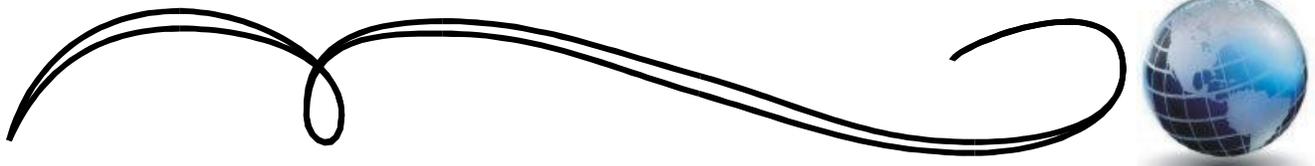


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Editorial Policy

The primary purpose of the *JTM* is to publish managerial and policy articles that are relevant to academics, policymakers, and practitioners in the transportation, logistics and supply chain fields. Acceptable articles could include conceptual, theoretical, legal, case, and applied research that contributes to better understanding and management of transportation and logistics. Saying that, our policy requires that articles be of interest to both academics and practitioners, and that they specifically address the managerial or policy implications of the subject matter. Articles that are strictly theoretical in nature, with no direct application to transportation and logistics activities, or to related policy matters, would be inappropriate for the *JTM*. Articles related to any and all types of organizations, and of local to global scope, will be considered for publication.

Acceptable topics for submission include, but are not limited to, broad logistics topics, logistics and transportation related legal issues, carrier management, shipper management of transportation functions, modal and intermodal transportation, international transportation issues, transportation safety, marketing of transportation services, transportation operations, domestic and international transportation policy, transportation economics, customer service, and the changing technology of transportation. Articles from related areas, such as third party logistics, purchasing and materials management, and supply chain management, are acceptable as long as they are related to transportation and logistics activities.

Submissions from practitioners, attorneys or policymakers, co-authoring with academicians, are particularly encouraged in order to increase the interaction between groups. Authors considering the submission of an article to the *JTM* are encouraged to contact the editor for help in determining relevance of the topic and material.

The Editor information is: Dr. John C. Taylor, Associate Professor of Supply Chain Management and Department Chairperson, Department of Marketing and Supply Chain Management, School of Business, Wayne State University, Detroit, MI 48202. Office Phone: 313 577-4525. Cell Phone: 517 719-075. Fax: 313 577-5486. Email: taylorjohn@wayne.edu

Publishing Data

Manuscripts. Submit manuscripts to the editor by email attachment at taylorjohn@wayne.edu. Manuscripts should be no longer than 30 double-spaced pages and 7000 words. Guidelines for manuscript submission and publication can be found in the back of this issue.

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From the Editor...

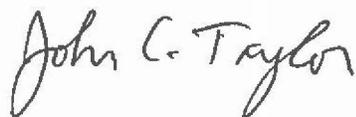
Welcome to the Winter Spring 2020 issue of the Journal of Transportation Management (JTM), being Vol. 30 No 2! Amazing the JTM has hit 30 years and is older than many other SCM journals! So Happy Birthday for JTM and its authors.

The issue starts with an article on trucking industry drug testing and the merits of hair vs. urine tests. The second article examines blockchain and RFID applications in the retail inventory supply chain. The third article is one of two on the airline industry. The third article looks at exogenous factors influencing flight delays. While the fourth article examines the role of size in airline profitability. The issue concludes with an overview of the evolution of the E-Grocery industry channel.

Our first article explores the advantages and disadvantages of trucking industry drug testing using the current urine sample approach vs. the use of hair samples. Results of their analysis indicates hair samples would offer a lot of advantages. The second article looks at the benefits that could be derived from additional use of blockchain and RFID applications in the retail inventory management space. The third article asks whether size matters in the airline industry. The authors find that cost efficiencies come with every increase in airline size. The fourth article examines the role of various types of delay causes in the total picture of overall delays. They find that non-weather sources of delays under the control of airlines were the primary contributor to overall delays. The last article looks at the e-Grocery channel and how it has evolved. They report on the resurrection of the e-Grocery channel after several years of decline.

At the *Journal*, we are continuing to make a number of changes that will improve the visibility of JTM, and improve its position in the supply chain publishing world. These include registering and updating journal information with several publishing guides, and placing the past and current content on services that provide visibility to Google Scholar. Authors will receive summaries of downloaded articles monthly, and can examine the Digital Commons web site for data on various aspects of the publication and their articles. One year old and beyond issues will be placed into the system.

I look forward to hearing from you our readers with questions, comments and article submissions. The submission guidelines are included at the end of this issue's articles and I encourage both academics and practitioners to consider submitting an article to the Journal. Also included in this issue is a subscription form and I hope you or your library will subscribe.



John C. Taylor, Ph.D.
Editor, Journal of Transportation Management
Chair, Department of Marketing and SCM, Ilitch School of Business
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DRUG TESTING IN THE U.S. TRUCKING INDUSTRY: HAIR VS. URINE SAMPLES AND THE IMPLICATIONS FOR POLICY AND THE INDUSTRY

**M. Douglas Voss
Joe Cangelosi
University of Central Arkansas**

ABSTRACT

Virtually everything we own was transported by truck at some point. Around 3.5 million truck drivers haul almost 71% of U.S. freight. To ensure the safety of our roadways, the U.S. government requires all drivers to pass urinalysis drug screens. However, urinalysis drug screens are easily thwarted and some trucking companies use hair drug screens, a more stringent test. This research examines trucking industry data and finds about 300,000 truck drivers would be removed from their positions if forced to pass a hair drug test. Hair testing opponents argue that the test is biased against ethnic minority groups. Comparing urine and hair pass/fail rates for various ethnic groups, our results indicate ethnic groups are significantly different irrespective of testing procedure. Factors other than testing method seem to underlie ethnic group pass/fail rate differences.

INTRODUCTION

Trucking is a critical component of the US economy (Kemp, Kopp, and Kemp, 2013). The trucking industry is composed of over 3.5 million truck drivers who move 10.5 billion tons annually, equal to almost 71% of all US freight (American Trucking Association, 2020). Many risks confront the industry and managers must manage these issues as part of their daily job functions. Among these risks, safety incidents are perhaps the most critical (Miller and Saldanha, 2016).

Safety incidents involving large trucks have a deleterious effect on health (Zaloshnja and Miler, 2006; Corsi et al., 2014), the operations of carriers, shippers, and receivers (Hendricks and Singhal, 2003), and U.S. transportation system efficiency (Cantor et al., 2006). Increasing insurance rates driven by large legal verdicts have led trucking companies to place an even greater emphasis on shoring up their safety performance (Huff, 2020). Insurance rates were responsible in part for an almost three-fold increase in trucking company bankruptcies during the first half of 2019 as compared to the same period in 2018 (Smith, 2019). Safety is a matter of life and death on the road and also impacts trucking company financial performance (Miller and Saldanha, 2016).

The Federal Motor Carrier Safety Administration uses the Compliance, Safety, and Accountability (CSA) program to measure trucking company safety performance. CSA gathers data from roadside inspections and crash reports and categorizes the data into seven Behavior Analysis and Safety Improvement Categories, which are commonly referred to as BASICs (Federal Motor Carrier Safety Administration, 2020). Kemp, Kopp, and Kemp (2013) recommend trucking companies create a culture of safety within their organization to improve safety performance. Mitra (2016) indicates a positive relationship between safety incidents and violations in the CSA controlled substances/alcohol BASIC. Maintaining a drug-free driver workforce is key to any safety culture (Knipling, 2009) and drug screens are a critical method used to help ensure driver sobriety.

However, evidence exists that the existing urine testing regimen may be less effective than we all hope. Lin et al. (2017) find that urine tests are often invalid. Giroto et al. (2014) find evidence that truck drivers may frequently abuse psychoactive substances and note that these drugs reduce driving competence while also increasing the risk of safety incidents. Mieczkowski (1992) posits that urine tests generally have a 2-3 day lookback period.

This means truck drivers could refrain from drug use for 3 days, pass a scheduled pre-employment urine test, then begin driving and using drugs again. In 1998 Oregon enforcement agencies conducted *unannounced* urine drug screens of commercial truck drivers during roadside and port of entry inspections (Couper et al. 2002). The unannounced nature of these tests negated drivers ability to prepare for the test. In total, enforcement personnel collected 822 urine specimens from commercial truck drivers and found 21% of the samples tested positive for one or more substances including stimulants, cannabinoids, and alcohol. They state (p. 562), "...in spite of comprehensive drug testing in the trucking industry, some tractor-trailer drivers are continuing to take illicit and other drugs with the potential of having a negative effect on their driving ability."

The preceding evidence highlights the possibility that current federally accepted urinalysis is insufficient to deter and catch drivers who may abuse substances that degrade their driving performance. Due to urine testing's insufficiency, and the lack of federal recognition for hair testing, many carriers including Schneider, Knight-Swift Transportation, J.B. Hunt Transport, Werner Enterprises and Maverick USA use more stringent hair drug tests to help ensure driver sobriety (Miller, 2016; Miller, 2017a; Mieczkowski, 2010). The Alliance for Driver Safety and Security (i.e. The Trucking Alliance) recently conducted a study comparing pass/fail rates for urine and hair drug screens (Gallagher, 2019). Using 151,662 paired pre-employment urine and hair drug test results from fifteen (15) different trucking companies, their results indicated that 949 (0.6%) applicants failed the urine test while 12,824 (8.5%) failed or refused the hair test ($\Delta = 7.9\%$). FMCSA classifies refusal to submit to a drug or alcohol screening as a failure (DOT Rule 49 CFR Part 40 §40.191).

The Trucking Alliance extrapolated their results over a population of 3.5 million U.S. truck drivers and claimed that, if their results were generalized across the U.S. driver population, almost 300,000 current drivers would not be on the road if forced to pass a hair test ($3,500,000 \times 7.9\% = 276,500$). However,

no evidence was presented to justify whether their sample was, in fact, generalizable. Further, some have argued that hair tests are biased against certain ethnic groups based on hair composition (Miller, 2015). Several authors, however, including Mieczkowski (1992; 1993; 2000; 2002; 2010), have argued that the bias claim is spurious.

Despite the importance of drug testing to roadway safety, the supply chain literature is largely silent on the drug testing debate with the exception of Henriksson (1992). Given this gap in the literature, the Trucking Alliance asked the University of Central Arkansas to engage in two studies and independently determine 1) whether their sample is generalizable to the broader U.S. driver population, thereby supporting their claim that hair testing would exclude roughly 275,000 drivers from the workforce and 2) whether hair testing is biased against ethnic groups based on drug test pass/fail rates.

This paper begins with an overview of recent contributions to the motor carrier literature with a focus on safety followed by a history and review of drug testing laws pertaining to transport workers. Next, we describe the method used to address sample generalizability and potential ethnic differences in drug test pass/fail rates coupled with the results of each study. Conclusions are subsequently presented with a discussion highlighting the implications of our research.

LITERATURE REVIEW

Overview of Motor Carrier Research

Research into the motor carrier industry has experienced a recent resurgence. Swartz et al. (2017) surveyed the influence of carriers' safety climate on drivers' job satisfaction and turnover. They find a strong, positive relationship between safety climate and job attitudes, which negatively influences turnover. Miller et al. (2019) examine the impact of Electronic Logging Devices (ELD) on safety performance and offer nuanced results indicating that improvements in Hours of Service (HOS) compliance is dependent upon current technology investments. Mitra (2016) examines the

impact of CSA BASIC scores on safety incidents per million miles and finds unsafe driving, fatigued driving, driver fitness, and controlled substances/ alcohol significantly influence crash rates. Guntuka et al. (2019) examine the frequency with which carriers exit the industry and find safety incidents are associated with exit propensity. Miller (2017b) tests the relationship between carrier size and safety performance and finds that continuous vigilance is necessary to encourage drivers to operate safely. He also finds that the relationship between size and safety is not linear: small carriers and large carriers were more likely to improve after being flagged for HOS violations. Miller and Saldanha (2018) examine the size of new entrants to the motor carrier industry as it relates to safety performance. Findings indicate that smaller new entrants are more likely to experience safety deficiencies compared to larger new entrants. Miller, Golicic, and Fugate (2018) examine the safety performance of carriers who rely more upon owner-operators compared to those relying on company drivers to a greater extent. They find that trucking companies using owner-operators exhibit worse safety performance. Tsai, Swartz, and Megahed (2018) examine the role of government in improving highway safety with particular emphasis on investment efficiencies. The government also ensures highway safety by regulating drug testing regimens to which drivers must comply as part of their duties in a safety sensitive position. Despite the increase in motor carrier research, no works of which we are aware address the issue of drug testing or the implications of carriers employing hair testing in lieu of/addition to urinalysis.

Overview of Drug Testing Rules and Research

Drug testing acts as a deterrent to the use of substances that would degrade driving performance (Henriksson, 1992). Urinalysis drug testing for safety sensitive positions came to prominence in the transportation industry following passage of the Omnibus Transportation Employee Testing Act of 1991, which was motivated by a subway train crash involving a driver with a high blood alcohol content (BAC) of 0.21 (Hall, 1995). The Act mandated drug and alcohol testing requirements for all safety

sensitive employees serving in the trucking and other transportation industries. Requirements for the trucking industry include (SAMSHA.gov, 2020):

1. Employers must test employees before beginning safety sensitive duties, when reasonable suspicion of substance abuse exists, after accidents, or before allowing an employee to return to work following a violation.
2. Implementation of a random drug testing program.
3. Drug testing must be administered by a certified Department of Health and Human Services laboratory.
4. All drug testing must check for the presence of five classes of drugs: marijuana, cocaine, amphetamines, opioids, and phencyclidine (PCP).
5. All alcohol testing must comply to DOT policies and procedures. Testing must be conducted using DOT approved devices.
6. All tests must be reviewed by a medical review officer (MRO).
7. All employees must receive drug and alcohol awareness training.
8. All supervisors must receive training in substance abuse detection, documentation, and intervention with the training consisting of equal parts drug and alcohol abuse.
9. Employers must refer employees to a substance abuse professional if a substance abuse problem is uncovered.

Among the first literary mentions of the new Omnibus Transportation Employee Testing Act drug testing rules came from the *Labor Law Journal* (1989). Despite its intuitive appeal, the Omnibus Transportation Employee Testing Act was not without controversy. *The Labor Law Journal* (1989) highlights labor union opposition to the Act on the basis of possible invasion of privacy and false positives.

Over time, urine testing has become a generally accepted method to determine compliance with Federal drug/alcohol rules but some trucking companies advocate for the use of hair testing due

to its increased rigor. Mieczkowski (1992) posits that urine testing is easily manipulated and generally only has a 2-3 day lookback period. Further, Mieczkowski (1993) argues that hair testing is superior to urinalysis because hair is easily handled, not as prone to degradation, and does not require special storage conditions. Despite these advantages, federal government agencies do not allow trucking companies to utilize hair testing in lieu of urine testing. This requires carriers employing hair testing to also incur urinalysis expenses.

Many of the arguments originally used against urine testing (Labor Law Journal, 1989) are put forth today against hair testing. In a 2015 letter to House leaders, labor groups and some trucking interests decried proposed hair testing regulations claiming the method is unsubstantiated, may yield false positives, and may also be racially biased (Miller, 2015). Some trucking interests agree and also oppose hair testing because they perceive it as another regulatory burden on companies and drivers (Douglas and Swartz, 2016; Williams, Thomas, and Liao-Troth, 2017). Regulatory burdens have been shown to decrease driver job satisfaction and quality of life (Johnson et al., 2010). Even managers who may be amenable to hair testing based on its scientific merit oppose its use because they fear reducing an already insufficient driver pool. Further, while hair testing is a more stringent drug test, it is also more expensive than urine testing. Managers may find it difficult to make the business case justifying the extra safety expenditures (Eroglu, Kurt, and Elwakil, 2016). Miller and Saldanha (2016) caution trucking managers against capturing short-term savings at the expense of safety benefits and posit they should instead view financial performance and safety as complementary goals.

Mieczkowski (1992; 1993; 2000; 2002; 2010) has published numerous works examining drug testing with a specific emphasis on the possibility of racial bias in hair testing. With regard to the role of ethnic differences, Mieczkowski (2000) argues that while race is sociologically and psychologically powerful, it is now commonly accepted as a weak biological differentiator. This would seem to invalidate arguments against hair testing based on biological

hair type differences. To wit, Mieczkowski (2010) compares urine and hair test results for the detection of cocaine among Whites and African Americans and finds no racial bias between the tests.

Given the potential benefits of hair testing, the FAST Act legislation of 2015 authorized the Department of Transportation “to use hair testing as an acceptable alternative to urine testing in conducting preemployment testing for the use of a controlled substance; and in conducting random testing for the use of a controlled substance if the operator was subject to hair testing for pre-employment testing.” Congress gave the Department of Health and Human Services (DHHS) one year to issue guidelines for hair testing and the Opioid Crisis Response Act of 2018 directed the Substance Abuse and Mental Health Services Administration (SAMHSA) to report to Congress on its progress creating and issuing hair test guidelines (Prevost, 2018). A proposed hair testing rule has now been relayed to the White House Office of Management and Budget for their consideration (Miller, 2019).

METHOD AND RESULTS

This section details the method and results for our two studies. The Trucking Alliance has long advocated for Federal recognition of hair testing. Like-minded members of the trucking industry have joined this effort in order to increase roadway safety and decrease compliance expenditures related to duplicative urinalysis and hair drug testing. University of Central Arkansas researchers were given access to data independently provided by cooperating trucking companies that employ hair testing in addition to urinalysis. Our goals were two-fold. We sought to determine whether 1) The Trucking Alliance sample is generalizable, which would support their claim that roughly 275,000 drivers would be unable to engage in safety sensitive functions if forced to pass a hair test and, 2) whether hair testing has a disparate impact on minority ethnic groups.

Study 1 – Sample Generalizability

Study 1 entailed two steps. First, we determined the sample size required to draw inferences to the U.S.

driver population. Second, we utilized correlation analysis to determine whether the Trucking Alliance sample is representative of the overall U.S. driver population. Researchers requested driver state of licensure information from the fifteen (15) participating trucking companies. Six (6) carriers provided usable data with location information for 56,491 of the 151,622 drivers (37.25%) hired across 2017 and 2018. Drivers are the unit of analysis. Sample driver location information is provided in Table 1.

Researchers then gathered 2018 state-level driver employment data from The U.S. Bureau of Labor Statistics (BLS) Occupational Employment Statistics Query System (Bureau of Labor Statistics, 2020). BLS classifies drivers into three Standard Occupational Classification (SOC) codes. These codes and their BLS descriptions are provided below:

- Light Truck or Delivery Services Drivers (SOC Code 533033): Drive a light vehicle, such as a truck or van, with a capacity of less than 26,000 pounds Gross Vehicle Weight (GVW), primarily to deliver or pick up merchandise or to deliver packages. May load and unload vehicle. Excludes “Couriers and Messengers” (43-5021) and “Driver/Sales Workers” (53-3031).
- Heavy and Tractor-Trailer Truck Drivers (SOC Code 533032): Drive a tractor-trailer combination or a truck with a capacity of at least 26,000 pounds Gross Vehicle Weight (GVW). May be required to unload truck. Requires commercial drivers’ license.
- Industrial Truck and Tractor Operators (SOC Code 537051): Operate industrial trucks or tractors equipped to move materials around a warehouse, storage yard, factory, construction site, or similar location. Excludes “Logging Equipment Operators” (45-4022).

State-level BLS data for each SOC code is provided in Table 2:

Researchers utilized correlation analysis to determine whether the Trucking Alliance sample and the national driver population are geographically related. The year 2018 represented the most recent BLS data available. The analysis compares the 2018 Trucking Alliance driver sample (n = 41,922) to the 2018 national BLS data.

The Required Sample Size

A sample of n = 41,922 greatly exceeds that required to make inferences about the national truck driver population. Given a margin of error of 1% and a confidence level of 99%, the sample size required would be 16,641. The formula to obtain this result is provided below:

$$n = Z^2 * p(1-p) / e^2$$

where,

- p = .5 (probability of a positive or negative outcome to a hair or urine test);
- e = .01 or 1% (the margin of error or level of tolerable error; sample results should be within 1% of the true population proportion);
- Z = 2.58 (the level of confidence desired; 99% in our sample results).

If p=.5 and e=.01, Z^2 for 99% confidence = 2.58, required sample size (n) = 16,641.

To further clarify, the sample results involved two possibilities: a positive hair or urine test or a negative hair or urine test. Hence, p = the probability of the occurrence of an event in the sample (n) (i.e. a positive or negative outcome of the urine or hair test; because the value of the event is unknown (50-50) before the test is administered, a value of .5 or 50% is utilized to yield the largest possible sample required to produce a representative sample). The numbers produced by the sample size formula indicate that the size of the sample taken exceeds the size of the sample required by over 2.5 times (41,992/16,641 = 2.52). The sample size issue is satisfied by the number of sample units in this analysis.

**TABLE 1
TRUCKING ALLIANCE DRIVER LOCATION INFORMATION**

CDL State	TA Carriers 2017	TA Carriers 2018	TA Carriers Total
AK	0	1	1
AL	389	441	830
AR	417	655	1,072
AZ	143	1,671	1,814
CA	1,666	4,536	6,202
CO	72	514	586
CT	236	342	578
D.C.	8	10	18
DE	62	116	178
FL	305	1,343	1,648
GA	1,156	3,887	5,043
HI	0	0	0
IA	100	133	233
ID	11	381	392
IL	942	2,259	3,201
IN	347	553	900
KS	78	633	711
KY	260	291	551
LA	255	381	636
MA	108	184	292
MD	288	320	608
ME	8	10	18
MI	302	820	1,122
MN	90	687	777
MO	349	551	900

CDL State	TA Carriers 2017	TA Carriers 2018	TA Carriers Total
MS	307	1,124	1,431
MT	6	5	11
NC	756	1,308	2,064
ND	5	9	14
NE	14	17	31
NH	15	31	46
NJ	384	474	858
NM	47	138	185
NV	54	204	258
NY	307	986	1,293
OH	402	1,616	2,018
OK	232	408	640
OR	61	251	312
PA	999	1,860	2,859
RI	14	26	40
SC	288	936	1,224
SD	7	15	22
TN	322	2,538	2,860
TX	1,783	5,654	7,437
UT	54	1,377	1,431
VA	422	1,282	1,704
VT	4	15	19
WA	206	372	578
WI	203	436	639
WV	84	113	197
WY	1	8	9
TOTAL	14,569	41,922	56,491

TABLE 2
2018 STATE-LEVEL BLS DATA BY SOC CODE

State	Light Truck or Delivery Services Drivers (SOC Code 533033)	Heavy and Tractor-Trailer Truck Drivers (SOC Code 533032)	Industrial Truck and Tractor Operators (SOC Code 537051)	BLS Total
AK	1,840	2,380	450	4,670
AL	14,650	32,170	9,010	55,830
AR	7,080	34,700	7,470	49,250
AZ	15,300	25,450	10,730	51,480
CA	111,100	138,380	62,460	311,940
CO	17,610	22,880	10,400	50,890
CT	11,580	12,560	2,820	26,960
DC	1,340	530	100	1,970
DE	2,620	4,370	2,010	9,000
FL	55,230	87,960	22,640	165,830
GA	27,890	62,500	39,400	129,790
HI	4,830	3,300	830	8,960
IA	9,580	38,470	7,810	55,860
ID	4,520	11,940	2,120	18,580
IL	49,140	70,380	30,080	149,600
IN	18,820	54,560	17,620	91,000
KS	8,400	20,370	5,460	34,230
KY	15,680	24,850	14,040	54,570
LA	15,950	21,070	7,010	44,030
MA	22,800	27,650	5,530	55,980
MD	21,180	23,320	6,280	50,780
ME	4,310	8,830	3,150	16,290
MI	28,860	55,940	20,360	105,160
MN	16,070	34,860	6,450	57,380
MO	16,840	44,470	12,490	73,800
MS	7,990	22,710	8,460	39,160
MT	3,690	6,440	1,080	11,210
NC	27,370	58,110	22,800	108,280
ND	2,060	10,560	1,280	13,900
NE	4,610	26,360	3,880	34,850
NH	4,030	6,870	1,250	12,150
NJ	32,310	48,760	17,990	99,060

State	Light Truck or Delivery Services Drivers (SOC Code 533033)	Heavy and Tractor-Trailer Truck Drivers (SOC Code 533032)	Industrial Truck and Tractor Operators (SOC Code 537051)	BLS Total
NM	4,660	10,970	1,090	16,720
NV	6,680	11,760	3,110	21,550
NY	46,030	62,360	16,010	124,400
OH	39,310	74,090	30,850	144,250
OK	8,730	25,750	7,070	41,550
OR	10,940	23,300	9,120	43,360
PA	37,140	82,330	31,070	150,540
RI	4,080	3,200	760	8,040
SC	13,570	29,620	7,670	50,860
SD	3,130	7,880	1,500	12,510
TN	18,250	63,030	16,720	98,000
TX	65,960	191,490	68,370	325,820
UT	8,190	24,760	4,380	37,330
VA	21,470	42,820	13,550	77,840
VT	2,190	3,440	780	6,410
WA	17,740	31,610	11,260	60,610
WI	15,360	49,760	13,800	78,920
WV	5,130	12,110	2,460	19,700
WY	1,480	6,340	1,070	8,890
Total	915,320	1,800,320	604,100	3,319,740

The Correlation Between Trucking Alliance Drivers and the National Driver Population

Discussion then turns to whether sufficient evidence exists that the distribution by state of Trucking Alliance drivers is representative of the distribution by state of drivers in the national population. SOC Code 533032 (Heavy and Tractor-Trailer Truck Drivers) is the only SOC Code whose members must possess a Commercial Driver's License (CDL) and is the most analogous to drivers in The Trucking Alliance sample. However, all three SOC codes were included in our analysis as well as a summated measure across all three SOC codes (BLS Total).

Results are presented below in Table 3:

Results indicate a significant .880 correlation between the distribution by state of Trucking Alliance drivers and that of drivers in the national

population (SOC 533032, $p < 0.01$; BLS Total, $p < 0.01$). Data visualization graphs are provided below and illustrate these relationships. Regression lines, which minimize the squared distance between the regression line and each data point, are plotted through the data.

