A Predictive Approach for Identifying High Performance Factories

by

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in Partial Fulfillment of the Requirements for the Degrees of

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Abstract

Li and Fung, the world’s largest apparel sourcing company, is facing rapid changes as customers demand lower prices and faster development cycles. To support the transformation of the supply chain, data analytics is used to explore leading indicators for firm survival in the garment industry. This project seeks to identify the major drivers of factory success through the lens of current factory performance metrics (quality, delivery, and compliance) and through a qualitative survey distributed to factories in China, Bangladesh, and Turkey.

Based on modeled historical trends, we find that current factory metrics vary significantly in their ability to signal long-term performance. Whereas on-time delivery is universally correlated with factory success, compliance is not. Furthermore, we find that there may be secondary indicators that are strongly associated with high performance factories, including technical audit scores.

These insights on the underlying drivers of high performance will increase internal transparency and enable improved data-driven strategic sourcing decisions. It is recommended that supply chain companies continue to explore these themes with data analytics. By proactively identifying high performance factories, the project enable transparent and sustainable supply chains, giving companies a powerful long-term competitive advantage.

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1 Introduction

The purpose of this chapter is to introduce the project background, including the motivation, the problem statement, and the approach.

1.1 Project Motivation

Before the 1980s, the garment industries produced more standardized styles. Compared to today's environment, the garment industry was more supply driven, production cycles were more predictable, and the supplier base was stable. Today, the situation has changed on all fronts.

Brands and retailers are facing hyper-competition, with the number of collections per year increasing every year. Some fashion brands now offer up to 20 collections each year (International Labour Organization, 2014). Zara is one such brand that is accelerating fast fashion trends, introducing 10,000 new articles throughout their store network every year (Kelley, 2013). This requires over 1 million replenishment decisions per week (Garcia, 2014).

At the same time, prices for goods have remained stable, if not cheaper when adjusted for inflation (see Figure 1).

![Apparel Price Index Adjusted for Inflation 1974-2014](image)

Figure 1: Apparel Price Index Between 1974 and 2014

The race for lower prices and higher flexibility has created enormous pressure on the factory floor. An example of the breakdown of the supply chain includes a series of fatal events in Bangladesh.
In 2013, a factory collapse in Rana Plaza killed nearly 1,200 workers, prompting global pressure to improve labor conditions. Disney was especially sensitive to public perceptions and temporarily terminated sourcing to Bangladesh due to the number of safety incidences within the country. The increased reputational risk is an important factor for retailers and customers, and highlights the pressure to identify factories that can be perform consistently with respect to health and safety conditions.

To address the supply chain changes caused by faster development cycles, lower prices, and greater demand for social and environmental compliance, Li and Fung is adopting a multi-pronged strategy. First, Li and Fung is rationalizing its supply base, partnering with a smaller number of high performance suppliers. Second, the company is considering long-term business arrangements to provide business stability and the opportunity to create longer-term investments. Third, the company is engaging in capacity building – the provision of resources to improve supplier capabilities in operational excellence. As a result, Li and Fung is fundamentally evolving how it works with its supplier network.

By working closely with a select group of high performance suppliers, Li and Fung can more effectively provide the incentives and attention needed to build a more robust and flexible supply chain. Partnerships would provide additional value through economies of scale and would be a powerful competitive advantage. This project is born out of this need to proactively identify high performance factories to support Li and Fung’s strategic sourcing decisions.

1.2 Problem Statement

With its network of more than 15,000 factories, Li and Fung would benefit from the ability to use data analytics to support its sustainable sourcing process.

The goal of the project is to identify leading indicators of business performance and to test the importance of these indicators against business realities. Li and Fung stores a large amount of historical data on its factory network, and the hypothesis is that there are characteristics of long-term factory performance that can be gathered from this historic data.

Specific topics of exploration for the project include:

- What metrics are being used to evaluate factories and how are they weighted?
How important have these metrics been in predicting the product performance or the social and environmental stewardship of the factory?

How important have these metrics been historically in predicting the survival rate of the companies (measured by the long-term business partnership with Li and Fung)?

Are there other metrics that may determine the likelihood that a factory will be a good partner in the long term?

By using analytics, the project aims to understand the current state of Li and Fung’s factory base as well as key requirements for high performance factories.

1.3 Project Approach

The project aims to build several models that correlate high performance factories with factory metrics and attributes. A key requirement is to optimize sustainable business performance. For robustness, we define business success in two ways:

First, business success can be measured by the total business value that a factory sources for Li and Fung. In many cases, if a factory is chosen as a supplier for large orders, it can be inferred that the factory has performed well (or well enough) in pricing, quality, on-time delivery, and compliance. Unfortunately, this approach may unfairly bias factories that are large and factories that specialize in high value goods, so a second complementary output is needed and described as well.

Second, “firm survival” - measured by the number of years that a factory is selected as a supplier - is also a useful proxy for business performance. If a factory is sourced continuously every year, it is likely that the factory has strong capabilities that can sustain long-term business performance. There are exceptions – personal relationships may sometimes be the primary driver of supplier decisions or Li and Fung may be required to source from certain factories because of its unique products.

However, on the whole, these two approaches serve as a useful first-hand approximation in identifying factories that are strong candidates for sustainable business performance.

Given outputs, the project has two phases of analysis:

• Phase 1: Test Existing Factory Metrics – Li and Fung currently tracks three metrics for many of its factories: quality, delivery, and compliance. The first phase of the project will
establish statistical relationships for these variables and identify whether and to what degree each variable impacts factory outcomes. Definitions for these performance metrics, as well as a brief discussion for each, are provided in Chapter 4.

- Phase 2: Explore and Test New Indicators – Li and Fung staff often cite informal drivers for sourcing decisions, such as the attitude of the factory owner, the ease of working with a factory, and the financial stability of the factory, but data on these factors is not collected regularly. In the second phase of analysis, the project will catalog, prioritize, and test additional attributes that may serve as direct or indirect measures of sustainable business performance. This exercise would provide valuable insights into new data that should be captured and evaluated systematically within Li and Fung.

