Simulation and Optimization of Immediate Delivery Networks

by

Mark Chi-Hsun Chen

Submitted to the Department of Electrical Engineering and Computer Science
in Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Electrical Engineering and Computer Science at the Massachusetts Institute of Technology

May 23, 2001

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Abstract

Instant delivery businesses have been built on delivery chains of dedicated centralized warehouses and customer attended order reception. Such business models are currently facing high rates of failure due to costs of delivery that can often surpass 100% of total revenue. Thus any significant decrease in delivery costs could drastically increase the probability of reaching profitability and a sustainable corporate entity. This thesis explores a simulation designed to model such delivery networks used by companies such as Kozmo. Changes to the distribution chain were further applied to discover possibilities for optimization and to quantify their effects. The results provide valuable insights towards replacing the current delivery scheme into a much more efficient and scalable infrastructure.

Thesis Supervisor: Amar Gupta
Title: Co-Director, PROFIT Initiative, Sloan School of Management
Acknowledgments

I would like to give great thanks to a number of people who have aided me in my work.

First and foremost, I would like to thank Jason Chicola who gave me the initial seed of curiosity about Kozmo and their business model that led to my research in this area.

To Sean Webb, former Director of Operations at Kozmo in Boston, for his great help in detailing operating conditions while Kozmo was still in business. They ran an incredibly smooth operation, and I am indebted to him. It is very unfortunate that Kozmo was unable to succeed.

To all of my roommates who kept me company during late night programming and thesis writing sessions, especially Dan Kokotov, who helped me through my limited understanding of program design and greatly improved the robustness, simplicity and efficiency of my code.

I'd also like to give thanks my parents, John and Dolly Chen, and my sister, Phyllis, for all the help and support they have given me throughout my life and academic career.
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Chapter 1

Introduction

The new economy has inspired a number of new business concepts; a massive influx of venture capital has provided sufficient funding for the exploration of those ideas in startups. Yet new businesses are still bound by the same realities faced by traditional companies. This maxim proved all too true for the many instant delivery businesses that have sprung up and died over the past few years. Companies such as Kozmo, UrbanFetch[91], Streamline.com[86], PDQuick[59] and Sameday.com[75] have tried to fill the “e-mmediate” gratification niche market, serving those who require a snack, drink or book within an hour. Such players were to spell doom for the local brick-and-mortar retailer - once a customer can order a CD online and receive it in less time than it would take to run to the local Tower Records and pick it up, why would anyone leave the house? Yet today following the demise of Kozmo in April 2001, no major instant delivery retail business exists. PDQuick has managed to remain as a niche player in the Los Angeles market, but is itself in the midst of looking for additional financial backing[76]. The reasons for the death of so many startups, despite the infusion of hundreds of millions of dollars in capital from respected venture capitalists and corporations, was widely publicized - the costs of delivery were too great to offset the costs of marketing, capital expenditures and payroll. However, despite the odds, some Internet grocery vendors like Webvan[95], Peapod[60] and HomeRuns[28], are still in operation, determined that a critical mass of customers can be reached at which point the delivery operation will turn profitable.
This thesis takes a heuristic approach to identifying some of the underlying problems facing such business models, in particular, the peculiarities faced by businesses such as Kozmo in the planning and utilization of their delivery chains. While the research can be generalized to accommodate a number of different rapid delivery services, including online grocers, the focus was placed particularly on Kozmo due to its former market leading position and the ease of information collection in regards to their operations and cost structures. To discover inefficiencies in the delivery network, a simulation of Kozmo’s fulfillment operations was developed to identify areas where service can be improved or provided at a lower cost. The conclusions provide insight into the future growth of Kozmo and how its delivery mechanisms must adapt to the conditions of this rapidly evolving market.

1.1 Instant Delivery Business Model

Companies in the instant delivery space offered rapid delivery of a variety of consumer goods and video rentals. Delivery times are also kept to a minimum; Kozmo for instance pledges one hour[37]. However, despite the reliance on the Internet for order procurement, recent technological advances have not changed the fundamental problem with such a business model - the need to physically transport products in a fast manner, usually at a high cost. Thus if transportation times and costs can be reduced, such businesses can become much more competitive.

In operation since 1997, Kozmo was the first major player in the rapid online shopping area by combining the promise of the Internet with the convenience of immediate delivery. Joseph Park, the founder, a 28-year-old former investment banker, began the venture after ending his first shopping experience with Amazon in frustration. He wanted a copy of John Grisham’s latest novel, but was unwilling to wait more than a week and pay an expensive fee for delivery. Park recalls:

The sooner I wanted it, the more I had to pay. I got so frustrated, I turned off my computer and ran down to Barnes & Noble and purchased the thing. That’s when the idea came to me. If I could marry online
shopping with instant gratification I’d have something big.

Companies such as Kozmo and Urban fetch offered thousands of products at a click of a mouse away, ranging from videos, DVDs, CDs, games, books, magazines, meals, drinks, electronics, housewares to health and beauty aids. A fleet of bike messengers, and car and van drivers provide instant gratification to customers short on time.

1.2 Problems

Home delivery companies, particularly those with tight time constraints such as the rapid transport market, face a few major problems in their attempts to deliver a wide variety of goods direct to the consumer. First and foremost is the cost of making the deliveries. Current estimates place the cost of delivery between $10-14 per order. With an average order size of $25, companies such as Kozmo clearly could not prevent losses from building up on their financial statements unless the cost of delivery could be reduced or the profits (delivery costs, excluded) per order increased. The second issue companies face is the scarcity of warehouse space. Despite the thousands of products that filled their warehouses, selection was miniscule compared to the 10 million products offered by online superstores such as Amazon. Amazon has an obvious advantage in warehouse space. Its warehouses/distribution centers have hundreds of thousands of square feet of space while Kozmo’s Boston-area warehouse had a scant 10,000 square feet. While instant delivery companies certainly aren’t competing head to head against Amazon, the lack of product selection has to some extent limited their ability to increase average order sizes. The prevalence of entrenched delivery mechanisms (UPS, USPS, FedEx) offering cheaper, albeit slower, delivery combined with the expense of rapid delivery and scarcity of selection had relegated Kozmo and its peers into niche markets that were incapable of supporting the infrastructure needed to provide service.
1.3 IDISE

To get a better understanding of the dynamic conditions that face the home delivery business, a simulation of an order fulfillment system was created based on Kozmo’s actual operations - Instant Delivery Simulation Environment (IDISE). The main purpose was to quantify the results of changes to the underlying infrastructure on the cost/performance of the delivery chain.

There are a number of delivery chain software packages on the market, but none seemed particularly appropriate for this application. The focus of current products is either too confined to a single industry or application, or the cost was too great to justify spending. Thus, the focus of this thesis was to write a simulator that could be specific enough to Kozmo to allow for accurate modeling, yet be general enough to enable future extensions to accommodate changing business practices, and possibly to other companies. To achieve more realistic results, rather than building up the cost structure from the bottom up, Kozmo was contacted for information specific to its delivery practice. Thus, the results are applicable only to Kozmo’s service area in Boston. Other markets served by Kozmo, in particular, New York and Seattle, had slightly different conditions that lead to diverse practices. Such differences ranged from the infrastructure in place (number and size of warehouses) to the delivery mechanism (more bikers vs. drivers).

1.4 Performance Enhancements

Once the simulation was complete, it was then used to optimize a specified infrastructure for usage. There are three independent variables to be controlled for:

1. Customer Characteristics - Customer attributes such as order density over time, by geographical region, individual product demand and average order size

2. Warehouse Locations - Infrastructure information such as the number of warehouses, location and capacity

3. Delivery Fleet - Vehicle specific data such as number, capacity and speed
Simulating the delivery chain can create valuable insight into potential changes that could be made to the actual distribution schemes used by any one of the number of direct-to-consumer services such as Kozmo, Webvan or Peapod. However, this thesis will focus on Kozmo due to its smaller variety of product types (15,000 vs. an online grocery store’s 25,000 SKUs), low established infrastructure (16 warehouses each of 10,000 sq. ft. warehouses vs. Webvan’s 9 distribution centers each of 300,000 sq. ft.) and its involvement with other strategic players as a distribution system (rather than a purely online grocery or convenience store). However, there is hope that enough wisdom can be gleaned from this research to provide any of these companies to improve their operating model and provide consumers with a much desired, but yet inexpensive service.
Chapter 2

Kozmo

The instant delivery industry was certainly not created by Kozmo. Food delivery services such as Domino’s Pizza and bike messenger services had existed for years before Jim Park ever ordered anything online. Throughout the past, there have been several different takes on the fundamental direct-to-home delivery concept. However, Kozmo did pioneer the use of an instant delivery network as the sole method of distribution, and thus following the description of its competitors and contemporaries, Kozmo’s operations will be detailed.

2.1 Instant Consumer Retail Delivery

Besides Kozmo, other players in this field included Urbanfetch, PDQuick, Same-day.com and other smaller companies. Focused on high margin items like video rental, junk food and drinks, and toiletries, these services essentially offer convenience store access through home delivery. Each particular company differs by service area, market segment focus and distribution method.

2.1.1 Kozmo

Before Kozmo shut down operations in April 2001, it operated in 9 cities: Atlanta, Boston, Chicago, Los Angeles, New York, Portland, San Francisco, Seattle, and Wash-
ington, D.C., and planned to open more and demand arises. Having secured financial backing from a number of major venture capital firms as well as strategic partners such as Amazon.com, Liberty Media, SOFTBANK, Universal Studios, and Warner Bros., Kozmo had a large amount of capital to fund its operations. After a scheduled IPO failed to materialize in May 2000 due to market conditions, Kozmo began running short on its $250 million in funding received because of the difficulties in serving the instant consumer delivery market[19]. However, Kozmo was unable to alleviate the issues it faced, and went the way of its competitors, Urbanfetch[52] and SameDay[3] - failures in the immediate delivery sector, the market that Kozmo has spearheaded.

Kozmo enabled consumers to order a variety of entertainment, food and convenience products over the Internet for free delivery in under one hour. They focused on selling frequently purchased, high margin items with well-known brand names. Additionally, they initiated a business-to-business service to enable select retailers to provide their customers with expedited delivery options on a fee-for-service basis. The principle components to Kozmo’s strategy were convenience, large selection of products, efficient logistics processes and a what is thought to be a low cost distribution model. Near the end of operations, Kozmo began a drive to increase revenues with minimum order requirements, increased product offerings and a more aggressive marketing campaign. However, from March 1999 to December 1999, revenues increased by 7.5x, while the cost of goods sold increased by 9.9x and delivery costs increased by 19.4x[38]. Thus, the strategy of pure revenue growth, while important nonetheless, was insufficient for improving profits, and actually increased the cost of delivery in some cases as orders were sent on longer distances and marginal customers spent less per order.