These findings indicate a very strong and positive relationship between the BLS data and Trucking Alliance sample.

Conclusions for Study 1

Results indicate significant correlations between The Trucking Alliance sample and BLS data across all three SOC codes individually and the combination of all three SOC codes. Each correlation coefficient was significant at $p < 0.01$.

With an $R^2 = 0.786$, Figure 1 indicates that almost 79% of the variation in the number of drivers by state across all three SOC codes can be explained

**TABLE 3
CORRELATION ANALYSIS**

		Light Truck or Delivery Services Drivers (SOC 533033)	Heavy and Tractor- Trailer Truck Drivers (SOC 533032)	Industrial Truck and Tractor Operators (SOC 537051)	BLS Total
TA Carriers 2018	R	.784*	.880*	.923*	.886*
	p-value	.000	.000	.000	.000
	N	51	51	51	51

*Correlation is significant at the 0.01 level (2-tailed)

by the variation in the number of drivers by state in The Trucking Alliance sample. Figure 2 focuses on SOC Code 533032, the only SOC code requiring a CDL, which is most analogous to drivers in The Trucking Alliance sample. Figure 2 indicates an $R^2 = 0.775$, meaning almost 78% of the variation in the total number of drivers by state for SOC code 533032 can be explained by the variation in the number of drivers by state in the Trucking Alliance sample.

Based on this information, we conclude that 1) The Trucking Alliance sample is large enough to generalize across the national driver population, 2) The Trucking Alliance sample is representative of the national driver population, and 3) The Trucking Alliance urinalysis v. hair test results can be generalized across the national driver population. This supports the notion that roughly 275,000 current drivers would be unable to perform safety sensitive functions if forced to undergo hair testing.

Study 2 – Assessing Hair Testing Ethnic Minority Disparate Impact

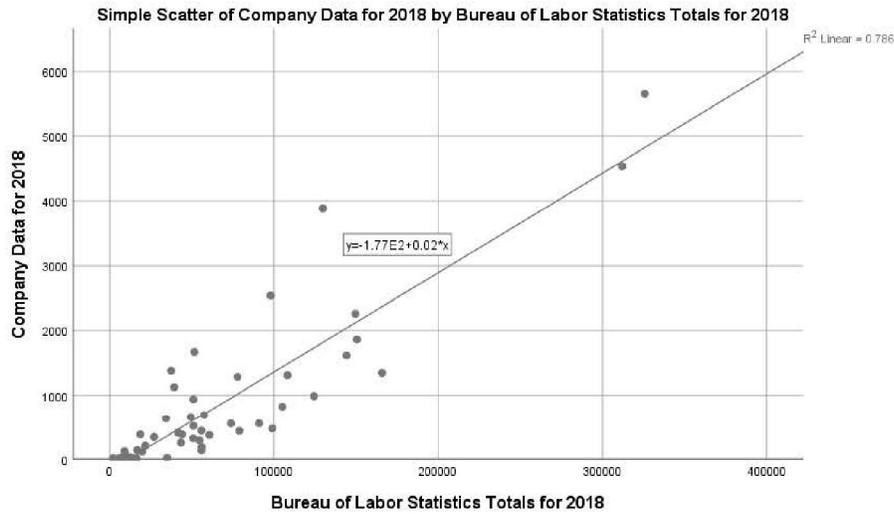
Researchers utilized two methods to assess possible disparate impact on minority ethnic groups resulting from the use of hair testing. First, the “Four-Fifths Rule” is defined in the Code of Federal Regulations, Title 29, §1607.4 - Uniform Guidelines on Employee Selection Procedures, Information on Impact as “a selection rate for any race, sex or ethnic group which is less than four-fifths (4/5) (or eighty percent) of the rate for the group with the highest rate will generally be regarded by the Federal enforcement agencies as evidence of

adverse impact, while a greater than four-fifths rate will generally not be regarded by Federal enforcement agencies as evidence of adverse impact” (Code of Federal Regulations, 2020). In other words, disparate impact is assumed if any ethnic group does not pass at a rate of at least 80% of the rate of the ethnic group with the highest passing rate.

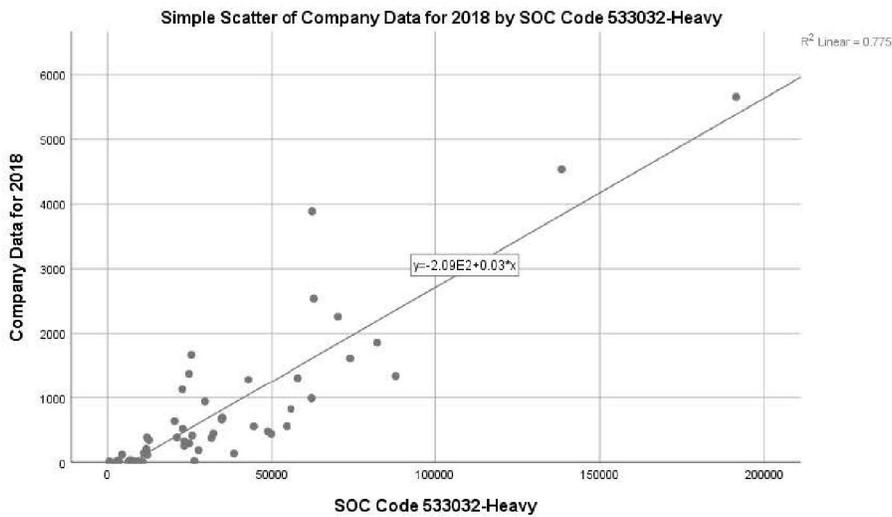
Second, researchers utilized chi-square (χ^2) difference tests to assess whether significant differences exist between ethnic groups within each test (e.g. whether a significant difference exists between ethnic groups for urine tests and, separately, whether a significant difference exists between ethnic groups for hair tests). Chi-square results would indicate disparate impact if no significant between-group differences exist for urine testing but do exist for hair testing. This would imply that the groups’ urine test pass/fail rate is statistically equivalent, but the groups’ hair test pass/fail rate is significantly different. Alternatively, chi-square results would indicate equal treatment if significant between-group differences exist for both/ neither urine and hair testing. This would imply that the groups pass/fail rates are statistically equivalent/ different irrespective of testing procedure.

Researchers were independently provided with paired urine and hair pre-employment drug screen results from three (3) commercial trucking companies for the years 2017-2019. These companies provide a representative sample of drivers, the unit of analysis. Two (2) companies provided results from 2017, three (3) provided

**FIGURE 1
SCATTER PLOT: TA CARRIERS 2018 AND BLS TOTAL**



**FIGURE 2
SCATTER PLOT: TA CARRIERS 2018 AND SOC CODE 533032**



results from 2018, and one (1) provided results from 2019. Aggregated data from 2017-2019 were examined. Sample sizes for each test are as follows:

- 2017-2019 urine test: n = 73,176
- 2017-2019 hair test: n = 72,023

As demonstrated in *study 1*, given a margin of error = 1%, and a confidence level = 99%, a sample size of 16,641 is required to generalize results across the broader U.S. truck driver population. Study 2

sample sizes exceed this threshold and results can be generalized nationally. Results are subsequently presented.

Results: Four-Fifths Rule

Table 4 details 2017-2019 urine test results. Ninety nine percent (99%) of drivers in the Asian ethnic group passed their pre-employment drug screens. To comply with the Four-Fifths Rule, every other ethnic group must pass at a rate equal to 80% of this figure (99% x 80% = 79%). Drivers who

chose not to report their ethnic group (“not specified”) passed at the lowest rate, which was 98.7% of the ethnic group with the highest passing rate. This exceeds the required Four-Fifths Rule 79% threshold.

Table 5 details 2017-2019 hair test results. Ninety six percent (96%) of drivers in the Asian ethnic group passed their pre-employment drug screens. To comply with the Four-Fifths Rule, every other ethnic group must pass at a rate equal to 80% of this figure (96% x 80% = 77%). Drivers who chose not to report their ethnic group (“not specified”) passed at the lowest rate, which was 91.7% of the ethnic group with the highest passing

rate. This exceeds the required 77% Four-Fifths Rule threshold.

Results: χ^2 Difference Tests: Chi-square results are presented as footnotes below tables 4 and 5. Significant differences across ethnic groups’ pass/fail rates were found for urine tests. Significant differences across ethnic groups’ pass/fail rates were found for hair tests.

Chi-square results indicate equal treatment if significant between-group differences exist for both urine and hair testing. This indicates the groups pass/fail rates are statistically different for urine

**TABLE 4
2017-2019 URINE TEST RESULTS**

ETHNIC GROUP	PASSED	FAILED	TOTAL	PERCENT PASSED	PERCENT OF HIGHEST PASSING RATE (ASIAN)
AM. INDIAN	753	6	759	99.2%	99.6%
ASIAN	1802	7	1809	99.6%	100.0%
BLACK	28632	294	28926	99.0%	99.4%
HAWAII/PACIFIC ISLANDER	276	2	278	99.3%	99.7%
HISPANIC	8191	44	8235	99.5%	99.9%
MULTIPLE	1777	25	1802	98.6%	99.0%
NOT SPECIFIED	8327	144	8471	98.3%	98.7%
WHITE	22664	232	22896	99.0%	99.4%
TOTAL	72422	754	73176	99.0%	99.4%

*Pearson chi-square = 67.52; p = 0.00; n = 73,176

**TABLE 5
2017-2019 HAIR TEST RESULTS**

ETHNIC GROUP	PASSED	FAILED	TOTAL	PERCENT PASSED	PERCENT OF HIGHEST PASSING RATE (ASIAN)
AM. INDIAN	709	48	757	93.7%	97.0%
ASIAN	1739	61	1800	96.6%	100.0%
BLACK	26329	2215	28544	92.2%	95.5%
HAWAII/PACIFIC ISLANDER	258	17	275	93.8%	97.1%
HISPANIC	7699	452	8151	94.5%	97.8%
MULTIPLE	1655	139	1794	92.3%	95.5%
NOT SPECIFIED	7149	925	8074	88.5%	91.7%
WHITE	21678	950	22628	95.8%	99.2%
TOTAL	67216	4807	72023	93.3%	96.6%

*Pearson chi-square = 624.6; p = 0.000; n = 72,023

testing and are also statistically different for hair testing. Irrespective of testing procedure, ethnic groups' drug test results are significantly different.

Conclusions for Study 2

Utilizing independently provided urine and hair pre-employment drug screen data, University of Central Arkansas researchers were unable to find disparate impacts of hair testing among the ethnic groups. Results for each test in each sample met the required Four-Fifths Rule threshold. Chi-square tests independently examine urine and hair tests. Chi-square results indicate that pass/fail rates are significantly different irrespective of testing method. Given these findings, we find no disparate impact among ethnic groups by testing method.

DISCUSSION AND CONCLUSIONS

Most of us share the road with motor carriers on a daily basis. We all hope that commercial truck drivers are well-trained, well-rested, and drug and alcohol free as they pilot 80,000 pound vehicles traveling within a few feet of our vehicle. To help ensure commercial motor vehicle driver sobriety, the federal government has long maintained strict urinalysis drug testing requirements. Previous research indicates urinalysis may be an insufficient method of ensuring commercial driver sobriety (Couper et al., 2002; Giroto et al., 2014; Lin et al., 2017). Evidence presented by The Trucking Alliance, and verified in this research, supports these findings and urinalysis' insufficiency.

This research was composed of two (2) distinct studies. The first assessed whether the Trucking Alliance was justified in generalizing its sample results over the U.S. driver population. By comparing differences in driver state of licensure information, we demonstrate a high degree of similarity between The Trucking Alliance sample and the national driver pool. This supports the notion that around 275,000 drivers would not be able to hold a safety sensitive occupation if they were forced to pass a hair drug test. The second study addressed concerns over potential disparate impacts posed by the use of hair drug testing. Consistent with the arguments of Mieczkowski

(2010), we were unable to find racially disparate impacts. Factors other than testing method seem to underly ethnic groups' pass/fail rate differences.

This work lends itself to several theoretical and managerial implications. First, our work sheds light on the importance of drug testing as an important area of supply chain inquiry. The supply chain literature is largely silent on the drug testing debate with the exception of Henriksson (1992). Future investigations may wish to examine trucking company drug testing best practices, such as when drivers are most likely to test positive or the relationship between the number of positive random drug screens and safety performance. Such research would be quite interesting. On one hand, higher random drug screen failure rates may indicate a more effective drug testing program and, therefore, fewer safety incidents. However, if random failure rates increase, driver recruitment and selection problems clearly exist. Second, managers should consider employing hair testing in addition to urinalysis. While this would increase the cost of doing business, any added cost would be more than offset if several safety incidents (and their associated liability) were prevented.

No trucking industry safety manager wants to get the call that their driver has been involved in a reportable safety event. Hair testing is a powerful tool that can help prevent safety incidents or lessen potential liability when they occur. Managers should ask themselves, "How many of our drivers could be included in the 275,000 who would be unable to drive if forced to pass a more stringent drug test?" While this question presupposes that these 275,000, left on the road, would lead to a number of additional deaths, this is a first order impact that, while accurate, may not tell the whole story. There is also a 2nd order impact. The trucking industry has to replace these 275,000 drivers with more qualified, sober employees if it wishes to improve roadway safety. Additional research is needed to better understand the impact of taking these 275,000 drivers off the road and how the trucking industry can improve driver recruitment and retention.

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**NO MORE MISSING INVENTORY:
BLOCKCHAIN AND RFID TECHNOLOGY APPLICATIONS WITHIN THE RETAIL
INVENTORY MANAGEMENT SYSTEM**

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ABSTRACT

Over the last two years blockchain technology has presented itself as a potential digital transformation that could disrupt and revitalize many business models. However, this digital transformation is still new and many companies grapple with possible applications of its theoretically sound benefits. Academic research is scarce and often limited to high level perspectives on how blockchain can benefit businesses in general. The time is right for exploring specific applications of the technology. This research considers how the digital transformation to blockchain could impact inventory management practices within the retail industry. The research relies on data collected through phenomenological interviews with management personnel of three clothing retail store franchisees.

**BLOCKCHAIN AND RFID TECHNOLOGY
IN THE NEWS**

Technology has helped business professionals make significant strides across all dimensions of supply chain management. Blockchain technology has entered the business domain and is showing tremendous promise in pushing supply chain management practices to the edge of a new information-sharing frontier. In a recent article from Forbes, IBM executives revealed that their blockchain ‘Food Trust’ system allows food processors, for example, Nestle, Kroger, and Tyson, to track produce from farm to the store shelf (Stanley, 2018). The system offers a variety of services to encourage its usage - securing data and access rights, integrating blockchain with current platforms, and finding a business model that benefits all parties involved. Brigid McDermott, vice president of IBM’s “Food Trust” reported that blockchain will have a significant impact on the food industry.

Supply chain professionals and academic scholars have begun to explore the various applications of blockchain technology across several business disciplines. However, many basic knowledge gaps exist. This research paper explores the gaps and contributes to the literature on how blockchain can assist retail operations and customer service. Existing research is limited primarily to conceptual studies. Further empirical inquiry is needed. In addition, current literature focuses on the overall benefits of blockchain in supply chain management (SCM) practice, but fails to pursue an understanding of the potential negative effects of blockchain on individual supply chain partner operations. This study is an effort to analyze the benefits and consequences of utilizing blockchain technology in a retail inventory management process through interpretive analysis of interviews conducted with professionals who work within retail operations of a national junior clothing retailer.

Clothing retailers' inventory management systems can be challenged in several ways, for example, keeping real-time records of product in route from the DC to the store, distinguishing product within the unloading process from product received and verified, maintaining visibility of SKUs during replenishment of the sales floor each night to processing damaged goods and even identifying store-specific trends.

Figure 1 illustrates a flowchart pertaining to common activities and processes pertaining to inventory flow within retail operations. While not all retail operations are identical there are many basic activities and processes that appear in some form within most operations. Prior to receiving freight at a retail store, the shipper and carrier interact to arrange freight pickup and transport. For some organizations, an advanced shipment notification (ASN) may be conveyed to the receiving party immediately upon loading and shipment. ASNs provide receiving departments opportunities to better plan for the unloading, disposition, and movement of the inbound freight prior to the freight actually arriving. This will provide benefits in labor allocation and critical product expediting upon receipt. Receiving entails the unloading and checking in of the freight, managing product discrepancies in the overages, short and damages (OS/D) rework area, and circulating received freight through value added service departments prior to stocking retail shelves. However these processes are often not optimized and could stand improvement in many cases.

Blockchain may be leveraged to establish improved documentation communication between distribution centers and retail stores and provide up-to-date inventory records. This paper highlights the possibilities of utilizing blockchain technology to improve retail operations and customer experiences. Moreover, major practical pitfalls associated with this new technology are discussed.

In this article The current state of the literature is discussed first. We then introduce the research

methodology and follow with a detailed discussion of the findings. Guidelines for practitioners and future research agenda for academics are offered last.

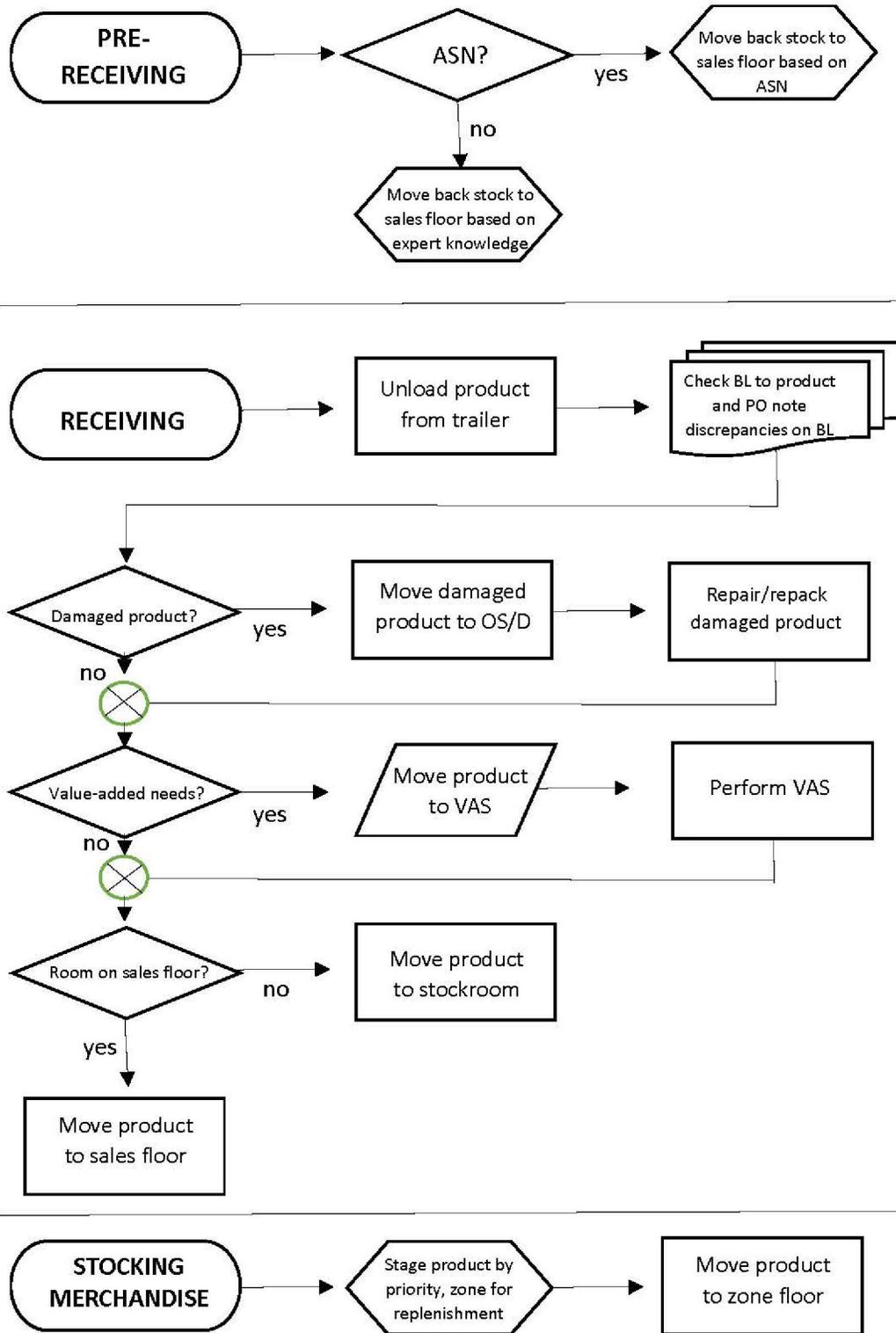
WHAT IS KNOWN ABOUT BLOCKCHAIN AND RFID TECHNOLOGY

Blockchain technology operates on a decentralized peer-to-peer basis, where it is impossible to artificially edit any information because of its unique heavy encryption and required verification protocol from all parties involved (Douaihy, 2018). Since the blockchain is decentralized and encrypted it has been deemed essentially "unhackable," ensuring security while keeping every transaction and document traceable to the original source. Fraud is prevented and identified by attaching a signature to each edit made by a user and making it public (Felin & Lakhani, 2018). Additionally, blockchain's ability to upload and share documents instantly minimizes courier costs for late paperwork. The ability to view the critical supply chain documentation from the beginning of materials or product movement to its end, and nearly instantaneously, would allow companies to verify goods, documentation, and cash flows while anticipating issues that might affect a company's part of the process and prepare for such issues (Dobrovnik, et al., 2018; Lindell, 2018). Moreover, it allows for identification of all the parties involved up and down the chain, allowing the channel captain to determine the level of risk at each node and link in the chain.

As blockchain becomes more widely accepted and less expensive practice, it is likely to trickle down through all sizes of companies and potentially include everyday consumers. Whether it will be widely accepted is still up for debate (Douaihy, 2018). Blockchain works best when all stakeholders involved in the supply chain use it, otherwise, non-conformity results in gaps in the data information chain.

How Could Blockchain and RFID Technology Affect the Supply Chain?

FIGURE 1
RETAIL OPERATIONS RECEIVING AND STOCK MOVEMENT



Sissman and Sharma (2018), discuss the positive and negative possible effects of blockchain implementation. Blockchain provides visibility and insight with respect to products and materials procured. For example, companies could confirm that raw materials and products are coming from ethical sources. Producers and end-users could have access to real-time updates regarding the production of their goods. Companies would be better equipped to proactively respond to shortages when manufacturing of their materials falls behind, and consumers could know ahead of time if a product will be out of stock in a specific retail store. Information could be made available to the public from the moment the supply chain begins until the end, making demand and inventory management less of a guessing game. Consumers could have access to the blockchain from their phone or computer making information critical to a customer's needs and wants immediately available. With the same touch of a button, consumers would be able to verify that what they are purchasing is verifiably organic, non-GMO, fair-trade, or made in a country of their choice. Investors would be able to use the blockchain to research companies' history, financial statements, and whether the company's current practices align with their own.

While the transparency throughout the supply chain may be valuable for some stakeholders within the supply chain and possibly for consumers and major manufacturers, such disclosure and visibility of proprietary information and data can become an issue if competitors have the same access because it limits a company's competitive edge. One proposed idea to safeguard a firm's competitive advantage is a private blockchain and "sharding" (Curran, 2018). Sharding breaks up the blockchain into shards or pieces that when put together form a complete blockchain. As number of transactions grows, the network bogs down and processing and recording of each transaction takes exponentially longer time. Breaking one blockchain into smaller "shards" limits this exponential growth of processing time. Related

to speed is scalability. If the speed of the network can be addressed, then larger more computationally taxing transactions can enter the network. Lastly, sharding allows companies to keep certain information public while proprietary and other sensitive information can remain private. In other words, some shards can be on a public blockchain to benefit consumers and business partners. Sensitive data and specific transactions can remain on a private blockchain. Speed, scalability, and visibility are all of concern when addressing retail inventory management practices.

While out of the scope of this research, blockchain has also become an ideal platform for cryptocurrencies. For example, Bitcoin transactions are recorded by all stakeholders from the buyer to seller to the credit card company involved in making the initial purchase. This same transaction method could be used in business-to-business sales to prevent fraudulent transactions. From a retail customer focused perspective, such digital currency through blockchain could be adapted for retail point of purchase currency exchange between consumer and retailer.

Incidents have been reported of fraud with cryptocurrency transactions being hacked, causing concern about the regulations surrounding blockchain (Russolillo & Jeong, 2018). So far there have been over 50 reports of hackings with millions of U.S. dollars lost in cryptocurrency. The hacks that have occurred are mostly focused on bitcoin and ethereum transactions because they are the dominant cryptocurrencies and there is a significant lack of regulations surrounding them. Cryptocurrency exchanges involve trading fees and store currencies making exchanges an easy and low-cost investment for hackers. This creates concern to many potential investors of blockchain for obvious reasons, will their business transactions be safe if blockchain is widely adopted? As of now there are no regulated security measures in place to protect bitcoin exchanges.

One of the many benefits to the blockchain is the inability to alter or change data/documents once posted and verified. This idea is an ensured way to prevent laundering and fraud; however, if confidential information is accidentally made public there is no way for it to be removed as it is a permanent ledger. All data and document changes in a blockchain system become shared knowledge with designated blockchain members (Niranjanamurthy, Nithya & Jagannatha, 2018). The possibility of private information being posted is also a concern of many companies. There are large cost savings in the long-run (Felin & Lakhani, 2018), but the initial cost of set-up and training will be expensive. These factors, plus blockchain being a new technology, will make companies hesitant about fully accepting it right away.

How Could Blockchain and RFID Technology Benefit the Retail Industry?

Blockchain technology implemented on a mass scale could provide outcomes beneficial to the consumer (Laposky, 2018). All stakeholders (consumers, suppliers, credit card companies) would have a restored sense of trust by being granted the same transaction information simultaneously. Consumers making purchases through the blockchain will benefit from instantly accessing proof of purchase documents. The extra time that was originally spent tracking down these items and transferring them from person to person will result in money that suppliers can put towards decreasing retail prices and increasing stakeholders' value. Once instant updates throughout the supply chain are made available it opens doors to improving individual processes along the supply chain. One of these processes is order fulfillment. Companies involved in business-to-business transactions will be able to communicate product fulfillment needs and reduce lead times by sharing information instantly.