In terms of data collection and analysis, the project will rely on existing data, which consists of six years of transaction data as well as background factory information, and on new data to be collected through factory surveys and interviews. The appropriate statistical models will measure the correlation between performance metrics and the long-term business performance.

1.4 Summary

In summary, Chapter 1 has provided the context, the motivation, and the general approach for the project. Chapter 2 provides background on Li and Fung. Chapter 3 summarizes the literature research performed to understand the structure of the analysis. Chapter 4 will then discuss the detailed methodology of the analysis. Chapter 5 concludes with a discussion of the results, as well as recommendations for next steps.


2 Background

The purpose of this chapter is to introduce the partner company and the context in which the project takes place.

2.1 Li and Fung History

Li and Fung is a leading consumer goods design, development, sourcing, and logistics company for global retailers and brands. A pioneer in the global supply chain orchestration model, Li and Fung works with 15,000 suppliers and has 300 offices and distribution centers in 40 economies around the globe (see Figure 2). With an annual turnover of over US$19 billion in 2014, the Hong Kong-based company is one of the largest consumer goods sourcing companies in the world.

The company has evolved dramatically in its 108-year history. Though it was originally founded as a trading company in porcelain and silk, the company has consistently reinvented itself to adapt to ever-changing business conditions. When margins crept lower, the company expanded production to new geographies and provided additional services along the value chain. Over time, Li and Fung gradually became the global leader in a diverse range of supply chain services for time-sensitive consumer products.

However, with increasing complexities within the supply chain, managing information becomes increasingly difficult, and more powerful data-driven tools will be required to enable more effective supply chain management. This analytics-focused project is a part of this initiative.

Figure 2: Li and Fung’s Global Network
2.2 Li and Fung Business

Li and Fung's core business model avoids the ownership of factories - its manufacturing requirements are contracted through an extensive network of third parties. Li and Fung operates, however, as the operator of a consumer goods supply chain. L&F activities include product design, material sourcing, production planning, quality assurance, and shipping consolidation, for example (see Figure 3).

![Figure 3: Li and Fung's Supply Chain Services for Consumer Goods](image)

Li and Fung customers are mostly American and European retailers. To serve these customers, Li and Fung offers a variety of business models and can serve as an agent or as a principal. In the agent model, factory prices are transparent and Li and Fung charges an additional fixed fee based on the cost of the order. In the principal model, customers see a single price from Li and Fung. Embedded in the offer is Li and Fung's internal premium. The difference in business models may seem subtle, but it may shift incentives for Li and Fung's sourcing strategy.

In the agent model, for instance, Li and Fung is incentivized to select higher cost suppliers. If all other things are equal, higher cost suppliers will likely provide higher margins for Li and Fung because the margin is calculated as a percentage of the cost of goods. Conversely, the principal model incentivizes Li and Fung to select the lowest cost supplier. Because the customer is generally not provided factory production costs, Li and Fung is able to make the highest internal profit by selecting the lowest cost supplier and keeping its cost savings as additional profit.

In reality, the incentive structure is more complex. The race to lowest cost only exists so long
as certain standards are met. For instance, Li and Fung staff are incentivized to build a trusting relationship with their customers. If a customer finds out that Li and Fung is driving her to high cost factories without good reason, she will be much more likely to end business relations with Li and Fung.

Thus, to evaluate if these business models create divergent sourcing strategies, the project will evaluate two businesses, one from each business model.

2.3 Project Focus

Li and Fung has undergone a number of internal changes which may impact the project analysis. For instance, Li and Fung has pursued numerous acquisitions. In 2013 alone, Li and Fung completed ten acquisitions with an aggregate annualized turnover of more than US$550 million (Li and Fung Limited, 2013). Li and Fung has also spun off major portions of the company. Global Brands Group, a single firm with revenue of more than $3 billion a year, became its own entity in 2014, taking then-CEO Bruce Rockowitz with the company. These internal changes have important implications for the project - the organization has been restructured often so data consistency issues may arise and may need to be accounted for in the analysis.

To mitigate data consistency issues, the project focuses on two business units within Li and Fung (see Table 2.3). They are roughly comparable: both business units focus on accessories and apparel and have a diverse set of customers. The first business unit relies on the principal model while the second business unit uses the agency model. The project will compare how the factory networks of these two business units have performed using a variety of metrics.

2.4 Summary

Li and Fung has a rich organizational history and its evolving business model presents unique challenges and opportunities for this project. The hope and expectation is that the project will identify patterns in factory performance for two business units, demonstrating how factory attributes and performance have shaped sourcing decisions and business strategy. The next section will describe the existing research that has shaped the project scope.
3 Literature Review

Within Li and Fung, factories are formally measured across price, quality, delivery, and compliance. However, hidden company attributes add long-term value, ensuring that these performance metrics stay competitive or even improve over time. Below is a review of industry and non-industry specific publications that have informed the scope of the project.

3.1 Non-Industry Specific Literature

Business schools and policy makers have long emphasized that management is critical for firm success (Bloom, Genakos, Martin, & Sadun, 2010). Yet, robust methods to track the impact of management techniques are still lacking. Management metrics have historically been difficult to measure, and there is a need for additional research to track these metrics and to quantify their causal impact. Below is a list of research publications that have explored these attributes.

3.1.1 Leadership Qualities

Strong leadership has long been considered an underlying driver for company direction and success. In “Good to Great” (Collins, 2001), Collins performed a detailed evaluation of the common leadership qualities of the most successful companies in the world. He questioned what differentiated the firms that have sustainably outperformed the market and the financial performance of its peers. Collins subsequently identified "Level 5 leadership" qualities - a mix of intense determination and
profound humility – as being instrumental to company success. Yet, though descriptive, Collins does not present a simple and scalable model to objectively measure leadership qualities across a large number of factories.

In a more academic driven approach, Bloom conducted a longitudinal study to understand which management characteristics were correlated with firm performance (Bloom, Genakos, Sadun, & Reenen, 2012). Bloom defined 18 management practices and investigated whether they resulted in differences in company performances. Bloom’s approach was comprehensive – he conducted double blind surveys with more than 10,000 companies across 20 countries. Using ordinary least square regression, the authors concluded that management capability is statistically correlated to company success. Bloom found that management aptitude could be measured as the percentage of a management team with a college education. In this project, we also consider using education level as a proxy for management capability.

