations in the US with annual revenues in 2008 of $37.95 and $51.48 billion respectively [2]. The four largest networked couriers with national and international delivery capabilities include United Parcel Service (UPS), Federal Express (FedEx), Dynamex and the US Postal Service. These four organizations which provide air, surface or combined delivery services of parcels, accounted for approximately 90% of the segment's revenues last year [3].

Small parcels within the US are shipped between different states (inter-state) or within the same state (intra-state) using various means of transportation. Typical collection, pick up and delivery operations that packages experience during the express shipments expose them to physical and climatic hazards such as shocks, vibration, compression, humidity, etc. Over the past two decades there has been a continuous increase in measurement studies related to the dynamic events that occur to packages in different transportation methods. This data offers very useful information to design and test packages to potential hazards like drops and impacts.

There has been a common belief that the number of drops per package and their severity is a function of distance between origin and destination. This study compared next day shipments between three different regions in the United States (Michigan, California and New York) and two different destinations within California (Redding and Carlsbad). This study compared drops experienced by packages during overnight shipments for the next day delivery service offered by FedEx for inter-state (Michigan, California and New York) and by FedEx and OnTrac for intra-state (California) shipping environments. FedEx provides next day services which include First Overnight, Priority Overnight and Standard Overnight with associated delivery times of 8:30 A.M., 10:30 A.M. and 4:30 P.M. respectively. OnTrac, a subdivision of Arizona's Express Messenger Service, Inc. (EMS) also offers several levels of next day services including Super Sunrise Gold, Sunrise Gold and Sunrise service that promise delivery at 7:00 A.M., 8:30 A.M. and 10:30 A.M. respectively.

During inter-state next day shipments, packages are commonly moved using trucks and aircraft, while they are more commonly moved in an intra-state environment by trucks and occasionally by aircrafts. In

order to move products successfully it is necessary to identify the causes for damaged products. There have been several past studies conducted to quantify the impact and drop levels that packages experience in single parcel shipments of different carriers [4–14]. These studies have measured the drops observed by various categories of packages such as small, mid-sized and large during small parcel distribution. Drops are a major cause of damaged products, and they typically occur when the package is manually handled during loading and unloading.

Due to the unpredictability in distribution center environments and delivery locations, packages must be designed to withstand the force experienced during drops from a range of heights. Prototyped product-package systems can be exposed to a replication of the real environment in a lab setting for the purpose of validating its resistance to expected hazards. Designing optimum packaging to meet the severity of the environment yields cost-effective and efficient protective packaging for the product. These tests are created from laboratory experiments as well as studies such as this one that conduct field measurement using data recorders.

There have been no studies conducted to compare the drops experienced by packages in the next day small parcel shipping environment for the inter-state and intra-state distribution. Due to a lack of data from past studies, this research focused on measuring and analyzing these environments with the following objectives:

1. To characterize the dynamics of the inter-state next day shipping drop environment for small and light weight packages shipped by FedEx within the United States
2. To characterize the dynamics of the intra-state next day shipping drop environment for small and light weight packages shipped by FedEx and OnTrac within California
3. To compare inter-state versus intra-state next day shipping drop environments
4. To provide recommended test levels for drop testing packages for express inter-state and intra-state single parcel shipping environment for small and light weight packages.

2.0 TEST PACKAGES AND INSTRUMENTATION

This study used electronic data recorders manufactured by Lansmont

Corporation (Monterey, CA, USA) to capture the shocks experienced by packages during drops. These data recorders have built in tri-axial accelerometers to measure the vibration levels for vertical, lateral, and longitudinal shocks. The data recorder used was model SAVER 3X90 as shown in Figure 1. The parameters for recording were as follows:

- Drop height range: < 122.8 cm
- Record time: 1.4 seconds
- Trigger level: 2 g
- Pre filter: 93%
- Filter frequency: 500 Hz

The data recorder was shipped in a regular slotted container (RSC) made from C-flute corrugated fiberboard. The test package measured 20.32 cm × 17.78 cm × 15.24 cm, and is shown in figure 2. Each of the data recorders were encased with 5.08 cm thick high-density polyethylene foam on all six sides, which secured the recorders in the geometric center of the test packages. The test packages were sealed with 5 cm wide pressure sensitive tape. The test packages, including the data recorders, weighed approximately 0.8 kg.