With the visibility that blockchain provides, retailers and consumers will be able to see exactly where their products are sourced (Radocchia, 2018).

Increasingly, companies have outsourced manufacturing to Asian countries, where cheaper labor is available. However, in some instances the low cost labor is associated with unethical and inhumane labor practices. Consumers worldwide are taking notice and are increasingly switching to locally produced goods with origins that are easily verifiable. Blockchain can provide such visibility and source verification at a global level for consumable products. For example, during Shanghai Fashion Week, in collaboration with a technology provider, one designer placed microchips (i.e. RFID tags) in each piece of clothing and recorded information pertaining to the clothing on the designer's blockchain (Sharma, 2018). Fashion show audience members, utilizing their mobile phones, were able to access the designer's blockchain and confirm that a garment within the designer's collection was legitimately produced by the designer or was a counterfeit garment.

Recent advancements in other technologies may be integrated with blockchain to further transform retail distribution (McCrea, 2018). Online retailer Amazon uses robots to locate and move bins of products directly to an order-filler's work station. (Wingfield, 2017). The improvement has enabled order fulfillment efficiencies and increased the number of items made available for Amazon Prime's two-day shipping. In the background blockchain records where the inventory is located at any given moment within the process and provides an immediate detailed track of the product's movement through Amazon's internal and external supply chain.

Technology exists to improve inventory management without the use of blockchain. For years, retailers have utilized radio frequency identification technology (RFID) and tags to help maintain inventory integrity within the warehouse and for some high value products within the retail sales floor (Hardgrave, Goyal & Aloysius, 2011). Sensors are placed at different points throughout the stock room and sales floor so that items are tracked whenever

they pass a certain point (RFID tag readers) and recorded. Opportunities exist for the integration of RFID and blockchain technology to improve inventory management and visibility for specific stakeholders.

METHODOLOGY

Sample

Management and front-line employees of three leading clothing franchises were interviewed to learn about their retail-floor and stockroom inventory management issues, their understanding of blockchain technology, and their perceptions of how such technology could improve their current inventory management processes. Four store managers, three full-time stock associates, and one part-time sales floor associate were interviewed. Their retail industry experience ranges from 2 to 15 years. More specifically, the employees were asked about their view of general inventory management practices, using their current stock replenishment information system, where they believe there is room for improvement, and their initial opinion of

the implementation of blockchain technology in retail-level inventory management.

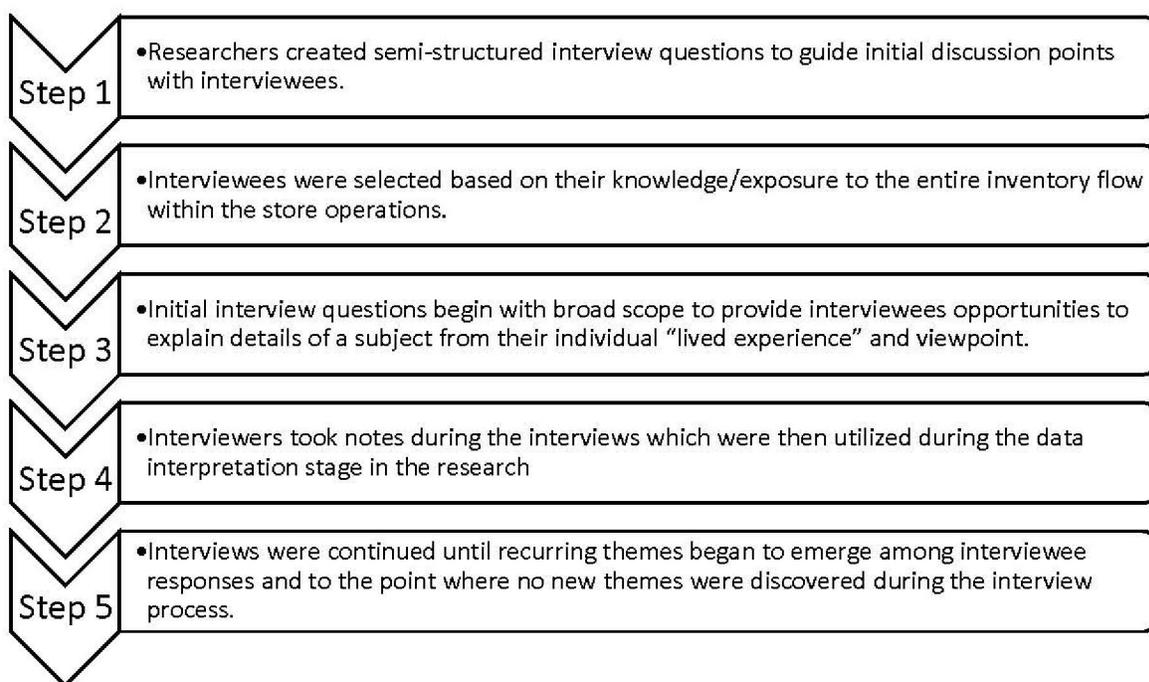
Data Collection Method

In order to develop and present a richer perspective on the topic we utilized an in-depth interview technique (McCracken 1988), which allows for a deep understanding of a phenomenon by interviewing relevant employees. This interpretive research methodology provides insights into the “lived experiences” of interviewees. By including management, stocking and sales floor personnel the data provides insights from multiple perspectives within retail operations.

Figure 2 provides the 5-step process taken to conduct phenomenological interviews with each interviewee.

Researchers began each interview by asking interviewees questions that were broad in scope, and as each interview progressed the questions would become more targeted. However, as the goal of phenomenological interviewing is to document the experience from the point of view of the subject, all

FIGURE 2
PHENOMENOLOGICAL INTERVIEWING PROCESS



interviewees were allowed and encouraged to provide detailed embellishments that would provide for a more robust interpretation of the interview outcome. Questions began with a focus on the interviewees' overall opinion of their company's current inventory management system and progressed to the subjects' viewpoints on how current practices positively and/or negatively impacted their jobs. Interviewees were provided a brief summary on blockchain technology and then asked to provide their thoughts on the benefits of utilizing the technology in their retail store operations. Interview notes were organized into subjects based on commonalities of themes that emerged from the discussions.

LEARNING OUTCOMES

How Is Blockchain and RFID Beneficial Within Retail Inventory Management?

Respondents indicated that the primary function of blockchain would be to provide employees instantaneous communication pertaining to the location and amount of a specific product. This is an overarching issue among all retail stores, suppliers, and distributors; lack of visibility and communication causes distrust and frustration between suppliers, carriers, and receiving departments. All interviewees felt that data exchange and visibility between IT systems was lacking to the point that jobs were impaired. With the implementation of blockchain, third-party programs can be integrated with blockchain (Sandoval, 2018). When systems are communicating, several steps of transferring information into additional programs are eliminated. The newly developed information network would constantly be expanding with more knowledge about products. With these improved capabilities, blockchain provides communication unlike ever before, opening a new world of possibilities. Figure 3 identifies the points when having inventory visibility is highly critical within a retail operational process. The dashed lines indicate a point where blockchain would be beneficial. The heavy arrows

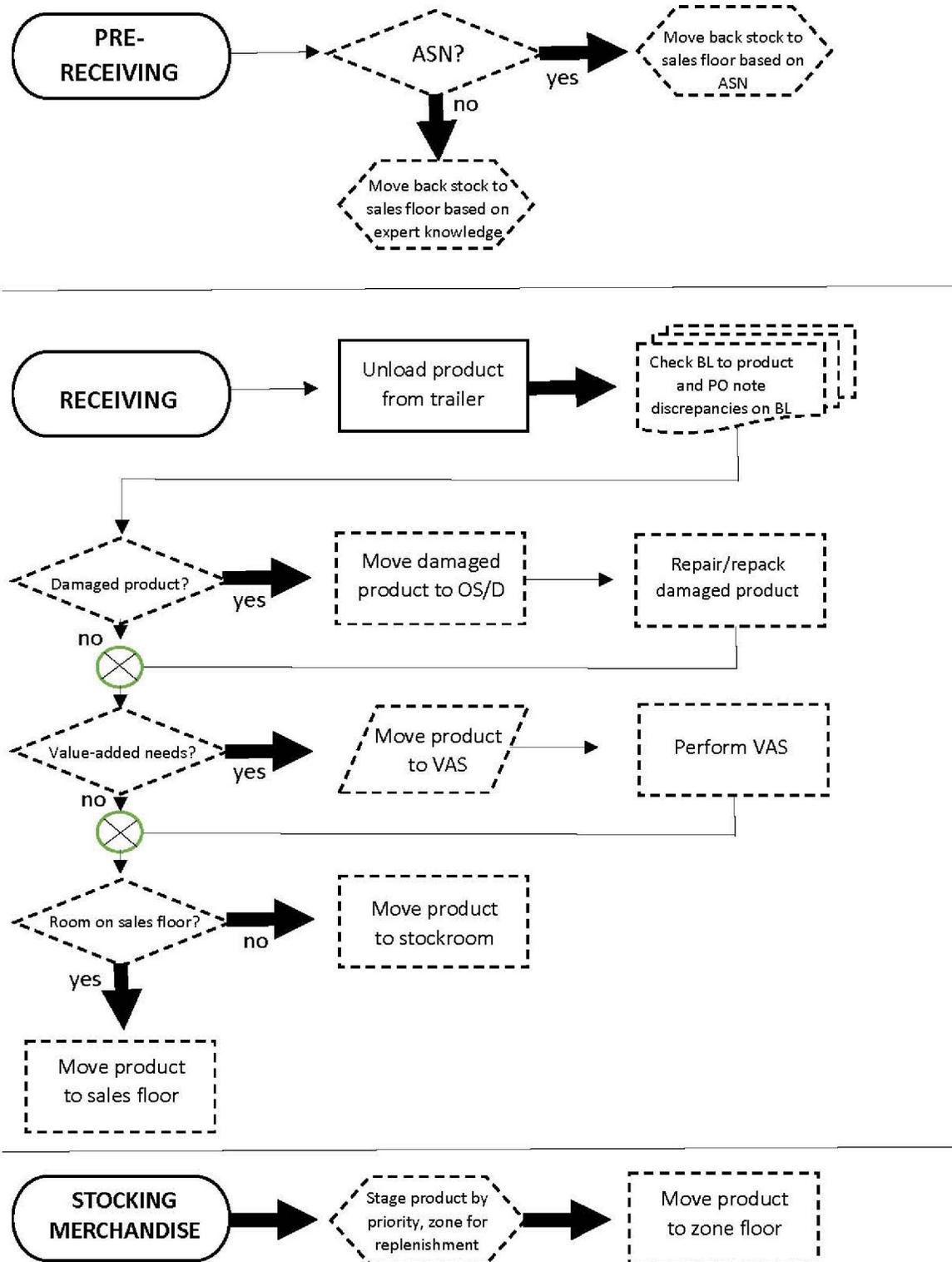
indicate product movement and where RFID tag technology would be beneficial. While each has merits, the technologies are different and promise to yield integrated benefits (Rometty, 2016).

Shipment reports are printed each week to give an estimated number of units to be delivered and an approximate processing time to help anticipate the number of labor hours needed to receive and process an inbound shipment. Some companies provide ASNs to verify that a shipment has been loaded and has physically departed the origin. Blockchain would allow all parties in need of the ASN to have immediate access to it. The ASN would not have to "be transmitted" through a data transaction to each individual in need. Blockchain would allow for the receiving manager to know the product was physically in route. Moreover, the stockroom and sales personnel would know that the product was in route and could have a qualified estimated time that the product would be available for customer purchase. This information would help employees to identify the critical products and to prioritize their work around the inbound product.

When a shipment is received at the retail store each case is scanned and each item in that case is also scanned to identify which items are to be placed on the sales floor immediately and what needs to be stored in the stock room. RFID tag technology would eliminate the need to scan products, whereas, when products are unloaded from the trailer they pass through RFID readers and are automatically updated into inventory. Again, while RFID tags provide efficiencies and accuracies during physical unloading and receiving, blockchain would allow all stakeholders the necessary documentation instantaneously. For example, a carrier may need to schedule dropping a trailer and picking up an empty trailer from the retail store. The carrier could be informed through blockchain technology that the trailer is over 50% unloaded (due to RFID tag indication), and the carrier could dispatch a driver ahead of time. In the same spirit, a customer that

FIGURE 3
RFID AND BLOCKCHAIN INTEGRATION WITHIN
RECEIVING AND STOCK MOVEMENT

(Dashed indicates blockchain potential and heavy weight arrows indicates RFID potential)



has an app providing inventory availability of a product would know if the product is available for purchase even though it is not yet positioned on the retail shelf. An online order fulfillment clerk would also know how many units of a particular SKU were received and could intercept the units in the stock room to prepare for parcel carrier pick up. This would reduce the need for the clerk to go to the retail floor to obtain the product only to have the product replenished from the receiving dock. Processes would be made more efficient.

During the shipment process, if a case of products is damaged the shipment carrier will refund or replace the case. This covers their liability of the items being damaged, however, in the process of doing so items are often lost or misplaced. When this happens, the retail store is unaware that they are missing it, if their system calls for the item later on, they simply assume that it is not in their inventory.

The interviewees agreed that blockchain would offer substantial solutions for shipment, as visibility increases between the distribution center, carrier, and retail store. All parties involved would know when and where the shipment items are and the exact contents of each case. If a carrier is required to re-package a shipment case the change would be made visible through blockchain, allowing the retail store to pinpoint where and which items are missing. They would also have insight as to the exact items that were shipped instead of only the number of items in each case.

Yearly the focal clothing retailers within the study, have inventory procedures where each item in the store and stock room is scanned and accounted for. After annual inventory, the inventory management system remains accurate for a couple of months. With the interaction between the product and delivery personnel, stock room associates, sales floor clerks, and consumers, the reconciliation is challenging between the physical and digital inventory count. With the addition of RFID tags and blockchain technology, one manager believes that inventory accuracy would improve to the extent that

store personnel would know the location of each product item, even if it was out of place, and be able to retrieve an item for a customer so that a retail sale would not be lost due to a lost item within the store. In this scenario, RFID and blockchain technology would actually help to increase sales transaction through inventory visibility.

With the new technology, time spent searching for items in the stock room could be minimized. If an item's location in the stock room is updated when shipment is processed, stock associates will waste less time locating items that are called for at the end of the night. This can be done through a combination of blockchain and compatible RFID-type chips implanted in all the clothing. Specific items can then be tracked and traced throughout the supply chain and once they hit retail stores, this would be similar to the technology used during Shanghai Fashion Week on the designer's fashion pieces mentioned earlier.

Retail stores across this particular clothing retailer are unable to see what items they will be receiving ahead of time. If they were aware of what items were coming store managers could compare the items to their best-selling departments and the current local trends to decide which items the store will need more or less of. Once the comparison is made managers can inform the upper management of their insight to possible trends which can help forecast future inventory needs more accurately.

One area of frustration expressed by a store manager was the lack of visibility on the retail side. While the upper management has access to detailed data about each retail store's profitability, sales, and trends, this information is not communicated well to individual retail locations. Blockchain would allow for that barrier to be broken and open up better communication between the corporate office and their stores by providing real-time updates accessible by both parties. It is not that the retailer is unaware of the trends, it is the manual approach that is prone to human error and miscommunication

between key stakeholders that causes inventory inaccuracies. Blockchain is a perfect automation solution that would get rid of these asymmetries between the corporate office and individual retail stores.

Additionally, there is an issue of visibility between retail stores. Often, customers will inquire about the availability of an item at another location; currently there is no visibility between retail locations about current inventory. Blockchain would minimize it, if not eliminate it, by allowing retail stores to search for items at another location for a customer. This is and would also be the case for visibility about what the distribution center has in stock. Currently, employees are only able to search the store website for items which pulls from a different distribution center than where store stock is shipped from. Having this level of information would improve the quality of customer service by letting them know

that while an item may be out of stock online and in-store it will be arriving at the store within x-amount of days. All benefits of blockchain technology within the retail inventory management are summarized in Table 1.

What Are Some of the Pitfalls of Blockchain and RFID in this Arena?

On a retail level there are lots of part-time employees and a small team of managers. With this comes lots of young adults and teenagers starting out at their first job, the learning curve is long, and the amount of human error may be substantial. A store manager said the following:

“If it wasn’t for human error the current system would work just fine.” - Kylie, Store Manager

Blockchain can improve the way that humans communicate with one another and share

**TABLE 1
SUMMARY OF BLOCKCHAIN TECHNOLOGY BENEFITS**

Benefit	Main Issue	Blockchain Solution
<i>Visibility</i>	Corporate office and distribution center does not share information about trends with retail store	Information about store-specific trends would be made available on blockchain and shipments would reflect statistics
<i>Accuracy</i>	Receiving shipment of unwanted items	Needed and already available items would be accurately accounted for through a form of blockchain-compatible RFID tagging. Information would be made available to all parties involved
<i>Time</i>	Non-value-added time spent looking for non-needed or unavailable items	Similar to accuracy, all available items would be properly calculated improving replenishment processes
<i>Communication</i>	Carrier, corporate office, retail store, and distribution center systems don’t have a secure platform to integrate and communicate on	Through blockchain, all systems would have a secured platform to communicate information about inventory

information, but it cannot force an employee to upload a document right away, check their calculations, or go the extra mile to take out a ladder and pull the requested shirts from the top shelf. On the positive side, however, an integrated use of blockchain and RFID technology can allow for a more automated account of stock movement from trailer to stock room to OS/D and to the retail sales floor. In fact, once on the sales floor, an item equipped with an RFID tag can be more easily located since the nearest tag reader will identify the item as out of place. In this manner, the technology can help to reconcile inventory discrepancies from improper stock movement by retail personnel or by customers moving product within the store.

Currently there is not a priority put on damaged items whether they come in from shipment, are found on the sales floor, or are returned as damaged. This is so because they are considered low-priority due to the extra time they take to process and their minimal effect on day-to-day sales. While it does not seem as though damaged items influence sales, there is an effect on stock. For example, if an item comes out of the shipment case damaged it is still processed, then hopefully “damaged out” (i.e., written off) within the next month; and “until it is “damaged out” it throws off inventory which can then have a domino effect on replenishment. This is a type of pitfall that blockchain could catch a bit earlier, but it still remains up to the retail store associates to properly record it on blockchain ledger as damaged.

One of the major concerns of blockchain implementation is the cost. Each company would have to perform extensive cost-benefit research to determine whether the short-term costs would outweigh the long-term cost savings. During the interview process, two key concerns surfaced about cost; that of employee training and long-term manufacturing costs.

“It [blockchain] could be helpful, but on a retail level it is so many peoples’ first job so there is a ton of human error.

Introducing new technology would be difficult and the [knowledge] requirements for employees could go up.” -Kate, Full-Time Stock Associate

If blockchain were to be used on a retail store level, all employees would require additional training to master its functions and procedures. Additional training would mean spending more money on employee compensation that does not increase sales. To counteract high employee turnover ratios companies would most likely increase the employee education or work experience requirements which would still cost the company money in increased wages.

One of the great benefits of blockchain is increased visibility throughout the supply chain, making it easier than ever for customers to trace the origin of the products they buy. This would be good from an ethical perspective for those companies that unknowingly may be associated with a supplier utilizing inhumane working practices. However, this may cause a shift for companies away from outsourcing their manufacturing to overseas suppliers that are less expensive.

“Most fashion retailers would like increased customer visibility, but when it comes down to it, it’s all about the money. The retail market is the first to take a hit when the economy is not doing well, if companies start outsourcing less it might hurt them in the end financially.” – Ryan, Store Manager

Many clothing retailers depend on outsourcing their manufacturing internationally in order to keep their prices affordable and maintain their customer base. When the economy declines consumers put off buying new clothes or search for cheaper substitute clothing outlets, such as, at thrift stores. Clothing stores have tried to offset this financially by sourcing manufacturing overseas.

IMPLICATIONS FOR MANAGEMENT

With new technologies constantly arising, it is imperative to stay up to date with what could be the next step. The implications of blockchain go much deeper and beyond the limits of this research, and lockchain can be applicable to a vast variety of fields and industries. Medical companies and hospital executives are already researching blockchain with plans to implement within the next 5 years according to an article from Forbes (Marr, 2017). They state:

“...to create a common database of health information that doctors and providers could access... higher security and privacy, less admin time for doctors so there's more time to spend on patient care, and even better sharing of research results to facilitate new drug and treatment therapies for disease.”

The benefits of blockchain on a base level are the same across all industries, increased visibility between practitioners, reduced non-value-added time, and broader accessibility while improving privacy. The biggest advantage within the medical field is the possibility for data management. The medical field is constantly conducting research on new therapies, medicines, and alternative treatments resulting in massive amounts of data left unorganized, unshared, or forgotten about. By using a blockchain platform all that data can be shared and verified within seconds. As mentioned earlier, the use of private and public blockchains will need to be developed more to allow for sensitive information, such as patient history, to be securely shared between medical practitioners.

More recently, there have been companies conducting extensive research on how blockchain and RFID technology could impact their industry. Walmart Inc. is among some of the first to put blockchain to use in their business operations; they are now requiring their vegetable suppliers to use

blockchain (Loten, 2018). The main reason Walmart chose this change was due to E. Coli outbreaks from recalled lettuce earlier this year. What they found was that customers avoided all lettuce products completely no matter the store or location, impacting their sales. By using blockchain they are now able to pinpoint the source of the E. Coli infestation and exactly which vegetables at which stores need to be recalled. This advancement protects their customers and their sales. For some more notable business applications, please refer to Table 2.

Our contributions illustrate the “extended potential” of blockchain integrated with individual operations; linking blockchain to an inventory management system of a retailer. What would be the benefit? There is an escalating need for retailers to fulfill online consumer orders from existing store inventory and shipping to customers from a store using a parcel carrier or even a local transport courier-type service, allowing pickup at multiple store stores, distributing direct from DC to consumer, or even the old fashioned back order from DC to store to rain check walk-in consumer at store. This has broadly been labeled omnichannel distribution. Retailers are truly searching for new strategies to manage the efficient fulfillment of such orders. Blockchain linked with operational inventory and stock movement systems, and enhanced with RFID-type technologies, could provide information visibility to the critical people in the supply chain so as to make the various processes and inventory visible where, when and to whom it counts most at this stage.

This suggests connecting consumers to the Blockchain, where access is granted in the Blockchain where they need critical information in order to most efficiently obtain their product. Consumers' confidence in products and orders being available to them when they want is very important. Without such consumer confidence, consumers will search for the product location from competitive sources. From this perspective, blockchain technology may have an extended benefit that reaches into the retail consumer domain.

TABLE 2
NOTABLE BUSINESS APPLICATIONS OF BLOCKCHAIN TECHNOLOGY

Initial research	Current/Intended Use
2017	Offering building of customized blockchain to customers. For example, ‘Food Trust’ to track and trace origins of produce
2017	Requiring all vegetable suppliers to use blockchain
2017	Currently offers a blockchain prototype to their customers for shipping operations
2014	Developed ‘Dragonchain’ for internal use and as of 2017 it is now available to the public as a way for companies to join blockchain
2018	Researching “new ways to share information”

The application of the Internet of Things (IoT) to blockchain suggests that it could help companies track, trace, and manage activities and processes with more precision attention to the value achieved within their supply chains (Rejeb, Keogh and Treiblmaier, 2019). While optimizing product management through warehousing and transportation by leveraging the IoT, combining IoT with Blockchain increases advantage and scope through enhancement of B2B management and accountability when it comes to materials and product flows. Rejeb, Keogh and Treiblmaier (2019) suggest that combining Blockchain technology to the IoT can enhance efficiencies and effectiveness of supply chains. Included in the IoT is RFID technology. They leave for discovery, however, the potential to move beyond the myopic focus on B2B and leverage the capabilities of the Blockchain technology within the walls of retailers and between the walls of retailers and DC’s and consumers by connecting the IoT RFID technology to Blockchain technology.

The IoT connected with blockchain technology can assist, for example, a transport driver in signaling when the temperature of a shipment is out of tolerance and the driver can take immediate steps to rectify the situation (Shrouf et. al, 2014). Hoffman and Rüsç (Hofman and Rüsç, 2017) propose that RFID and Blockchain can work in tandem to integrate information exchange within the manufacturing process to alert the need for materials replenishment at the specific production line point. Similarly, connecting IoT to Blockchain through RFID can assist retailers and customers when a product location or stocking level is “out of tolerance” and the retailer can take measures to replenish while a customer can know the status of inventory to fulfill their immediate need whether stock is at the retailer, in transit to the customer’s home or available at a secondary retailer location. Specific information would be made accessible by approved consumers (as approved private BC network members) as permitted and each consumer can identify the location of products and check the progress of an ordered item (Bashir 2017; Kim and Laskowski 2016). In this way, the combination of

RFID and BC can enhance the timeliness and accuracy of information exchange and provide consumers with the availability of the items of need (Chen et. al 2014; Cui 2018; Yan-e 2011). The IoT information via RFID can reside in the cloud and be distributed to consumers, as a need arises for a retail item. A consumer network member/ subscriber can access the specific information via an application through a smart phone, for example. The machine-to-machine and machine-to-human interactions provide a consistent and seamless flow of credible specific information that is most useful for consumer purchase decisions and retail product inventory positioning (Saragih et. al 2018).

The word “credible” being the operative word here in the reference above. The distributed ledger behind any blockchain makes a record of any and all retail purchases, returns, item movements across RFID enabled technologies, loading and unloading of inventory, and essentially all transactions taking place between the point of manufacture and point of sale. The distributed ledger records are immutable and, therefore, impossible for retailers or retail associates to edit any inventory transactions manually. Inventory miscounts, wrong charges, losses, and damages are all traceable via blockchain ledger. Consequently, credibility of inventory keeping rises, creating efficiencies from which both the retailer and the consumer benefit. Rejeb, Keogh and Treiblmaier (2019) propose key areas to leverage the interaction of the IoT and blockchain. Within inventory management and warehouse operations, such interactions have the capability to provide real time inventory visibility, avoidance of stockouts, agility and quick response to process and inventory inadequacies associated with, for example, lost items within a facility. It is our position that such competencies of leveraging the IoT, such as with RFID technology, and with blockchain technology, could also be applied within the retail setting. Doing so, would potentially provide retail to consumer gains similar to the service efficiencies and effectiveness that are achieved within the DC.