Bloom extended his analysis in subsequent work by assessing the causal impact of management practices on firm performance (Bloom, Mckenzie, & Roberts, 2013). To do so, the team worked with an international management consulting company to perform a randomized management study. The controlled study collected panel data on company performance for Indian firms with and without the support of outside management experts. The consultants shared a variety of management expertise, spanning topics in operations, inventory, and human resources. Within the first year, the firms with management consultants increased their average productivity by 17%, implying that there is a strong impact of skills and capacities on firm performance. Similar managerial knowledge and capacities will be assessed in this project.

3.1.2 Organizational processes

In addition to leadership capabilities, organizational processes are often seen as a key lever for company performance. Based on his experience with the Toyota Production System, Spears believes that organizations create sustainable competitive advantage with: 1) the development of empowered teams and 2) the use of rigorous root cause analysis and corrective action procedures (Spear, 2010). As a result, elements of dynamic work processes and supportive culture may be leading indicators for firms that excel in continuous improvement activities. These elements are also considered within the project scope as well.
Nike offers a similar observation that internal organizational changes result in improved performance. When the company introduced lean concepts to its footwear factories, nearly all factories saw increased productivity, reduced defect rates, and shortened lead times (Distelhorst, Hainmueller, & Locke, 2014). Several other empirical studies support the theory that human resource innovations - including incentives, training, job enrichment, and teamwork - have positive impacts on firm performance (Ichniowski, Shaw, & Prennushi, 1997).

These publications provide credence to the idea that measurement of company capabilities is possible and even core to understanding a company’s long-term potential and success. Though not comprehensive, these studies provide a strong foundation of general attributes to measure and compare across Li and Fung’s companies.

### 3.2 Industry Specific Literature

There is a growing body of research that looks at performance specifically within the apparel industry. The majority of work is focused on compliance issues because social and environmental issues have come under intense scrutiny in recent years. Some major themes and insights are discussed below.

#### 3.2.1 Factory characteristics that improve compliance

In general, size and ownership type are believed to be correlated with a factory’s ability to achieve compliance. There are several hypotheses for this assertion. First, larger firms generally have more resources to employ better management and to fix compliance violations, so they should perform better in compliance. Second, domestic-owned firms may have inferior compliance performance because they generally have less knowledge of best practices in compliance (Oka, 2012). Third, government and founder-owned firms may be more likely to perform poorly (Bloom et al., 2012) because government and founder-owned firms have a greater lack of incentives and/or knowledge commensurate to privately held firms. This project will explore some of these themes in detail.

#### 3.2.2 Buyer characteristics that affect compliance

The nature of the buyer-supplier relationship can also cause differences in performance. With Nike’s supplier lean program, participating factories saw an average 15-percentage point reduction
in serious labor violations, suggesting that lean training supports compliance activities (Distelhorst et al., 2014). In another large supply chain management company, Locke found that the number of audit visits, especially when combined with programmatic initiatives by the buyer, could improve social compliance scores significantly (R. M. Locke, Brause, & Qin, 2007). Thus, greater buyer investment of time and energy appears to create supplier goodwill and commitment to common goals around compliance.

Oka and others extend this analysis by showing that the type of buyer is critical to the degree of factory compliance (Frenkel & Scott, 2003; R. Locke & Romis, 2006; Oka, 2012). Large reputation-conscious customers, for instance, are much more likely to pressure factories to perform well in social and environmental audits. Conversely, when business is conducted through third party intermediaries, compliance performance may suffer because of weakened customer-supplier expectations. This specific impact will be ignored in this project since all transactions will be conducted through Li and Fung, but this may be an opportunity for future follow-on research.

3.2.3 The impact of compliance

In a unique paper on factory working conditions, Brown demonstrated that compliance capability is a predictor of firm survival (Brown, Dehejia, & Robertson, 2013). The study showed that compliance, particularly after the first visit, positively predicts survival. However, this study primarily focused on factories from Cambodia, which limits the global applicability of the insights because of the country’s unique history of international scrutiny and mandates. As a result, we extend this analysis by considering a more global network of factories.

Oka has parallel analysis where she researches whether compliances capabilities can be used to attract and retain customers. She concludes that better labor compliance is a necessary but insufficient condition for attracting buyers. She asserts that additional compliance can result in competitiveness or non-competitiveness, largely dependent on buyer behavior (see Figure 4). This tension matches intuition because buyer demands for social compliance are a rather recent phenomenon, and reputation risk is often less tangible than commercial factors such as competitive costing, reduced lead-times, and smaller order sizes.
3.3 Summary

The existing literature provides extensive context adding both industry and non-industry specific insights to the project. This project seeks to extend previous analyses in three ways: 1) use a more global dataset of factories to test existing insights, 2) apply unique proxies for management and organizational capabilities to the apparel industry, and 3) consider new metrics for success, namely firm survival and value of business within Li and Fung’s sourcing strategy and network. The next section describes the methodology to achieve these goals.
4 Methodology

This section describes the methodological approaches of the project with details on data inputs and model development. The project is divided into phase 1 in which existing performance metrics are evaluated, and phase 2 in which new indicators are explored.

4.1 Phase 1: Test Existing Factory Metrics

The first goal of the project is to determine the relevance of existing factory performance metrics. When choosing factories to source from, Li and Fung personnel rely on three primary metrics: quality, delivery, and compliance. In phase 1, we test how strongly these performance metrics are correlated with long-term sourcing patterns, namely the value of business and firm survival.

4.1.1 Data inputs

This project primarily draws on Li and Fung databases which contain information on past transactions (individual order information including product, delivery, and customer type). To limit the scope of the analysis (in terms of business unit, product type, data quality, etc.), the project was limited to the transactions and factory network for two business groups at Li and Fung. The data used for this study spans six years of transactions from January 2008 to December 2013.

As described in Chapter 1, the two outputs are the value of business and the years of firm survival. First, the value of business is calculated based on the average annual value of goods from that factory. The calculation starts with the first year a factory is sourced so that we do not unnecessarily bias newer factories in the analysis.