2.1.2 Urbanfetch

In March, Kozmo approached Urbanfetch founder and CEO Ross Stevens, then the CEO of a hedge fund called Integrity Capital Management, as a possible investor. Integrity closed down soon after the meeting, and Stevens set to work on launching
Urbanfetch. Kozmo quickly sued Urbanfetch for intellectual theft. But after failing to prove the uniqueness of Kozmo’s business model, the suit was later dropped[74].

Urbanfetch was a near facsimile of Kozmo. Their product lines included videos, magazines, food and tobacco products. However, as the underdog, it was unable to raise as much capital as Kozmo in the venture community. Total funding is estimated to have been around $70 million. As such, Urbanfetch focused on only two markets: New York City and London. The international presence led to a proposed merger between Kozmo and Urbanfetch near the end of Urbanfetch’s life. Within the New York market, where the best comparison between the two companies lies, Urbanfetch differed from Kozmo in a few key areas. While nearly 95% of all Kozmo’s orders contained video rentals, Urbanfetch was unable to secure the rental market, and only 7% of its orders contained such products[81]. Urbanfetch instead focused on the higher-end, yuppie market. Serving professionals with greater disposable income and more expensive tastes, Urbanfetch was able to sell higher margin products and goods, and maintain larger average order sizes. However, relegated to this niche, Urbanfetch was unable to capture enough market share to overcome the economies of scale that Kozmo was offered with its appeal to younger workers and college students.

Ultimately, Urbanfetch was unable to raise enough capital to continue and could not directly compete with Kozmo. In October 2000, Urbanfetch closed all consumer delivery operations in New York and London to focus on its UrbanfetchExpress service, a corporate point-to-point courier service. In its current state, Urbanfetch Express is thus a messenger service that is extremely different from the vision that Ross Stevens originally set out to build.

2.1.3 PDQuick

Founded in 1987 in Los Angeles by Bill Toro, Pink Dot was a small, local delivery company. Toro dreamed up the idea while watching the cartoon character George Jetson order instant-delivery items from his television. Orders were originally received over phone and fax and serviced from small convenience store locations dispersed throughout the city. In 1997, it too caught the Internet wave and began accepting
By May 2000, it received $35 million in funding and renamed itself as PDQuick[26]. Plans to expand from its 16 fulfillment centers in LA with 30 new centers in Baltimore, Phoenix, Sacramento, San Diego, San Francisco, San Jose and Washington, D.C. were later cancelled after the failure to secure another round of financing.

PDQuick differed from Kozmo primarily in its product line and delivery chain. PDQuick began with heavy sales in the Beverly Hills area, catering to wealthy individuals and was famous for offering home-cooked foods along with gallons of vodka. The prepared foods and liquor/tobacco products gave PDQuick large gross margins that enabled it to charge just $2 per delivery and still turn a profit. However, as it grew into an 800 employee operation, PDQuick widened its product offering to include lower priced deli goods to compliment the original gourmet foods. Still, PDQuick has bucked the trend in offering a one-stop shop for videos, CDs and electronic like Kozmo and Urbanfetch. Instead, it has retained its core offerings of the gourmet/corner-store market. PDQuick’s delivery chain was also significantly different from Kozmo. While Kozmo employs a small number (1-5) of warehouses in a given city, PDQuick serviced deliveries from its 16 locations which also operated as convenience stores. This distributed storage was beneficial in Los Angeles which is characterized by its large urban sprawl that increases the average distance of deliveries.

PDQuick was eyed in an acquisition by Kozmo in early 2001, citing its regional profitability. However, failing to see synergy between PDQuick’s distribution system and Kozmo’s own operations in LA, talks fell apart, and Kozmo closed operations less than 2 months later. PDQuick is now in limbo, barely profitable due to over expansion in an effort to compete with Kozmo, but incapable of national expansion, it is pursuing other strategies to partner with a national delivery company[77].

2.2 Home Grocery Delivery

Instant delivery companies such as Kozmo also face competition from online grocery companies. Not only do they share similar technology savvy and busy customers, but
they also face the same last mile problem. Groceries are also in a crucial position in business-to-consumer commerce because they form the major volume of the material flow to consumers’ homes[79]. The main difference between online grocers and their instant convenience relatives lies in the scope of product selection and the timeliness of deliveries. While Kozmo delivers videos and snack foods within an hour, companies such as Webvan will deliver orders containing fresh meat alongside 20 pound bags of pet food scheduled 24 hours in advance. Each grocer has chosen different approaches for their logistical strategies and have had varied success. The following is a description of a few of the major online players in the $650 billion grocery industry.

2.2.1 Webvan

Webvan is an online grocery service that attempts to combine the convenience of one-stop shopping online with a courier service that delivers the order within a time window of the customer’s choice. Orders can be placed at any time of day, seven days a week and are packed in Webvan’s custom distribution centers and delivered by a Webvan courier. Deliveries can be scheduled up to seven days in advance and delivery is free for orders over $100. Webvan features several product categories in addition to traditional groceries, including: pet supplies, consumer electronics, books, CDs, DVDs and videos, and specialty shops (Old Navy, Gymboree, Beauty & Spa, The Florist, The Smoke Shop, Games & Toys).

Webvan began commercial operations in the San Francisco Bay Area in June 1999, and rapidly moved into Atlanta, and Chicago by August 2000. In September 2000, Webvan acquired HomeGrocer, a competing home grocery delivery service in a merger transaction. HomeGrocer had commercial operations in Seattle, Portland, and Southern California. Webvan has the illustrious position as the online delivery company that has received the most capital. To date, over $900 million has been invested in the business by investors such as Knight-Ridder, CBS, Softbank as well as public shareholders[96]. In November 1999, Webvan completed an initial public offering raising $402 million in return for 25% of the shares outstanding. Since then, Webvan has spent lavishly despite slowing sales growth. In April 2001, Webvan’s
auditors expressed concerns about the company’s ability to continue operations and reach profitability in lieu of further cash infusions[10].

The model that Webvan employs differs significantly from other retail delivery companies. Instead of employing more traditional warehouses and packing methods, Webvan has invested significant capital in the construction of state of the art distribution centers as the center of a hub-and-spoke system. Each system consists of a highly automated distribution center feeding 10 to 12 substations situated within a 50-mile radius. These mega warehouses are to store 50,000 different products - the equivalent of 18 traditional supermarkets. By the time Webvan enters the 26 planned markets, it will have spent $1 billion.

The warehouses at the hub of each market are no ordinary distribution centers. For instance, at Webvan’s original warehouse in Oakland, CA, national and local suppliers drop off goods at the 336,000-square-foot facility, every morning. Webvan then relies on a five-mile network of conveyor belts to carry color-coded bins around the different areas where packaged goods, freezer items, produce, meats and other products are stored. Instead of stocking shelves, Webvan workers stock rotating carousels of in-stock goods. The carousel system, developed exclusively for the company by custom machinery manufacturer Diamond Phoenix, produces a turnaround in warehousing theory: bring products directly to pickers, rather than having the pickers go through countless rows to fill orders.

Webvan claims its carousel system lets workers pick roughly 2-1/2 times more items per hour than they could manually[22]. That automation allows it to staff each of its geographic operations with about 900 employees - one-third the 2,700 employees it claims would be required to staff 18 supermarkets. Once orders are picked and packed, they’re loaded onto refrigerated delivery trucks and taken to one of 10 to 13 substations. At these substations, the orders are broken down to individual routes. Webvan’s drivers then shuttle orders to the customers’ countertops and unpack the bins.

However, the advantage that Webvan observes with its automation comes at a cost. Its famous carousels cost five or six times what manual rivals spend on packing
technology. It’s enormous distribution centers cost $25 million to $35 million each, while competitors erect smaller warehouses at $4 million to $6 million[33]. Yet once the centers are operating at capacity, Webvan does see enormous cost savings relative to bricks and mortar as well as other online grocery retailers, due to its lower marginal costs. Thus Webvan’s current efforts have been to curtail further capital spending and to increase its current share of the $650 billion grocery goods market in each of the regions it already serves.

2.2.2 Peapod

Peapod was the first major grocery delivery service. Founded in 1989 by brothers Andrew and Thomas Parkinson in Chicago, Peapod was originally a grocery picking service for those short on time and long on money. Orders would be placed over phone or fax and dispatched out to a picker. Instead of using their own distribution center, Peapod pickers would go to the nearest supermarket, and literally walk down the aisles picking products into a shopping cart. After checkout, the order would be delivered to the customers door at a slight markup to retail plus a handling fee. Despite the laborious effort involved, Peapod was profitable, and the founders saw the Internet boom of the 90’s as the way to reach a much larger audience.

Based on their original business model, except enabled for Internet-based order acceptance, Peapod tried from the start to do business on the cheap. Unlike Webvan, instead of building costly warehouses to compete with local grocers, Peapod sent its green-aproned workers into grocery stores to pluck its customers’ orders directly off the shelves. This saved Peapod money up front, but it left the company facing an odd dilemma—how to make money selling goods it was buying at retail prices. Clearly unable to scale up the initial business model to compete effectively, Peapod nearly went bankrupt in 2000, before being acquired by Dutch supermarket operator Royal Ahold[80]. Following the acquisition, the company was restructured to leverage the existing assets of the parent company. Ahold, which also owns the Stop & Shop, and Giant Food supermarket chains, setup Peapod delivery services from its own supermarkets, allocating space in some retail locations to be mini-distribution centers.
This blending of old and new business models should benefit Peapod with lower inventory, warehouse, and picking costs. However, Peapod has recently again shifted business models towards Webvan in building dedicated distribution centers to achieve better operating margins.

In each market that Peapod operates, Peapod uses a dedicated fulfillment model. Despite the logistical support from Ahold-affiliated stores, Peapod has distanced itself from its former business model. President and CEO Marc van Gelder stated, “We don’t believe the future is in in-store picking. We believe in a centralized distribution model.”[17] But he later commented on the advantage Peapod’s link to Ahold affords the company, “If you look at the pure Internet plays in grocery delivery, it’s a tough story. Linking up a grocery chain with a Net delivery service, however, gives you a good foundation for a profitable company.”[18]


The free-standing model is similar to the strategy used by Webvan, except without the high tech conveyors. Large platform warehouses that range in size from 70,000 to 100,000 square feet hold all the inventory and processing equipment. These warehouses were either built by Peapod directly, or acquired through Peapod’s purchase of Streamline[72].