CONCLUDING REMARKS

The purpose of this research was to explore the potential benefits blockchain technology could have on current inventory management practices within retail. The interviews conducted revealed some core issues at the retail store level such as inability to find a clothing item, replenishment issues, shipment, time, visibility, and human error. Blockchain could have a major impact on the visibility between corporate, distribution centers, shipping companies, and the retail store by providing real-time updates on productivity and shipments. Time can be used more effectively towards customer service if associates are able to locate replenishment and make shipments quicker than current processes allow for. With increased accuracy of current inventory, “can’t find” replenishment items would be better customized to the stores’ exact needs.

While blockchain could be very beneficial in most areas of inventory management, there are still concerns to overcome. The main concern from a business and economic standpoint is the cost of implementation and if costs outweigh the potential benefits in the long or short run. One of these costs would be the additional training required for associates; a possible solution to that cost, at least temporarily, would be for only managerial level employees and above to receive training due to high turnover rates among part-time associates. However, when RFID and blockchain technology work in tandem the benefits far outweigh the costs.

While some companies mentioned like IBM and Walmart are already researching and implementing blockchain usage, it is likely that smaller companies will have to take smaller technological steps to get there. Research on blockchain is a part of those smaller steps towards improved supply chain and inventory management practices.

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RELATIVE TRENDS IN EXOGENOUS FACTORS INFLUENCING AIRLINE FLIGHT DELAYS

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ABSTRACT

This study investigates the impact of four subcategories of flight delays on total flight delays over the period from May 2005 through December 2019. Total flight delays are divided into weather, air carrier, security, and non-weather National Aviation System (NAS) delays. Using the flight data provided by the Air Travel Consumer Report of the U.S. Department of Transportation for a consistent set of ten airlines, each time-series is decomposed. Trend and seasonality are determined. Total flight delays, and each of its subcategories, demonstrate strong seasonality and follow a random walk model without drift during the sample period. Total flight delays are composed of approximately one-half air carrier caused, one-third weather related, and one-sixth non-weather NAS delays. In the period prior to 2012, weather, air carrier, non-weather NAS, and security delays follow the same pattern as total flight delays. After 2012, air carrier and non-weather NAS (infrastructure) delays follow a similar pattern as total flight delays, but weather and security delays are far fewer than would be suggested by the pattern of total delays. The latter period was consistent with a period of increased investment in “disruption management,” which may have had the desired effect on weather and security delays. Flight delays under the control of air carriers or from infrastructure issues (non-weather NAS delays) increased from 2012 through 2019.

INTRODUCTION

The commercial airline industry has a history of innovation in meeting technological and financial challenges. Nevertheless, disruptions to normal operations has remained a difficult problem. Airlines operate under two regimes of delays. The first are endogenous strategies implemented by the airlines to “pad” operations to minimize perceived overall delays. The second is the set of exogenous factors, over which airlines have no ex ante control, which cause interruptions to normal, scheduled operations. These two regimes are not independent of one another. The first, in fact, is a conscious strategy implemented in anticipation of the second.

Kohl, Larsen, Larsen, Ross and Tiourine (2007) provide a comprehensive summary of the elements

of the first regime. The simplest is adding extra buffers to flight turnaround time. That is, extra buffers are added in response to frequently delayed flights. This provides slack in the schedule that can be used in the recovery from unexpected events. Similarly, slack can be added to aircraft and crew turnaround times providing each line of work a degree of self-recovery. Finally, airlines can adjust the cruising speed of aircraft although increasing speed to recover lost time comes at the expense of additional fuel being burned and increased mechanical wear. Thus, normal operations may have implicit delays built into published schedules.

This paper focuses on the second regime of delays that airlines face. These are the exogenous delays to which an airline must react and implement recovery strategies in real time. A white paper by Travel

Technology Research Ltd. (2016a) identifies five factors that present impediments to devising solutions for these disruptions. First, the consideration of costs is a key element in the design of such solutions. However, while hard costs such as airline operations, hotel and meal vouchers and staff overtime are easily discernible, soft costs such as customer service and passenger delay times are less quantifiable. Second, regardless of the dichotomy between hard and soft costs, there is a lack of consensus as to how to measure disruption costs¹. This lack of consensus, which makes measuring the savings from potential solutions difficult, inhibits comparisons across given sets of solutions. Third, decisions related to real-time disruptions are made in airline operational control centers. These centers are staffed by people who frequently are overwhelmed by the amount of data that must be processed at any moment in time. Fourth, associated with this issue is the need for any IT software solution to integrate a myriad of internal and external data sources. Finally, it is only recently that the management of operational disruptions has become a focus for senior airline executives. These factors, taken together, present many problems for airlines trying to find solutions.

The white paper goes on to note that since 2010 there has been a significant investment in disruption management solutions. There has been growth in investment that has come in two ways. First, information system vendors have developed commercial generic products that are applicable to a large number of potential airline customers. Second, the larger airlines have pursued internal solutions that address idiosyncratic factors of disruption to their specific operations. Solutions, in general, have progressed from passenger accommodation to managing aircraft rotations and the restoration of crew assignments. However, no set of breakthrough solutions have emerged.

¹ For example, see Ferguson et al., 2013; Britto et al., 2012; Lubbe and Victor, 2012; Ball et al., 2010; and Schumer and Maloney, 2008.

A comprehensive overview of airline operations and delay management is provided in Wu (2016). He notes that the essential characteristic of airline scheduling is its four sequential and sometimes iterative stages: schedule generation, fleet assignment, aircraft routing and crew rostering. Historically, the scheduling process, which has evolved in this manner, involves synchronization across these “layers” and is extremely complex. Additionally, generating robust optimization solutions that integrate all four of the above stages is challenging because individually complex mathematical frameworks characterize each of them.

Wu puts forth the interesting concept that the future in airline operations may in fact, lie in greater simplicity. Simplicity specifically refers to simplicity in network design and the associated operations. In addition to lowering the planned cost of network design and operating costs, such strategies should lead to lower disruption costs. Examples of these strategies are the related concepts of de-peaking and rolling hubs. De-peaking, in general, addresses the typical practice at hub airports that optimizes flight schedules by minimizing passenger transfer times. Thus, a high number of flight arrivals and departures during peak periods leads to inefficient use of infrastructure and personnel. A de-peaking strategy spreads flights more evenly across the day allowing for more optimal use of resources and reducing airport congestion. Very much related to this is the notion of continuous or rolling operations. Under such a regime, arrivals and departures are scheduled so that there is a constant flow in the hub throughout the day. This leads to a reduction in total aircraft ground time and, again, better resource utilization. While these kinds of strategies may increase passenger travel times, this is offset by greater reliability in scheduled operations.

However, such strategies are a small part of the solution. As he observes, “. . . airline schedules are pre-planned well ahead of operations, and the operating environment involves random forces which may disrupt schedules and incur operating costs in actual operations” (Wu, 2016). Thus, a robust scheduling process is needed to reduce the

impact of operational disruptions by minimizing delay propagation and incorporating potential future disruptions and their associated recovery options into scheduling planning. Such an integrated modelling approach overcomes the deficiencies of the four-stage scheduling process discussed above. The complexity of this process is captured by the following observation in a second white paper by Travel Technology Research Ltd (2016b):

“If we view disruption management projects as parts of a complex system involving implementing applications software, systems integration, database management, personnel training, continuous improvement processes, and executive oversight, then the implementation process is very different from that of a mature proven system...”

In addition to internal operational considerations, a recent International Civil Aviation Organization report (ICAO, 2016) highlights a variety of impacts that climate change will have on commercial aviation. Increasing temperatures at ground level affect the wing-lift performance of aircraft. Less lift requires longer runways. Airports that do not have runways of sufficient length may be faced with the necessary cancellation of flights. Even with flights not being cancelled, extremely hot days may force airlines to fly flights with fewer passengers, cargo, or fuel. Maintaining traffic levels would require more flights, which would affect schedules and infrastructure. Long-haul flights that operate at maximum weight limits would be particularly impacted.

Rising sea levels due to climate change will also have an impact. Many airports are built on flat, low-lying land, which is close to the ocean or in drained swamps (Ensia, 2018). LaGuardia airport was closed for three days when Superstorm Sandy hit New York City in 2012. The San Francisco and Oakland airports are built on low-lying reclaimed land on the shore of San Francisco Bay. Climate change may also impact the prevailing Jetstream affecting optimal flight routes and times as well as fuel consumption. There will also be an increase in the number and intensity of thunderstorms with these phenomena moving upward into cruising altitudes. In

addition to making normal flights more challenging, this also increases the risk of high-altitude ice with possible concomitant engine failures. Finally, longer drought periods increase the occurrence and intensity of sand and dust storms affecting aircraft safety and airline schedules.

The purpose of the current study is not to survey the large number of approaches to operational disruption management. Rather, it presents a framework for examining the ex-poste efficacy of airline management of schedule disruptions by U.S. commercial air carriers. Specifically, it looks at the relative trends in exogenous factors that influence airline flight delays. The model utilized allows for the examination of the stochastic versus non-stochastic nature of several factors, any trends in these factors, and a means for forecasting the impacts of these factors. This study is conducted with delay data available from the BTS website both in terms of the number of delayed flights and in terms of the number of delayed minutes. The number of flight delays provides the frequency of flights arriving 15 or more minutes later than specified by the schedule. The minutes of delay per flight provides the impact of each type of flight delay. For this purpose, total flight delays are separated into three categories: weather, air carrier and security delays.

DATA METHODOLOGY

This research focuses on the time-series behavior of flight delays for a consistent sample of ten airlines using monthly flight delay data from January 2006 through December 2019. The data applies to the non-stop scheduled service between points within the United States (including territories) of Alaska, American, Atlantic Southeast/ExpressJet, Delta, Frontier, Hawaiian, JetBlue, SkyWest, Southwest, and United. These air carriers provide a variety in airline sizes and business models. Thus, the results generated are not idiosyncratic to one particular class of operating strategies.

The source of the flight delay data is the U.S. Department of Transportation’s (DOT) Bureau of

Transportation Statistics (BTS, 2019), which tracks on-time performance of domestic flights of large air carriers. Summary information on the number of on-time, delayed, canceled and diverted flights appears in DOT's monthly Air Travel Consumer Report, as well as in summary tables posted on the BTS website. The Air Travel Consumer Report separates causes of reported delays into the following five categories:

Air Carrier: The cause of the cancellation or delay was due to circumstances within the airline's control (e.g. maintenance or crew problems, aircraft cleaning, baggage loading, fueling, etc.).

Extreme Weather: Significant meteorological conditions (actual or forecasted) that, in the judgment of the carrier delays or prevents the operation of a flight such as tornado, blizzard or hurricane.

National Aviation System (NAS): Delays and cancellations attributable to the national

aviation system that refer to a broad set of conditions, such as non-extreme weather conditions, airport operations, heavy traffic volume, and air traffic control.

Security: Delays or cancellations caused by evacuation of a terminal or concourse, re-boarding of aircraft because of security breach, inoperative screening equipment and/or long lines in excess of 29 minutes at screening areas.

Late-arriving aircraft: A previous flight with same aircraft arrived late, causing the present flight to depart late.

However, the data needs to be refined by careful parsing. NAS delays are comprised of five categories: weather, volume, equipment, closed runway, and other. Additionally, each of the first four categories needs to be allocated to that of late arriving aircraft. This, in fact, is suggested in the DOT database where the total weather variable is defined as:

“Weather delay is the sum of Extreme Weather delays, NAS delays caused by the weather, and the Weather’s pro-rata share of late-arriving-aircraft delays based on delay minutes.”

Thus:

$$Total\ Weather\ Delay = Extreme\ Weather\ Delays + NAS\ Weather\ Delays + (Allocation\ Factor \times Total\ Late\ Arriving\ Aircraft)$$

(1)

where

$$Allocation\ Factor = \frac{(NAS\ Weather\ Delay\ Minutes + Extreme\ Weather\ Delay\ Minutes)}{(Total\ Delay\ Minutes - Late\ Arriving\ Aircraft\ Minutes)}$$

Prior literature has focused on extreme weather as the primary proxy for weather-related flight delays (e.g., McCrea et al., 2008; Abdelghany et al., 2004; and Allen et al., 2001). However, extreme weather provides only part of the effect of weather on flight delays. This measure includes non-extreme weather impacts on the system infrastructure not directly under control of airlines.

Additionally, NAS delays attributable to infrastructure and mechanical issues can be separated out:

$$Total\ Non - Weather\ NAS\ Delays = Non - Weather\ NAS\ Delays + (Allocation\ Factor \times Total\ Late\ Arriving\ Aircraft)$$

(2)

where:

$$\text{Allocation Factor} = \frac{(\text{NAS Non-Weather Delay Minutes})}{(\text{Total Delay Minutes} - \text{Late Arriving Aircraft Minutes})}$$

Similarly, for air carrier and security delays:

$$\text{Total Air Carrier Delays} = \text{Air Carrier Delays} + (\text{Allocation Factor} \times \text{Total Late Arriving Aircraft}) \quad (3)$$

where

$$\text{Allocation Factor} = \frac{(\text{Air Carrier Delay Minutes})}{(\text{Total Delay Minutes} - \text{Late Arriving Aircraft Minutes})}$$

and

$$\text{Total Security Delays} = \text{Security Delays} + (\text{Allocation Factor} \times \text{Total Late Arriving Aircraft}) \quad (4)$$

where

$$\text{Allocation Factor} = \frac{(\text{Security Delay Minutes})}{(\text{Total Delay Minutes} - \text{Late Arriving Aircraft Minutes})}$$

Thus total flight delays is the sum of these four components:

$$\text{Total Flight Delays} = \text{Total Weather Delays} + \text{Total Non-Weather NAS Delays} + \text{Total Air Carrier Delays} + \text{Total Security Delays} \quad (5)$$

As summarized in Table 1, over 12 million flight delays occurred during the period of January 2006 through December 2019. During this fourteen-year period, air carrier delays were the highest of the four categories with 49% of flight delays. Weather was next, accounting for 34% of total delays. Non-weather NAS delays accounted for 16%, and security delays 0.31%, of total flight delays. Figure 1 also presents the annual number of flight delays for 2006 through 2019 for each of the four categories. As can be clearly seen, the number of air carrier delays exceeds the other categories every year. While prior literature has suggested that weather is

the primary factor leading to flight delays (e.g., McCrea et al., 2008; Allen et al., 2001), the current research clearly indicates that air carrier delays exceeded weather related flight delays for this sample of air carriers during the sample period.

¹ The available data extended through March 2020. We ended our sample in December 2019 to avoid the anomalous period of January – March 2020 when COVID-19 caused an unusual number of flight cancellations.

² ARIMA is used to provide an initial characterization of the flight delay time-series prior to use of Proc UCM as discussed in the Appendix.

TABLE 1
DESCRIPTIVE STATISTICS FOR THE ANNUAL NUMBER OF FLIGHT DELAYS

<u>Annual</u>	<u>Weather</u>		<u>Air Carrier</u>		<u>Security</u>		<u>Non-weather NAS</u>		<u>Total</u>
	<u>Delays</u>	<u>Percent</u>	<u>Delays</u>	<u>Percent</u>	<u>Delays</u>	<u>Percent</u>	<u>Delays</u>	<u>Percent</u>	<u>Delays</u>
2006	340,107	38.60	411,372	46.69	5,123	0.58	124,502	14.13	881,104
2007	379,768	39.06	462,566	47.57	4,578	0.47	125,404	12.90	972,316
2008	362,450	41.46	381,606	43.65	2,740	0.31	127,415	14.58	874,211
2009	288,558	41.15	309,454	44.13	1,867	0.26	101,403	14.46	701,282
2010	272,445	35.80	389,482	51.18	2,575	0.33	96,553	12.69	761,055
2011	267,850	35.78	380,129	50.78	2,496	0.33	98,108	13.11	748,583
2012	263,928	31.64	439,583	52.70	2,479	0.30	128,164	15.36	834,154
2013	323,305	33.58	480,414	49.90	2,778	0.29	156,239	16.23	962,736
2014	306,452	29.16	540,225	51.40	1,736	0.18	202,429	19.26	1,050,842
2015	273,036	29.66	482,327	52.41	2,098	0.23	162,897	17.70	920,358
2016	280,475	30.73	460,054	50.41	2,446	0.27	169,675	18.59	912,650
2017	301,394	30.83	473,538	48.44	2,551	0.26	200,088	20.47	977,571
2018	337,840	32.49	502,782	48.35	3,082	0.29	196,237	18.87	1,039,941
2019	348,664	33.03	520,275	49.29	3,234	0.31	183,365	17.37	1,055,538
All	4,346,272	34.24	6,233,807	49.11	39,783	0.31	2,072,479	16.33	12,692,341
Monthly									
Mean	25,871		37,106		237		12,336		75,550
Median	25,931		36,389		216		11,877		74,415
Std Dev	7,624		935		148		3,868		17,490

The average monthly total flight delays during this period were 75,550 (Table 1). Of this, 37,106 were air carrier delays, 25,871 were weather delays, 12,336 were non-weather NAS delays, with only 237 security delays per month. The monthly median values were close to the monthly means. The standard deviation of the monthly flight delays was highest for weather delays and relatively less for air carrier delays.

THE BASIC STRUCTURAL MODEL

The monthly number of total flight delays and each of its components were examined for the period from May 2005 to December 2019². The SAS Unobserved Components Model procedure was used to decompose the basic structural model into trend, seasonality, and random error. The time-series is characterized as a sum of these three components.

$$Y_t = \mu_t + \gamma_t + \varepsilon_t \tag{6}$$

Where,

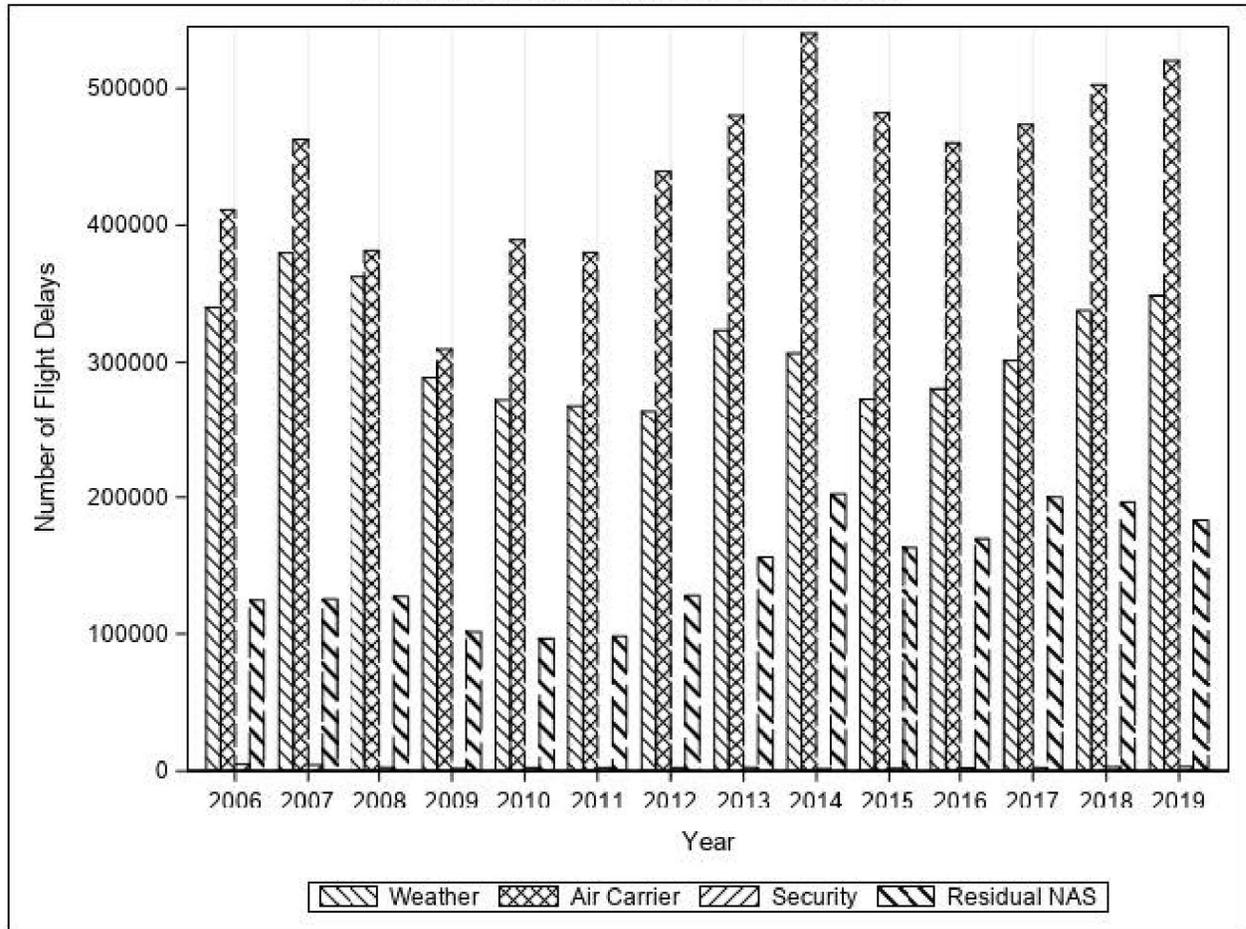
Y_t = Time-series data in time t

μ_t = Trend component

γ_t = Seasonality component

ε_t = random error (white noise) component

**FIGURE 1
ANNUAL FLIGHT DELAYS BY TYPE**



The log-transformed number of flight delays provides the required stationarity for the analysis³. Model fitting extracts random error (white noise) to produce a “de-noised” model that combines seasonality and trend. Further decomposition isolates the underlying trend.

The behavior of seasonality is characterized by its significance and variance (Milhoj, 2013). The length of the season may be set as a constant or allowed to vary. Trend is characterized with level and slope. The level can be allowed to vary over the time-series, while the slope may change deterministically (zero variance) or stochastically (nonzero variance). If a trend has a slope that is insignificantly different from zero and zero variance, it is referred to as a random walk model. Combined trend and seasonality are often used to forecast several months to years ahead, but this model was not used

to forecast flight delays for part or all of 2020 because of the anomalous behavior of air travel in 2020 due to the effect of the COVID-19 pandemic on air travel.

RESULTS AND DISCUSSION

The model developed for the logarithm of the total flight delays (Table 2, Model 1) demonstrates a characteristic trend and seasonality also evident in the other models for air carrier delays (Model 2), weather delays (Model 3), security delays (Model 4), and the non-weather NAS delays (Model 5). Trend for total delays (Model 1) is characterized by slope and level. The slope should demonstrate a gradual increase or decrease, if any, over the entire sample period from May 2005 to December 2019. The error variance for slope was set to zero to

TABLE 2
BASIC STRUCTURAL EQUATION MODELS

		Model 1	Model 2	Model 3	Model 4	Model 5
Type		LTD	LAC	LW	LS	LNAS
Trend Information:						
Level (Chi-square)	Stochastic	11.339690 (29467.4)***	10.636662 (31446.2)***	10.195752 (15163.0)***	5.468090 (1050.37)***	9.636795 (10257.0)***
slope (Chi-square)	Deterministic	0.001840 (0.22)	0.002273 (0.23)	0.000415 (0.01)	-0.000421 0.00	0.004032 (0.46)
Seasonality (Chi-square)	Constant	12 (359.69)***	12 (560.33)***	12 (259.59)***	12 (94.81)***	12 (35.29)***
Irregular error (Chi-square)	Stochastic	(0.49)	(0.28)	(0.94)	(1.61)	(0.07)
Fit Statistics:						
Root Mean Square Error		0.14758	0.12753	0.21505	0.39964	0.20951
Mean Absolute Percentage Error		0.98650	0.95153	1.61558	5.81271	1.82957
R-square		0.63793	0.75806	0.50556	0.33069	0.56899
Adj. R-square		0.63568	0.75656	0.50249	0.32653	0.56631
AIC		-159.9	-194.9	-33.8	172.3	-35.9
BIC		-145.8	-188.7	-27.6	178.5	-29.7

determine a single value for the period. The slope of 0.001840 was not significantly different from zero. Trend level was allowed to change randomly over the period. The trend level for total delays was a significant 11.339690 and demonstrated a significant variation around this value (0.01 level). Together the trend level and slope characterize the model as a random walk model without drift. This model demonstrated strong seasonality (0.01 level) and insignificant random error.

Each of the four components demonstrated a similar pattern of a random walk model without drift, strong seasonality, and insignificant random error. The model for the logarithm of air carrier delays provided the strongest fit with the lowest root mean square error, lowest mean absolute percentage error, and highest adjusted R-square of any of the models. The logarithm of weather delays (Model 3) and non-weather NAS delays (Model 5) demonstrated a good fit, but with greater variance than delays controllable by the air carriers. Security

delays (Model 4) provided a relatively small sample size. However, all five models described their time-series of flight delays well with only insignificant random error remaining unexplained.

Graphical analysis of the logarithm of total delays provides a comparison of the combined seasonality and trend (Figure 2A, top left) and trend alone (Figure 2A, top right). The combined seasonality and trend demonstrate the fit of actual data (circles) to the model (line) after elimination of the random error. The trend graph provides a cleaner display of the trend component of the model. The pattern for the trend of total delays demonstrates a large drop from 2008 to 2010 with a subsequent rise from 2010 to 2011. Air travel would increase during the recovery period which could explain the increase in flight delays from 2010 to 2011. Beyond 2012, the number of flight delays increase to a peak level in 2014 that exceed the 2007 to 2008 period and remain at elevated levels.

