



## On the brink: Predicting business failure with mobile location-based checkins



Lei Wang<sup>a,\*</sup>, Ram Gopal<sup>b</sup>, Ramesh Shankar<sup>b</sup>, Joseph Pancras<sup>c</sup>

<sup>a</sup> Department of Supply Chain & Information Systems, Smeal College of Business, Pennsylvania State University, University Park, PA 16802, USA

<sup>b</sup> Department of Operations and Information Management, School of Business, University of Connecticut, CT 06269, USA

<sup>c</sup> Department of Marketing, School of Business, University of Connecticut, CT 06269, USA

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### ABSTRACT

Mobile-enabled location-based services are generating a huge amount of customer checkin data every day. It is vital to understand how small businesses, like restaurants, use this real-time data to make better-informed business operation decisions in this mobile marketing era. Using data collected from Foursquare, a leading location-based service provider, and Yelp, we aim to find out the predictive power of customer checkins on business failure of restaurants in New York City by using several predictive modeling techniques, such as Neural Network, Logit model and K-nearest neighbor. Our findings are encouraging. The customer checkin data from both a focal restaurant and its neighbors have shown strong predictive power on business failure. Compared to the baseline model in which we only use business characteristic variables to predict failure, incorporating the checkin data captured from location-based services gives a remarkable improvement on predictive accuracy. Our findings provide the foundation for future studies on the predictive power of information obtained from location-based services on business operations.

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### 1. Introduction

Making an accurate prediction on bankruptcy or failure is a question that has been puzzling researchers and managers for decades. This problem has been studied in a variety of disciplines, such as finance and accounting, using different frameworks or models, for instance, ratio analysis [6,14,19], Altman Z-scores [2–4], rough sets [15], and Bayesian models [48]. The common feature of these models and frameworks is that they rely on financial data, like stock prices, working capital, and debt. Therefore, they are very useful for medium and large businesses (especially publicly traded ones). However, such methods are of little help for small businesses such as restaurants, since they are not publicly traded and there is no financial data or measures that we can adopt. Previous research has largely ignored small businesses because of the difficulties of getting financial data. Another issue is that the data is usually out-of-date. Traditional economic forecasts are mainly based on the statistics gathered by government agencies, such as the Census Bureau, or the Department of Labor. A clear drawback of these statistics is that there is a significant delay between data collection and data publication. Moreover, the data is too aggregate and is sometimes not suitable for small businesses.

Due to recent developments in mobile information technology, location-based services now provide us a unique opportunity to obtain highly disaggregate data on hundreds of billions of economic decisions almost instantaneously as they are made, at nearly zero cost. The data obtained from location-based services can potentially be leveraged to make predictions on large as well as small businesses. Defined as “information services accessible with mobile devices through the mobile network and utilizing the ability to make use of the location of the mobile device” [55], location-based services are gaining popularity due to their abilities to acquire new customers for small businesses [21,51]. Foursquare, a leading location-based service provider, has gained tremendous popularity in recent years. The growth of its registered users and the checkins made by these users is remarkable, from 7 million users and 0.45 billion checkins by March 2011 to 40 million users and 4.5 billion checkins by September 2013 [24]. Customers reveal their intention to have dinner at a restaurant by “checking in” on Foursquare using their mobile device. With the observations of billions of customers and their shopping intentions, as revealed by location-based services, in this paper we investigate whether the accuracy of predictions about retailers business performance can be significantly improved using checkin data. This paper addresses the following research questions: (1) can we use checkin information captured from location-based services to make a better prediction on business performance? (2) If yes, by how much can we improve our prediction compared to a prediction without such information?

\* Corresponding author at: 440 Business Building, Penn State University, University Park, PA 16802, USA. Tel.: +1 814 867 5838.

E-mail address: [luw21@smeal.psu.edu](mailto:luw21@smeal.psu.edu) (L. Wang).

Understanding the predictive power of the checkin information provided by location-based services is critical for business owners to understand their business performance in this mobile era. By adopting location-based services, businesses gain access to customers' visits statistics from their checkins. Businesses can use location-based services, such as Foursquare, to monitor their customer traffic. Information that can be collected from customer checkins include how many checkins a business gets per day and per week, who are loyal customers, and whether promotions and discounts help attract more customer traffic. Analysis of these fine-grained customer traffic data can help businesses understand their business performance in real-time. Exploring the predictive power of customer checkins can help businesses to identify any potential downward trends in their business performance, and provide timely warning to business owners to take any necessary corrective actions. Our method should be viewed as a diagnostic tool for businesses to detect symptoms of failure and possibly take remedial action before the trend towards ultimate business failure becomes irreversible.

In the electronic commerce era, the website of a business provides a critical interface between buyers and sellers. Researchers have shown that a well-developed website can be an effective vehicle for delivering services to customers, and businesses can leverage website technology to provide augmented customer services [9,32,58]. It has been found in literature that customer acquisition impacts a firm's business performance [47]. While in the e-commerce era, the metrics to measure customer acquisition were website visits or online orders, in this mobile era, with location-based services, customer checkins are a new metric that can measure real-time customer acquisition and foot traffic. Interesting insights could emerge from investigating how customer checkins offered through location-based services may affect business performance. Despite its importance and usefulness, empirical research on location-based services and its impact on business performance have been limited.