In fast-pick centers, one or two retail locations are selected to serve the entire market, which tend to be smaller than those served by free-standing warehouses. In these centers, Ahold performs certain services for the benefit of Peapod. These fulfillment services consist of, among other things: storage services, inventory management, replenishment services, specialty shop support (deli, butcher, bakery, etc.), product packing and human resources. The key area of aid is inventory storage and management. Dry goods are stored and picked from the back-room fulfillment cen-
ters, while perishables are selected from the grocery store shelves. By sharing storage space with existing retail locations, fast-pick centers are able to fulfill orders from an area of approximately 8,000 to 14,000 square feet, as an extension of the retail location it operates from. Each fast-pick center has its own vehicle fleet and inventory. Orders are received at the appropriate center depending on the delivery address. For all intents and purposes, each fast-pick center serves separate markets. There are no transfers of inventory between such centers either since inventory is replenished by the retail location from its own warehouse supplies.

It is unclear whether either of Peapod’s double-pronged strategy will succeed. Financials indicate a lower cost of fulfillment than its competitor Webvan[62][96], but Webvan is operating significantly below capacity, and has a lower marginal cost of order processing than Peapod, which will see difficulty in scaling its operations to handle growth. However, Peapod has announced profitability in Boston where a significant market for online grocery shopping already exists. The future still remains uncertain for Peapod; only time will prove whether Peapod can reach profitability in all of its markets.

2.2.3 Streamline

In 1993, following Peapod’s success, Streamline became the second company to tempt grocery shoppers with a home-delivery service. Streamline partnered with other businesses to expand the service beyond groceries, including dry cleaning, film processing, shoe repair, video rental, meals, flowers, package delivery and other household services. The company estimated that it saved regular users three hours a week.

Streamline’s business model was perhaps the most aggressive of all the online grocery retailers[89]. Like Webvan, Streamline employed dedicated distribution centers - except without most of the expensive sorting and packing technology. In addition to the use of distribution centers to lower costs, Streamline also employed a reception box at each customer location. The reception box was a full-sized refrigerator/freezer unit kept in either a basement or garage. Through the use of these reception boxes, Streamline deliveries could be made in the absence of the customer. The elimination
of delivery time windows greatly increased scheduling flexibility and decreased the cost of delivery. It also enabled Streamline to include other value-added services such as dry cleaning pickup, video rental, etc. Customers were billed for the groceries and services rendered in addition to a monthly fee of $30.

The use of a reception box has been regarded as an evolutionary development for online grocery shopping[99]. The cost advantages are evident. It is also beneficial to the online entity by increasing overall revenues on the service side as well as decreasing customer churn due to the installation of a permanent fixture in the home. However, the need for subscription and a reception box also decreased market share growth rates as people were reluctant to sign up to a monthly fee, and the recurring cost of refrigerator purchases dragged down on the company’s earnings.

In the first quarter of 2000, Streamline announced that it had finally turned its basic Boston-area operations profitable, considering only the cost of taking an order, then packing and delivering it. The company released the news in hopes of convincing investors that it could soon be profitable even when adding the cost of rent, utilities, taxes, marketing and other corporate overhead. But the market downturn left Streamline unable to issue stock to raise needed cash. In September 2000, on the verge of bankruptcy, Streamline thus sold off its Chicago and Washington, DC operations to Peapod[72]. In November 2000, unable to find a buyer for its New Jersey and Boston facilities, it shut down permanently. Ultimately, Streamline was unable to partner with a larger grocery supplier to enable to achieve lower product and warehousing costs. Yet its innovative use of the reception box has laid the path that many similar services may follow to eventual success.

2.3 Traditional E-Commerce/Mail Order Delivery

While not direct competitors to instant delivery companies, traditional e-commerce and mail order companies do attempt to cater to the same markets. In addition to video rentals and food, Kozmo also offered CDs, electronics and books for sale, all delivered within one hour. As the leading online retailer, Amazon.com is a good
model to examine the issues facing this sector and its relevance to the instant delivery
arena.

2.3.1 Amazon.com

Amazon.com was founded in July 1995 by CEO Jeff Bezos with the intent to use the Internet to sell books directly to the consumer. The plan was simple - to supply customers with access to the database of books available from large book distributors. Once a customer places an order, the book is ordered from the distributor at wholesale prices, and shipped to the consumer for a price discounted from retail, but above the original wholesale price. By eliminating inventory, Amazon was able to offer a much larger selection of books at lower prices than bricks and mortar competitors. The only drawback was speed of delivery, since the customer had to wait for books to be delivered to Amazon’s distribution center and then repackaged and delivered to the end customer. Amazon’s long lead times were the original inspiration for Kozmo. What started as the world’s biggest bookstore is rapidly becoming Earth’s biggest store for any product. Amazon.com’s main site offers millions of books, CDs, DVDS, and videos (which account for about 70% of sales), not to mention toys, tools, electronics, health and beauty products, prescription drugs, and services such as film processing. Expansion is propelling the company in many directions; it owns stakes in online sellers of prescription drugs, wine, wedding services, and more.

Since its founding, Amazon has expanded its distribution network from a single 350,000 sq. ft. warehouse in Seattle to eight distribution centers with over 4 million sq. ft. of floor space. Due to its reliance on third party delivery services such as the US Postal Service and United Parcel Service, Amazon is limited in its ability to reduce delivery times. However, each distribution center is strategically located to enable Amazon to keep delays to a minimum; three centers are located in Kentucky alone, where United Parcel Service locates its delivery hub. In 1999, Amazon built a warehouse in Nevada just to reduce average delivery time to west coast destinations by one day[63].

Amazon’s dedicated distribution centers represent a marked change in strategy
from its former use of leased space or outsourced logistics. The private warehouses allow Amazon to achieve greater capacity and decrease handling times, while also lowering marginal costs. Amazon has been so effective in their logistical efforts that many companies have decided to shutter their own online operations and allow Amazon to handle all order fulfillment[9]. Toys 'R' Us was the first major competitor to do this in August 2000. In this arrangement Toys 'R' Us purchased and managed inventory that was stored in Amazon warehouses, while Amazon was responsible for the development and maintenance of co-branded site, and for all fulfillment and shipping services[44]. In return, Amazon receives fixed periodic payments, payments based on the number of units handled, as well as a percentage of total revenue in addition to warrants to purchase 5% of Toysrus.com. Borders, a retailer of books, music and videos, has followed in Toys 'R' Us' footsteps by allying with Amazon in April 2001. Unlike the Toys 'R' Us deal, since Amazon already has a strong online book retailing business, Borders will effectively exit the online market altogether, as Amazon is responsible for inventory purchasing, management, and order fulfillment and customer service. Borders will promote the co-branded site in its retail locations and provide some editorial content for the site.

Amazon's distribution system has thus become a model for other online vendors. But a few caveats must be made before incorrect assumptions are drawn towards its applicability to the instant delivery problem.

1. Amazon has acquired a customer base large enough to support its distribution capacity.

2. Deliveries are still handled by third parties and is can be made no quicker than what is normally available from such outsourced service providers.

3. Amazon isn't profitable yet. Despite its efficient order handling, Amazon has not achieved profitability - the book sales division is profitable on a stand alone basis.
2.4 Bricks and Mortar Home Delivery

The Internet is not the only fertile ground for instant delivery of products; throughout history there have always been goods delivered directly to the home (milk, newspapers, ice, etc.) That continues today with mostly goods that are too heavy to be transported by the customer with ease, but also with smaller goods that increase convenience to the consumer.

2.4.1 Office Supplies

Office supplies and furniture, usually ordered in large quantities and often quite bulky and heavy, are available for next-day delivery from major suppliers such as Staples, OfficeMax and Office Depot. Delivery is usually free for orders over $50; orders below that cutoff are assessed a delivery fee of about $8. Deliveries are picked from a local retail location and delivered by corporate trucks. Orders placed outside of a 20 mile-radius from a retail store are shipped via UPS. Without a dedicated distribution center, such a service allows companies to make deliveries with limited capital expenditure and little concern over cannibalize in-store sales with delivered transactions (due to the large order threshold required).

2.4.2 Barnes & Noble/New York City

Barnes & Noble has introduced an innovative service in New York City to combat Kozmo's rapid delivery and to leverage its bricks and mortar locations in its struggle against Amazon.com. Online customers can place orders for books that are in-stock at retail locations and have them delivered to locations in Manhattan for the same price as standard ground shipping rates (UPS). Qualifying orders are picked from the Barnes & Noble retail location closest to the destination and then delivered on bike or foot. With eight stores distributed throughout the 8-mile long island, Barnes & Noble can keep delivery costs low, and since inventory is shared with the retail locations, storage costs are minimized[7]. This has enabled Barnes & Noble to offer similar convenience to Kozmo shoppers, although nowhere close to the product selection,
while also luring customers in the area away from Amazon altogether since given
the choice of paying the same price to receive a book within a few hours or a few
days, most anyone would choose same-day delivery. However, the true success of this
limited operation is unknown. Manhattan is particularly dense in population and
retail store presence (Barnes & Noble was founded in Greenwich Village in 1965). It
is doubtful that the same strategy would work in other regions. Financials are not
broken out for the same-day delivery business alone, and it is impossible to accurately
judge the true profitability of such deliveries.

2.5 Food Delivery

Even before Domino’s Pizza was made infamous by its guarantee of one hour delivery
or free food, take out restaurants have offered delivery services to its customers.
Delivery policies vary by business, but the entire industry shares similar traits. There
are usually minimum order sizes of around $10 and or a delivery charge of about
$2. Deliveries are made within a radius of a few miles around the retail location.
Delivery time is usually under an hour. This is a very profitable area of operation for
many restaurants since the gross margin on prepared food is so high and the costs
of maintaining a kitchen and staff are best distributed over the greatest number of
orders possible, both in-store and delivery.

2.6 Kozmo Distribution Network

Kozmo served each of their markets from one or two distribution centers, which were
approximately 10,000 square feet in size and located in primarily low-rent areas with
access to key thoroughfares. According to Kozmo, “such a business model enables us
to quickly establish operations in a new market with a moderate capital expenditure
and is designed to eliminate the high lease expense, build-out cost and inventory
requirements normally associated with having multiple retail locations in a single
market.”[38] The product offerings were concentrated in the following categories:
• **Books** - Approximately 300 of the best selling book titles in hardcover and paperback

• **Food** - Beverages, candy, snack foods, ice cream and pre-prepared foods were all offered

• **Home Videos** - Over 10,000 movie titles were offered at each Kozmo location for rental as well as purchase

• **Magazines** - Traditionally high margin products, these impulse purchases were often added to the end of a typical order of video rental and food

• **Mini-Mart** - The need for over the counter drugs, batteries, film, tobacco products, etc. was often the initial agent that results in a Kozmo order

### 2.7 Fulfillment Process

There were 16 Kozmo distribution centers in operation at the time of the company’s demise. Each center is linked to the web site through a central web server. The web server automatically routed orders to the distribution center nearest to the customer’s zip code. The operational processes within each center, including product gathering and packaging, inventory management, customer service and delivery route planning were all managed using proprietary, Kozmo-developed systems. The Kozmo Intelligent Dispatch System (KIDS) attempted to optimize delivery sequences and routes, minimizing travel distance. The system attempted to integrate environmental factors such as time of day, weather conditions, mode of transportation, etc. It was not integrated with electronic positions systems to allow real-time tracking of deliveries.