FIGURE 2A
COMPARISON OF AIR CARRIER AND NON-WEATHER
NAS DELAYS TO TOTAL FLIGHT DELAYS

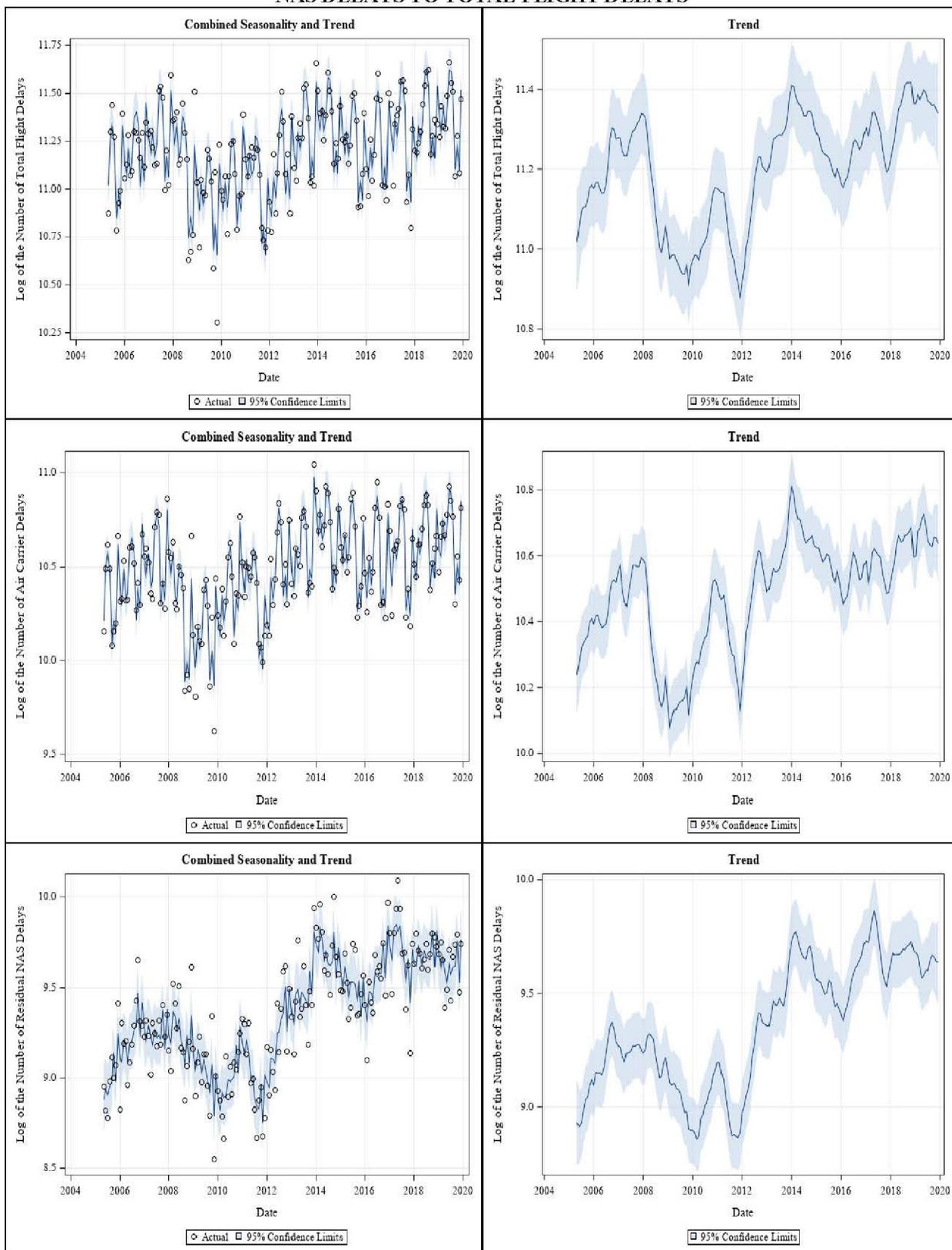
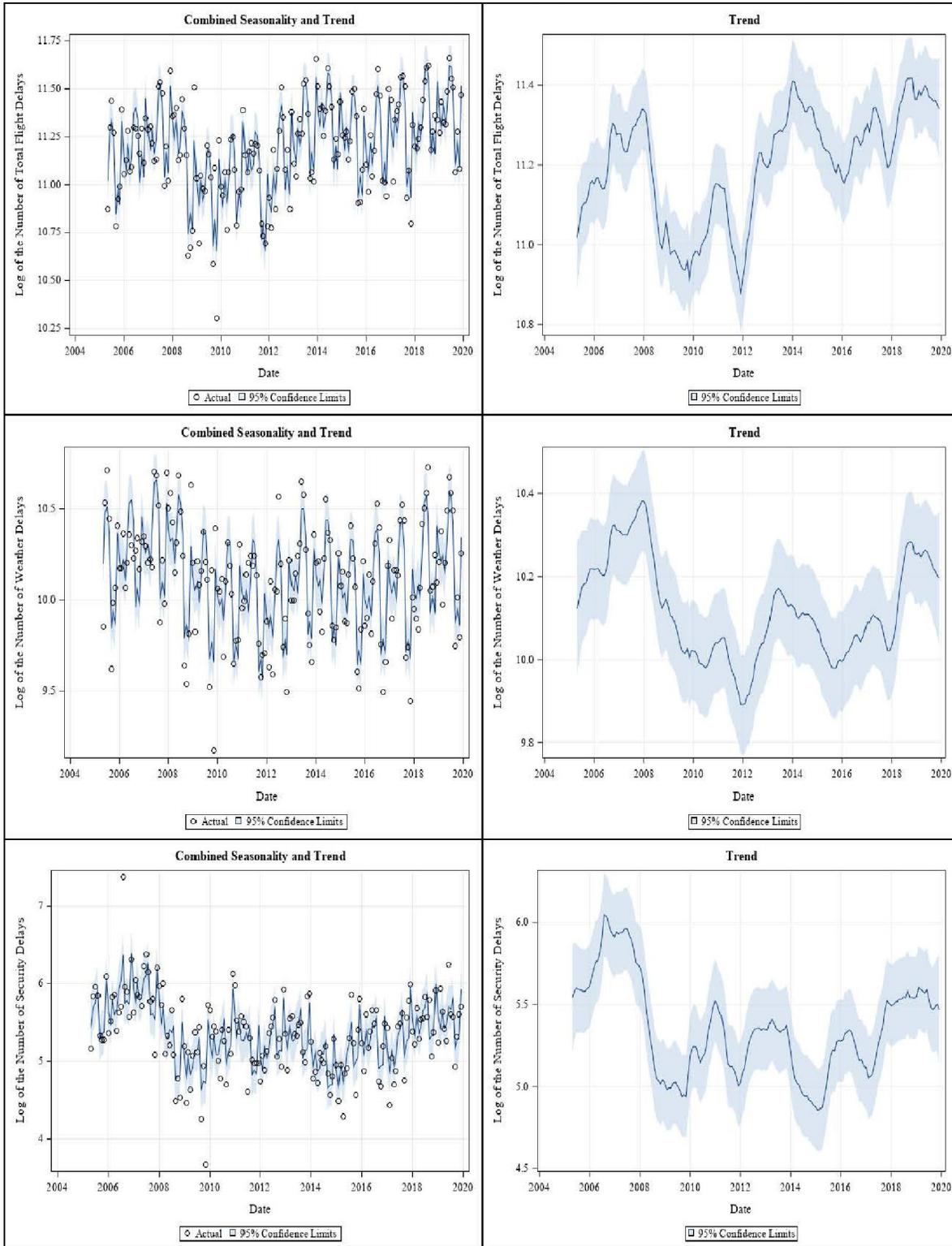


FIGURE 2B
COMPARISON OF WEATHER AND SECURITY DELAYS TO TOTAL FLIGHT DELAYS



Both models, logarithm of air carrier delays (Figure 2A, center) and non-weather NAS delays (Figure 2A, bottom), demonstrate a similar pattern for trend to total delays throughout the sample period. If the reported investment in “disruption management solutions” (Travel Technology Research, 2016a) by the air carriers had the desired effect, one would expect the number of air carrier delays to remain lower than the 2006-2008 peak during the period after 2012. This did not happen. The number of air carrier delays rose to a new peak level in 2014 and remained relatively high for the remainder of the sample period.

The air carrier delays category consists of those flight delays under the direct control of air carriers such as aircraft maintenance, crew scheduling, aircraft cleaning, baggage handling, and fueling. They, the air carrier delays category more under control of the airlines, account for 1/2 of total flight delays and appears to be the major source of total flight delays for these air carriers during this period. Non-weather NAS delays consist of infrastructure issues that account for 1/6 of the total flight delays, which appear to be an important secondary source of total flight delays. These findings are in contrast with the prior literature noted above (McCrea et al. (2008), Abdelghany et al. (2004), and Allen et al. (2001) that suggested that weather delays are the primary source of flight delays. Interestingly, Zou and Hanson (2012) identified air carrier delays as a major secondary source of flight delays.

Figure 2B provides a comparison of models of total delays and weather and security delays. In the period prior to 2012, both weather and security delays follow a pattern similar to total delays. In the period after 2012 their patterns differ from total delays. While total delays rise to a new peak level in 2014 and remains high, both weather and security delays peak in 2014 at a lower level and remain relatively low for the remainder of this period. Weather delays comprise approximately 1/3 of total delays and appear to constitute a major secondary

component of total flight delays regardless of the difference in its pattern, but security delays appear not to have a major effect on total flight delays due to their small number.

The pattern for weather and security delays differs from air carrier and non-weather NAS delays in the period after 2012. The “disruptive management solutions” that management of the air carriers were reported as implementing for issues under their control did not have the desired effect. While management could not alter the number or severity of infrastructure issues, weather events, or security events, the number of flight delays appeared to remain lower for both weather and security delays.

CONCLUSIONS AND DISCUSSION

Analysis of the time-series data for flight delays for the period from May 2005 through December 2019 provides a number of interesting observations. Decomposing the basic structural model for total flight delays demonstrated a random walk model without drift and strong seasonality. The data for each of the four components reasonably fit similar models. The air carrier related delays category emerged as the primary driver of total delays. They provided best fit to the model and represented the largest component of total flight delays. Weather delays and non-weather NAS delays were major secondary sources of total flight delays.

Air carrier, weather, non-weather NAS and security delays follow a similar behavioral pattern in the period prior to 2012. In all cases, the number of flight delays dropped from a peak in the period 2006-2008 to a relatively low value in 2010. This may be due to a reduction in the total demand for flights (Dobruszkes and Hamme, 2011; Pearce, 2011) during the financial crisis of 2008 and subsequent recession. Recovery from the recession seemed to be associated with increased flight delays between 2010 and 2012.

After 2012 the behavior of the components diverged. Air carrier delays and non-weather NAS delays followed similar patterns to total delays. They rose from a low point in 2012 to a peak in 2014 and remained high through 2019. Weather delays and security delays also rose from 2012 to 2014, but only recovered partly compared to the 2006-2008 peak. After 2014, the number of flight delays weather and security remained relatively low.

One possible explanation for the lower number of weather and security delays is that increased investment in “disruption management solutions” may have had the desired effect on weather and security delays. Such solutions seemed to have had a selective efficacy as demonstrated by the rise in air carrier delays.

Greater focus is needed on air carrier and non-weather NAS delay. The importance of this is demonstrated by the fact that combined, air carrier and non-weather NAS flight delays account for 2/3 of total flight delays. Internal issues such as maintenance, crew scheduling, cleaning of air craft and baggage handling have as yet to be successfully addressed by senior management. At a more macro-level, infrastructure issues, another major source of flight delays, also need greater attention.

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APPENDIX

ARIMA models were developed for total flight delays, and each of its components, to gain an understanding of their time-series properties (Yaffee, 2000; Brocklebank and Dickey, 2003; SAS Institute, 1991). To establish stationarity, a natural log transformation was performed on the first differences between observations (SAS Institute, 2015).

As summarized in Figure A1, the autocorrelation function (ACF) and partial autocorrelation function (PACF) demonstrate the classic pattern characteristic of a moving average model with ACF dropping off to zero and PACF declining more gradually. Multiplicative seasonality was indicated on the ACF by a large spike at month 12 and two smaller spikes of opposite sign in months 11 and 13 (lobes) (Yaffee, 2000; Brocklebank and Dickey, 2003). Together they suggest a $(1,1,0) \times (1,1,0)_{12}$ ARIMA model provides a reasonable tentative fit to the total flight delay data.

The model's fit is summarized in Figure A2, ACF and PACF demonstrated no spike beyond the zero spike for ACF were significantly different from zero. The white noise graph (Figure 2A, lower right) demonstrates that no spike exceeds the 0.05 level suggesting that this model provides a reasonable fit to the total flight delay data.

Similar moving average models were developed for air carrier, weather, security, and non-weather NAS delays (not shown). Each of these models also demonstrated the $(1,1,0) \times (1,1,0)_{12}$ ARIMA model provided a reasonable fit. Each demonstrated a strong seasonality, but with no clear trend to the underlying data.

FIGURE A1
EVALUATION OF THE TIME SERIES OF TOTAL FLIGHT DELAYS

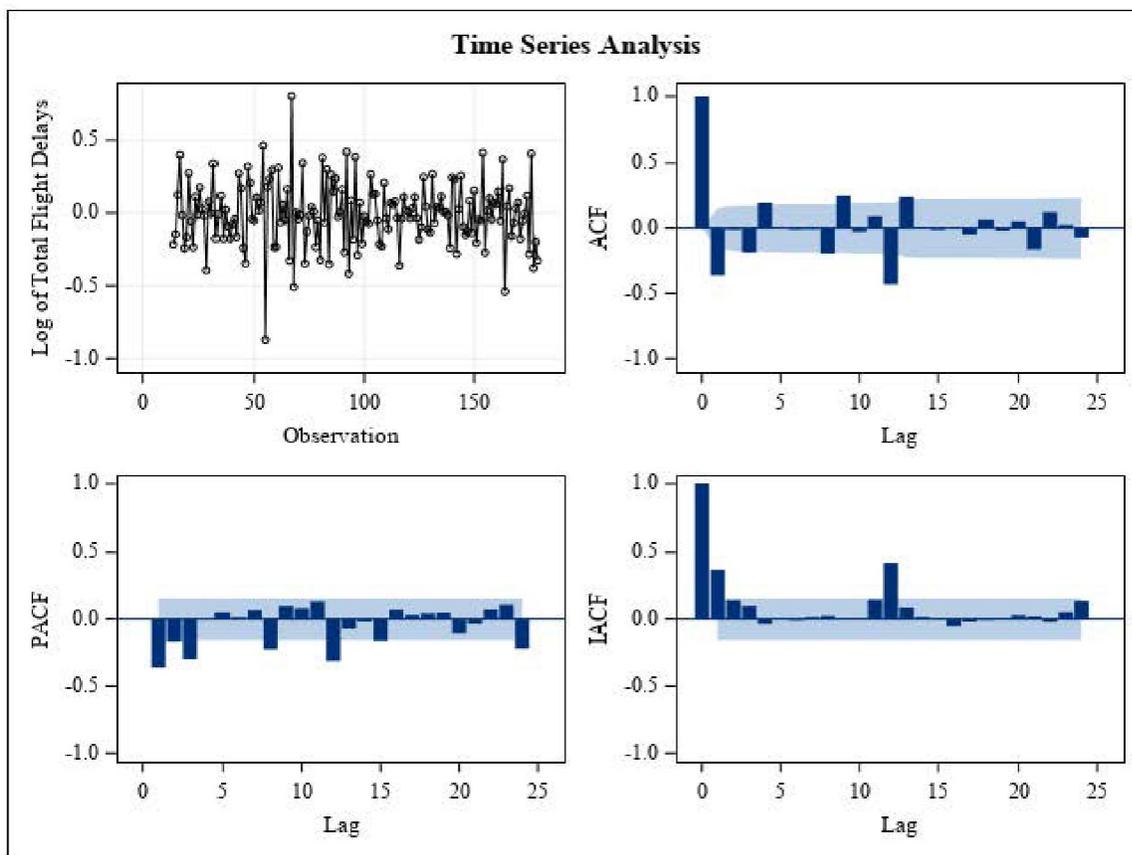
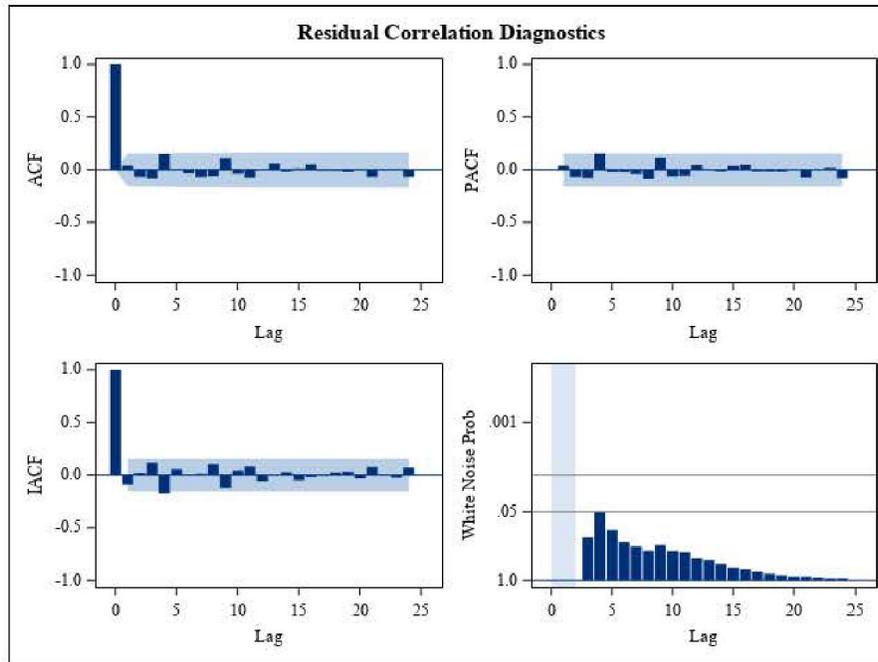


FIGURE A2
RESIDUAL CORRELATION USED TO EVALUATE OF THE ARIMA MODEL



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DOES SIZE MATTER IN THE AIRLINE INDUSTRY?

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ABSTRACT

Over the last decade, the U.S. airline industry has transformed itself through mergers, restructurings, bankruptcies, and dissolutions. Also during this time, the airline industry focused on a business model that was driven by an emphasis on asset utilization. This was driven by increasing the load factor to increase cost efficiencies through economies of scale so that the return on invested capital could be improved by reducing the operating costs. This study evaluates economies of scale and resultant cost efficiencies in the U.S. passenger airline industry for the period 2013 to 2018. The research finds that the airline industry is experiencing cost efficiencies with every increase in the size of the airline, but cost efficiencies are not evenly distributed. The paper also finds that the main source of cost efficiency appears to be aircraft maintenance expenses.

INTRODUCTION

This study evaluates economies of scale in the U.S. airline industry over the period of 2013 to 2018. Commercial aviation has a direct impact on our nation's economy, creating more than 10 million well-paying American jobs and driving 5 percent of the U.S. gross domestic product and nearly \$1.7 trillion in annual economic activity.¹ The airline industry in the United States has undergone transformational changes within recent decades with several mergers, acquisitions, bankruptcies and restructurings. A spate of mergers that completely changed the competitive landscape of the U.S. airline industry occurred in the period around 2008-2016. A major event occurred on October 31, 2010, when UAL Corp., parent company of United Airlines, and Continental Airlines Inc. completed their merger, creating United Continental Holdings Inc. Other important deals include the merger of Delta Air Lines and Northwest Airlines Corp. in 2008, the acquisition of AirTran Holdings Inc. by Southwest Airlines for \$1.4 billion in cash and stock in May 2011, and the \$3.0 billion purchase of Virgin America by Alaska Air Group in December 2016.

During this process of restructuring and reorganization, the airline industry has learned that market share alone is not enough to survive and compete in this highly competitive market. Instead,

they also need profitability by emphasizing and obtaining a better rate of return on capital through improvement in load factor and cost efficiencies. The goal of this new emphasis on profitability and a better rate of return is to focus on cost reduction with the goal of earning a rate of return that is higher than the cost of capital so that these decisions add long-term value to the company. Mergers and acquisitions in the U.S. airline industry have been driven by this desire to reduce costs and improve the rate of return.

According to Federal Aviation Administration (FAA), the U.S. commercial aviation industry consisted of six airlines that control about 85% of the commercial market in November 2017. These airlines are Alaska Air Group Inc. (which completed its merger with Virgin America Inc. in December 2016), American Airlines Group Inc., Delta Air Lines Inc., Jet Blue Airways Corp., Southwest Airlines Co., and United Continental Holdings Inc. The rationale for these mergers was that it will help airlines attain cost efficiencies through economies of scale and earn a superior rate of return on their capital.

In this study, we evaluate cost efficiencies of these six major airlines in the U.S. passenger airline

¹ Source: <https://www.airlines.org>

industry over the past six years from 2013 to 2018. The study is important for several reasons. First, we are not aware of any study that evaluates cost efficiencies of the major airlines in the United States. Secondly, in the wake of the mergers and restructurings, size and scale have become more important than ever. The U.S. airlines industry has fewer competitors and less capacity chasing customers, which should help the industry to be more disciplined on capacity, so airlines can price their product in a way that generates a sustainable return on invested capital.

Finally, the industry will help regulators understand the impact of mergers on the cost reduction and profitability of companies. Companies usually argue that they need to merge, because it help them improve their operating efficiency and profitability. Also, if mergers reduce operating costs and airlines are able to operate at a lower cost then some of this cost savings should be passed on to consumers in the form of lower ticket prices.

The rest of this paper is organized along the following lines. The first section summarizes previous studies. The second section discusses the model used in this study. Data and methodology are discussed in the following section. The next section provides a discussion of the empirical findings. The final section summarizes and concludes this study.

LITERATURE REVIEW

There have been several studies on economies of scale in different industries, but few studies have specifically focused on the U.S. airline industry. Johnston and Ozment (2013) investigated economies of scale in the U.S. airline industry using annual data from 1987 to 2009. They found that the U.S. airline industry operated under modest economies of scale. The study reported that, on average, the largest major U.S. airlines have enjoyed increasing returns to scale for the previous 22 years. Caves, Christensen, and Tretheway (1984) studied economies of scale for the U.S. airline for the period 1970-1981. They found that small airlines have a higher cost, but differences in

scale did not explain the higher cost for smaller airlines. They concluded that density of traffic within an airline's network is responsible for explaining cost differences among airlines. Creel and Farrell (2001) evaluated economies of scale in the U.S. airline industry after deregulation of the airline industry. They analyzed the cost structure of the US airline industry after deregulation and found that there were economies of scale at moderate levels of output. They concluded that due to the existence of economies of scale, airlines will try to grow to the efficient size.

Seong-Jong & Fowler (2014) used data envelopment analysis for measuring the relative efficiency of 90 airlines in Asia, Europe, and North America. They found that the efficiency of the airlines in Europe is the lowest among the airlines in these three regions. Min & Min (2015) developed a set of target performance standards that help airlines monitor their service delivery process, identify relative weaknesses, and take corrective actions for continuous service improvements. Wu & Ying-Kai (2014) used an integrated DEA-BSC model to evaluate the operational efficiency of 38 major airlines across the world to evaluate their relative performance. The study indicated that airlines with excellent performance in the efficient frontiers tended to perform better in energy, capital, and other operating costs. Carastro (2010) emphasized the use of non-financial measures to evaluate the airline industry. Assaf & Josiassen (2011) measured the technical efficiency of U.K. airlines through by using data envelopment analysis (DEA) bootstrap methodology. They reported that the efficiency of UK airlines has continuously declined since 2004 to reach a value of 73.39 per cent in 2007. Factors which were found to be significantly and positively related to technical efficiency variations included airline size and load factor. Schefczyk (1993) studies 15 airlines by using data envelopment analysis as a technique to analyze and compare operational performance of airlines. The study concluded with an analysis of strategic factors of high profitability and performance in the airline industry.

In this paper, we extend previous studies by examining cost efficiencies U.S. airlines. To our knowledge, no study has examined the operating efficiency of the U.S. airlines since the shakeup of the airline industry in the United States.

MODEL

To evaluate economies of scale in the airline industry, we estimate the coefficients of a translog cost function to determine which factors contribute to economies of scale and their degree of contribution. We then estimate cost elasticity with respect to the amount of output (output is being measured in two different methods: total assets and total revenue) using the first derivative of the translog cost function. Cost elasticity is estimated for the total sample for each year.

In order to investigate economies of scale in the airline industry, we use a two-part methodology. The first part is an estimation of coefficients for a translog cost function to determine which factors contribute to economies of scale and the extent to which they contribute for each of the five years in the period 2013 to 2018. We estimate economies of scale for total operating expenses of an airline and also with respect to each component of the total operating expenses, namely salary & benefits, aircraft fuel, station operations, maintenance & repairs, sales & marketing, and aircraft lease rentals.

The second part is an estimation of coefficients for a translog cost function using the panel data approach. The panel data approach allows for pooling of observations on a cross-section of U.S. airlines over five years. When observations possess the double dimension (cross section and time series), the crucial aspect of the problem is to have a clear understanding of how differences in behavior across individuals and/or through time could and should be modeled. A panel data set offers several econometric benefits over traditional pure cross section or pure time series data sets. The most obvious advantage is that the number of observations is typically much larger in panel data, which will produce more reliable parameter estimates and, thus, enable us to test the robustness

of our linear regression results. Panel data also alleviates the problem of multicollinearity, because when the explanatory variables vary in two dimensions (cross-section and time series), they are less likely to be highly correlated. Panel data sets make it possible to identify and measure effects that cannot be detected in pure cross section or time series data. For instance, sometimes it is argued that cross section data reflect short-run behavior, while time series data emphasize long-run effects. By combining the cross-section and time series features of a data set, a more general and comprehensive dynamic structure can be formulated and estimated. The use of panel data suggests that individuals, firms, states, or countries are heterogeneous (Balestra 1995). Time series and cross-section studies not controlling for this heterogeneity run the risk of obtaining biased results (Baltagi 2000). Panel data controls for individual heterogeneity.

The most intuitive way to account for individual and/or time differences in the context of panel data regression is to use the fixed effects model. The fixed effect model assumes that difference across airlines can be captured in differences in the constant term. The regression coefficients (the slope parameters) across groups in this model are unknown, but fixed parameters. It is also known as the least square dummy variable (LSDV) model and we use the LSDV fixed-effect model to estimate cost efficiencies in the airline industry.

Translog Cost Function

In financial economics, the translog model is the most pervasive approach for investigating economies of scale. The translog cost model implicitly assumes a U-shaped average cost function. It is used here because it allows economies of scale to vary with level of assets.