Second, firm survival counts the number of years in which a factory has been a supplier for Li and Fung. For instance, between 2008 and 2013, the most successful firm will have been sourced six times, whereas a low performing factory will have only one year of sourcing. It should be noted that factories that have not produced anything for Li and Fung over the six years of data will not show up in the dataset.

Three of Li and Fung's current performance metrics - quality, delivery, and compliance - serve as the primary dependent variables in our analysis. Definitions for these metrics and the hypothesis for each metric’s impact on factory sourcing are below.
• Quality - First Time Pass Rates: This metric measures a factory's ability to manufacture defect-free products. Before any products are shipped, Li and Fung inspectors test whether a statistically significant portion of the order is of acceptable quality. We hypothesize that first pass rates should be strongly correlated with business performance because low pass rates indicate that a factory has low quality controls and that it will be a poor candidate for future business.

• Delivery - On-Time Delivery: A second critical measure of factory performance is whether factories can be punctual with their orders. This metric compares the product's release date at the factory gate with the original scheduled date of the order. We hypothesize that on-time delivery should correlate with business performance because timing is increasingly a non-negotiable expectation for many customers.

• Compliance - Social and Environmental Score: A third and increasingly important measure of factory performance is the factory's ability to meet social and environmental standards as defined by Li and Fung. Compliance scores are generally rated A, B, C, or D, based on the severity of issues observed at the factory (see Figure 5). For instance, factories that achieve A scores demonstrate no serious violations of the standards. On the other hand, factories with D scores have at least one egregious “zero-tolerance” violation.

Li and Fung may withhold and even cancel orders from factories with a D rating. In addition, there may be informal benefits, such as an implicit understanding that compliance performance will result in future deals. In addition, higher compliance often goes hand in hand with overall factory performance in pricing, quality, and delivery. Yet, higher rated factories are generally not provided explicit incentives either through higher prices or guaranteed business (Ruwanpura & Wrigley, 2011). Because social compliance can be seen as an added cost in some cases, we hypothesize that compliance scores result in worse long-term business performance if factories score below a C rating.

Model Description The above three performance metrics will be the primary inputs to the model, but we also incorporate secondary factors that may affect factory business. Several variables will be controlled for, including country, factory size, and factory year of entry:
- Country – production country is an important control variable because factories are often chosen (or not chosen) because of country-specific factors that have little to do with individual factory capabilities. Labor costs, import/export regulations/incentives, and physical infrastructure are several examples of how country-level attributes will impact individual sourcing decisions.

- Size – the size of the factory (measured by number of employees) is likely to affect performance for two reasons. First, larger factories are likely to be higher performing because of the greater availability of resources to allocate to quality, delivery, and compliance initiatives. Second, because of these larger investments, the opportunity costs to exit are increased, which justifies a greater commitment to performance (Oka, 2012).

- Years with Li and Fung – the number of years Li and Fung has known a factory is important because a long-term relationship will improve the likelihood that Li and Fung may source from a firm. In addition, firm survival itself may be biased towards older factories, so this variable will control for this bias.

To estimate the average value of business with factory performance metrics (quality, delivery, and compliance), a Ordinary Least Squares (OLS) model is used. It is important to note that the value of business is transformed with a log function to create a viable Gaussian distribution for the model.

(see Figure 6)

The first model will have the form of:

\[ X_i = a + b_1 \times country + b_2 \times size + b_3 \times quality + b_4 \times delivery + b_5 \times compliance + b_6 \times offset + \varepsilon \]
Figure 6: Distribution of Annual Factory Spend

where:

- $X_i$- log of the average annual value of goods sourced from factory $i$
- $a$- intercept
- $b_i$- coefficients for the $i$th variable
- $country$- control variable for country of production
- $size$- control variable for # of employees at company (if applicable)
- $quality$- most recent quality score from 0 to 100% (first pass inspection rates)
- $delivery$- most recent delivery rating: 0 to 100% of deliveries (on-time delivery)
- $compliance$- most recent score of A, B, C, or D for factory’s social and environmental rating
- $offset$- # of years the factory has existed in the Li and Fung network
- $\varepsilon$- error term

To estimate firm survival (measured in the years it is sourced from), a generalized linear model (GLM) is required because the response variable (number of years of sourcing) follows a Poisson-like distribution (see Figure 7).

The second model will have the form of:

$$\log(Y_i) = a + b1*country + b2*size + b3*quality + b4*delivery + b5*compliance + b6*offset + \varepsilon$$

where:

- $Y_i$- # of years sourced from factory $i$
• \(a\)- intercept

• \(b_i\)- coefficients for the \(i\)th variable

• \(country\)- control variable for country of production

• \(size\)- control variable for \# of employees at company

• \(quality\)- most recent quality score from 0 to 100% (first pass inspection rates)

• \(delivery\)- most recent delivery rating: 0 to 100% of deliveries (on-time delivery)

• \(compliance\)- most recent score of A, B, C, or D for factory’s social and environmental rating

• \(offset\)- \# of years the factory has existed in the Li and Fung network

• \(e\)- error term

4.2 Phase 2: Explore and Test New Indicators

In the second phase of analysis, the project seeks to identify new factory attributes that may be predictive of quality, delivery, and compliance performance. Based on literature review and on interviews at Li and Fung, a list of attributes is created and tested.

4.2.1 Data Inputs

A working group at Li and Fung provided critical input on a set of indicators to support sourcing decisions (see Figure 8). Based on these discussions, a framework for performance measures is created, which focuses on three categories of attributes:
- Product Performance: metrics to measure past supplier behavior. These include past price competitiveness, quality rates, and delivery timeliness.

- Human Capacity: metrics that measure the innate human potential of people at the factory. Several proxies were proposed in measuring the strength of management and front-line workers. One example is that management capability can possibly be measured indirectly by considering the percentage of college-educated managers at a specific factory.

- Firm Characteristics: metrics that measure the technical strengths and weaknesses of the factory's operations itself. For instance, past compliance scores and the company's financial strength could be initial indicators for the long-term health of the organization.

Data on the new indicators is collected in two ways, 1) a manual review of existing internal documents and, 2) factory surveys created for this project.