For the inter-state shipments four instrumented packages were shipped between East Lansing, MI to San Luis Obispo, CA and Rochester, NY each. These round trip shipments resulted in 16 one-way trips for next day shipments. Similarly, for intra-state shipments, test packages were shipped round trip from San Luis Obispo, CA to Redding, CA and from San Luis Obispo CA to Carlsbad, CA. The distance between East Lansing, MI and San Luis Obispo, CA is 3,868 km and distance between East Lansing, MI and Rochester, NY is 626 km. Similarly, the distance

Figure 1. *SAVER 3X90.*

Figure 2. *Instrumented test package.*

between San Luis Obispo, CA to Redding, CA is approximately 692 km and the distance between San Luis Obispo CA to Carlsbad, CA is approximately 443 km.

The actual shipping distances varied from these point-to-point distances due to the hub-and-spoke models employed by both couriers. The carriers use the hub-and-spoke system to route packages to one major hub every night that is located geographically in the center, where packages are sorted and then shipped on to the final destinations. Ideally packages shipped to major cities like Los Angeles, Chicago, Atlanta, New York, etc., may go through a sort at the major hub at night and delivered the next morning. However for destinations such as San Luis Obispo, CA, the packages may get additional handling after reaching Los Angeles, and either sent on to San Luis Obispo in a smaller aircraft also known as the "feeder" or trucked. This results in additional handling of the packages due to a secondary sort and delivery.

Figure 3 presents the inter-state FedEx Priority Overnight shipments with routing through the local and major hubs, Indianapolis and Memphis respectively and Figures 4 and 5 represent the round trip OnTrac Sunrise shipping routes to each destination for the intra-state shipments.

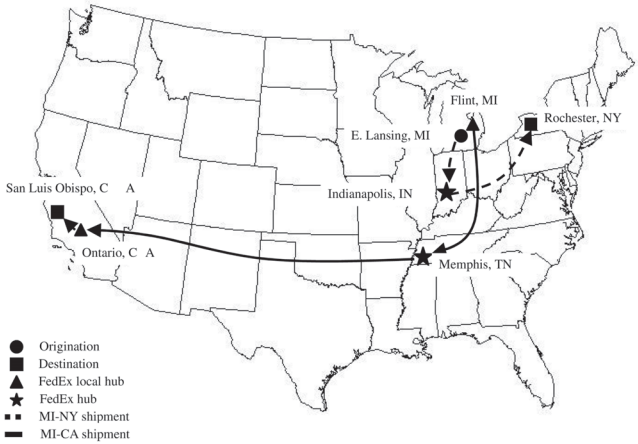

Figure 3. *FedEx Priority Overnight Inter-State Shipment Routes from Michigan to California and New York.*

Figure 4. *FedEx Priority Overnight Intra-State Routes from San Luis Obispo to Redding and Carlsbad.*

Figure 5. *OnTrac Sunrise Routes Intra-State Routes from San Luis Obispo to Redding and Carlsbad.*

3.0 RESULTS AND DISCUSSION

Based on the data collected, drop height and frequency of occurrence were tabulated for the two types of shipments (inter-state and intra-state). Tables 1 and 2 show the top ten severe drops in the order of severity, for the inter-state and intra-state shipments. Figures 6 and 7 show the cumulative percent of occurrence versus drop height for inter-state and intra-state shipments. During the data analysis, drop heights below 76 mm (3 inches) were not considered in the final analysis, since they typically produce very little damage on single parcels, as observed in previous studies [5, 6, and 7].

Tables 1 and 2 summarize the ten highest drop heights observed for both distribution environments. The highest drop height measured in this study was 2.58 m. This happened within the intra-state shipments (OnTrac Sunrise) between San Luis Obispo and Redding. This drop was approximately 30% higher than other drops measured in this study.