An order began to be processed from the moment a customer logs on to the Kozmo website. The products available for delivery from the warehouse location closest to the customer’s zip code are displayed. When the customer added a product to an order, the inventory was updated such that subsequent customers could not place an order for a product of insufficient quantity. If the order was cancelled, the
Figure 2-1: Order FlowChart

product was placed back into the operating inventory. If the customer proceeded to the check out, a credit card number was requested, and upon verification, the order was sent to the warehouse for handling. Once the customer pressed the checkout button, approximately 40 seconds passed before a printer in the warehouse closest to the customer spooled a completed packing invoice. The packing invoice was then used by the warehouse staff to pick the selected products off the shelves and place them into order bins. When the order was completed, the items in the bin were each scanned into the computer for verification of the order, and packed into bags along with receipts for the order. The packed orders were organized according to zip code, and queued for delivery.

Meanwhile, as each order was placed by the customer a flag was superimposed over a regional map on the KIDS system display. A dispatcher could then begin to create a delivery log for a driver, assigning various order from across zip codes to a single driver. While the system could create delivery routes once orders have been assigned to a driver, the process of order assignment was fairly manual in nature, and heavily dependent on the expertise of the dispatcher to create efficient delivery run. When all the orders assigned to a given delivery run had been picked and packed, the driver was dispatched. Although the drivers all carry mobile phones, there was very little contact with the warehouse once the delivery had been loaded, short of unexpected traffic delays.
The final leg of the delivery was made at the customer's doorstep. The customer signed for the delivery and tipped the driver in exchange for the order. This portion of the process usually took 2-5 minutes, as the driver had to wait for the customer to answer the door.

The last remaining portion of the logistical efforts occurred on the backend when a customer drops off a video for return. A significant portion of Kozmo’s revenues were comprised of video rentals; 95% of all deliveries contained a VHS or DVD rental[94]. As such, the pickup of rental returns was a substantial concern. In each of its markets served, Kozmo had negotiated agreements with local retailers such as Starbucks for the installation of drop-off boxes. A customer could return a Kozmo rental at any of these locations. Drivers picked up the returned videos from each of the drop-off boxes daily. Since there could be nearly a hundred such locations in any given city, multiple drivers had the sole task of such pickups. The pickups were then returned to the warehouse where they are scanned and placed back into circulation. If rentals from other warehouses were received, a delivery would be made to the corresponding warehouses.

2.8 Boston Operations

The focus of this research was primarily on Kozmo’s Operations in Boston. The vicinity of their warehouse in Allston, a Boston suburb, allowed for firsthand observation of their activity. The Boston location was a typical Kozmo distribution center of 10,000 square feet holding over 15,000 thousands types of products. Nearly half of the space was devoted entirely to storage of products, while the remainder was used for packing and scanning equipment, office space and scooter/bike storage. In addition, there was also a small lounge areas for drivers and messengers to use between deliveries. Overall, it seemed that driver utilization was well managed, as there were never any more than one or two drivers sitting down while 19-25 were on the road. Each city used a different vehicle mix depending on the traffic conditions and the order density. In New York City, all but the largest orders were handled
by bicycle. In Boston, however, the vehicle mix tended to float between 60%/40% car/bike ratio during the summer, when it’s warm enough to send out bicyclists to distant destinations, and 90%/10% car/bike ratio during the winter, when driving conditions limited non-car deliveries to a confined radius around the warehouse. The distribution center serviced between 800-1,500 transactions today throughout the entire Boston metropolitan area between the operating hours of 8 AM and 12 midnight, using anywhere between 10 to 40 messengers at a time. Boston is a city with a very large proportion of college students comprising the population. As such, it was a good target market for Kozmo, due to the age group’s disposable spending habits, product choice and residential density surrounding major colleges. This last point was an additional advantage to Kozmo’s Allston location. In addition to the low cost of property in the area, it laid in close proximity to Boston’s major colleges, Harvard, Boston University and MIT. As a result, the Allston/Brighton area, which has a heavy student population, was the single busiest region of business. During the standard work day between 8 AM and 5 PM, however, the Downtown Boston area had heavier order flow due to the sheer number of people contained in the area during business hours. This geographic locality of their business proved to be a great benefit when searching for areas for optimization.

2.9 Characteristics of Current Delivery Chain

Kozmo’s current delivery model can be viewed as a point-to-point distribution system. Each delivery left the warehouse towards its intended destination. A particular order might have shared a delivery run with on average three other orders, but for the most part, delivery to the consumer is a straightforward process. There are several advantages to such a scheme.

- **Low rollout cost** - With a single, low-rent, warehouse and inexpensive rental drop-off boxes, there is little capital expenditure on the infrastructure side.
• **Widespread geographical coverage** - The range of service coverage is limited only by the distance that can be covered by a driver within the time window - this can lead to service up to 20 miles away.

• **Product variety** - A dedicated distribution warehouse can offer a much larger variety of goods than a number of smaller storage facilities can.

• **Lower inventory carrying costs** - With all inventory in one location rather than distributed across numerous facilities, an overall smaller amount of inventory is necessary as no particular region runs out of goods while others are overstocked.

However, there are also significant disadvantages to Kozmo’s delivery chain.

• **High marginal cost of deliveries** - Scalability is a challenge with a point-to-point distribution scheme, and each additional delivery does not considerably decrease the average cost of delivery.

• **Dependence on efficient number of delivery staff** - Since each order requires the efforts of approximately 1/4 of an extra driver, Kozmo must maintain enough deliverers to meet demand, yet overstaffing greatly reduces efficiency.

• **Low customer loyalty** - As long as the driver reaches the customer’s doorstep, there is little reason for a customer to remain with a particular delivery service. As shown in New York City, Kozmo regularly shared customers with Urban-fetch, with a given company chosen due to a special gift (for example, cookies or a t-shirt) being offered.

While Kozmo’s delivery chain had many advantages over competing distribution schemes it is clear that to increase profitability, it had to reduce the marginal cost of delivery. While its last model had enabled its rapid expansion and market penetration, a more sustainable strategy was not developed to carry the company into the future.
Chapter 3

Logistics Simulation Tools

There are a few different approaches with simulating Kozmo's operating characteristics. A commercial simulator can be acquired and applied to this particular situation. Or a simulator specific to the immediate delivery model can be developed from scratch. In this particular application, the custom simulator approach was used, while the model is relatively simple, and the use of a personalized simulator could be made generic enough to allow for the significant modifications that would be necessary when applying the optimization principles. A custom design would best fit the purpose and needs of this particular research. The cost of the commercial programs, as well as the desire to pursue further research without great expense or license limits also reduced the attractiveness of commercial software.

There are a number of commercial applications that could fulfill any subcomponent of the business modeling problem. However, each of the commercial solutions has its own faults, as well as strengths, not to mention enormous costs of licensing, usage and training. Systems modeling software like Arena or Witness could be applied to give insight into the inventory and logistics issues. Vehicle routing software from SAP or Baan could be used to solve specific delivery optimization problems.
3.1 Multipurpose Simulation Tools

Multipurpose simulation tools allow users to model and analyze a wide variety of processes. Performance projections can be generated as results of “what-if” analysis. As general purpose tools, they can model any aspect of a business, from order processing to shipping. They can incorporate all activities, resources, business rules, decision logic, costs, and assumptions into one dynamic model to analyze current and future processes. These tools are incredibly powerful, but they require a great deal of effort to program and setup as they are not designed for very sophisticated users, and typically require a significant level of programming experience and effort.

3.1.1 Arena

Arena is a leading software simulation package, made by Rockwell Software Automation. Arena is a flow oriented simulation language with the basis language SIMAN, that has existed for over 15 years. Models are created by drag and drop modules in a large window. These modules represent one or more statements of the SIMAN language. It closely follows a flow chart building block method of construction. It is best used in flow oriented environments like banking and insurance where documents flow through the different processes. It’s also commonly used in higher level studies where the activity of entities is not obliged (for example, supply chains). Although SIMAN allows a lot of control, it is not suited for complex systems due to the entity driven approach, and lack of flexibility.

Cost: $295-$2,995

Strengths:

- Importing features from and to databases

- Full documentation and simulation community support

Weaknesses:

- Creation of custom building blocks is only allowed with professional license, and is a cumbersome task in any event
• The use of strings is not allowed as all variables are converted into numerical data

• Granularity of control is limited

• Modeling language has learning curve

### 3.1.2 Witness

Witness, produced by the Lanner Group, is a discrete event simulator that is often used by automotive and communications firms for manufacturing planning and resource utilization studies. It uses a simple building block design process and has built in elements for discrete manufacturing, call centers, health and finance.

Cost: $5,000-$25,000

**Strengths:**

• Powerful customization tools

• Importing features from a range of external data sources including databases, spreadsheets, CAD, etc.

• Good visualization tools for 3D/VR views of models

**Weaknesses:**

• Animation tools are sub-par

**Cost**

### 3.1.3 ModSim

ModSim is essentially an object oriented simulation layer on top of C++. ModSim compiles to C++ code, but very useful customizations allow the creation of models of complex situations, or very detailed technical simulations.

Cost: $500-$2,000

**Strengths:**
• Fully object oriented language

• A great deal of statistical support

• Used by the Department of Defense - lots of previous research to draw upon

Weaknesses:

• No longer available

3.2 Supply Chain Management Solutions

There are a number of additional supply chain management suites available from companies such as Baan, J.D. Edwards, SAP, i2 Technologies and Manugistics. Such enterprise level all-in-one packages are incredibly powerful programs that integrate well with other enterprise applications from the same provider for accounting, business planning and enterprise resource planning (ERP) functions. Order management, manufacturing execution, warehouse planning and transportation management is integrated into one quite of programs. Manugistics describes supply chain management: “Effective supply chain management enables you to make informed decisions along the entire supply chain, from acquiring raw materials to manufacturing products to distributing finished goods to the consumer.”[45] While these applications can greatly aid in this respect, they require enormous investments in implementation, management and training to realize such benefits.

3.2.1 i2 TradeMatrix

i2 Technologies is the leading supply chain management solutions provider. As such, their software has become a model for competitors to achieve. Over 700 customers have used i2 solutions to plan the design, procurement, production and distribution activities of more than $800 billion of purchased goods. TradeMatrix is a software platform that supports supply chain functions for web enabled companies and enables integration into back-end ERP systems. There are two major components of this
system that are applicable to the extent of this research - Fulfill Solution and Factory Planner.