The estimation of scale economies with a translog cost function requires cost and output measures. For the airline industry, the output in this paper has been defined in terms of

- Total assets of the airline
- Total revenue of the airline

Total operating cost of each airline is defined as the total cost of operating an airline that includes wages & benefits expenses, aircraft fuel, aircraft maintenance, aircraft rent, landing fees & other rentals, contracted services, selling expenses, depreciation & amortization expense, food & beverage service expense, other operating expenses. An airline's total operating expense is modeled as a function of total assets and control variables that affect level of expenses.

We use a translog cost function to estimate economies of scale in the airline industry. Ordinary least squares (OLS) regression is used to find coefficients of the independent variables. Equation 1 shows the translog cost function to estimate economies of scale for the airlines with respect to total output (See Latzko, 1999):

$$\ln \text{COST} = \beta_0 + \beta_1 \ln \text{TOTAL OUTPUT} + \frac{1}{2} \beta_2 (\ln \text{TOTAL OUTPUT})^2 + \sum_j \beta_j X_j + e \quad (1)$$

In the translog function, the definition of COST depends on the input variable with respect to which one we are computing economies of scale. Therefore, cost can be the dollar amount of a company's total operating expenses and each component of the total operating expenses that includes salary & benefits, aircraft fuel, station operations, maintenance & repairs, sales & marketing, and aircraft lease rentals. Output is being measured in terms of either total assets of the airline or in terms of total revenue of the airline.

X_j includes control factors that affect the costs of management and administration of an airline. In Equation 1, ASSETS represent the total assets under management at a company. When we measure cost efficiency with respect to total assets, we use total revenues of the company as a control variable. Similarly, when we measure cost efficiency with respect to total revenue, we use total assets of the company as a control variable.

Cost Elasticity

The most common measure of operating efficiency in economies of scale studies is the elasticity of cost with respect to the output. When the rate of

increase in output exceeds the rate of increase in cost in an industry, economies of scale characterize that industry. For the industry, cost elasticity with respect to assets can be used to evaluate the existence and extent of economies of scale. It is measured by percentage change in cost associated with a percentage change in output. We calculate this elasticity by taking the first derivative of the translog cost function (Equation 1) with respect to assets. The result is Equation 2.

$$\frac{\partial(\ln \text{COST})}{\partial(\ln \text{OUTPUT})} = \beta_1 + \beta_2(\ln \text{OUTPUT}) \quad (2)$$

Where COST can represent

- o Total operating expenses; or
- o salary & benefits expenses, or
- o aircraft fuel expenses, or
- o station operations expenses, or
- o maintenance & repairs expenses, or

And output represents

- o Total assets; or
- o Total revenue

If cost elasticity is less than one, airline's expenses increase less than proportionately with changes in its assets. This implies that economies of scale exist. If the elasticity is greater than one, we can infer that diseconomies of scale exist.

To investigate the existence of economies of scale, we estimate the scale economy measure for each observation and then average across observations to derive the group scale economy measure. The cost elasticity is found for each observation (airline). Then an average across observations is computed to obtain the group average elasticity.

We estimate cost elasticities for the total group of airlines in each annual sample as well as for the combined sample period from 2013 to 2018.

DATA AND METHODOLOGY

The data for the airline industry is obtained from *Mergent Online*. Table 1 provides summary statistics of the data used in this study.

TABLE 1
SUMMARY STATISTICS OF THE DATA USED IN THIS STUDY
FOR THE PERIOD 2013 TO 2018

	Total Assets	Total Passeng Revenue	Wages and Benefits	Aircraft Fuel	Aircraft Maintenance	Total Operating Expense
<u>2013</u>						
Mean	\$19,022,519	\$15,282,304	\$3,428,708	\$4,443,097	\$850,510	\$14,278,572
Std. Dev.	\$19,691,119	\$15,375,664	\$3,307,005	\$4,529,451	\$685,116	\$14,526,932
<u>2014</u>						
Mean	\$19,746,316	\$ 17,599,152	\$3,925,105	\$4,868,635	\$919,797	\$16,159,416
Std. Dev.	\$20,206,522	\$18,026,929	\$3,771,778	\$5,069,964	\$775,165	\$16,755,833
2015						
Mean	\$20,842,140	\$17,563,024	\$4,346,958	\$3,002,694	\$895,343	\$14,581,433
Std. Dev.	\$21,007,061	\$17,594,108	\$4,159,925	\$3,022,635	\$727,453	\$14,802,467
2016						
Mean	\$21,658,603	\$17,366,402	\$4,792,876	\$2,476,993	\$910,372	\$14,745,476
Std. Dev.	\$20,658,175	\$17,035,412	\$4,622,920	\$2,397,358	\$720,908	\$14,621,842
2017						
Mean	\$22,571,474	\$18,301,075	\$5,180,869	\$,941,152	\$970,389	\$16,018,393
Std. Dev.	\$21,130,800	\$17,579,424	\$4,895,755	\$2,742,474	\$767,644	\$15,649,678
2018						
Mean	\$25,025,281	\$19,144,282	\$5,403,903	\$3,999,335	\$939,337	\$17,723,826
Std. Dev.	\$24,095,267	\$18,413,506	\$5,043,936	\$3,842,414	\$711,182	\$17,272,898

Table 1 shows that for the airline industry, on an average:

- total assets have increased by 31.6 percent in 2018 relative to 2013

- Total passenger revenue increased by 25.3 percent in 2018 relative to 2013; however, this increase has not been consistent. Total revenue shows an increase in 2014 relative to 2013, but shows a decline in 2015 and 2016 relative to the previous year. In 2017, total passenger revenue again shows an upward tick with an increase over the previous year.

- Wages and benefits have increased by more than 57.6 percent in 2018 relative to 2013.

- Aircraft fuel charges show an increase in 2014 relative to 2013, but show a decline in 2015 and 2016 due to a decline in crude oil prices. In 2017 and 2018, fuel prices now show an upward tick.

- Aircraft maintenance expenses do not show any consistent trend. In 2014, maintenance expenses showed an upward tick, but in 2015, they declined. In 2016 and 2017, maintenance expenses again trend upward, but in 2018, maintenance expenses again show a decline over the previous year. On average, aircraft maintenance expenses show an increase of 10.4 percent in 2018 over 2013.

- Total operating expenses show an increase of 24.1 percent in 2018 relative to 2013.

EMPIRICAL ANALYSIS

Cost Efficiencies With Respect To Total Assets

Table 2 summarizes the regression results of the translog cost function specified in equation 1. Table 2 shows four variations of equation 1. In the first model the natural logarithm of total operating expenses are the dependent variable. In the second, third, and fourth model, we use wages and benefits, aircraft fuel, and aircraft maintenance as the dependent variables, respectively.

Model 1 shows that the natural logarithm of assets has a positive coefficient estimate that is statistically

significant. This implies positive cost elasticity in that the level of assets directly affects total operating costs of an airline. Total operating revenue is positively related to the total operating expenses and is statistically significant. Model 2 shows that there is a positive relationship between wages and benefits and size of the airline as measured by total assets, because the coefficient on natural logarithm of assets is positive in model 2 and is statistically significant. Once again, total operating revenue has a positive and statistically significant coefficient.

In model 3, natural logarithm of aircraft fuel costs is the dependent variable. The natural logarithm of assets has a negative coefficient estimate, but it is not statistically significant. This implies the level of assets does not directly affect total aircraft fuel costs for an airline. It is not surprising, because aircraft fuel costs beyond a point are a market determined variable and cannot be influenced by the size of the airline. In model 4, the natural logarithm of assets has a positive coefficient and is statistically significant in explaining the natural logarithm of aircraft maintenance. This implies positive cost elasticity in that the level of assets directly affects the aircraft maintenance costs of an airline.

For all of the four models, the average cost elasticity for the overall sample is positive and below 1.0. A two-tailed t-test shows that the differences are significantly different from 1.0 for total operating expenses, wages and benefits, and aircraft maintenance. For aircraft fuel, the average cost elasticity is 0.98, but it is not statistically significant.

So, airline total operating expenses increase less than proportionately with increases in the total assets. For every one dollar increase in the airline's assets, total operating expenses, on average, increase by \$0.58. Cost elasticity for aircraft maintenance is 0.20 and this is the biggest source of cost efficiencies for larger airlines and seems to be the motivating force and argument for mergers in the airline industry. For every one dollar increase in total assets, aircraft maintenance expenses, on average, increase by \$0.20. Airlines also reap benefits of economies of scale in wages and benefits

TABLE 2
PANEL DATA REGRESSION RESULTS FOR THE TRANSLOG COST FUNCTION TO
MEASURE ECONOMIES OF SCALE WITH RESPECT TO SIZE OF THE AIRLINE AS
MEASURED BY TOTAL ASSETS FOR THE PERIOD 2013 TO 2018.

Dependent Variables	Total Operating Expenses	Wages and benefits	Aircraft Fuel	Aircraft maintenance
Number of Banks	9	9	9	9
Dependent Variable: Natural Logarithm of Total Operating Expenses				
Adjusted R-Square	0.99	0.98	0.83	0.90
Ln of Assets	4.17 (4.10*)	6.30 (3.94*)	-2.41 (-0.48)	7.35 (2.85*)
½ (Ln of Assets ²)	-0.22 (-3.24*)	-0.35 (-3.27*)	0.21 (0.62)	-0.44 (-2.54**)
Total Operating Revenue	0.0 (4.45*)	0.0 (2.75*)	0.0 (0.26)	0.0 (2.16**)
Cost Elasticity	0.59 (-10.95*)	0.61 (-6.56*)	0.96 (-1.21)	0.20 (-10.73*)

*statistically significant at 1% level; **statistically significant at 5% level; ***statistically significant at 10% level.

through larger size. Table 2 shows that with every dollar increase in total assets, wages and benefits, on average, increase by \$0.61. By combining operations and reducing duplication of efforts, airlines have been able to improve labor efficiency in terms of reduced labor costs.

Although the cost elasticity for aircraft fuel expenses is 0.96, but it is not statistically significant. Aircraft fuel cost is more dictated by market price of crude oil rather than the size of the airline and, as a result, we do not see any economies of scale in aircraft fuel expenses.

Cost Efficiencies With Respect to Total Operating Revenue

Table 3 summarizes the regression results of the translog cost function specified in equation 1 with output being measured in terms of total operating revenue. Table 3 shows four variations of equation 1. In the first model, natural logarithm of total

operating expenses are the dependent variable. In the second, third, and fourth model, we use wages and benefits, aircraft fuel, and aircraft maintenance as the dependent variables, respectively.

Model 1 shows that the natural logarithm of total operating revenue has positive coefficient estimate that is statistically significant. This implies that the level of total operating revenue directly affects total operating costs of an airline. The coefficient on total assets are positively related to the total operating expenses and is statistically significant. Model 2 shows that there is a positive relationship between wages and benefits and size of the airline as measured by total operating revenue, because the coefficient on natural logarithm of operating revenue is positive in model 2 and is statistically significant. Once again, total operating revenue has a positive and statistically significant coefficient.

In model 3, natural logarithm of aircraft fuel costs is the dependent variable. The natural logarithm of total operating revenue has negative coefficient estimate and is statistically significant. With higher operating revenue, aircraft fuel cost is lower. Since revenue is a factor of number of tickets multiplied by the price of the ticket, it seems that airlines continue to charge a higher price even when the fuel cost has declined. In model 4, natural logarithm of assets has a positive coefficient and is statistically significant in explaining the natural logarithm of aircraft maintenance.

Average cost elasticity is below 1 and statistically significant for total operating expenses and aircraft maintenance, which points to economies of scale for the airline when size is measured by total operating revenues. For wages and benefits and aircraft fuel, average cost elasticity is more than 1 and statistically significant. With every one dollar increase in total operating revenue, airlines to spend more than a dollar on wages and benefits as well as on aircraft fuel.

Cost Elasticity by Each Year F2013 to 2018

Table 4 summarizes cost elasticity for total operating expenses, wages and benefits, aircraft fuel, and aircraft maintenance for each of the six years from 2013 to 2018.

Table 4 shows that the airlines have been engaged in cost cutting measures since 2013 and have been successful through improved efficiency measures. The average cost elasticity for total operating expenses was 0.63 in 2013. In 2018, the average cost elasticity for total operating expenses for the airline industry was 0.54, which means with an increase in total assets, total operating expenses, on an average, increased more slowly in 2018 relative to 2013.

Similarly, cost elasticity for wages and benefits was 0.68 in 2013 and 0.53 in 2018 and it again shows higher efficiencies in wages and benefits in 2018 relative to 2013. The cost elasticity for wages and salaries continues to show a steady decline since

TABLE 3

PANEL DATA REGRESSION RESULTS FOR THE TRANSLOG COST FUNCTION TO MEASURE ECONOMIES OF SCALE WITH RESPECT TO SIZE OF THE AIRLINE AS MEASURED BY TOTAL OPERATING REVENUES FOR THE PERIOD 2013 TO 2018.

Dependent Variables	Total Operating Expenses	Wages and benefits	Aircraft Fuel	Aircraft maintenance
Number of Banks	9	9	9	9
Dependent Variable: Natural Logarithm of Total Operating Expenses				
Adjusted R-Square	0.998	0.98	0.90	0.89
Ln of Total Operating Revenue	1.47 (3.40*)	2.48 (1.96***)	-7.92 (-2.36**)	5.55 (2.34**)
½ (Ln of Total Operating Revenue ²)	-0.03 (-1.05)	-0.09 (-1.02)	0.60 (2.68**)	-0.32 (-2.00**)
Total Assets	0.00 (0.79)	0.0 (0.87)	0.0 (-2.34**)	0.0 (1.40)
Cost Elasticity	0.99 (3.77*)	1.04 (2.37**)	1.70 (6.86*)	0.41 (-10.64*)

*statistically significant at 1% level; **statistically significant at 5% level; ***statistically significant at 10% level.

2013. It seems like airlines continue to find ways to improve labor productivity.

The cost elasticity measure shows the biggest gains in aircraft maintenance costs. Average cost elasticity for aircraft maintenance was 0.29 in 2013 and declined to 0.10 for 2018. Elasticity measures for aircraft maintenance costs also show a steady decline in maintenance expenses relative to size of the airline. In 2018, for every one dollar increase in total assets, aircraft maintenance costs increased by \$0.10 only.

Efficiencies with Respect to Total Revenue

Table 5 summarizes the regression results of the translog cost function specified in equation 1b in which size is measured in terms of total revenue. Table 4 shows four variations of equation 1. In the first model, natural logarithm of total operating expenses are the dependent variable. In the second, third, and fourth model, we use wages and benefits, aircraft fuel, and aircraft maintenance as the dependent variables, respectively.

Model 1 in Table 5 shows that increase in total operating revenue results in higher total operating

costs, because the coefficient on natural logarithm of total operating revenue is positive and statistically significant. Model 1 in Table 4 shows that the cost elasticity of total operating expenses with respect to total revenue is slightly below 1 at 0.99, but it is statistically significant.

Cost Elasticity for Each Airline For The Period 2013 to 2018

Table 6 summarizes the average cost elasticity for each of the nine airlines with size being measured in terms of total assets for the period 2013 to 2018.

The most efficient airline in terms of keeping the total operating cost down is Delta Airline with an average cost elasticity of 0.23. Even on a year by year basis, Delta's cost elasticity with respect to total operating expenses is 0.23. It is closely followed by American airlines with an average cost elasticity of 0.25. American airlines has shown a consistent decline in the cost elasticity since 2013. United Continental Holdings, Inc. is at number three in attaining cost efficiencies in total operating expenses with average cost elasticity at 0.29. United Continental Holdings, Inc. is also showing consistent improvement in attaining cost efficiencies since

TABLE 4
COST ELASTICITY OF TOTAL OPERATING EXPENSES, WAGES AND SALARIES, AIRCRAFT FUEL, AND AIRCRAFT MAINTENANCE WITH RESPECT TO TOTAL ASSETS BY EACH YEAR FROM 2013 TO 2018

	2013	2014	2015	2016	2017	2018	Panel Data
Total operating Expenses	0.63 (-3.52*)	0.61 (-3.91*)	0.60 (-4.02*)	0.54 (-4.49*)	0.56 (-4.85*)	0.54 (-5.10*)	0.59 (-10.95*)
Wages and Benefits	0.68 (-1.94**)	0.65 (-2.33**)	0.63 (-2.36**)	0.59 (-2.73*)	0.57 (-3.02*)	0.53 (-3.27*)	0.61 (-6.56*)
Aircraft Fuel	0.92 (-0.87)	0.93 (-0.72)	0.94 (-0.59)	0.97 (-0.37)	0.98 (-0.21)	1.00 (0.02)	0.96 (-1.21)
Aircraft Maintenance	0.29 (-3.53*)	0.25 (-3.82*)	0.22 (-3.95*)	0.18 (-4.41*)	0.14 (-4.76*)	0.10 (-5.01*)	0.20 (-10.73*)

2013. The least efficient airline group is Alligiant Travel Company with an average cost elasticity of 1.04. Alligiant Travel Company showed a cost elasticity below 1.0 in 2017 only. In all other years, they show a cost elasticity above 1, which means that with increase in assets, total operating expenses increased by more than 1.

When we average cost elasticities with respect to wages and benefits for each airline, Delta Airlines is again the most efficient. In fact, Delta is reporting a negative cost elasticity at -0.02, which means with increase in size, Delta's cost in terms of wages and benefits is slightly declining. American airlines has an average cost elasticity of 0.02 for wages and benefits, which means for every one dollar increase in total assets, wages and benefits increase by \$0.02 only. United Continental Holdings, Inc. is number three with a cost efficiency score of 0.09. The least efficient airline is Alligiant Travel Company with a cost elasticity of 1.33, followed closely by Hawaiian Holdings, Inc. with a cost elasticity of 1.11.

For aircraft fuel cost, Alligiant Travel Company has the best efficiency score at 0.51 on an average. American airlines, Delta Airline, United Continental

Holdings, and Southwest Airline have an average cost elasticity that is above one, which means with increase in size, their aircraft fuel cost has gone up more than proportionately.

Table 5 shows that the main source of cost efficiencies for the airline industry is aircraft maintenance expenses. For each of the five years in the sample, United Continental Holdings, American Airline, Delta Airline, and Southwest Airline have a negative cost elasticity. Negative cost elasticity means that with every increase in the size of the airline fleet, maintenance cost is actually declining. Alligiant Travel Company is the least efficient with a cost elasticity of 1.13.

Table 7 summarizes the average cost elasticity for each of the nine airlines with size being measured in terms of total operating revenue for the period 2013 to 2018.

When size is measured in terms of total operating revenue, American airline, Delta Airline, and United Airline are equally efficient, because cost elasticity of total operating expenses, on average, is 0.94 for each of these three airlines. Alaska Air Group, Inc.,

TABLE 5
COST ELASTICITY OF TOTAL OPERATING EXPENSES, WAGES AND SALARIES, AIRCRAFT FUEL, AND AIRCRAFT MAINTENANCE WITH RESPECT TO TOTAL OPERATING REVENUES BY EACH YEAR FROM 2013 TO 2018

	2013	2014	2015	2016	2017	2018	Panel Data
Total operating Expenses	0.99 (-1.111)	0.98 (-1.30)	0.98 (-1.37***)	0.98 (-1.45**)	0.98 (-1.67***)	0.98 (-1.80**)	0.99 (3.77*)
Wages and Benefits	1.05 (1.24)	1.04 (0.98)	1.04 (0.95)	1.04 (0.93)	1.02 (0.76)	1.02 (0.64)	1.04 (2.37**)
Aircraft Fuel	1.62 (2.32**)	1.68 (2.48**)	1.70 (2.57*)	1.70 (2.68*)	1.75 (2.93*)	1.78 (3.06*)	1.70 (6.86*)
Aircraft Maintenance	0.46 (-3.79*)	0.43 (-3.90*)	0.42 (-4.02*)	0.41 (-4.17*)	0.39 (-4.44*)	0.38 (-4.59*)	0.41 (-10.64*)

TABLE 6
TRENDS IN COST ELASTICITY FOR EACH AIRLINE WHEN SIZE IS MEASURED
IN TERMS OF TOTAL ASSETS FOR THE PERIOD 2013 TO 2018

	Alaska Air Group Inc	American Airlines Group Inc	Delta Air Lines Inc	United Continental Holdings Inc	Jet Blue Airways Corp	Southwest Airlines Co.	Allegiant Travel Company	SkyWest, Inc.	Hawaiian Holdings, Inc.
Cost Elasticity with respect to Total Operating Expenses by each airline									
2013	0.74	0.30	0.26	0.33	0.69	0.48	1.14	0.81	0.96
2014	0.73	0.30	0.25	0.33	0.67	0.47	1.08	0.80	0.92
2015	0.71	0.27	0.25	0.31	0.65	0.45	1.06	0.78	0.93
2016	0.62	0.26	0.26	0.31	0.63	0.43	1.01	0.77	0.91
2017	0.60	0.26	0.25	0.30	0.63	0.42	0.96	0.75	0.90
2018	0.60	0.22	0.23	0.29	0.61	0.41	0.93	0.72	0.87
Average	0.67	0.27	0.25	0.31	0.65	0.44	1.03	0.77	0.91
	(-12.48*)	(-62.73*)	(-146.31*)	(-102.48*)	(-29.02*)	(-50.87*)	(0.92)	(-17.21*)	(-7.42*)
Cost Elasticity with respect to Wages and Benefits by each airline									
2013	0.85	0.15	0.08	0.20	0.77	0.43	1.49	0.96	1.19
2014	0.83	0.14	0.07	0.20	0.74	0.41	1.39	0.95	1.13
2015	0.81	0.11	0.07	0.17	0.71	0.39	1.36	0.92	1.14
2016	0.66	0.09	0.09	0.17	0.68	0.36	1.28	0.89	1.12
2017	0.63	0.09	0.07	0.15	0.67	0.34	1.19	0.87	1.10
2018	0.63	0.03	0.03	0.13	0.64	0.32	1.14	0.82	1.06
Average	0.73	0.10	0.07	0.17	0.70	0.38	1.31	0.90	1.12
	(-6.29*)	(-48.62*)	(-114.22*)	(-77.89*)	(-15.47*)	(-35.85*)	(5.88*)	(-4.75*)	(6.57*)
Cost elasticity with respect to aircraft fuel by each airline									
2013	0.82	1.23	1.27	1.20	0.86	1.06	0.44	0.75	0.61
2014	0.83	1.23	1.28	1.20	0.88	1.07	0.50	0.76	0.65
2015	0.84	1.25	1.27	1.22	0.90	1.08	0.51	0.78	0.64
2016	0.93	1.27	1.27	1.22	0.92	1.10	0.56	0.79	0.66
2017	0.94	1.27	1.27	1.23	0.92	1.12	0.61	0.80	0.67
2018	0.95	1.30	1.30	1.24	0.94	1.13	0.64	0.83	0.69
Average	0.88	1.26	1.28	1.22	0.90	1.10	0.54	0.79	0.65
	(-4.65*)	(23.61*)	(57.49*)	(34.43*)	(-8.48*)	(9.28*)	(-14.67*)	(-17.30*)	(-31.29*)
Cost elasticity with respect to aircraft maintenance by each airline									

TABLE 7
TRENDS IN COST ELASTICITY WITH RESPECT TO SIZE WHEN SIZE IS
MEASURED IN TERMS OF TOTAL OPERATING REVENUE FOR EACH AIRLINE
FOR THE PERIOD 2013 TO 2018.

	Alaska Air Group Inc	American Airlines Group Inc	Delta Air Lines Inc	United Continental Holdings Inc	Jet Blue Airways Corp	Southwest Airlines Co.	Allegiant Travel Company	SkyWest, Inc.	Hawaiian Holdings, Inc.
Cost Elasticity with respect to Total Operating Expenses by each airline									
2013	1.00	0.95	0.94	0.94	1.00	0.96	1.05	1.01	1.03
2014	1.00	0.93	0.94	0.94	0.99	0.96	1.04	1.01	1.02
2015	1.00	0.94	0.94	0.94	0.99	0.96	1.04	1.01	1.02
2016	0.99	0.94	0.94	0.94	0.99	0.96	1.04	1.01	1.02
2017	0.99	0.93	0.94	0.94	0.99	0.96	1.04	1.01	1.02
2018	0.98	0.93	0.93	0.94	0.99	0.95	1.03	1.01	1.02
Average	0.99	0.94	0.94	0.94	0.99	0.96	1.04	1.01	1.02
	-2.92*	(-26.97*)	(-97.16*)	(-243.72*)	(-5.44*)	(-42.54*)	(17.34*)	(44.26*)	(16.43*)
Cost Elasticity with respect to Wages and Benefits by each airline									
2013	1.09	0.94	0.91	0.91	1.08	0.98	1.24	1.13	1.17
2014	1.09	0.90	0.90	0.91	1.08	0.97	1.23	1.13	1.16
2015	1.08	0.90	0.90	0.91	1.07	0.97	1.22	1.13	1.16
2016	1.08	0.90	0.91	0.91	1.07	0.97	1.21	1.13	1.16
2017	1.05	0.90	0.90	0.91	1.06	0.96	1.20	1.13	1.15
2018	1.05	0.89	0.90	0.91	1.05	0.96	1.19	1.13	1.14
Average	1.07	0.91	0.90	0.91	1.07	0.97		1.13	1.16
	-9.49*	(-13.45*)	(-49.41*)	(-119.75*)	(15.08*)	(-10.98*)	(30.95*)	(151.90*)	(41.08*)
Cost elasticity with respect to aircraft fuel by each airline									
2013	1.35	2.34	2.55	2.56	1.39	2.09	0.37	1.09	0.83
2014	1.38	2.62	2.59	2.57	1.43	2.12	0.45	1.07	0.87
2015	1.40	2.60	2.59	2.55	1.48	2.16	0.51	1.05	0.87
2016	1.44	2.59	2.58	2.53	1.50	2.18	0.56	1.05	0.91
2017	1.61	2.61	2.60	2.55	1.54	2.20	0.61	1.07	0.96
2018	1.64	2.65	2.65	2.55	1.59	2.22	0.68	1.07	1.00
Average	1.47	2.57	2.59	2.55	1.49	2.16	0.53	1.07	0.91
	9.36*	(33.96*)	(121.88*)	(307.89*)	(16.07*)	(58.88*)	(-10.30*)	(11.45*)	(-3.67*)

Cost elasticity with respect to aircraft maintenance by each airline

2013	0.60	0.08	-0.03	-0.04	0.59	0.21	1.13	0.75	0.88
2014	0.59	-0.07	-0.05	-0.04	0.57	0.19	1.09	0.75	0.86
2015	0.58	-0.06	-0.06	-0.03	0.53	0.17	1.05	0.77	0.86
2016	0.56	-0.05	-0.05	-0.02	0.52	0.16	1.03	0.76	0.84
2017	0.47	-0.07	-0.06	-0.03	0.51	0.15	1.00	0.76	0.81
2018	0.45	-0.09	-0.09	-0.03	0.48	0.14	0.97	0.75	0.80
Average	0.54	-0.04	0.06	-0.03	0.53	0.17	1.04	0.76	0.84
	-17.11*	(-42.38*)	(-151.63*)	(-385.15*)	(-28.86*)	(-78.55*)	(1.81**)	(-78.53*)	(-11.70*)

Jet Blue Airways Corporation, and Southwest Airlines Company have a cost elasticity of total operating expenses with respect to total operating revenue equal to 0.99, 0.99, and 0.96, respectively, which means that their operating cost is rising less than proportionately to increase in revenue. On the other hand, Allegiant Travel Company, SkyWest, Inc., and Hawaiian Holdings, Inc. have an average cost elasticity of 1.04, 1.01, and 1.02, respectively. For every one dollar increase in total revenue, their operating cost increased by more than a dollar.