Table 1. *Drop Height Levels for Shipments: Inter-State.*

	FedEx Standard Overnight	
Drop Height (m)	**East Lansing/San Luis Obispo**	**East Lansing/Rochester**
Highest	1.63	2.11
2nd Highest	1.45	1.70
3rd Highest	1.43	1.50
4th Highest	1.36	1.22
5th Highest	1.33	1.15
6th Highest	1.32	1.06
7th Highest	1.09	1.01
8th Highest	1.06	0.86
9th Highest	1.05	0.85
10th Highest	0.99	0.77
Average	1.30	0.127

It was also observed that shipping distance can not be directly correlated to the severity of the handling i.e. number of drops and drop heights. When comparing the drops observed during the inter-state shipments, the highest drop height of 2.11 m was observed for the shorter shipments between Michigan and New York as compared to 1.63 m for the shipments between Michigan and California. The overall average of the ten highest drop heights observed for the shipments to the two destinations were similar. While the highest drop observed for the OnTrac shipments from San Luis Obispo to Redding was approximately 37% higher as compared to the FedEx shipments, the same for shipments to

Table 2. *Drop Height Levels for Shipments: Intra-State.*

	FedEx		OnTrac	
Drop Height (m)	**Redding**	**Carlsbad**	**Redding**	**Carlsbad**
Highest	1.61	1.75	2.58	0.94
2nd Highest	1.45	0.92	1.74	0.82
3rd Highest	0.97	0.62	1.46	0.60
4th Highest	0.93	0.51	1.23	0.38
5th Highest	0.79	0.49	1.12	0.33
6th Highest	0.76	0.40	1.06	0.23
7th Highest	0.75	0.37	0.51	0.17
8th Highest	0.63	0.34	0.51	0.14
9th Highest	0.63	0.32	0.38	0.13
10th Highest	0.58	0.26	0.23	0.13
Average	0.91	0.59	1.08	1.30