Fulfill Solution is a comprehensive supply chain management system designed to handle three models of activity:

- **Build-to-stock and ship-to-stock** - Goods are built in large production runs and put into inventory, which is then restocked at the retailer’s shelf within the store.

- **Build-to stock and ship-to-order** - Analogous to the home appliance industry, goods are assigned to a customer as they leave the manufacturing facility and shipped directly to the customer, either by the manufacturer or the retailer.

- **Build-to-order and ship-to-order** - Products are custom built to customer specifications and shipped directly. An example of this is Dell’s custom configured computer sales.

In each model, FulFill Solution aids in the demand forecasting and supply planning, marketplace order enabling, execution (pick, pack, ship and deliver) and monitoring and control.

Factory Planner is a constraint-based planning toll that optimizes the performance of a manufacturing operation. It manages dynamic material and capacity constraints and develops feasible operating plans for multiple plants and production lines to meet the customer’s objectives.

Unlike its competitors in the SCM sector, i2 was founded upon SCM software and has been adding additional features, rather than vice versa.

### 3.2.2 Baan

Baan has traditionally been a supplier of ERP software, but has moved into a comprehensive solutions package containing supply chain management (SCM) and customer relationship Management (CRM) components in the past 3 years. Its most recent software platform, iBaan is designed for collaboration between suppliers and customers.
iBaan TransPro, a component of iBaan, lets one manage complex transportation plans with intelligent planning tools. Interactive map-based graphics allow users to visualize transportation plans, making it easy to understand and change a plan and illustrate costly orders and underutilized resources. TransPro features a wide variety of rating data structures and a rating engine for costing of carrier choices.

3.2.3 SAP

SAP a leader in providing collaborative business solutions for all types of industries and markets. It’s latest e-business platform, mySAP is designed to be a collaborative tool for suppliers, market makers and manufacturers.

SAP Transportation Management Solution offers a number of features important for logistics planning and execution including supply chain monitoring, demand planning supply network planning, production planning and detailed scheduling, global transportation planning, vehicle scheduling, and fleet and warehouse management.

3.2.4 Commercial SCM Market

In general, the commercial supply chain management solutions on the market are overpowered for the purposes of this research and for the typical online retailer. Except in the case of i2 and Manugistics, SCM functionality has been added more as a second thought than as a tier one solution. Thus, a best-of-breed solution from one of these suppliers is very high, often in the millions. Furthermore, such enterprise level software must also be maintained on expensive corporate servers and require a team of IT professionals and consultants for support. These solutions are also designed primarily to optimize existing networks and to perform demand and factory planning rather than full scale scenario design. In conclusion, with licensing prices ranging from $5,000-$30,000/seat and total implementation costs upwards of $5 million in addition to maintenance costs and fees, these applications are poorly suited for more generalized simulation and scenario planning.
Cost: $250,000-$10 million

Strengths:

- Complete package of tools in one software suite
- Full support in the form of consultant programmers

Weaknesses:

- \textit{COST}
- Lack of focus on simulation

3.3 Delivery Planning Software

Transportation routing and scheduling software can handle sequencing and timing vehicle stops, route determination, preparation of shipping documents, vehicle availability and scheduling a host of other tasks. Routing software takes actual delivery routes data combined with mapping information and fleet characteristics to optimize routes for speed and/or cost. Routing software can shave expenses from a wide-range of areas including increased utilization and fleet reduction, increased productivity, reduction of personnel and increased customer service. On the whole, these specialized programs are not designed for simulating the wide-scale effects of changing customer demand or additional warehouse locations, rather they are used on a day-to-day basis for routing operations.

3.3.1 ArcLogistics

ArcLogistics Route software is a desktop solution for complex routing and scheduling problems. Dynamic routes and schedules can be created to minimize costs and improve customer service. The creators, ESRI are a major player in geographic information systems (GIS) software services. ArcLogistics can easily be integrated into ESRI’s other modules including mapping and area-based customer profiling.
Cost: $8,995

Strengths:

- Easy integration with other software modules
- Accurate mapping and routing data used, not just estimates

Weaknesses:

- Focus on only vehicle routing

3.3.2 TerritoryPlanner

Territory Planner is a software application developed by the United Parcel Service’s (UPS) Logistics Group. A powerful suite of tools allows for top down management of regional operations. Routing results, management cost and performance reports as well as driver utilization can all be managed. It can be used in combination with any of UPS’s other packages, such as Roadnet 5000, Fleetloader, Mobilecast and eRoadnet for added fleet management and route planning functionality.

Cost: $76,000

Strengths:

- Good customer support from experienced logistics provider.
- Management reports give insight into driver utilization and marginal delivery costs.

Weaknesses:

- Cost

- Software is designed primarily for management of existing infrastructure and must be adopted for use for simulating proposed changes.
- Does not include inventory management functions
3.4 Previous Logistical Simulation Research

Previous attempts of simulation of a logistical processes have been either too broad or otherwise inappropriate for application to the particular problem of instant delivery.

3.4.1 Generalized Modeling Proof of Concept

In addition to the commercially available simulation applications, several institutions have developed their own multipurpose modeling package. Such packages can be as detailed as Princeton University CASTLE Laboratory’s Pilotview[65], or as broad as Eindhoven University of Technology’s Exspect, which attempts to solve the same problems as commercial modeling programs like Arena. However, to date, research towards applying such tools to logistical problems have been too broadly focused.

Exspect has been used to model logistical systems, but to date, it has only been as a demonstration of Exspect’s capabilities as a general purpose modeling tool with the capability of important domain specific (i.e. logistic, financial and medical systems)[93]. Both Simo, a business simulation environment, and MetaCASE[42], a domain specific modeling language, were applied towards a virtual plant delivery simulation. The disadvantages of the virtual plant simulation in particular were described by the researchers, “(These) are general tools to model organizational process. Models are less accurate in simulational sense, but they are more detailed and documentary. Our modeling strategy emphasizes the product model and limits actions to the procurement and big assembly level business actions...The software will actually serve as an estimation tool, not as a simulation tool.”[51]. System dynamics, a field developed by Jay Forrester at MIT in the 1950’s has been applied to large systems modeling with some benefit as well[58]. However, while system dynamics was generally found to be widely applicable to studying organizational dynamics, business processes, and environmental and ecological systems, Parunak concluded that agent based and discrete event modeling was more suitable to supply chain simulation.
3.4.2 Application Specific Modeling

There has been some research in the area of creating application specific simulations towards the design of logistics networks. Ford Motor Company uses simulation as a "prototype" tool for production systems in order to understand the interactions among various system components[2]. This internal tool was also used to reduce inventory throughout the supply chain through the simulation of the Just-in-time manufacturing techniques[90]. General Motors has followed suit in designing its own agent based simulation system called Agile Manufacturing Information system (AMIS). This tool has been used to manage manufacturing process at various GM plants[20].

PricewaterhouseCoopers has done a great deal of consulting work for clients in applying a variety of modeling techniques to logistics strategies[21]. They have used Arena in simulating a Railway-Mine-Port operation[56] and in designing a logistic network simulator for a leading European manufacturer[55]. PwC has also written their own custom simulation of a cement delivery network. In each case, a team of consultants designed the simulator for the express purposes of the client.

3.4.3 Human-in-the-Loop Simulations

Another form of simulation involves human-in-the-loop interaction. Such designs require a human to operate the experiment and function in some capacity to make key decisions. These designs can be more realistic since many operating choices are made by employees rather than optimizing software. Such a setup has been employed in the simulation of rail dispatcher operations[4] and traffic management[34].

The major disadvantage of human-in-the-loop interaction is repeatability and efficiency. Since human operators can introduce random errors and miscalculations, experimental results are hard to guarantee. Repeated trials may lead to different conclusions. The inability to achieve true repeatability has hampered human-in-the-loop simulation as a modeling tool. Also, a human-in-the-loop can only be run at a reasonable fraction of real-time operations. Thus, to simulate the effects of a change to a system over a week, an operator may have to participate in the experiment.
over the course of a few days, while a fully autonomous system could complete a simulation run in a matter of minutes. However, in Kozmo’s situation, since delivery decisions are made by a dispatcher and not by the KIDS software platform, a human-in-the-loop setup could be desirable.

3.4.4 IDISE Design

This thesis has attempted to create a simulation of the logistics particular to the instant delivery business model. In departure from more generalized modeling tools, the simulation software has been designed from the ground up to emulate the conditions of an actual distribution network. However, despite the potential greater accuracy afforded by human-in-the-loop simulation, the simulator designed runs autonomously. This allows more accurate scenario testing. In addition, the improved performance times by orders of magnitude enables a much larger number of simulations to be run over the time available. Furthermore, since the dispatching of deliveries is an experience and intuition-driven position, the lack of access to such an expert forced the simulation to internalize all logistical decisions. The next chapter will describe the actual simulator design in greater detail.
Chapter 4

Instant Delivery Simulation

The Instant Delivery Simulation Environment (IDISE) is the custom simulation which has been designed to meet the desired attributes. It operates on a pull-based model. Orders are generated based on a random distribution, which can either be assigned vehicles for immediate delivery or deferred for future assignment. Upon dispatch of the assigned vehicles, each vehicle must first pick up the products from the closest warehouse, at which point the inventory is transferred to the vehicle. Once the vehicle makes the delivery at the specified customer at the calculated time, the total delivery time is calculated and recorded. When all deliveries in a route are completed, the vehicle is deemed "available" and can be reassigned for further deliveries. When the simulation ends, all vital statistics for the simulation run are reported.

4.1 Program Structure

The simulator is based on a hybrid event-driven model. Typically, in a pure event-driven simulation, the state of the system can only change due to an event occurrence. IDISE uses not only events to change the state, but also allows for methods to change the state at the instant of a given event. For example, IDISE allows for the availability of vehicles to be checked while processing event, rather than explicitly making a change in the availability a formal event. There are two events that are processed by the system, orders and deliveries, and both are held in a structure call an event
Figure 4-1: IDISE Flow Chart
4.1.1 Orders

Orders have an associated time, location, and order list. The time of the order is used as a unique identifier. It is calculated as the number of milliseconds that have passed since 00:00:00 GMT on January 1st, 1970. While this does imply that no millisecond in time can contain more than one event, the granularity is fine enough to accurately model the number of events that occur. The location is given in XY-coordinates in miles from a specified origin. The order list is a list of the quantities ordered of each product available. If no products of a given type were placed in an order, it is recorded in the list as a zero.