SUMMARY AND CONCLUSIONS

Over the last decade, the U.S. airlines industry has transformed itself through mergers, restructurings, bankruptcies, and dissolutions. Also during this time, airline executives have changed their focus from a “market share at all costs” mentality to one based on obtaining and preserving profitability, along with a focus on improving return on invested capital by reducing the operating costs. This study evaluated cost efficiencies of U.S. airlines for the period 2013 to 2018. We found that the airline industry is experiencing cost efficiencies with every increase in the size of the airline, but cost efficiencies are not evenly distributed. We also found that the main source of cost efficiency appears to be aircraft maintenance expenses. This study was completed before the current tsunami unleashed by coronavirus. The airline industry is perhaps the hardest hit industry due to coronavirus. It will be interesting to analyze the impact of this event on the industry in years to come and how the industry restructures to

get out of the economic downturn that started with this virus.

Coronavirus (COVID-19) has impacted the airline industry in the worst possible manner with, at one point, practically all flights grounded around the globe. In the pre-pandemic era, the airline industry’s profits rose with an increase in their load factor from 75% in 2005 to close to 85% in recent years. In the post-pandemic world, the airline industry will have to rethink its strategy by reinventing its business model. The business strategy of focusing on asset utilization, to cost leadership, to economies of scale will need to be reevaluated and rebalanced with market needs in the post pandemic world.

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THE RISE, THE FALL, AND THE RESURRECTION OF THE eGROCERY CHANNEL: A TRANSFORMATION IN RETAIL LOGISTICS AND U.S. CONSUMER BEHAVIOR

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ABSTRACT

Nearly 20 years ago this journal published “Where Have All The On-Line Grocers Gone?” about the growing online grocery market and correctly predicted that the concept would fail until logistics issues were resolved. This article considers the changes that have taken place since then and why there has been a resurrection and exponential growth in the eGrocery channel. It considers how the forced disruption from the COVID-19 virus has served to help further the development and growth of this channel.

EVOLUTION OF THE GROCERY INDUSTRY

More than ten decades have passed since the first modern American supermarket opened doors. In 1916, Piggly Wiggly supermarket pioneered a self-service model that redesigned food shopping strategies (Piggly Wiggly, 2011). Prior to that, customers would give the store clerk a list, and the clerk would personally pick out the groceries from the shelves, place them into bags and give them back to the customer (Ross, 2016).

The introduction of the shopping cart in 1936 shifted fulfillment away from the store clerk and placed fulfillment responsibility directly on the customer. This transformation allowed multiple customers to roam freely throughout the store and pick their own groceries from the shelves and collect them in a shopping cart. It required an extensive physical redistribution and reconfiguration of the stores to increase customer capacity, and lower costs, but it increased sales (Wilson, 1978). Previously, grocers considered consumption as a manner of “grocery hydraulics” rather than a matter of consumer psychology (Cochoy, 2009).

In the 1990’s retailers began experimenting with the concept of online retailing, where goods would be shipped from central distribution centers directly to the consumer. This later evolved in some cases into e-shopping where the consumer would pick up their

order at the store. However, by the early 2000’s the online concept had largely failed. The authors of “Where Have All the On-Line Grocers Gone? Lessons Learned from the Demise of On-Line Grocers” (Farris and Wilson, 2002) investigated the online grocery market structure and concluded that the logistical elements made the concept cost prohibitive. In a thriving dot.com environment, startups had been flush with venture capital that covered inefficiencies and cost deficits in the short run. The industry did not evolve the model, and the concept failed when the start-ups burned through their cash. Rapid expansion, substantial investments in warehouses, high costs in operations, and costly transportation models were the principal reasons for ceasing operations for many early online grocers. A recent report shown in Table 1 points out that compared to other retail the grocery industry had fallen behind in modernization and application of technology. It also recognizes that the grocery industry has made significant improvements in recent years.

Smart shopping carts now offer checkout-free shopping with a built-in technology to automatically scan and charge the customer’s item once it is placed into the cart. Artificial intelligence systems

¹ Throughout this paper, we use the term “eGrocery” to represent a channel that has developed supporting the overall grocery industry and recognizing that some sales figures include products that may be sold exclusively online and are not available in grocery stores.

TABLE 1
U.S. FOOD RETAIL EXECUTIVES' OPINIONS ON MODERNIZATION AND
TECHNOLOGY IN GROCERY STORES
JUNE 2018

	% of Respondents*
While grocery stores may not be as tech-savvy as other retailers, they have come a long way over a short time	82%
The grocery store layout is changing to accommodate microvisits	72%
If grocery stores do not enter the modern age, more people will look for other ways to get their food	71%
Grocery stores serve a basic function and there is not a great need to change them drastically	50%
Grocery stores haven't figured out how to use technology like other retailers have	49%
Grocery stores haven't changed in decades and it's time they started to adapt to the modern age	46%

*Note: agree or strongly agree; (Garcia 2018)

tally customer purchases and post the results directly on the customer's phone via a mobile app (Boyle, 2019). For example, Amazon Go operates more than 20 cashier-less supermarkets where the customer uses an app to enter the store, take the products, and exit without human interaction checking out, all powered by computer vision and machine learning (Amazon, 2019).

Prior to COVID-19, Statista pre-COVID-19 projected potential eGrocery sales of \$41.31 billion by 2021 and \$59.3 billion by 2023 (Conway, 2020). Since this projection, the forced disruption from COVID-19 has served to further the development of eGrocery channels. Shakespeare penned the phrase "the past is prologue." We have learned from the past mistakes of the eGrocery channels from decades past in order to improve the eGrocery channel approach today and going forward.

EARLY eGROCERY FAILURES

Ordering groceries on the internet was initially expected to be a very promising opportunity to lower costs and increase revenue in an industry which typically has had only 1% to 3% profit margin. For customers, it was considered (and still is) a suitable option adding convenience, time, and

labor-savings. Early studies pointed to development of the eGrocery channel as a means of improving the life of grocery consumers.

- A survey by the University of Michigan ranked 22 favorite household tasks and found that grocery shopping came in next-to-last, just ahead of cleaning (Henry, 2000).

- According to the Food Marketing Institute, the average American household made 2.3 trips to the grocery store a week and spent \$87 per week on groceries (Richards, 1996).

- The average grocery trip took an estimated 47 minutes, not including time to drive, park and unload groceries (Linstedt, 1998).

Consider the difficult operating environment for the eGrocery industry:

- relatively low order value
- extremely low profit margins per item
- short product life
- compressed delivery windows
- restrictions on customer availability
- customized customer orders
- highly competitive market
- specialized costs in storage and transportation

While customers recognized and valued a home delivery system, many eGrocers could not compete with traditional bricks- and-mortar grocery retailers (Kämäräinen, et al., 2001). There were a number of failures due to excessive costs and misguided priorities due to irrational exuberance.

Early participants including Streamline, HomeGrocer, and Webvan ended operations, filed for bankruptcy, or were sold to competitors. Table 2 identifies the companies competing in the eGrocery channel in 2001. Many are still recognizable as thriving bricks-and-mortar retailers but exited the eGrocery channel.

Streamline started operations in November 1996 as a service providing home delivery groceries, movie rental, dry cleaning, and film. It delivered groceries on a weekly schedule from its own warehouses and put them away at the customer’s property for a \$30 monthly flat fee (Borrego, 2001). Shortly after a 1999 IPO, Streamline ceased operations and discontinued service in November, 2000 due to extremely high expenses to maintain their business model (WSJ, 2000).

HomeGrocer provided next-day delivery of fresh produce, seafood, and meat to more than seven U.S. states (CNN, 2000a). Online orders under \$75 were charged a \$10 delivery fee, while orders above \$75 had no delivery charge (Fisher and Kotha, 2014). HomeGrocer developed all of its own technology including an award-winning website, wireless picking systems that used Wi-Fi,

and a driver smart phone application, years before they were mainstream. Facilities were opened in Oregon, Washington, California, and Texas. Each 100,000 square foot facility operated 7 days a week with 50 delivery vehicles and a staff of 200. By June, 2000 daily sales exceeded \$1 million per day. Construction started on 16 additional facilities in Georgia, Illinois, Washington, DC, and Colorado (Fisher and Kotha, 2014). In spite of raising \$288 million with an IPO it was not enough to continue operations. In September, 2000 stockholders approved a \$1.2 billion all-stock sale to Webvan (Sandoval, 2002). After the sale, the brand’s sales peaked in November, 2000 at \$1.5 million daily. Amazon eventually bought the brand in 2002 for \$42.5 million (cnet, 2002).

Webvan initially started developing their concept in 1997. Under their model, customers would order online and specify a delivery time. Groceries were delivered to the customer the next day within a 30-minute window (Aspray, et al., 2013a). Investors pressured the company for very fast growth in order to capture first-mover advantage. Webvan responded by placing a \$1 billion order with Bechtel to build warehouses and bought a fleet of delivery trucks (Wolverton, 2001). This rapid growth has been cited as one of the reasons for the failure of the company. Webvan started taking orders in the San Francisco Bay Area in June 1999. By 2000, it had \$178.5 million in annual sales but \$525.4 million in annual expenses, servicing 10 U.S. cities and hoping to expand to 26 cities by 2001 (CNN, 2001; Goldman, 2015). Venture capitalists invested more

TABLE 2
TOP 30 RANKING U.S. eGROCERS IN THE 3rd QUARTER OF 2001

1. Marsh	11. Why Run Out	21. Net Grocer
2. Harris Teeter	12. Stater Bros	22. Ethnic Grocer
3. Giant Food	13. Easy Grocer	23. Grocer Online
4. Albertson	14. Publix	24. Kroger
5. Stop & Shop	15. Walgreens	25. Metro Food Market
6. Bashas	16. Simon Delivers	26. Electric Food
7. Peapod	17. My Web Grocer	27. Your Grocer
8. Schnucks	18. Market One Stop	28. Groceries Express
9. Hy-Vee	19. House Calls Online	29. Bluelight
10. Ingles Markets	20. Price Chopper	30. Giant

(Lim, et.al 2004)

than \$396 million and the company raised an additional \$375 million in an IPO which valued the company at more than \$4.8 billion (Richtel, 1999). Up to the time of the IPO, the company had reported cumulative revenue of \$395,000 and cumulative net losses of more than \$50 million (SEC, 1999) and had spent between 25% and 35% of its revenue on advertising (compared with about 1% for traditional grocery chains). It filed bankruptcy in June 2001 losing \$830 million (Delgado, 2001).

Key reasons contributing to Webvan's failure include:

- Excessive initial fixed cost investments of \$35 million for each warehouse (Hays, et al., 2005)
- High operating costs of \$125 million per quarter (Aspray, et al., 2013a).
- Not effectively utilizing capacity. Their warehouses averaged 350,000 square feet each, the equivalent to 18 average grocery stores, and were running at one-third capacity (Aspray, et al., 2013b)
- High cost of customer acquisition and retention. The company invested \$210 to acquire a new customer while achieving less than a 50% customer return rate (Aspray, et al., 2013b).

Many early online grocery retailers, such as Webvan, Netgrocer, and Peapod were considered e-tailers or pure-play companies because they would only sell over the internet and fulfilled out of warehouses. This was a “click” strategy and companies found it difficult to provide comparable customer service to that offered by conventional retailers using a “brick strategy.” Since the early failures, many grocers have adopted a “bricks-and-click, also known as online-plus-physical-stores, strategy” (Lim, et al., 2001).

Not all the eGrocery businesses failed. Peapod started in 1989 and introduced online grocery features such as personalized specials, digital coupons, and online lists early in its business model with a delivery fee of \$6 and two-hour delivery windows. It required customers to physically download software from CD-ROMs onto their

computer to place a grocery order and would then fulfill the groceries from Jewel stores and deliver them to the customer (Dalke, 2017).

Unlike other eGrocers, Peapod worked in partnership with local groceries. Peapod pioneered many of the online grocery ordering tools that are commonplace today, such as being able to sort by price, description, and size. It was the first grocer to use digital coupons, personalized specials, and allow shoppers to create online lists. It was the first company to have software that recalled past order history so the customer could easily reorder items in the future (Dalke, 2017).

By 2017, Peapod was in 24 markets, mostly in the Midwest and Northeast, with more than 2,000 full-time employees along with over 350 part-time workers and 600 product selectors (Dalke, 2017). After Royal Ahold bought Peapod, they cancelled their contracts with all grocery companies except for Royal Ahold's two main American chains - Stop & Shop and Giant Food - (PYMNTS, 2017) and February 2020, announced they would be ceasing operations in the Midwest (Illinois, Indiana, and Wisconsin) and focus exclusively on serving the East Coast markets (Elejalde-Ruiz, 2020).

It is estimated in 2018 that people spent an average of \$121 for Peapod orders, compared to \$72 at Walmart Pickup Grocery and \$60 with AmazonFresh in 2018. Peapod had a 93% satisfaction rating. 40% of Peapod's shoppers were millennials compared to 25% of people who visited Ahold bricks-and-mortar store — making the food delivery company a key way for Ahold to expand its customer base (Doering, 2018).

EARLY FULFILLMENT MODELS

There were initially two types of fulfillment models; dedicated fulfillment centers (DFC) and in-store fulfillment centers (SFC):

- **Dedicated Fulfillment Centers (DFC):** Used by Streamline, Homerun, Web Van, and GroceryWorks to process orders, this model is a warehouse/depot model which takes the retail store out of the cost

structure by delivering directly from the warehouse. It consolidates delivery of multiple product classes as well as services to the home, with a lower cost structure (Casper, 1998). Streamline offered an innovative, but labor intensive approach to using this model. A setup team was dispatched to a customer's house where the contents of the kitchen were scanned to create a personal shopping list which typically accounted for 70% to 75% of a family's weekly order. The family was given a UPC code list as its core shopping list, plus another list of the products and services available through Streamline including video rentals, dry cleaning, and bottled water. To order, family members checked off from their core list and the additional services list to identify their weekly needs. As long as the order was placed by midnight, delivery would take place by 6 p.m. the next day. Customers received a combination refrigerator, freezer/dry storage cabinet measuring 5 feet wide by 5 feet high by 2 feet deep which was placed in their garage. Streamline operated a fleet of trucks with three different temperature zones to maintain the integrity of the products and made weekly deliveries to the box. Streamline customers paid a box installation charge of \$39 and a monthly fee of \$30 (Matthew 1999). The average Streamline customer ordered goods 47 times per year and spent an average of \$5,200 per year. Box installation and monthly fees accounted for 7.7% of the annual expenditure by the customer (Liebeck, 1997a).

- **In-store Fulfillment Centers (SFC):** Used by Peapod and Tesco this model tapped into the existing logistics infrastructure, utilizing retail stores for fulfillment. Peapod bridged the gap between store and home and charged for the service (Casper, 1998). In its early days as a Chicago-area start-up, Peapod fulfilled orders by picking items from the shelf of a local Jewel grocery chain. Their delivery costs averaged about \$12 per order. A typical Peapod customer would spend \$120 per order (Lindsay, 1999) and was charged a \$4.95 flat monthly fee per order and 5% of the total order. The additional cost per order averaged \$13.42 or about 11.2% (Leibs, 1997).

THE RESURRECTED eGROCERY CHANNEL

The eGrocery channel concept has continued to evolve and capture an increasing share of the grocery market. In 2018 a study suggested 42% of people would rather be stuck in rush hour traffic in Manhattan than not be able to do their shopping online (DHL, 2018). The forced disruption from COVID-19 may be enough of an incentive to force eGrocery channels to mature and become embedded into consumer purchasing behavior.

Between 2016 and 2018 the eGrocery channel doubled in size. (Magana, 2019) Pre-COVID-19 projections, close to the estimates cited for Statistica, suggested by 2021, U.S. eGrocery sales could reach \$38.16 billion and be as high \$59.5 billion by 2023. In spite of the market share growth in the U.S., it pales in comparison to growth elsewhere in the world, as shown in Table 3. China is the biggest digital grocery player in the world, with eGrocery revenues expected to nearly quadruple by 2023. (Kats, 2019).

Table 4 shows that nearly one-third of digital grocery shoppers in the Netherlands, the U.K., Germany and France had groceries delivered at least weekly in 2018. Pre-COVID-19, Capgemini projected by 2021 more than half of respondents in the Netherlands, U.K. and Germany will have groceries delivered once per week (Kats, 2019).

Domestically, eGrocery shopping in the United States continues to grow. Table 5 suggests that prior to COVID-19 U.S. shoppers were gradually adopting and using the concept with a sizable increase in 2019.

Contrast the 2001 list of eGrocers in business shown in Table 2, with the list in Table 6 which reflects eGrocery market share in 2019. By 2019 three competitors, Amazon, Walmart, and Target held 81% of the market (Droesch, 2020).

Table 7 offers a slightly different perspective reflecting growth from 2018 to 2019. This may be

TABLE 3
DIGITAL GROCERY SALES IN SELECTED COUNTRIES, 2018 AND 2023
 (Billions, % of total digital sales and CAGR)

	2018		2023		
	Sales	% of digital sales	Sales	% of digital sales	CAGR
China	\$50.9	3.8%	\$196.3	11.2%	31.0%
U.S.	\$23.9	1.6%	\$59.5	3.5%	20.0%
Japan	\$31.9	7.1%	\$46.5	9.9%	7.8%
U.K.	\$14.6	6.0%	\$22.1	7.9%	8.7%
South Korea	\$9.9	8.3%	\$21.3	14.2%	16.5%
France	\$11.6	4.5%	\$17.2	6.0%	8.2%
Australia	\$2.1	2.1%	\$4.2	3.7%	15.3%
Germany	\$1.3	0.5%	\$3.8	1.2%	23.2%
Canada	\$0.8	0.8%	\$2.1	1.8%	0.8%
Spain	\$0.9	0.7%	\$2.0	1.4%	0.7%
TOTAL	\$147.9		\$374.9		20.4%

(Kats 2019)

TABLE 4
DIGITAL GROCERY SHOPPERS IN SELECT COUNTRIES THAT HAVE
GROCERIES DELIVERED ONCE A WEEK OR MORE
 (% respondents, 2018 and 2021 (Pre-COVID19 projected))

	2018	2021
Netherlands	43%	62%
U.K.	43%	56%
Germany	38%	56%
U.S.	38%	52%
France	37%	49%
Worldwide	40%	55%

Note: ages 18+, Internet users who have purchased groceries online in the past 6 months;
 (Kats 2019)

TABLE 5
U.S. INTERNET USERS ONLINE GROCERY SHOPPING BEHAVIORS, 2015-2019
 (% of respondents)

	Purchased Groceries Online	Purchased Groceries Online Regularly
2015	34%	11%
2016	31%	12%
2017	35%	13%
2018	38%	17%
2019	56%	37%

Note: ages 18+; (TABS Analytics 2019)

TABLE 6
WHERE DID U.S. INTERNET USERS BUY GROCERIES ONLINE?
 (% of respondents, 2015-2019)

	2015	2016	2017	2018	2019
Amazon	14%	16%	25%	24%	36%
Walmart	12%	12%	14%	15%	29%
Target	7%	5%	9%	9%	16%
Grocery Banner	16%	11%	7%	9%	10%
Jet	-	1%	5%	2%	3%
Peapod	2%	1%	2%	2%	2%
Netgrocer	0%	0%	2%	1%	1%
FreshDirect	2%	2%	2%	1%	2%
Other	2%	0%	1%	2%	2%
None	66%	69%	65%	62%	44%

Note: ages 18+; (TABS Analytics 2019)

TABLE 7
TOP 10 DIGITAL RETAILERS, RANKED BY U.S. eGROCERY SALES
 (% change 2018 vs. prior year)

	Sales	Percentage Change
Amazon	\$8,200,000,000	12.5%
Walmart	\$2,840,000,000	10.1%
Kroger	\$1,510,000,000	66.0%
Royal Ahold	\$1,170,000,000	2.6%
HelloFresh	\$960,000,000	41.0%
Costco	\$880,000,000	12.0%
FreshDirect	\$670,000,000	3.8%
Bluer Apron	\$670,000,000	-24.9%
Albertsons	\$590,000,000	4.9%
Target	\$420,000,000	28.9%

(Katz 2019)

due to a different definition of what constitutes the term “groceries” or represents ownership in a different manner. For example, Ahold owns Peapod.

Amazon’s 2018 sales increase has been fueled by their evolving omnichannel grocery strategy. In May, 2018, Amazon expanded its same-day Whole Foods delivery service into 88 U.S. markets and plans to open thousands of Amazon Go stores by 2021. Walmart’s sales growth has been fueled by Walmart’s large brick-and-mortar footprint which gives them the opportunity to develop curbside pickup capabilities. 76% of U.S. shoppers prefer Walmart’s curbside pickup to 14% who prefer to

shop in-store. Kroger saw the biggest year-to-year gain of 66% by expanding home delivery capability to 91% of available households and making grocery pickup available at 1,581 of its 2,764 stores (Koch, 2019).

FOCUSING GROWTH IN URBAN MARKETS

Markets with a denser concentration of customers and shorter travel distances to the customer make the most economic sense for growing eGrocery channels. Table 8 identifies the share of the eGrocery market in top metropolitan areas and is sorted by population.

TABLE 8
ONLINE GROCERIES – JUNE 2019 SHARE OF CUSTOMERS
 (Top Metropolitan areas by Population)

	Walmart Grocery	Instacart	FreshDirect	Peapod	Amazon Prime		
					Now	Shipt	AmazonFresh
NYC	-	15%	31%	14%	18%	1%	20%
Los Angeles	9%	42%	-	-	26%	1%	21%
Chicago	19%	31%	-	10%	20%	6%	14%
DFW	59%	14%	-	-	13%	2%	10%
Houston	39%	25%	-	-	15%	21%	-
Wash DC	18%	35%	1%	7%	22%	2%	13%
Miami	14%	45%	-	-	19%	11%	11%
Philadelphia	20%	33%	6%	10%	21%	1%	7%
Atlanta	35%	40%	-	-	12%	6%	8%
Boston	8%	26%	-	14%	36%	1%	14%
Phoenix	56%	22%	-	-	19%	1%	-
San Francisco	-	40%	-	-	35%	1%	-

(Rieck 2019)

eGROCERY LOYALTY

eGrocery shoppers are loyal. Most Americans regularly shop at just one or two grocery stores, so it is not surprising that most online grocery shoppers also stick with their favorite service (Rieck, 2019). Once a customer tries shopping with an eGrocery channel and decides to continue using the channel, they typically continue to use that provider and do not readily switch to another provider (Rafiq and Fulford, 2005). This is in contrast to the meal delivery industry, where diners frequently hop between apps to get the broadest selection of restaurants. As the eGrocery market increases, capturing market share will come from obtaining new customers to the concept instead of luring them from the eGrocery competition. Table 9 reflects that the highest potential conversions in 2019 came to Instacart who provided service to 5% to 13% of customers using other services.

While initially online shopping was viewed as a separate channel to sell groceries, many retailers have realized the need to add online channels to existing traditional distribution channels to provide a customer-oriented multichannel experience and keep their market share (Herhausen, et al., 2015). It

has been recognized that physical stores are key for supporting an eGrocery channel. A hybrid business model using physical stores as well as warehouses to support fulfillment has been adopted to bolster both online and offline services. Presently Albertsons, ShopRite, Loblaws, Stop & Shop, and Sedano’s use this model (Dudlicek, 2020).

Hy-Vee’s eGrocery concept involved fulfilling orders at its four fulfillment centers but found that it was unable to match the service levels afforded by personalized shoppers and same-day pickup at the store. It shifted to fulfillment at its retail locations as well as partnering with Instacart and Shipt for grocery delivery.

Amazon entered into the grocery business in 2007 with Amazon Fresh, a grocery delivery company where consumers shop online and receive same day or next morning delivery service (Page, 2019). In 2016 the company introduced its first physical bricks-and-mortar retail store ‘Amazon Go’ that uses technologies such as computer vision, deep machine learning, and sensor fusion without cashier operators, and with minimal human interaction (Cheng, 2019). The ‘Grab-and-go’ shopping concept uses an electronic recipient application to

TABLE 9
ONLINE GROCERIES – U.S. CUSTOMER OVERLAP: HOW MANY CUSTOMERS
ALSO USED A COMPETITOR
2Q 2019

	Shipt	Instacart	Walmart Grocery	Peapod	FreshDirect	Amazon Prime Now	AmazonFresh
Shipt	-	10%	9%	0%	0%	7%	1%
Instacart	3%	-	7%	1%	1%	8%	3%
Walmart Grocery	2%	5%	-	0%	0%	2%	0%
Peapod	1%	7%	1%	-	4%	4%	4%
FreshDirect	0%	6%	0%	3%	-	7%	7%
Amazon Prime Now	3%	13%	5%	1%	2%	-	7%
AmazonFresh	1%	10%	1%	2%	4%	13%	-

(Rieck 2019)

register, check out, and charge the product while the customers leave the store (Johnston, 2018). The strategy used in Amazon Go stores is an innovation from the self-checkout version concept that many retailers use in brick-and-mortar stores today (Polacco and Backes, 2018).