**Manual data collection**

Critical data can be collected from internal and external audits. These reports can be generated as a normal part of business, but much of the data is not inputted into the company database and is
not reviewed regularly. These reports may contain details on the factory's technical and operating capabilities, which may often be critical to a factory's long-term performance. In this project, we gather and evaluate this data, focusing on two items in particular:

First, internal technical audits are factory evaluations to gauge production readiness. These are often performed as part of the onboarding process, and provide a broad range of factory details, including but not limited to: the market served by the factory, the factory’s quality assurance system, and the specific technical equipment that is available onsite. These technical audits result in a single score for factory readiness, and we hypothesize that these scores will be a strong indicator of long-term factory performance.

Second, there are publicly available lists of factory certifications. One standard – called the SA8000 certification - is developed by Social Accountability International (SAI) is especially transparent. Factories with SA8000 certification are publicly listed on the SAI website. By matching this list with Li and Fung’s factories, we can assign additional information to those factories. Research has shown that garment manufacturers with SA8000 often face increased investment costs (Stigzelius & Mark-Herbert, 2009), which may ultimately result in lower margins. However, we believe that SA8000 compliance should signal a factory’s commitment ability to reach compliance and hypothesize that certificates should be a leading indicator of high compliance scores.

Factory surveys

Remaining attributes and characteristics are collected through a factory survey. Below, we describe the scope and content of a factory survey that was distributed to a subset of Li and Fung’s factories.

The surveyed factories were selected based on two considerations. First, they were factories that had been sourced at least once between 2008 through 2013. Second, to limit the country-specific noise, only factories in the top three countries for the business unit (China, Turkey, and Bangladesh) were surveyed. The online survey was translated into the native languages of the factories to maximize factory participation. Of the business unit studied, approximately 500 factories were contacted to answer 38 qualitative multiple-choice and fill-in-the-blank questions on the factory’s background, human resources, and internal investments.

Below are some questions included in the survey. A key challenge of the survey was to balance comprehensiveness, ease of use, and reasonable accuracy. Some questions are more qualitative in
nature and a limitation of the survey is that responses to the survey were not verified. The complete list of questions can be found in the appendix.

**Factory Background**

- How old is your factory?
- What is the ownership structure of your company?
- How supportive has Li and Fung been in its relationship with your company?

**Human Resources**

- What percentage of your management team is college educated?
- Do you have a Quality Assurance (QA) Manager? If so, how many years of experience does he/she have?
- What is the annual turnover of new workers (1-3 years) at the factory?

**Internal Investments:**

- Do you invest in R&D?
- Do you own any of the buildings you operate in?
- Do you have any external certifications? (SA8000, BSCI, WRAP, IS09001, ICTI, GMP, etc.)

The expectation is that the responses to the survey will test three general hypotheses:

1. Company structure, including age, ownership, and relationship with Li and Fung, which can serve as leading indicator for firm sophistication. For instance, we attempt to confirm whether the type of ownership will impact the level of compliance and of firm survival.

2. Human capacity, namely managerial experience and worker engagement, can be a leading indicator for long-term improvement efforts. For instance, we expect that managers with a higher level of education will be a useful proxy for managerial competence, which should lead to improved factory performance.
3. Investments in factory, such as lean programming or building infrastructure can lead to sustainable improvements in quality or compliance performance. We anticipate that factories with lean operations should have higher quality performance and be a preferential long-term sourcing partner for Li and Fung.

4.2.2 Model description

Response rates to the survey were at 10% (52 responses). The response rate was low for several reasons: 1) some factories were contacted through a middleman supplier, thus reducing the likelihood that the right person at a factory would be reached, 2) some factories no longer exist, and 3) others found little motivation to reply to the survey if they do minimal business with Li and Fung.

As a result, no comprehensive statistical models were developed for the survey responses because of the relatively limited number of responses. However, we share and explore the patterns in Section 5.5.

4.3 Summary

The purpose of this chapter is to provide the detailed methodology required to evaluate both existing and new potential factory performance metrics. The data inputs rely on internal and external data collection, including a management survey distributed to more than 500 factories in Li and Fung's network. Two separate models are described (ordinary least squares and a generalized linear model). The next section provides the results and discussion of the insights gained from the analysis.
5 Results and Discussion

The quantitative results of our models are presented, followed by an interpretation of the results. The section concludes with observations and insights from the survey responses.

5.1 Overall Model Results

Tables 5.1 and 5.1 present the results of the estimates for a factory's business value for based on quality, delivery, and compliance metrics for two business units. It should be noted that the coefficients are scaled logarithmically – there is a 10x change in business value for each unit change in the dependent variable.

<table>
<thead>
<tr>
<th>Business Unit 1: OLS Model for Value of Business</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variable</strong></td>
</tr>
<tr>
<td>Intercept</td>
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<tr>
<td>Offset</td>
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<tr>
<td>Country [Bangladesh]</td>
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<tr>
<td>Country [China]</td>
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<td>Country [India]</td>
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<td>Country [Thailand]</td>
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<td>Log [Employees]</td>
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<tr>
<td>Delivery (On-Time Rates)</td>
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<td>Quality (First Pass Rates)</td>
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<tr>
<td>Compliance [B]</td>
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<tr>
<td>Compliance [C]</td>
</tr>
</tbody>
</table>

Table 2: Ordinary Least Squares (OLS) Model for Average Spend of Business Unit 1's Factories

We observe that the direction of most effects is broadly in line with the pre-stated hypotheses. However, we note that few variables are statistically significant. Key observations include:

- Offset (or exposure) is positively correlated with firm survival, which is consistent with the fact that a factory's tenure in the Li and Fung network will lead to the likelihood that it will be sourced from more often.

- Country of production has important implications for business value. In Business Unit 2, India is negatively correlated with business value, implying that Indian factories have common challenges.
Table 3: Ordinary Least Squares (OLS) Model for Average Spend of Business Unit 2's Factories

- Quality performance has mixed results and are not statistically significant.

- Compliance has mixed results and all of the variables are not statistically significant. These results are discussed in Section 5.3.

- Delivery has a positive impact on business value, though it has high variability in the degree of statistical significance. This discrepancy is explored in Section 5.4.