4.1.2 Deliveries

Deliveries have time, vehicle ID, operand ID, mode, and transfer list properties. The time field is identical to the time structure used for orders. Vehicle ID's attribute the delivery with a specific vehicle making the delivery. The transfer list is very similar to the order list field; it contains a list of goods to be transferred during the delivery event. The mode varies by delivery type. There are three modes of delivery specified in the current model:

Mode 0: Vehicle ⇒ Customer - Deliveries are made to the end user to complete the order fulfillment process

Mode 1: Warehouse ⇒ Vehicle - Goods are loaded from a warehouse onto the vehicle before a delivery route
Mode 2: Vehicle ⇒ Warehouse - Inventory is transferred from the vehicle to restock a warehouse.

The operand ID field identifies the opposing party in delivery event. In mode 0, the operand ID is the time identifier of the customer order. In modes 1 & 2, the operand field contains the identification number of the warehouse.

### 4.2 Event Queue

The event queue contains the state of the simulation at any point in time, by listing the only two events defined - orders and deliveries. Each event is listed in the queue in chronological order. Starting from the first event, the simulation increments the index pointer as each event "passes" in time. In this manner, IDISE steps through the queue handling each event until the queue is empty at which point the simulation ends. Some events must be kept in the queue for future reference, while others, as soon as they are unnecessary, are removed from the queue. Figure 4-4 shows an example of an event queue containing three orders and two deliveries.
4.3 Setup

IDISE is initialized by reading in 3 dataset files, *customer.dat*, *vehicles.dat*, and *warehouse.dat* containing respectively the characteristics of the customer districts, vehicles and infrastructure. Each file is be modified by the use of a helper setup program which can accept human input in the modification of any of the above attributes.

The customer dataset contains information regarding the profile of a typical consumer. Within the dataset, the entire service area is broken into districts, which is designated by a geographical center and a width and height. Each district has ordering characteristics. They have demand curves that describe the density of orders over time (i.e. 80 orders/hour at 8 AM on Monday vs. 240 orders/hour at 9 PM on Saturday). Each district may also have order different preferences, so there is additional information regarding product specific demand for each district.

![Figure 4-5: Customer Districts](image)

The vehicle dataset contains information regarding the vehicle fleet. Such information includes the hours that each driver works, and thus the total number of drivers available at any time, the cost of running each vehicle, vehicle capacities, and the average speed a vehicle can travel by time of day (a car might travel 20 miles/hour at midnight, but may only be able to average 5 miles/hour during rush hour).  

48
The warehouse dataset contains information regarding the infrastructure available to support operations. The location, capacity and inventory of each warehouse is stored within this file.

4.4 Initialization

Initialization begins by reading in the prepared dataset files. The system environment is then set using this information. The program operator is asked to set starting and ending dates/times for the simulation to run between, thus setting simulation length. An empty event queue is then created for storage of simulated events. The event queue is initially populated by generating a list of orders that must be handled over the duration of the entire run. The interarrival times of each order is modeled using an exponential process random number generator. Thus at each sampling of the random number, an order is created. Since each customer district has an associated product demand as well (i.e., the average number of videos or pints of Ben & Jerry’s Ice Cream in a single order), a Poisson process is then used to sample the exact list of items in the order. Once the completed order has been generated, it is added to the queue and the simulator samples the interarrival time of the next order until the time of the next order is after the simulation end time. At that point, the order generation process is completed, and the initialization is completed. As described earlier, the simulator proceeds to advance through the event queue handling orders and/or deliveries and inserting more events as necessary.

4.5 Order Event Handling

As each order "occurs", it is passed to the automated "operator". The operator can either choose to handle the event by assigning it to a delivery route, or defer

---

1 Since the Poisson sampling can be zero for any given item, it is possible for an order to be generated, yet completely devoid of any actual product order. Thus, the simulator checks to ensure that the sampled order also demands products. If one is created with no products, it is simply regenerated. This does shift out the average number of products in each order, but by such a negligible amount, it is reasonable to handle it in such a manner.
handling to a future delivery run. Thus, an order can be held until more orders are compiled together to make a delivery, thereby increasing the efficiency of the delivery vehicles. The operator is first queried regarding whether or not a delivery run should be assigned given the current orders outstanding. If an affirmative response is received, the operator is then called upon to schedule the deliveries and assign each order a vehicle. Once the operator has handled an order by assigning it a delivery that fulfills the entire order list, it is removed from the queue. If the order is only partially fulfilled (a vehicle only delivers a subset of the items ordered) the order's order list is updated and the order is kept in the queue for later handling. Each order is handled in this manner until the event queue is empty of orders.

As each vehicle is assigned to an order, a delivery event is created and inserted into the event queue by the operator. The time required for the delivery (travel and handling time) is calculated using the average speed of the vehicle for the given time of day and is added to the current time to supply the time index of the delivery event. A corresponding "delivery" event is also scheduled to occur from a warehouse to the vehicle such that a vehicle will have the products on hand to fulfill an order once they reach the destination. Since a vehicle may not be located at a warehouse upon assignment, the travel and loading time must also be calculated and added to the entire delivery route.

4.5.1 Operator Automation

The operator function, normally completed by a human dispatcher, has been automated for purposes of consistency and testing efficiency, as described in Chapter 3. The operator takes in the current state of the system and determines if a delivery run should be made, and if so, which orders to assign to that run. The system uses a number of simple rules to apply to make this decision, which attempts to emulate the type of decision that a human dispatcher might use. ² Each parameter of these rules can be changed; the rules themselves can be deleted or new ones added. The

²Each Kozmo dispatcher was given great leeway in determining his/her own dispatch policy and varied from one shift or distribution center to the next.
operator deems a delivery run to be necessary in one of the following cases:

- An order has been waiting for over 20 minutes and there is a vehicle available to make the delivery.
- An order has been waiting for over 7 minutes and there are at least 3 vehicles available.
- An order has four or more orders awaiting delivery within a radius of 0.7 miles.

In each situation, the operator is trying to make the most efficient use of the available fleet while also keeping outlying delivery times to a minimum. If a delivery run is deemed necessary, the operator then proceeds to assign orders to that run. The operator identifies all orders within 0.7 miles of the order that initiated the delivery run, and assigns them to the same run.

4.6 Delivery Event Handling

Delivery events are handled automatically as they “occur” and cannot be deferred like orders. As each delivery is handled, the state of the system is changed to reflect the flow of products as indicated by the delivery event. The attributes that are changed include inventory levels of the parties involved, the time spent making deliveries for the vehicle, and the fulfillment status of the end customer. There are two categories a delivery can fall under, non-customer or customer deliveries. Non-customer deliveries include vehicle loading, and warehouse restocking. Such deliveries do not accrue to the vehicle’s “delivery” count, as these are not deliveries in the formal sense. Nor is the time spent making such deliveries considered when calculating a vehicle’s utilization rate. Customer deliveries are deliveries made directly to an order location. Each customer delivery that is made is counted towards the total number of deliveries made by the specific vehicle. If the delivery is the last delivery to be made to fulfill the order, the total time of order fulfillment is recorded at this time. Once all changes to the system stemming from the delivery have been made, the event is considered
handled and is removed from the event queue. The queue index is then advanced and another event is requested for processing.

4.7 Termination and Reporting

The simulation ends upon reaching the end of the event queue with no events left for handling. The status of each vehicle is returned to “unavailable” and the drivers in effect are “punched-out” for purposes of cost accounting. Then the vital statistics of the simulation are calculated and reported. The important results that are calculated by the simulation are:

- Average Delivery Time - Average time a customer waits from placing the order to receiving the last item in their order list.
- Maximum Delivery Time - Maximum time any customer waited for the fulfillment of his/her order.
- Number of Deliveries Made - Total number of customer deliveries made
- Cost of Delivery Operations - Cost of vehicles, drivers and warehouse staff
- Average Order Cost - Cost of delivery operations/Number of orders fulfilled
- Utilization Rate - Percentage of time working spent by vehicle on delivery run
- Number of Unused Vehicles - Number of vehicles that were never assigned to a delivery run
- Average Number of Deliveries Made per Run - Number of deliveries made/Number of delivery runs

Delivery time and cost information is used as a measure of performance of the system. The end result of research is to improve customer service through the reduction of delivery times, or lower expenses through the reduction of delivery costs. Utilization data, including the average number of deliveries made during each run, are used as a
metric of operator performance. If utilization rates are notably low, or any vehicles go unused, blame can be placed on the operator for failing to efficiently distribute available resources.

Each of these simulation results are printed to the screen for reference. See Figure 4-6 for an example of the result of a simulation run. Using these values, the simulator can be used to test various situations. For each situation, the operator is refined until a reasonable rate of utilization is achieved, since different operator rules may be optimal for different scenarios. Operator optimization then allows the results of changes to the customer makeup, vehicle fleet, or infrastructure can be analyzed.

4.8 Comparison to Alternatives

IDISE has been designed from a clean slate to best simulate the logistics network as deployed by instant delivery companies such as Kozmo. In comparison to simulation tools such as Arena and Witness, IDISE allows in-depth analysis of different scenarios, and vehicle specific modeling, versus high-level business process viewing. Is also requires no previous programming expertise to manipulate and run.
IDISE also offers easier scenario manipulation than commercial supply chain management solutions. While SCM platforms are designed primarily for operational support - carrier selection, factory production planning, supplier communication, etc. - this simulator is specifically designed to present results of different operating environments on performance. It is also much free of restrictive licenses, and can be run on any Microsoft Windows-based PC, vs. enterprise servers. It provides the elements essential to the problem at hand, without extra overhead and unnecessary features.

The main advantages of this custom-designed simulator are cost, freedom from commercial licenses and royalties, flexibility, and the ability to make endless enhancements particularly suited to the instant delivery market. As shown in cases with GM, Ford and others, a domain-specific simulator can be helpful in analyzing logistics issues. IDISE captures these characteristics in its ease of use, applicability to the problem focus, and ability to be adapted to any instant delivery environment.
Chapter 5

Simulation Results

The simulator developed was applied to Kozmo’s Boston operations to analyze its delivery network and identify inefficiencies, potential performance enhancements and gather insight into the business model as a whole.

5.1 Baseline Environment

The baseline environment was built to emulate the Boston area as closely as possible. The customer information was estimated from aggregate daily order levels observed by Kozmo, and a list of zip codes within the service area. Based on this data, along with qualitative statements from the Boston Director of Operations regarding customer density, the city of Boston was divided into a set of 10 rectangular customer districts, each with it’s own demand curve, and of course center location and size (See Figure 5-1).

The vehicle fleet was built out given a weekly time schedule of drivers employed at Kozmo-Boston. While the fleet size is seasonal, the schedule of an average spring week was chosen for modeling purposes. In all, an average of 20 drivers are used at any given time, ranging from 8 during morning hours on Monday, to 29 on Saturday evenings. Each driver has a capacity of 6 orders, and drives at various speeds throughout the day, depending on traffic conditions.

The Kozmo warehouse, located in Allston, was also placed in the environment to
Figure 5-1: Boston Service Area

represent its actual position relative to the service area. The only simplification made as to the infrastructure available was that for the purposes of this work, warehouse inventory was assumed to be infinite.