BUSINESS MODELS

Although food retailers are struggling to meet demand for home delivery in the COVID-19 crisis (Ryan, 2020), there are two business models that are being used for current eGrocery operations.

1. Store pickup. Customers order online and pick up at the store usually for free or a very low cost. This model is preferred over in-store shopping among young, busy, and affluent professionals, with children (Thakker, 2019). As COVID-19 restrictions started to be imposed, grocery retailers experienced significantly reduced in-store foot traffic and turned to the curbside business model while accommodating social distancing practices (Melton, 2020).

2. Home Delivery. Customers order online and items are picked at the store and delivered to customer homes, usually for an annual subscription. Walmart offers an annual subscription of \$98 or

\$12.95 per month or \$7.95 per same-day delivery with unlimited numbers of orders per customer (Dumont, 2019). Walmart installs a smart lock or smart garage door opener on the home, which gives the Walmart delivery employee a one-time entry code. Each employee also wears a video camera that records the delivery, and the footage can be viewed live or later the customer’s smartphone. The app notifies customers when the employee arrives and leaves (Lore, 2019). Similarly, Amazon offers unlimited online grocery which delivers from its brick-and-mortar stores (Disis, 2017; Monica, 2017).

IMPROVING FULFILLMENT

A successful fulfillment strategy relies on giving customers what, when, and how they want it at the lowest possible cost (Ricker and Kalakota, 1999). However, this is not always possible given the nature of the market. When the eGrocery boom began in 2015, SKUs at average warehouse or fulfillment centers increased by 18.5 percent. The increased demand on pick, packing and shipping operations left many operations short-handed as they aimed to fulfill orders at a faster rate. To reduce costs, increase efficiency, and keep profitable margins online retailers need to control “picking” costs. In 2018 food retailers incurred a \$5 to \$15

TABLE 10
CURRENT vs. PLANNED OMNICHANNEL FULFILLMENT CAPABILITIES
ACCORDING TO LOGISTICS PROFESSIONALS, WORLDWIDE, 2017
 (% of respondents)

	Current in 2018	Planned by 2028
Stores enabled to fulfill web orders	63%	96%
Stores enabled to ship to warehouse or direct to consumers	52%	95%
Stores enabled to transfer product between store locations	50%	96%
Direct ship from manufacturer or other retailer	45%	93%
Dedicated fulfillment centers for online	44%	96%
Shared fulfillment centers for offline and online	41%	95%
Regional/nearshoring of fulfillment centers	40%	93%

(Zebra Technologies 2018)

loss on every manually picked order and losses will be higher as online orders increase (Ladd, 2019). The picking in-store “bricks-and-mortar” shoppers experienced congested aisles competing with store workers serving as “personal shoppers,” other customers, and third parties’ services personnel (Meyersohn, 2019).

Table 10 offers an inventory of the current capability and pre-COVID-19 projections of fulfillment capability by 2028.

Some eGrocers are implementing robotic fulfillment technology to reduce labor, and increase speed and efficiency of fulfillment, while releasing pressure on store inventory (Cosgrove, 2019; Wells, 2019). For example, Albertsons has built automated mini-warehouses inside their stores and opened up “dark stores” - locations that look like supermarkets but are closed to customers - to make deliveries and prepare pickup orders. As a customer enters their order using Albertsons’ e-commerce interface, the order is delivered to the automated system which handles the fulfillment process. AI-enabled robots and a system of totes and conveyors collect items for online grocer orders in minutes (Moralez, 2019). Whole Foods followed suit in 2020 as part of its response to meeting the increased demand stemming from COVID-19 (Tyko, 2020). Execution of the Micro Fulfillment Centers (MFCs) is complex and it still requires a high volume of

order to become economically profitable. But back-of-store-automated robotic systems are capable of collecting 800 products an hour, and bagging them for home delivery or pick up at store by customers, filling orders 10 times faster and more accurately than store workers (Nassauer, 2020).

MANAGING THE LAST MILE

Companies need to optimize not only internal fulfillment processes but also the transportation costs for the last-mile delivery. Last-mile distribution accounts for 25% to 50% of transportation total supply chain costs (Stiffler, 2020). For retailers in the food and grocery segment, a smooth and satisfactory delivery to the customer is more significant than ever. Meeting demand and service-level expectations impacts profitability as consumers expect faster, more frequent and often-times free delivery.

The development of “Buy Online, Pick Up in Store,” also known as BOPUS, has been one of the key drivers in the growth of the eGrocery channel. As shown in Table 11 and Table 12 the number of retail locations offering BOPUS nearly doubled in 2018 among U.S. grocery retailers including Walmart, Kroger and Target, increasing the collective number of click-and-collect locations from 2,451 to 5,800 (Koch, 2019).

TABLE 11
NUMBER OF CLICK-AND-COLLECT LOCATIONS FOR SELECT MAJOR U.S.
RETAILERS
 (January to December 2018)

January 2018	June 2018	December 2018
2,451	3,414	5,800

Note: Company data analyzed includes Walmart (and various third-party partners), Kroger, (and Instacart), Target (and Shipt), Ahold and Albertsons; (CommonSense Robotics 2019)

TABLE 12
RETAILERS SIGNIFICANTLY EXPANDED PICKUP LOCATIONS IN 2019
 (Total number of curbside grocery pickup locations by retailer)

	2018	2019
Walmart	2,050	3,050
Kroger	1,600	1,800
Target	1,000	1,750
Instacart	250	1,500
Albertson's	450	600
Ahold/Peapod	200	600
Amazon/Whole Foods	25	100

(Ford 2020)

While the BOPUS concept continues to grow and catch hold, Table 13 and Table 14 suggest customers still prefer to have their orders delivered to their home. BOPUS is still not the preferred means for the customer to receive their order.

Cost of delivery continues to vary from provider to provider. Table 15 offers an example of the expenses incurred by the customer for eGrocery delivery options in 2020.

THE FORCED DISRUPTION OF COVID-19 HAS HELPED SERVE AS A CATALYST FOR ACCEPTANCE

On January 20, 2020 the first confirmed case of COVID-19 in the United States was reported at the Providence Regional Medical Center in Edmonds,

Washington (Holshue, et al., 2020). While the COVID-19 impact on eGrocery is yet to be completely measured, the forced disruption caused by self-quarantine, social distancing guidelines, and travel restrictions have served as a catalyst for many consumers to try using eGrocery channels. This may result in a significant boost to help increase acceptance of eGrocery channel options (Back, 2020).

Table 16 suggests older consumers were more likely to embrace social distancing requirements during the COVID-19 crisis. More than 8 in 10 (85.6%) respondents ages 60 and older in February, 2020 indicated they were likely to avoid shopping centers and malls. That is not surprising given that COVID-19 hits older people the hardest, but it may have had an unintended consequence on their shopping habits. Since older individuals are the ones for

TABLE 13
DELIVERY METHODS USED BY U.S. INTERNET USERS FOR DIGITAL
PURCHASES BY AGE, MAY 2018
 (% respondents in each age group)

	18-29	30-39	40-49	50-59	60+	Total
Deliver to home	83.1%	80.5%	80.6%	69.4%	74.2%	75.4%
BOPUS	24.6%	18.8%	23.5%	20.7%	13.7%	18.0%
Ship-to-store	12.3%	11.3%	14.7%	9.5%	6.8%	9.5%
Deliver at work	6.2%	11.3%	10.6%	5.0%	3.4%	6.0%
Curbside pickup	3.1%	4.5%	5.9%	1.2%	0.8%	2.3%
Deliver to locker	3.1%	0.8%	0.0%	0.4%	1.0%	0.8%
Other	0.0%	0.8%	2.4%	1.2%	0.8%	1.1%

Note: In the past month/30 days; (eMarketer Ecommerce Insights Report May 2018)

TABLE 14
HOW INTERNET USERS PLAN TO USE PICKUP OR DELIVERY SERVICES
 (% of respondents, Feb 2019)

	Definitely Would Use	Probably Would Use	Probably Would NOT Use	Definitely Would NOT Use
Germany				
Delivery	78%	17%	3%	2%
Store Pickup	21%	38%	29%	12%
U.S.				
Delivery	72%	20%	5%	3%
Store Pickup	41%	37%	16%	6%
U.K.				
Delivery	69%	22%	7%	2%
Store Pickup	47%	30%	16%	7%
France				
Delivery	63%	29%	6%	2%
Store Pickup	37%	44%	14%	5%

Note: ages 18-69; (McKinsey 2019)

whom the virus has been most fatal, they may be especially likely to alter their behavior. This could mean increased adoption of ecommerce, an area where they have been laggards (Enberg, 2020).

To further support the argument that COVID-19 would increase the number of consumers considering eGrocery channels we need only to look at China where there was a significant increase in the number of downloads of eGrocery apps as COVID-19 infections worsened. Figure 1 uses the

number of eGrocery application downloads on January 16 as a base. As the number of known cases grew after the first known infection in the United States on January 20, downloads increased by as much as 585% of the January 16 base (Wernau, 2020).

In China and South Korea, where there were the earliest confirmed cases of coronavirus on December 31, 2019 (Taylor, 2020), consumers increased their reliance on e-commerce. Food

TABLE 15
EXAMPLES OF eGROCERY DELIVERY COST
 (March 2020)

	Grocery Delivery	Store Pickup
Target	\$99 for an annual Shipt plan	n/a
Amazon Fresh	Free for Amazon Prime members	n/a
Aldi	\$5.99	\$4.99
Kroger	\$9.95	Free
Walmart	Free for orders \$30 or more	Free for orders \$30 or more
Wegmans	\$5.99	Free
Costco	No fee for orders of \$75 or more	Free
Whole Foods	Free for Amazon Prime members	Free for Amazon Prime members
Albertsons	\$5.99	\$3.95 to \$4.95 depending on location
Publix	Prices vary; uses Instacart	Prices vary
Sprouts	\$3.99 plus a 5% service fee	Fees start at \$1.99

(Castellano, 2019)

TABLE 16
U.S. INTERNET USERS WHO ARE LIKELY TO AVOID STORES IF THE
CORONAVIRUS OUTBREAK WORSENS IN THE U.S., BY AGE, FEBRUARY 2020
 (% of respondents in each group)

Age	Shopping Centers/Malls	Shops in General
18-29	67.9%	44.7%
30-44	67.8%	55.5%
45-60	79.3%	53.8%
61+	85.6%	61.1%
TOTAL	74.6%	52.7%

Note: n=1,121; on February 28 Coronavirus totals were over 83,000 known cases worldwide with 2,923 deaths, 64 known cases in the U.S.; (Enberg 2020)

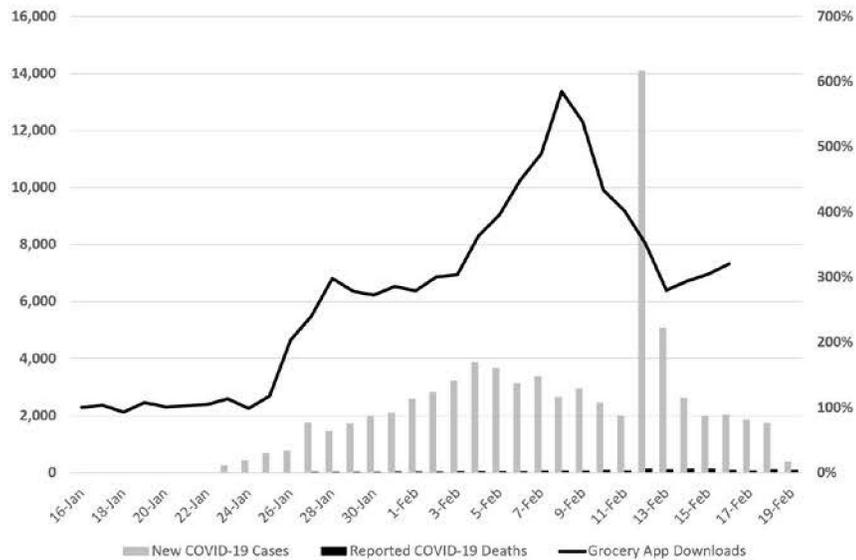
delivery spending in China shot up 20% in January while some South Korean grocers saw triple-digit online sales increases. Similarly following suit in February, 2020 21% of U.S. shoppers bought perishable groceries online, up from 18% during the same period last year. Figure 2 reflects the major demand increase in Chicago where online grocery orders spiked two to three days after major news announcements involving COVID-19 (Wells, 2020a).

Some stores were quickly overwhelmed by the COVID-19 surge in demand. Grocers shifted

workers into e-commerce fulfillment roles as ninety percent of their business shifted to online because nobody was leaving their home. Stores that previously had one or two workers picking and packing online orders changed to as many as 20 doing those jobs (Wells, 2020b).

In March, the RetailX Coronavirus Consumer Confidence Tracker (RetailX, 2020) reported 14.2% of U.K. internet users ages 18 and older increased their online grocery shopping as shown in Table 17. The U.K.'s leading online-only supermarket Ocado saw its website and app crash multiple times on March 13. Some customers who

FIGURE 1
CHINA TURNS TO eGROCERY APPS DURING COVID-19

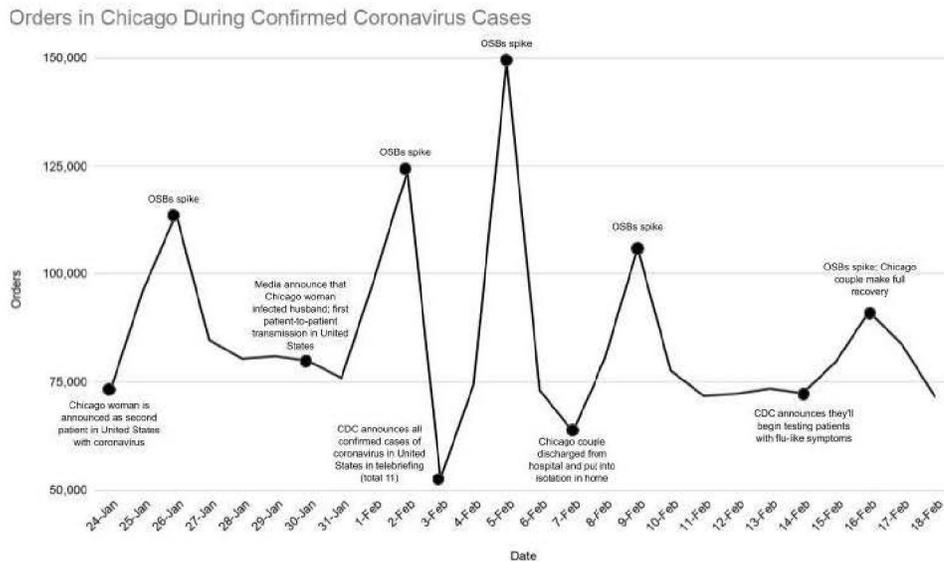


	Grocery App Downloads	New COVID-19 cases in China	Reported Deaths in China
1/16	100.000%		
1/17	103.622%		
1/18	92.749%		
1/19	107.880%		
1/20	101.206%		
1/21	103.106%		
1/22	104.849%		
1/23	113.325%	259	8
1/24	98.902%	457	16
1/25	117.537%	688	15
1/26	203.359%	769	24
1/27	240.294%	1,771	26
1/28	298.301%	1,459	26
1/29	278.470%	1,737	38
1/30	272.551%	1,981	43
1/31	286.031%	2,099	46
2/01	279.540%	2,589	45
2/02	300.740%	2,825	57
2/03	303.648%	3,235	64
2/04	363.572%	3,884	65
2/05	395.115%	3,694	73
2/06	448.765%	3,143	73
2/07	489.756%	3,385	86

2/08	585.020%	2,652	89
2/09	539.134%	2,973	97
2/10	433.667%	2,467	108
2/11	402.351%	2,015	97
2/12	351.949%	14,108	146
2/13	280.395%	5,090	121
2/14	294.128%	2,641	143
2/15	304.944%	2,008	142
2/16	320.303%	2,048	105
2/17		1,888	98
2/18		1,749	136
2/19		391	114

Numbers reflecting known cases and deaths in China (Worldmeters, 2020 <https://www.worldometers.info/coronavirus/country/china/>) combined with data from Wernau 2020.

FIGURE 2
ORDERS IN CHICAGO DURING CONFIRMED CORONAVIRUS CASES



(Wells 2020a)

managed to place orders found that they could not book a delivery sooner than a week away. Several days later, the firm temporarily suspended access to Ocado.com and refused all new orders to concentrate on work behind the scenes. A March 19 statement confirmed that the grocer was “fully booked and at full capacity and would be delivering to over 170,000 households in the next four days.”

As of March 20, Ocado site visitors were greeted with an update: “The website is currently only available for customers with a delivery booked for this Saturday and Sunday.”

the United States Instacart developed a new “Leave at My Door Delivery” service offering the option to have groceries left at the customer doorstep at a

TABLE 17
HOW THE CORONAVIRUS AFFECTED U.K. INTERNET USERS DIGITAL SHOPPING
 (% respondents, by category, March 2020)

	Stopped Completely	Reduced	No Change	Increased
Shopping for groceries	4.0%	3.8%	78.0%	14.2%

Note: ages 18+; (RetailX 2020)

TABLE 18
PROJECTED CHANGES IN IN-STORE vs DIGITAL PURCHASING HABITS IN THE U.K.
 (% of respondents, by demographics, May 2020)

	Will shop more digitally	Nothing will change	Will shop more in-store
Gender			
Female	40%	52%	7%
Male	44%	51%	5%
Age			
18-25	46%	44%	10%
26-35	59%	35%	6%
36-45	43%	53%	4%
46-55	37%	58%	5%
56-65	31%	62%	7%
66+	31%	64%	6%
Total	42%	52%	6%

ChannelAdvisor, "COVID-19 Consumer Shopping Habits" in collaboration with Dynata, May 22, 2020. Note: May 21-24 n=1.002 ages 18+; compared to before the coronavirus pandemic

designated time instead of being hand-delivered. The new service had been in the testing phase but was rolled out to all customers. At the same time, due to COVID-19 isolation, the company sales jumped by a factor of ten times and in some places such as California and Washington by a factor of twenty times (Sampath, 2020).

The disruption caused by COVID-19 boosting demand quickly exposed flaws or gaps in the eGrocery channels. How the industry addressed and corrected these flaws has helped make the

eGrocery channels stronger and increase acceptance.

HOW COVID-19 HAS IMPACTED eGROCERY USE

As we continue to be impacted by the on-going COVID-19 infections we are starting to see changes in consumer behaviors and the use of the eGrocery channels. Table 17 offers early insight in March in the U.K. reflecting an increase in the use of digital shopping for groceries. By May 2020,

TABLE 19
ONLINE GROCERY DELIVERY AND PICKUP
(Prior 30 days)

	August 2019	March 2020	April 2020	May 2020	June 2020
Sales (Prior 30 days)	\$1.2 B	\$4.0 B	\$5.3 B	\$6.6 B	\$7.2 B
Spend (Average per Order)	\$72	\$85	\$85	\$90	\$84
Orders (# Prior 30 days)	16.1 M	46.9 M	62.5 M	73.5 M	85.0 M
Customers (# Active during prior 30 days)	16.1 M	39.5 M	40.0 M	43.0 M	45.6 M
Frequency (Monthly average / customer)	1.0	1.2	1.6	1.7	1.9

(Kleckler 2020)

surveys of U.K. shoppers shown in Table 18 reported changes in purchasing habits across all ages. It is notable that while the older respondents were less likely to change, approximately one-third indicated they would shop more digitally.

Table 19 offers a longitudinal perspective of the changes in the use of eGrocery channels before COVID-19 in August, 2019 and during the summer months as COVID-19 infection continued to grow (Kleckler, 2020). This reflects significant growth in the use of eGrocery channels.

IMPLICATIONS FOR PRACTITIONERS

The expected increase of eGrocery channel use resulting from COVID-19 has led to the development of new avenues and approaches to reach a wider variety of customers such as development of the ‘dark store’ concept.

On-going improvements have required investments in logistics and online marketing. Makers of consumer staples have found that they are in a race to secure prominent online slots with eGrocery retailers and must develop new forms of digital advertising and promotion. The shift to online shopping likely will increase price transparency and competition across the board, pressuring margins for the whole industry (Back, 2020).

One of the biggest challenges retailers faced, as COVID-19 developed, was a surge in eGrocery demand, and the need for syncing up their inventory with online availability and demand. As eGrocery grows this represents a critical hurdle which must be

overcome. Grocers traditionally had to keep close track of how many SKUs of toilet paper, for example, they had coming into their warehouses or store backrooms. But with the movement of product onto shelves and into shoppers’ baskets accelerating, at unprecedented speed, retailers struggled to know what was available for online fulfillment (Wells, 2019).

IMPLICATIONS FOR RESEARCHERS

There are a number of research questions for academic researchers to investigate. For example:

- Why are eGrocery customers so loyal to their provider?
- Does the “cost to change” influence consumer decisions to change channels?
- Why does eGrocery acceptance differ by country?
- How does eGrocery acceptance differ by age?
- How can eGrocery reach the older population who are independent, live alone, and are not close to family members, may not have smart phones and are not computer savvy?
- How does eGrocery acceptance differ by gender?
- How does eGrocery acceptance differ by economic standing?
- How does eGrocery acceptance differ by race?
- What are the key factors that increase the likelihood of using an eGrocery channel?
- Which investments or improvement to the process offer the greatest leverage to improve the eGrocery channels?

- How does the “last mile” differ from the “middle mile” for eGrocery fulfillment?
- How does eGrocery channel pricing and profitability differ from traditional grocery channels?

CONCLUSIONS

eGrocery channels have resurrected from the failures of the early 2000’s as we have learned how to effectively manage fulfillment and we continue to innovate with last-mile issues to further drive down cost. While the impact of the COVID-19 pandemic is yet to be completely known it is likely that it will serve as a means to further boost customer’s acceptance of eGrocery channels. eGrocery channels are being stressed and tested under conditions that will build, strengthen, and change online business practices on the long term.

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1. First Page - Title of the paper, name and position of the author(s), author(s) complete address(es) and telephone number(s), e-mail address(es), and any acknowledgment of assistance. Times New Roman with 12 point font.
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$$y = c + ax + bx$$

$$y = a + 1x + 2x + 3x + ax$$

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5. Appendices follow the body of the text and references and each should be headed by a title of APPENDIX (#) in caps and 12 Point, and bolded.

6. The list of references cited in the manuscript should immediately follow the body of the text in alphabetical order, with the lead author's surname first and the year of publication following all author names. The Reference Section should be headed with REFERENCES in caps, bolded, and in 12 point font. Work by the same author with the same year of publication should be distinguished by lower case letters after the date (e.g., 1996a). For author names that repeat, in the same order, in subsequent cites, substitute a .5 inch underline for each name that repeats. Authors' initials should have a space between the initials, e.g., Smith, Jr., H. E., Timon, III., P. S. R., etc. A blank line should separate each reference in the list. Do not number references.

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Journal Article:

Pohlen, Terrance L. (2003), "A Framework for Evaluating Supply Chain Performance," *Journal of Transportation Management*, 14(2): 1-21.

Book Chapter:

Manrodt, Karl (2003), "Drivers of Logistics Excellence: Implications for Carriers," In J. W. Wilson (Ed.), *Logistics and Transportation Research Yearbook 2003* (pp. 126-154) Englewood Cliffs, NJ: Prentice-Hall, Inc.

Book:

Coyle, John J., Bardi, Edward J., and Novack, Robert A. (2004), *Transportation*, 6th ed., Cincinnati, OH: South-Western College Publishing.

Website:

Wilson, J. W. (2003), "Adapting to the Threat of Global Terrorism: Reinventing Your Supply Chain," [On-line]. Available: <http://georgiasouthern.edu/coba/centers/lit/threat.doc>. Created: 11/01/02, Accessed: 11/12/03.

MANUSCRIPT SAMPLE**A FRAMEWORK FOR EVALUATING SUPPLY CHAIN PERFORMANCE**

Terrance L. Pohlen, University of North Texas

ABSTRACT

Managers require measures spanning multiple enterprises to increase supply chain competitiveness and to increase the value delivered to the end-customer. Despite the need for supply chain metrics, there is little evidence that any firms are successfully measuring and evaluating inter-firm performance. Existing measures continue to capture intrafirm performance and focus on traditional measures. The lack of a framework to simultaneously measure and translate inter-firm performance into value creation has largely contributed to this situation. This article presents a framework that overcomes these shortcomings by measuring performance across multiple firms and translating supply chain performance into shareholder value.

INTRODUCTION

The ability to measure supply chain performance remains an elusive goal for managers in most companies. Few have implemented supply chain management or have visibility of performance across multiple companies (Supply Chain Solutions, 1998; Keeler et al., 1999; Simatupang and Sridharan, 2002). Supply chain management itself lacks a widely accepted definition (Akkermans, 1999), and many managers substitute the term for logistics or supplier management (Lambert and Pohlen, 2001). As a result, performance measurement tends to be functionally or internally focused and does not capture supply chain performance (Gilmour, 1999; *Supply Chain Management*, 2001). At best, existing measures only capture how immediate upstream suppliers and downstream customers drive performance within a single firm.

Table 1 about here

Developing and Costing Performance Measures

ABC is a technique for assigning the direct and indirect resources of a firm to the activities consuming the resources and subsequently tracing the cost of performing these activities to the products, customers, or supply chains consuming the activities (La Londe and Pohlen, 1996). An activity-based approach increases costing accuracy by using multiple drivers to assign costs whereas traditional cost accounting frequently relies on a very limited number of allocation bases.

$$y = a^2 - 2ax + x^2$$

REFERENCES

Manrodt, Karl (2003), "Drivers of Logistics Excellence: Implications for Carriers," In I. W. Wilson (Ed.), *Logistics and Transportation Yearbook 2003* (pp. 126-154) Englewood Cliffs, NJ: Prentice-Hall, Inc.

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