Electronic commerce logistics and the knapsack problem

Dissertation zur Erlangung des Grades eines Doktors der Wirtschaftswissenschaft

Eingereicht an der Fakultät für Wirtschaftswissenschaften der Universität Regensburg

Vorgelegt von: Li Zeng

Berichterstatter:

Prof. Dr. Andreas Otto

Prof. Dr. Hans-Gert Penzel

Tag der Disputation: 22.02.2022

Contents

1. Introduction

This dissertation focuses on two issues often discussed from the perspective of logistics and controlling, namely, e-commerce and the knapsack problem.

First of all, electronic commerce or e-commerce is nowadays one of the most current subjects in the realm of business. Almost every company, regardless of its industry segment and whether it is part of the old or new economy, has this topic on the agenda now.

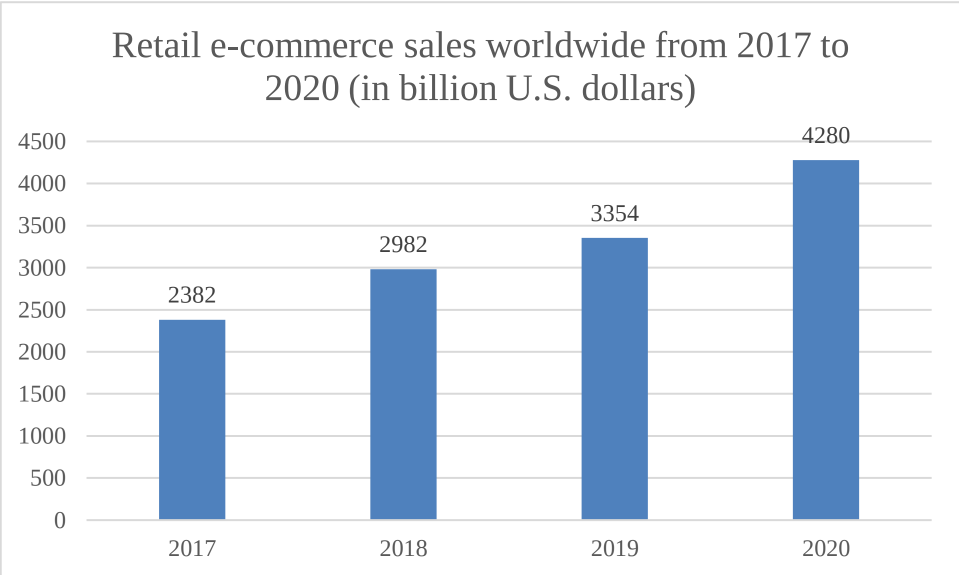


Figure 1: Retail e-commerce sales worldwide from 2017 to 2020 in billion U.S. dollars (Chevalier, 2021)

The rapid growth of e-commerce turnover is staggering. Online shopping has become very popular especially in Europe, the Americas and Asia, and in recent years, online retail has continued to grow significantly. Global retail e-commerce was worth over $2,382 billion in 2017 (Figure 1). By 2020, retail e-commerce sales had almost doubled to $4,280 billion. According to one global e-commerce report (Statista, 2021a), China had the highest e-commerce revenue at $1,343.5 billion in 2020 (United States: $537.7 billion, Europe: $460.5 billion) while the United Kingdom had the highest level of Internet penetration at 90.5% in 2019 (Germany: 85.9%, United States: 85.4%). By January 2021, the number of global Internet users had reached 4.66 billion, and continues to grow (Johnson, 2021).

The e-commerce market in Germany, meanwhile, has become increasingly competitive. In 2020, the turnover of the German online retail industry (B2C) was worth 72.8 billion euros and e-commerce in Germany achieved double-digit growth in 2020 with a growth rate of 23% (Statista, 2021b). The products most frequently sold were clothing, electronics and telecommunications. In the future, online sales of furniture, medicines and food are also predicted to rise. The top three online shops in Germany with the highest turnover are Amazon, OTTO und Zalando (ecommerceDB, 2021). The great competitive advantages of Amazon are its high level of name recognition and its comprehensive product range. Although Amazon is not very dependent on measures for customer satisfaction and customer loyalty, it still remains the sales leader in German e-commerce.

In 2020, the share of Internet users in Germany reached 88% (Koptyug, 2021). Considering that the current population of Germany is close to 83 million, such a high proportion of Internet users is decisive in itself. In terms of payment, although Germans prefer cash, traditional payment methods are now facing fierce competition from digital wallets (J.P. Morgan, 2019). Driven by the increase in the use of smartphone applications, digital wallets are expected to grow at 22.5% per year and will account for 28% of the market by 2021. The report "Launch of Regional Roundup 2021: Germany" (Lynn, 2021) shows that online payment is the most popular online payment method in Germany, such as PayPal and Amazon Pay (75%), invoice (64%), debit card (56%), credit card (40%), and prepaid cards and vouchers (30%). Mobile payments are also playing an increasingly important role. However, compared to other markets such as China or the USA, this segment lags far behind.

According to the "2020 E-commerce Payments Trends Report: China" from J.P. Morgan, China is by far the largest and fastest-growing e-commerce market in the world, with $1.7 trillion in sales in 2020 (J.P. Morgan, 2020). The growth rate of China's e-commerce market in 2019 is 17% and double-digit growth is expected to continue there until 2023. With huge market demand, China provides immense opportunities for ambitious e-commerce merchants. German companies can take advantage of e-commerce to reach a potentially enormous number of Chinese customers. On the other hand, new technologies, such as AI and 5G, are increasingly being developed and applied in the Chinese e-commerce market. The Chinese government regularly changes laws and regulations, involving logistics, payment, taxation, etc. Therefore, continuous observation and research on the Chinese market remain indispensable.