Using this baseline environment, the operator was then optimized to give the best view of the system. The results for a simulation of March 5, 2001, a Monday, are shown in Figure 5-2.

Kozmo was unwilling to give actual performance data regarding delivery times, costs, etc. However these results do seem empirically accurate. Less than 1% of all deliveries took longer than 70 minutes to deliver, supporting Kozmo’s attempts to fulfill all orders within an hour. Utilization rate is a reasonable 71%. This baseline test gives support to the simulation’s reliability as a model of the system as a whole and supplies a control case to which results from changes in the environment can be compared. Three scenarios were tested: adding an additional warehouse, expanding
the vehicle fleet, and distributing the customer demand evenly across the entire service area. The results from these modifications are shown in Table 5.1.

### 5.1.1 Additional Warehouses

Kozmo’s service area is spread across a 9 square mile region, which is not centered about the current warehouse location. Distribution centers are “located primarily in low-rent areas with access to key thoroughfares.”[38] The Boston location is no excep-

<table>
<thead>
<tr>
<th>Type</th>
<th>Avg. Del. Time</th>
<th>Max. Del. Time</th>
<th>Cost/Delivery</th>
<th>Util. Rate</th>
</tr>
</thead>
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<td>$10.08</td>
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<td>$10.78</td>
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</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>Uniform Dist.</td>
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<td>77.62</td>
<td>$10.93</td>
<td>69%</td>
</tr>
<tr>
<td>% Change</td>
<td>13.1%</td>
<td>-1.9%</td>
<td>8.4%</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.1: Baseline Simulation Results w/ Adjustments
tion, but is obviously not optimally placed in terms of average distance to customers, since most of the customers are further east. One potential performance enhancement would be to obtain an additional distribution center closer to downtown Boston and East Cambridge, where travel time will be greatly reduced during daytime and afternoon hours, when hour density is highest from these outlying districts.

The baseline environment contains one warehouse at location (0.6, 1.2). To reproduce the effects of adding another distribution center in Downtown Boston, the infrastructure dataset was modified to include a second warehouse at location (2.5, 1.6) (See Figure 5-3). The hope was that a second location would decrease the average distance from a distribution center to a random customer. The lower distance would decrease travel and fulfillment time, and thus increase performance.

While the maximum delivery time decreased by 17 minutes, the average delivery time only decreased by 7.6%, a mere 2.5 minutes in absolute terms. Thus, despite the addition of a second distribution center, the overall customer service does not improve due to the smaller driving distances. The greatest advantage arises in cost savings. Due to increased utilization of vehicles for delivery purposes, rather than traveling to and from the warehouse for additional products.
5.1.2 In-Vehicle Inventory

Nearly 30% of the time spent by traveling vehicles is on the return trip to the warehouse to pick up products for a delivery run. Larger vehicles such as vans could hold their own stock of inventory of the most commonly ordered products. If an order contains only those products, the return warehouse trip could be avoided altogether and the vehicle could proceed directly to the customer and fulfill the order from it available stock. Vehicles that also act as mini-warehouses in this manner could potentially decrease average delivery times, while also increasing utilization, thereby reducing the size of the vehicle fleet needed to service orders. However, fleet vehicles must also have enough capacity to store many more products; the costs of operating a van is much greater than those of a compact car.

The environment was adjusted to reflect these changes. Since videos, snacks, drinks and ice cream comprised the bulk of the orders received by Kozmo, it can be assumed that a van can hold a reasonable subset of such available products. Thus, 30% of all orders could be served by the van alone, and would not require an return trip to the warehouse to pickup products. Vehicle costs were also assumed to increase by 15% due to the increased costs of the fleet. While average delivery times were improved, the maximum delivery time worsened due to the increased likelihood of an order being received by the dispatcher with no vehicles available to fulfill it. However, overall, costs only increased 6.9% while average delivery time decreased by 10.7%, suggesting that this could be an effective way to improve performance of current delivery networks at low cost. In reality, the breadth of products could be a limiting factor in a single vehicle's ability to provide all of the goods for an order. Yet, under circumstances of low order levels and relatively limited product selection, such a method could enhance the efficiency of instant delivery networks.

5.1.3 Additional Vehicles

The number of vehicles available for delivery directly affects the operator’s dispatching policy. If Kozmo had more drivers on staff, a dispatcher could schedule delivery runs
with much greater frequency and thus lower delivery times. The baseline simulation uses an average of 20 drivers at any given time. The environment was adjusted to have 25% more drivers, or an average of 25 drivers.

The benefit of additional vehicles is even greater than that of an extra distribution center. Delivery times decrease significantly, at the expense of utilization; baseline delivery runs carry an average of 2.48 deliveries, while with less efficient dispatching policies, vehicles average only 2.08 deliveries each time it leaves the warehouse. Since more drivers are kept on staff, the marginal cost of delivery is 25% greater than baseline as well.

5.1.4 Customer Distribution

The baseline environment assumes a great deal of temporal correlation in order density. For instance, as described earlier, the majority of orders from the Downtown area are received during regular business hours, when professionals are placing order to be delivered to work, or business use Kozmo for catering purposes. During the evening, there is a shift in order density to the Allston/Brighton neighborhood, where heavy concentrations of college students depend on the service for meals and entertainment. This allows delivery runs to be scheduled to make more efficient use of available vehicles. A vehicle driving to a college dorm for instance, can handle up to 6 orders at a time. However, in cities other than Boston, where the downtown area is not relegated to a peninsular location, and order distribution is more uniform throughout the service area, performance can differ significantly. A uniform spatial demand was modeled into the environment to examine the potential results.

The lack of customer “clumping” forces the operator to adopt a less efficient dispatching policy. With fewer orders able to be serviced during a single delivery run, average delivery times increase by over 16%. The maximum delivery is not affected, since the baseline simulation also generated orders from outlying areas. However, in the case of uniform distribution, more orders arrive from those areas than is typical, thus pushing up the delivery times that other users experience.
5.1.5 Baseline Summary

The baseline simulation was optimized for efficiency in the given environment. However, there are modifications that can be made to the underlying infrastructure that can improve the productivity of the system. Most notably, prestoring inventory in vehicles to satisfy small orders, allows vehicles to make more deliveries in a single run, thereby lowering the average waiting time, at the expense of a few customers which must wait longer due to increased maximum delivery times. Additional warehouses, attractive on the surface, prove to be very inefficient at a low rate of utilization, and only serve to improve the performance of deliveries to a minority of customers living along the outskirts of the service area. The uninvolved use of additional vehicles seems an easy method to increase performance, if not efficiency. Yet, it simply highlights the inability of the system to scale in this manner. Vehicles are forced to become less efficient, delivering fewer orders in each run, thereby increasing the cost per delivery, with limited effectiveness at even decreasing delivery times. The importance of customer density also cannot be underscored. Holding system-wide demand constant, a shift in customer usage from one that exhibits spatial locality to one that is uniformly distributed can decrease fulfillment performance by 13% and increase costs by nearly 10%.

Most of the modifications simulated show that the current system is operating under capacity, and that further development of the distribution chain through the addition of warehouses and vehicles is ineffective and wasteful. Furthermore, great attention should be paid not only to a given market’s demand for service, but the presence of local spikes in demand that can enhance the productivity of the logistic network.

5.2 Increased Demand

One of the precepts of home delivery models is that once a specific customer base threshold is reached, the marginal cost of additional customer is very low, thereby achieving great economies of scale. Before subsequently running out of business, al-
most all of the instant delivery companies in operation were engaged in expansionary
behavior, each intent on achieving the break-even level of patronage as soon as pos-
sible. In its initial public offering registration, Kozmo states, “The success of our
business depends on attracting and retaining a large number of customers. If we are
unable to do so, we will not be able to achieve profitability.”[38] If Kozmo could have
increased market acceptance and attracted a large number of users, would Kozmo
been able to capitalize on the ability of its delivery network to delivery goods at low
prices? The simulation environment was adjusted to reflect this potential change.

Demand was assumed to be twice the average level for any given day - the increased
demand situation generated 1,600 to 3,000 orders/day. The results from the standard
infrastructure along with adjustments are shown in Table 5.2. It is easily seen that
there are indeed economies of scale present in the distribution system. Not only are
delivery times beneficially impacted since the operator does not have to wait as long
to fill a delivery run up to capacity to make efficient use of the vehicles. The number
of vehicles also increases by less than 100%, as vehicles can be sent out with greater
numbers of orders in a single delivery run. Warehouse costs are also distributed
amongst a larger order base. Thus, there is an overall decrease in the marginal cost
of delivery at this higher rate of service.

The advantages of each of the proposed infrastructure modifications differ in this
new scenario. The usefulness of an additional warehouse is much greater as there
are more orders that are relatively far away from the single distribution center. The
cost economical impact of a second warehouse is also lessened by the greater number
of deliveries over which to amortize the fixed facility cost. The forward storage of
inventory in vehicles also loses effectiveness since a greater vehicle fleet of expensive
vans is required. In addition, the greater customer demand has increased the average
number of orders carried in a single delivery run, as the benefit of saving the return
trip for the fulfillment of one additional order is mitigated. Additional vehicles still
provide improved performance, but again, at the cost of maintenance of a larger
standing fleet. The impact of geographical distribution is moderated by the increased
overall density, thereby reducing the “penalty” in serving distant locations.
<table>
<thead>
<tr>
<th>Type</th>
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<th>Max. Del. Time</th>
<th>Cost/Delivery</th>
<th>Util. Rate</th>
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</thead>
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</tbody>
</table>

Table 5.2: Increased Customer Base Simulation Results w/ Adjustments

Increased customer demand greatly affects the efficiency of the delivery network. Distribution centers and vehicles are used at greater levels of utilization, allowing for cost savings. The change in demand also forces a shift in logistics strategy, for if a substantial increase in the customer base can be produced, the dynamics of the system shift greatly in favor of the modifications. The use of vehicles for forward storage of inventory loses its advantage as an increasing number of deliveries outstrip a given vehicle’s available stock. Under increased utilization, additional warehouses can now lead to gains in efficiency as more orders arrive from locations far away from existing distribution centers, and a larger customer base can bear the financial burden of the facility. Additional vehicles however, still do not improve the delivery network; expansion of other infrastructure enablers are better suited for improved delivery performance. Furthermore, the presence of greater demand decreases the impact of widespread spatial arrangement of customers, possibly allowing profitable operations in even uniform service areas, while lower overall demand would have made such a distribution uneconomical.