Tables 5.1 and 5.1 present the results of the estimation of firm survival (years of sourcing) based on quality, delivery, and compliance metrics for two separate business units at Li and Fung.

Major trends and takeaways include:

- Country of production can be a significant driver for years of firm survival. Both China and India are statistically significant drivers for Business Unit 1. India is positively correlated with years of sourcing, which is interesting because it runs counter to the relationship observed in the first model. One rationale may be that Indian factories are sourced often, but primarily for low-value goods.

- Quality has a negative impact on the number of years a factory is chosen as a supplier. This observation runs counter to the original hypothesis that quality performance should result in
Table 4: Generalized Linear Model (GLM) for Years of Sourcing for Business Unit 1’s Factories.

Table 5: Generalized Linear Model (GLM) for Years of Sourcing for Business Unit 2’s Factories.
improved factory performance. This discrepancy is explored in more detail in Section 5.2.

- Compliance does not have any statistically significant impact on years of firm survival. This suggests negligible observable impact on years of firm survival.

- Delivery continues to have a strong positive impact on the number of years a factory is chosen as a supplier for Business Unit 1.

In summary, model results have both supported and rejected the different hypothesis described at the beginning of the project. In the following sections, the implications for each performance metric (quality, delivery, and compliance) are discussed.

5.2 Quality Discussion

As observed in Section 5.1, quality performance does not have a statistically significant impact on business value. In fact, quality performance may have a negative impact on firm survival. This result does not match intuition. In discussions with Li and Fung staff, the overarching conclusion is that improved quality performance should indeed make a factory more attractive for investment.

The negative correlation of quality with firm survival may be caused by a complex interaction of two or more factors. For instance, quality scores and the country of production are highly correlated. In fact, when country of production is removed from the analysis, quality performance is predicted to have a positive impact on firm survival.

In a scatterplot of factory survival with factory quality scores (see Figure 9), it can be seen that there is a strong positive correlation between quality and years of firm survival. An observable cluster of factories is observed to have high first pass inspection scores and a high number of years of sourcing. This supports the hypothesis that factories with good quality scores are chosen as long-term sourcing partners for Li and Fung. This relationship may also be understated because of sampling bias. For instance, because quality results are only reported for factories that still exist, the poor performers who were dropped as a supplier were ultimately excluded from the analysis.

Alternatively, this could support the hypothesis that suppliers improve quality scores as they enter long-term partnerships with Li and Fung. It is not within the scope of this project to differentiate the two hypotheses, but this can be a subject of future work.
5.3 Compliance Discussion

In both models, compliance ratings are not statistically significant for business performance. Still, there is an important trend nonetheless. In a scatterplot of average spend with factory compliance scores (see Figures 10 and 11), C rated factories are found to be amongst the highest performing factories in both Business Units.

These results suggest that compliance scores do not necessarily translate to business performance. High compliance scores will protect a factory from unexpected violations in social or environmental standards that result in a factory shutdown. Yet, high compliance scores may also be interpreted as overinvestments in internal measures, which make the factory less competitive in
The original hypothesis was that the business units may perform differently due to specific business unit needs (e.g. customer base requirements, management goals, or business model). These results show that the most “successful” factories are those that have C level compliance. Successful factories are defined as those that have the highest annual shipments, but this itself may be a flawed approach. Bigger does not necessarily mean better, as many units may have grown due to acquisition, internal consolidation, and other reasons not related to their performance. Nonetheless, the data shows that a large proportion of Li and Fung’s factory partners are rated at C, the minimal compliance level required for production.

5.4 Delivery Discussion

In two models, on-time delivery performance is positively correlated with business success. This confirms the original hypothesis, though the effect is relatively weak. To explore the relationship, we consider a scatterplot between individual factory on time delivery performance and the business performance.

Though there may be a weak correlation, Figure 12 shows that a large number of “successful” factories have poor on-time delivery. This is a surprising observation – anecdotally speaking, delivery timeliness was often described as a critical requirement for many customers. One possible driver of the weak correlation is that high performance suppliers are given more difficult orders. For instance,
jobs with more aggressive timelines may be given only to competent suppliers, resulting in lower overall delivery scores for these suppliers.

Interviews with Li and Fung staff, however, reveal that a big driver of the discrepancy is due to how delivery data is collected. Depending on the business unit or the individual staff members, data is inputted in dramatically different ways. For one, changes in delivery dates are sometimes not updated in the database. For another, delivery dates are sometimes defined as internal deadlines, so late delivery dates may still be within end-customer expectations. These differences in data collection can thus dramatically weaken the predictive power of this delivery metric.

5.5 New Data Insights Discussion

In this section, we review other potentially predictive indicators of factory performance. We consider manually collected data within Li and Fung as well as survey distributed to a subset of Li and Fung’s factories. No quantitative model is developed due to the limited amount of responses in the factory survey, but initial observations are described, which will be useful in prioritizing data streams to explore in subsequent studies.
5.5.1 Existing data

Two types of existing data from audit reports were explored: Li and Fung’s technical audits and external SA8000 social compliance reports. The technical audit results are evaluated against quality performance and the SA8000 results are tested against internal compliance scores.

First, we find that technical audit results may be a strong predictor of a factory’s quality performance. Specifically, factories with “outstanding” audit results have consistently higher first pass inspection rate performance (see Figure 13). A greater number of testing is required to confirm this response, but if true, the technical audit results will establish an innovative way to proactively measure the quality capability of a factory.

![Figure 13: Quality vs. Technical Audit Results Plot](image)

Second, we observe that external SA8000 certification results do not noticeably impact a factory’s ultimate compliance score. This discrepancy is likely due to the limited overlap of issues between SA8000 and Li and Fung certification. An SA8000 certification specifically assesses labor violations, which may offer limited value because it only covers a small subset of comprehensive Li and Fung’s social and environmental assessment.
5.5.2 New factory data

Survey results with data on company structure, human capacity, and factory investments are explored in this section as leading indicators for factory performance. The insights are preliminary because of the limited available data and the high likelihood of interaction among the variables. As a result, statistically significant results between inputs and outputs are not feasible. Nonetheless, several observations on the most interesting attributes are described below.