Therefore, in this paper, we utilize techniques from the literature on econometrics, forecasting, and predictive modeling to examine whether location-based services have a significant predictive power with respect to retailers' business performance. In particular, we focus on using checkin data, along with other business characteristics, to predict business failure. Failure has been defined in several different ways: a business declaring bankruptcy, defaulting on interest payments on its debt, or overdrawing its bank account [6]. In this paper, business failure is defined as a retailer having less than one checkin per day on Foursquare over a three-month period. In other words, a restaurant is virtually dead if it has very limited or no activity in the mobile world. The ultimate goal is to predict real world business failure. However, in our data set, very few restaurants have closed during our data collection period. Even so, we do observe that for all the closed restaurants, their real world closure is preceded by virtual death, and virtual death is a good indicator for real business failure. There is some recent work that identifies and analyzes factors that lead to business failure [10,43]. Motivated by these studies, as well as by unexplained and contradictory observations made in practice, this paper provides initial empirical evidence pertaining to the predictive power of customer checkin data associated with the failure of small businesses.

In this paper, we focus on the restaurant industry in New York City. To ensure statistical significance, we compiled a large data set from Foursquare and Yelp with customers' checkin information and other business characteristics, such as price and rating. We first use a neural network to detect any possible complicated non-linear relationship among our independent variables and then apply a Logit model to show the predictive power of customer checkin data. After that, we adopt K-nearest neighbor, a nonparametric approach, to predict business failure. We then compare the predictive accuracy between the Logit and K-nearest neighbor models. We perform several robustness checks to show that our findings are consistent.

Our findings are very encouraging. We find that the total number of competitors a restaurant has, the growth rate of daily checkins, and the growth pattern of daily checkins all have a significant predictive

relationship with its business performance, failures in particular. The effect of the total number of competitors on the odds of failure is higher for restaurants with low ratings than restaurants with high ratings. Besides its own checkin information, a restaurant's neighbors' checkin history is also highly associated with the odds of business failure. Our results suggest that incorporating the checkin information obtained for both the focal restaurant and its neighbors into a standard Logit model can yield more accurate predictions about the business's failure. For instance, there is a significant improvement in predictive accuracy, over a model without the checkin information-around a 60% drop for misclassification rate and 50% decrease for both in and out-of-sample mean absolute deviation.

Our study contributes to the growing body of literature on location-based services: to the best of our knowledge, this is one of the first studies that focus on the predictive power of the data from location-based services. Location-based services are gaining a lot of attention because of their unique features. In particular, it is interesting to explore whether retailers can use information captured from these services as an indicator or predictor of their business performance. More concretely, this paper contributes to current work on location-based services by providing an empirical examination of whether checkins are a valuable and viable method of predicting business performance. Our findings provide the foundation for further research on the predictive power of information captured from location-based services.

In the remainder of this paper, we first detail our research design in Section 2, and describe our data and the definition of our variables in Section 3. We discuss the analysis of our results in Section 4 and also our robustness tests. Section 5 contains the discussion and possible directions for future research.

## 2. Research design

### 2.1. Previous studies on business failure prediction

Business failure is a term that can be defined and explored in many aspects. The extent of failure can also be measured in different ways. Accurate or meaningful assessments are extremely difficult to make given the nature of failure. Problems of business classification, various definitions of failure, and data collection issues all provide underlying difficulties to study business failure [27].

From the 1960s onwards, there has been considerable interest in predicting business failures, as reflected in a large number of studies [2–4,6,16,19,44]. Early research on predicting business failure relies on discriminant analysis and financial ratios. Beaver [6] found that financial ratios are vital for classifying healthy versus bankrupt businesses. Using discriminant analysis, Altman [2] proposed the Z-score, a weighed combination of five ratios, to detect possible future bankruptcies. Later, other methodologies have been applied to business failure prediction, such as the Logit and Probit models [10,40]. In order to develop a more accurate and generally applicable prediction approach, data mining and machine learning approaches have been applied in this prediction domain, such as, decision trees, Neural Network, rough sets [16], and Kohonen map [31]. Please see Dimitras et al. [15] and Kumar and Ravi [33] for complete reviews on the methods used for the prediction of business failure. However, most of the research in this area mainly focuses on predicting the failure of large and medium size enterprises using financial ratios as independent variables. Little attention has been paid to small businesses because of the difficulty of collecting financial data.

Two exceptions to this trend are the studies by Ciampi and Gordini [10] and Edmister [19]. Edmister [19] tested the usefulness of financial ratio analysis for predicting small business failure. Ciampi and Gordini [10] applied the Logit model to a sample of small Italian firms using both financial ratio and managerial variables. They found that incorporating managerial variables improves the prediction accuracy remarkably, and suggested that small firms should be assessed with

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