5.3 Analysis

IDISE can be used to achieve very similar results to those observed by actual instant delivery companies. When run under an environment modeled after current operating conditions, the high cost of home delivery can be examined. Simulation
results do indicate that the logistics networks used by companies such as Kozmo and Urbanfetch were operating relatively efficiently. Modifications such as increasing the number of available distribution centers and vehicles were unable to significantly improve performance without also increasing cost. Forward storage of inventory in delivery vehicles could increase efficiency, but would require restructuring of the existing vehicle fleet as well as extend driver responsibility, which may require extended training. Once a large customer base is developed, the capacity of distribution centers can be put to better use and the cost per delivery drops significantly. The effects of changes in infrastructure also improve to a large extent.

The simulator has indicated the criticality for companies operating in this domain to build up a large customer base as soon as possible, while also highlighting the dangers of entering markets that may be either too small to achieve such levels or geographically widespread that may impair performance in the short term. Overall, the simulator has proved its value and ability in modeling the environment and projecting the effects of different changes in both the operating scenario and underlying infrastructure.
Chapter 6

Future Work

While the simulator developed here has been able to provide valuable insight into the issues faced in planning logistics networks, there are a few areas that could be further developed and explored. Future research in these areas would be of great benefit to the simulator as well as the rapid delivery industry as a whole.

6.1 Automatic Optimization

Optimization of the operator policies and vehicle fleet sizes were completed heuristically. The use of goal seeking algorithms could have led to more practical results. Since the improvement would likely have an impact of a few percentage points, it wasn’t deemed relevant for the current research focus. However, IDISE is to be used in a corporate setting, it should be able to guarantee the optimality of results. There are a number of parameters that can be controlled to adjust for the best possible performance. Operator dispatch rules such as waiting 7 minutes before making a delivery run, and vehicle working hours should be dynamically controlled to provide optimal results. Future work on this simulator will hopefully incorporate this feature.
6.2 Dynamic Demand

Customer demand is assumed to be constant from week to week. In reality, customer demand not only fluctuates seasonally, but is also heavily dependent on expected delivery times. The system should exhibit a certain level of feedback; if demand rises, delivery times will also increase due to either undercapacity of the delivery fleet, or sub-optimal dispatch policies. Increased delivery times would place downward pressure on customer demand as the utility of the instant delivery service falls. A better model of customer demand and density could be developed for use in building the event queue. The current event driven design might need to be discarded, instead using a discrete time simulation or system dynamics approach to be able to model such dynamic behavior.

6.3 Inventory Modeling

One of the simplifications made in building the simulator was to assume that warehouses had an infinite inventory of goods. This is of course not the case. Distribution centers, especially ones as small those employed by Kozmo, frequently run out of popular products and the latest releases of rental videos. The use of in-vehicle inventory also made certain assumptions regarding a single vehicle’s ability to hold enough inventory on hand to satisfy a subset of the total orders received. If inventory is more explicitly modeled, these concerns would disappear. A greater level of complexity would be involved in the incorporation of inventory modeling. The carrying costs of inventory could be included as an additional cost of service and fulfillment. Spoilage and shrinkage characteristics would require implementation. Furthermore, customer demand would require modifications; customer profiles must be able to determine if a warehouse has run out of vanilla ice cream if the it could be substituted with a different flavor or if the purchase would be cancelled altogether. Despite the effort required in modeling inventory at a fine level of granularity, its usage would allow for more accurate simulation results.
6.4 Dispatcher AI

The simulator has not only provided results of several modifications to the infrastructure but has also highlighted the importance of dispatcher policies in the efficiency of the system in general. The instant delivery companies did not use a complex dispatching system; rather, it was built on dispatcher experience. While this is a simple method for easily predictable customer behavior, the system does exhibit unintuitive properties. For instance, delaying orders by a few minutes can improve average delivery times, which does not seem logical on the surface. Only upon analysis does one realize that by delaying a delivery run, more orders can be fulfilled in that delayed run. More customers experience a short delivery time, than if a delivery had been dispatched immediately upon receipt of the first order, leaving the remaining orders waiting for available vehicles. While not a modification to be applied to IDISE, the development of an artificial intelligence dispatcher to be used in practice could greatly improve the productivity of existing logistics networks.
Chapter 7

Conclusion

The focus of this thesis was to design and implement a simulator that could realistically emulate the behavior of logistics chains employed by instant delivery companies. IDISE is the result of this work. It was effectively used to analyze delivery networks and propose changes that could increase performance. The simulator uses an event driven model to track incoming orders, deliveries in progress and record performance.

In an attempt to offer enhanced efficiency, modifications were simulated and shown to have varying results. While systems currently employed appear to be operating very efficiently, the use of in-vehicle inventory can allow for better performance at low cost. The simulator also highlighted the importance of reaching a high level of customer demand; delivery costs per order dropped significantly with increases in demand.

E-commerce companies have always used the term “economies of scale” when describing their business model and path to profitability. Nowhere is this more apropos in describing the home delivery sector. High upfront capital costs required in setting up a warehouse, building up a vehicle fleet and organizing the entire delivery chain must be distributed over a large number of customers to be successful. Companies such as UPS and FedEx have already achieved such level of operations in home delivery, but companies such as Kozmo and Urbanfetch were unable to reach a sustainable level of business.

The collapse of the instant delivery market has shone light upon the problems
faced with the business model. Millions of dollars of venture capital money have been lost trying to develop the customer base to the point of profitability. Kozmo and Urbanfetch were just the largest players in this failed space. Many similar concepts such as home grocery delivery are still in operation, but share the same quagmire of profitable home delivery under short time constraints. Such ventures are risking not just millions but billions of dollars on a larger yet riskier market. The research and simulator presented here will hopefully allow such companies to examine their delivery networks and even their fundamental business models.

Gerry Burdo, President and Chief Executive of Kozmo, commented on the company’s demise in April 2001:

Given more time and more hospitable market conditions, Kozmo would have succeeded in rounding the corner and would have continued to grow. However, some decisions made early in the company’s development, combined with current market conditions, prevented Kozmo from overcoming the challenges associated with conquering the last mile... I think Kozmo was unique and really was a lifestyle changing company and I think that others will try to duplicate what we began[82].

Instant delivery companies provided a much needed service to many busy customers. If they can only overcome the home delivery/customer level threshold problem, a highly successful and profitable business can be found. IDISE will be an instrumental tool in identifying the distribution methods that will succeed under various operating environments and project effects of evolution in the market and delivery networks.
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Appendix A

IDISE Users Manual

A.1 Overview

The IDISE simulator runs only on Microsoft Windows-based operating systems. For best performance, it is recommended that the computer running the simulation have at least 128 MB of RAM and a Pentium III processor. Running times for a simulation length of 24 hours is about 10 minutes on such machines. Computers with less computing power can run the program, but would suffer a performance hit.

IDISE was written using Java 1.1 in Microsoft Visual Studio, and requires a Java Virtual Machine (JVM) version 1.1 or later. The most recent JVM can be downloaded from http://java.sun.com.

The simulator operation is broken into two main components:

- SetupEnv - used to setup customer, infrastructure and vehicle fleet data files to be used during simulation
- IDISE - application that performs the actual simulation function

A.2 SetupEnv

SetupEnv is used to modify the simulation environment. The simulation environment contains descriptions of the customer districts, infrastructure and vehicle fleet.
SetupEnv can be run either by double-clicking on the SetupEnv icon from the desktop or running SetupEnv.exe from the command line. The program will then automatically check for previous versions of data files. If previous versions do not exist or the user elects to overwrite previous data, the user will be prompted to either input the new data, or use the default simulation environment. The default environment uses Kozmo-Boston operating parameters. If new data is chosen to be entered, SetupEnv proceeds to prompt for all necessary information to build the data files.

A.2.1 Customer.dat

To build the customer district data file, SetupEnv requires the following information:

- Number of districts in the service area - The entire service area is broken into rectangular districts (See Figure A-2). This must be an integer.

- Average number of orders placed per hour in each district - The data files contain information regarding a week’s worth of time-sensitive information. Thus, 168 (24 hours x 7 days/week) data points must be entered in for each district, since
each district can exhibit different demand curves. This can be either an integer or a decimal value.

- Number of products for sale - The total number of products offered for sale by the instant delivery company. This must be an integer.

- Average number of each product contained in a given order - The total number of a specific product sold, divided by the total number of orders accepted. For example, if 100 videos are ordered based on 50 specific orders, the average number of this product contained in a given order is 2. This can be either an integer or a decimal value.

- Cost of each product sold - The total dollar cost or of products is used to generate average order size information. This can be either an integer or a decimal value.

- Coordinates of each district center - The center of each district is assigned an
XY-coordinate system based on miles from an arbitrarily set origin. This can be either an integer or a decimal value.

- X-Width of each district - The distance from the center of each district to the leftmost and rightmost points of the customer district. This can be either an integer or a decimal value.

- Y-Width of each district - The distance from the center of each district to the topmost and bottommost points of the customer district. This can be either an integer or a decimal value.

**A.2.2 Infrastructure.dat**

- Number of warehouses - The total number of warehouses used to service customers. This must be an integer.

- Coordinate locations of each warehouse - The location of each warehouse in the XY-coordinate system used to place customer districts. This can be either an integer or a decimal value.

- Capacity of each warehouse - The total number of products that can be held be a warehouse. This must be an integer.

- Initial inventory of each warehouse - The initial contents of each warehouse. This must be an integer.

**A.2.3 Vehicle.dat**

- Number of vehicles in the fleet - The total number of vehicles used in the fleet. This must be an integer.

- Cost to run each vehicle - The hourly cost to run each vehicle. This can be either an integer or a decimal value.
- Speed of each vehicle for each hour of operation - The speed of each vehicle in miles per hour. Since speed varies throughout the day, for example, rush hour vs. late night, speed is required for each hour of the day for seven days a week for a total of 168 data points. This can be either an integer or a decimal value.

- Hours that the vehicle is available - The hours that a specific vehicle is available to make deliveries. For the 168 hours in a week, if a vehicle is unavailable, a 0 is recorded. If it is available, a 1 is recorded. This must be a boolean value (0 or 1).

A.2.4 Results

When all the data has been processed, SetupEnv will generate the three data files and write them to a "files/" subdirectory. If the subdirectory does not exist, SetupEnv will create it and automatically store the files there.

Figure A-3: IDISE Screen
A.3 IDISE Application

IDISE is the main simulator program. To run IDISE, either double-click on the icon from the desktop or run it from the command line by invoking IDISE.exe. It first reads in the environment files stored by SetupEnv from the “files/” directory.

The user is asked for the time period to simulate. This is derived from a beginning and ending date/time combination.

The date and time must be entered in the following formats:

- Date: $DD\ MM\ YYYY$ - with spaces separating each element
- Time: $HH\ MM$ - with space separating each element, with the hour being based on a 24-hour clock

Once the simulation time is defined, the simulator runs with out further assistance until completion at which point it outputs all relevant simulation information.