First, we evaluated company structure attributes including ownership structure, age, and relationship with Li and Fung. However, none of these factors appear to impact a factory’s observed business value nor firm survival. These results are not consistent with reported results in literature, but the responses may be subject to biases in the survey responses since no responses were verified.

Second, we consider human capacity attributes such as managerial education and experience, employee engagement (measured by annual turnover), and the presence of specific roles within the company (e.g., the existence of a process engineer). The strongest observation is that the most successful factories appear to have a full-time compliance manager (see Figure 14). This may be worth further exploration in subsequent analysis.

![Figure 14: Survey Results for Years of Sourcing vs. Full-Time Compliance Manager](image)

We also observe that managerial education level and employee turnover are not shown to be significant drivers for factory performance, though this may also be due to the qualitative and unverified nature of the survey. Annual turnover of employees is a particularly difficult data point to verify in a survey.
Finally, factory investments in R&D spend, building ownership, and technical systems are evaluated for their impact on factory performance. We find that many of the highest performing factories (see Figures 15 and 16) have an enterprise resource planning (ERP) system and own at least one building. This may be due to several reasons: First, the use of an enterprise resource planning (ERP) system may contribute to the factory's capability to scale with complexity. Second, building ownership may signal more robust company financials, or at the very least, a commitment to stay in the business. Alternatively, higher performing businesses may simply be able to afford to purchase ERP systems or buildings. More data is needed to verify these trends and the direction of causality.

Figure 15: Survey Results for Years of Sourcing vs. Enterprise Resource Planning (ERP) System

Figure 16: Survey Results for Years of Sourcing vs. Building Ownership
5.6 Summary

In this chapter, current metrics for factories (quality, delivery, and compliance) and a number of new metrics at Li and Fung are evaluated. We find that current metrics have varying degrees of impact on a factory's long-term performance, most likely due to how the data is collected and the specific business unit being considered. In terms of new metrics, several indicators show promise in predicting factory performance. However, more work is required to verify these trends and the next chapter describes some of the potential ways to extend the project's insights.
6 Recommendations and Conclusion

The project has revealed a number of preliminary insights into the use of data in understanding long-term factory success. Based on the analysis conducted in this project, there are several tangible ways to take advantage of the project results and to continue developing deeper data-driven insights. This section provides short and long-term next steps as well as a concise summary of the entire project.

6.1 Recommendations

To further enhance the project’s insights, it is recommended that the company focus on three major themes: 1) improve data integrity; 2) expand scope of data collection and analysis, and 3) explore innovative applications.

1. Improve data integrity

Li and Fung has strong technical systems to collect and evaluate large amounts of data. However, the utility of the data depends on data integrity and consistency, which varies dramatically from business unit to business unit. Because of nonstandard definitions and a lack of clarity on how and when data should be inputted into the system, there are significant gaps in the analysis. As described in section 5.4, on-time delivery is a specific example where a single metric has different meanings depending on the staff member.

Fixing these inconsistencies represent a rare opportunity. By standardizing and collecting regimented internal data, important patterns will emerge about both micro and macro trends in sourcing. In turn, by partnering with the highest performing factories, Li and Fung would strengthen relationships with partner factories and their leadership, which would further improve the quality of collected data. However, this solution will require a cultural shift within Li and Fung. As initiatives are typically driven by individual business units, this would require significant buy-in and coordination within Li and Fung.
2. Expand scope of data analysis to other business units

The insights generated from this project should be tested for robustness with other business units. In particular, the hypotheses described in this project should be evaluated with a greater number of factories that reflect the diversity within Li and Fung’s network. As pointed out in section 5.3, compliance expectations and requirements can vary dramatically between business units, and the robustness of the project hypotheses should be rigorously stress tested in different contexts.

Moreover, several business units were observed to have unique sources of data, which should be incorporated into a single, larger study. For instance, in one business unit, detailed financial data was collected on a subset of factories to ensure that they were financially solvent. This type of data collection across the company could add significant value the current scope of the project.

3. Explore innovative applications

Finally, the data in this project was used to test a relatively simple hypothesis – that a factory’s future business value and survival is linked to common performance metrics. However, predictive analytics could drive other internal decisions as well. For instance, claims data is collected in the Li and Fung database, so it is entirely possible to use historic data to predict an expected claim rate for each customer and factory. This information would result in powerful implications for sourcing decisions and in managing downstream and upstream relationships for Li and Fung.

The outputs of this analysis can also be used in internal cost accounting. In parallel work to this project, Xiaodi Sui proposes the use of transactional cost multipliers to reflect additional manpower costs at a factory, such as auditing time due to low compliance scores (Sui, 2015). By integrating predictive analytics on a factory’s performance, it is possible to integrate a factory’s risk profile into a more complete estimate of the cost of doing business.

In summary, these proposed next steps will provide a roadmap to extend and leverage the insights found in this project.

6.2 Conclusion

High performance is defined as the ability to consistently meet social, environmental, and financial expectations, driving increased value within the supply chain. To adapt to changing needs within
the apparel industry, Li and Fung plans on partnering with high performance factories to create a more robust and adaptable supply chain. To advance this effort, this project analyzes Li and Fung’s historic data to identify leading indicators of high performance factories.

The project tests multiple hypotheses related to current and future data streams at Li and Fung. First, it is hypothesized that there is a direct relationship between factory performance metrics (in quality, compliance, and delivery) and business success (defined by value of business and firm survival). Second, it is hypothesized that unexplored sources of data could be critical measures of underlying drivers for factory performance. These two hypotheses are evaluated with historical data, and several insights were revealed.

First, we find that current factory metrics have varying degrees of impact on a factory’s long-term performance. For instance, whereas on-time delivery is correlated with factory success, social and environmental compliance is not. Instead, the optimal level of compliance can be dependent on business needs, staff mentality, or business model (agent versus principal). We also find that there may be secondary indicators that are strongly associated with current factory metrics. Technical audit scores, in particular, are strongly associated with quality performance.