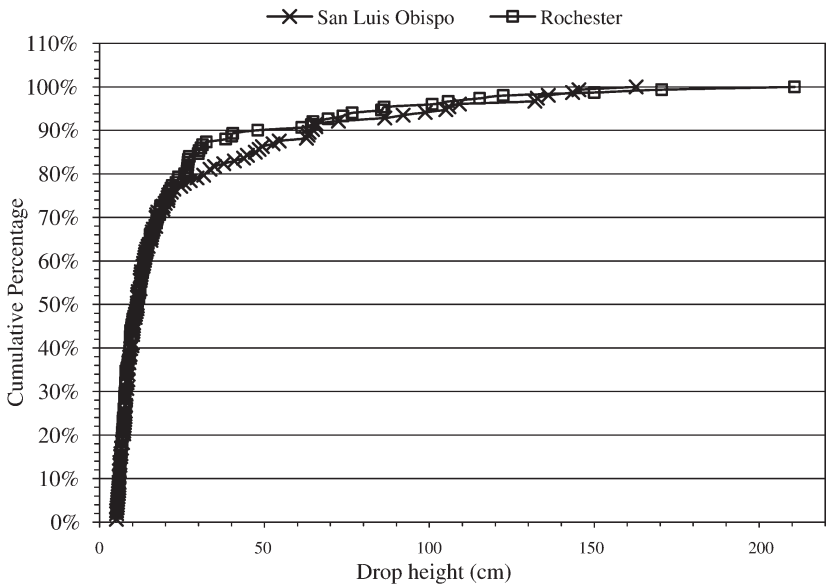

Figure 6. *Cumulative Percentage versus Drop Height: Inter-State Shipments.*

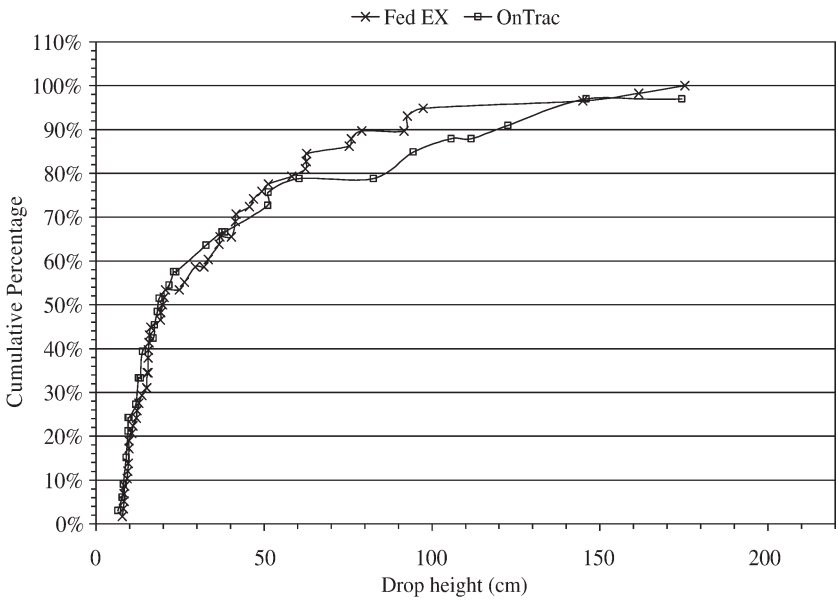

Figure 7. *Cumulative Percentage versus Drop Height: Intra-State Shipments.*

Table 3. *Summary of Drop Height Data Measured above 76 mm: Inter-State.*

Drop Data	MI-NY	MI-CA	Overall
Number of Drops	110	118	2.28
Maximum Drop Height (m)	2.11	1.63	2.11
Drop Height at 99% Occurrence (m)	1.70	1.45	1.63
Drop Height at 95% Occurrence (m)	1.05	1.32	1.15
Drop Height at 90% Occurrence (m)	0.69	0.86	0.77

Carlsbad was approximately 46% lower. The overall averages of the ten highest drop heights were higher for the OnTrac shipments to Redding and Carlsbad, 16% and 54% respectively, as compared to the FedEx intra-state shipments.

Tables 3 and 4 show the number of drops measured above 76 mm (3 inches) in inter-state and intra-state shipments, the highest drop height recorded during any one-way trip, and the 90th, 95th, and 99th percentile drop heights. The term "90% occurrence" means that 90% of all recorded drop heights were below this level.

Based on the data collected and analyzed as shown in Figures 6 and 7 and listed in Tables 1–4, it is clear that the drop height in next-day single parcel shipments is not a function of shipping distance. Drop heights are often a function of the number of times a package is subjected to loading and unloading as part of load sortation. In the next-day air shipments, regardless of the shipping distance, often only one hub is used to conduct the sortation. The more automated a hub, the less is the interaction of manual handling resulting in lesser drops and lower drop heights. As presented in the data, the intra-state shipments actually saw higher drop heights due to the carrier's practices as opposed to the distance between origin and destination.

Tables 5 and 6 show the orientation of all drops measured for the two types of shipments above 76 mm (6 inches). The most common

Table 4. *Summary of Drop Height Data Measured above 76 mm: Intra-state.*

Drop Data	FedEx	Ontrac	Overall
Number of Drops	58	31	89
Maximum Drop Height (m)	1.75	2.57	2.57
Drop Height at 99% Occurrence (m)	1.61	2.47	1.75
Drop Height at 95% Occurrence (m)	0.97	1.74	1.45
Drop Height at 90% Occurrence (m)	0.79	1.23	0.97

Table 5. *Percent Orientation of Impacts for Packages: Inter-state.*

	Orientation of Drops (%)		
	Face	**Edge**	**Corner**
Michigan to California	17%	42%	41%
Michigan to New York	21%	41%	38%

orientations for drops are edges and corners, followed by face (flat drops).

4.0 CONCLUSIONS

The study concludes the following:

- The highest drop height experienced for all roundtrip shipments happened within the intra-state shipments on OnTrac Sunrise service between San Luis Obispo and Redding. This drop was approximately 30% higher than the other measured drops in this study.
- Both types of shipments (inter-state and intra-state) exhibited multiple drops from heights significantly higher than the ASTM 4169 and ISTA 3A for packages in the 0 to 9.1 kg (0–20 lb) weight range [15,16].
- The shipping distance does not impact the severity of drop height for next day single parcel shipments.

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Table 6. *Percent Orientation of Impacts for Packages: Intra-state.*

	Orientation of Drops (%)		
Carriers	**Face**	**Edge**	**Corner**
FedEx	22%	45%	33%
Ontrac	18%	42%	39%

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