Second, the project has identified potential new leading indicators of factory performance. These insights will need to be verified, but we find evidence that enterprise resource planning (ERP) systems, building ownership, and the presence of a full-time compliance manager are linked to high performance factories. To develop deeper and more robust insights, Li and Fung should: 1) improve data integrity, 2) expand the scope of data collection and analysis, and 3) explore innovative applications of the data analysis as described in section 6.1.

In conclusion, the project objective is to better understand how data analytics can be used to support Li and Fung’s business. By proactively identifying high performance factories, the project enables sourcing transparency and more sustainable supply chains, giving Li and Fung a long-term competitive advantage.
A Appendix - Factory Survey

The factory survey described in Section 4 was distributed to more than 500 factories. The goal of the survey was to collect new data that may serve as strong signals for long-term factory performance. About 10% of the factories responded, though a number of responses were removed because 1) there were many incomplete answers, or 2) a number of responses did not make sense (e.g. they listed only 5 employees at a factory that was responsible for millions of dollars of goods). The online survey is translated into Turkish and Chinese as well to maximize factory participation. We include below the English version of the survey. In total, there are 38 qualitative multiple-choice and fill-in-the-blank questions on factory background, human resources, and internal investments.

Introduction

Dear Valued Business Partner,

We are writing to request your participation in a study conducted by scholars from Massachusetts Institute of Technology (MIT). This study is intended to learn more about the company’s supplier base to better serve our customers.

You can participate by completing a brief online survey. We suggest that the survey be completed by staff who is knowledgeable about the factory’s history, human resources, and operations. All responses are anonymous and private; they will not influence orders from Li & Fung.

We highly value your time, and truly appreciate your participation. Results of the research will be shared with survey participants.

With gratitude,

Li & Fung Limited

Background

Please indicate your position with the company.

- General Manager / Factory Manager
- Sales Manager
• Human Resources Manager

• Merchandiser

• Other

What is your email address?

What is the name of your factory?

What city is your factory located in? (example: Shanghai)

How many years has your factory been in operations? (round to the nearest year)

What is the ownership structure of your company? (check all that apply)

• Family Owned Business

• Public Corporation (traded on stock exchange)

• Government Owned

• Hybrid Partnership

• Other

On average, what percentage of your orders come from Li and Fung?

• 0-1%

• 1-5%

• 6-10%

• 11-20%

• 21-40%

• >40%
How supportive has Li and Fung been in its relationship with your company? (0 is not supportive; 100 is very supportive)

What are the main reasons you gave for your score? (check all that apply)

- Li and Fung offers a number of useful services (helpful staff with technical/compliance/quality advice).
- Li and Fung is neither supportive nor unreasonable in doing business.
- Li and Fung places high demands on the factory (price, compliance, etc).
- Other

Human Resources

During low season, what is the total number of your employees? (include both full and part time employees)

During high season, what is the total number of your employees? (include both full and part time employees)

On average, what percentage of your factory are full-time employees?

- 0-10%
- 11-20%
- 21-40%
- 41-60%
- 61-80%
- 81-100%
What is the annual turnover of new workers (1-3 years) at the factory? Annual turnover is percentage of workforce that changes every year (# of separations / average number of employees)

- 0-5%
- 6-10%
- 11-20%
- 21-30%
- 31-40%
- >40%

What percentage of your management team is college educated?

- 0%
- 1-20%
- 21-40%
- 41-60%
- 61-80%
- 81-100%

How many years of factory experience does the factory manager have?

- 0-2 years
- 2-5 years
- 5-10 years
- >10 years
Does your factory have a full-time Human Resources manager?

- Yes
- No

If "yes", what is the educational background of the Human Resources manager? Choose the best that applies.

- Middle or High school graduate
- Vocational school graduate
- College/University graduate
- Master's degree or higher
- Other

Does your factory have a full-time industrial engineer?

- Yes
- No

If "yes", what is the educational background of the industrial engineer? Choose the best that applies.

- Middle or High school graduate
- Vocational school graduate
- College/University graduate
- Master's degree or higher
- Other
Does your factory have a full-time compliance manager?

- Yes
- No

How many years of factory experience does the compliance manager have?

- 0-2 years
- 2-5 years
- 5-10 years
- >10 years

Does your factory have a full-time quality assurance role (example: certified factory auditor)?

- Yes
- No

How many years of factory experience does the quality assurance person have?

- 0-2 years
- 2-5 years
- 5-10 years
- >10 years

Do you provide any of the following trainings to your employees? (check all that apply)

- Orientation training
- Health and safety training
- Language training
• Production / machinery training
• Lean manufacturing
• Management training
• Other

Have you delayed employee payments in the past year?
• Yes
• No
• Don’t know

If "yes", what were the reasons for doing so?
• Problems with IT system
• Disputes with employees
• Insufficient cash flow
• Other

Factory Investments

Do you own any of the buildings you operate in?
• Yes
• No

Do you invest in research and development (R&D)? (Include product development capabilities such as a sampling room)
• Yes
• No
If yes, what percentage of your revenue has been reinvested into R&D in the past year?

- 0%
- 0-2%
- 3-5%
- >5%

In the past 3 years, have you invested in new equipment and facilities?

- Yes
- No

If yes, how have you funded your investments? Check all that apply

- Internal cash
- Outside investment
- Bank loans
- Other credit source

Does your factory rely on any of the following lenders? Check all that apply

- Banks
- Money lenders
- Bank loans
- Other credit source

How often were customers or Li and Fung late in paying for your orders in the past year?

- Never
• 1-2 times
• 3-5 times
• 6 or more times

What were the reasons for your customers to be late in paying for your orders?

• Not Applicable (they were not late)
• Quality issue(s)
• Late delivery
• Don’t know
• Other

Do you have a system and process for managing inventory and production? (e.g. Enterprise Resource Planning system)

• Yes
• No
• Don’t know

Please check any external certifications that your factory has.

• SA8000
• BSCI
• WRAP
• ISO9001
• ICTI
• GMP
• Other
Do you participate in any of the following programs? Check all that apply.

- ILO Better Work / Better Factories
- Higg Index / Sustainable Apparel Coalition
- Li and Fung Training Programs / Guidebooks
- Other Customer programs (energy efficiency, lean manufacturing, water conservation)
- Others
References