Since e-shops do not have brick-and-mortar storefronts to house inventory, they must rely on third parties to help store and ship products and services. As one of the most important factors in the success of e-commerce, logistics is getting more and more attention. The combination of efficient and secure logistics services and the global availability of the Internet determine the wide and convenient availability of e-commerce. With the optimization of logistics services, the application of new technologies and the deepening of globalization, the influence of e-commerce will further expand. Logistics and e-commerce influence and promote each other. The practical significance and market value of research and discussion on the relationship between them is also increasing.

The second issue of this dissertation is the knapsack problem, which is an optimization problem of combinatorics. The problem can be described thus: In a given group of items, each item has its own weight and price. Which items should be selected to maximize the total price, while at the same time not exceeding the total weight limit? The knapsack problem is widely used in the commercial field to assist decision making. Furthermore, these problems often appear in the fields of computational complexity theory, cryptography, applied mathematics and so on. Early works on knapsack problems date back to 1896 (Mathews, 1896), and the mathematician Tobias Dantzig (1884–1956) used the knapsack problem to pack the most valuable luggage without exceeding the weight limitation factor.

There are many ways to solve the knapsack problem, such as the dynamic programming and branch and bound approach. On this basis, many variants and hybridizations have been produced. However, in reality, it is not always easy for companies to find a specifically suitable method. In recent years, genetic algorithms have been increasingly recognized as just such a solution. Genetic algorithms are a stochastic and natural analogue optimization method, the functionality of which is inspired by the evolution of natural life. Genetic algorithms were first introduced in the early 1960s by John Holland from the University of Michigan (Holland, 1975). Around the same time, Ingo Rechenberg and Hans-Paul Schwefel founded the evolutionary strategies at the TU Berlin (Rechenberg, 1973; Schwefel, 1975), based on the idea that every life carries in its cells the characteristic genetic information that changes in the course of being inherited and passed on. According to Charles Darwin's evolutionary principle of "survival of the fittest," the organisms best adapted to the prevailing external environmental conditions will survive. These organisms thus have the largest number of offspring and most decisively influence the further development of their species. The offspring of a variety of living beings are always better adapted to their environment in the nature than were their progenitors. This phenomenon is often referred to as "natural selection." Based on nature, then, possible solutions for a specific problem are artificially evolved. The second part of this dissertation focuses on the use of such so-called genetic algorithms to solve the knapsack problem for businesses.

E-commerce and the knapsack problem are important research areas from the perspective of logistics and controlling. The application of the knapsack problem is also very extensive in the field of e-commerce. For instance, a generalized knapsack problem can be used to solve multi-unit combinatorial auctions (Kelly, 2005). In a combinatorial auction, participants can place bids on combinations of multiple discrete items. Due to their immediacy and convenience, auctions are widely used in e-commerce. In order to increase the benefit of enterprise, based on knapsack optimization, Gao (2012) improved the personalized recommender system, which is one of the most important research objects in e-commerce.

1.1. Dissertation structure

The research behind this dissertation is divided into two parts, each of which refers to a specific issue covered by two articles. The first part of this dissertation considers the significance of logistics to e-commerce and solves two concrete problems in this area. Additionally, this part focuses on some practical problems often encountered by companies in e-commerce and attempts to find solutions for these. First, China is regarded as the most attractive growth market for e-commerce. But the relatively slow pace of logistics development there has weakened e-commerce growth. The aim of this first portion, then, is to present the growth of e-commerce against the backdrop of logistical development in China. Existing problems are analyzed and solutions to possible perspectives are presented. Second, many traditional multichannel retailers use the Internet as a complementary business channel. By contrast, online pure play retailers only sell products via the Internet (Xing & Grant, 2006). The question of which business form is more efficient for warehousing, delivery or fulfilment operations thus merits debate and research.

<u>Research Question of Part One:</u>

Paper 1: How can German dealers position themselves in the Chinese e-commerce market regarding to logistics?

Paper 2: Which corporate structure (multi-channel retailer vs online pure player) is more efficient in terms of logistics?

The second part of this dissertation reviews, compares and analyzes several genetic approaches on solving the 0-1 multidimensional knapsack problem and develops an optimization software as a multidimensional knapsack problem solver for practitioners, especially for micro and small companies on the market. Companies are usually faced with the situation of having to make a decision with respect to several action alternatives with limited resources and aimed at maximizing profits. This is often described as the 0-1 knapsack problem in subject literature. On account of the transparent information available through the Internet, companies need faster reaction rates that respond to market changes. Because of seasonality, e-commerce companies in particular work frequently on the question of which products should be manufactured and sold within a given time period. However, it is difficult for practitioners to choose the right method for solving the knapsack problem. Commercial software such as IBM ILOG CPLEX or LINDO LINGO come at high license costs. In their place, one can install free software types (e.g. LPSolve, COIN-OR, GLPK) on the computer(s) in question. Yet the installation of third-party software and unknown data connections are regularly prohibited by IT security teams. The solver function in Microsoft Excel is usually used but cannot solve large complex problems. Consequently, users expect a free efficient software that does not need to be installed. For this research, two articles have been published. In the first, the genetic algorithms are reviewed and compared, and the suitable genetic approaches for solving the knapsack problem are confirmed. In the second, following the results of the previous article, individual software solving the 0-1 multidimensional knapsack problem is developed.

Research Question of Part Two:

Paper 3: Which genetic approach should be applied to solve the 0-1 multidimensional knapsack problem?

Paper 4: What benefits can be achieved by applying individual software solving the 0-1 multidimensional knapsack problem?

The following sections will discuss the problems, objectives and research methods of the four papers separately.

1.2. E-commerce logistics in China: Status quo and options for German online retailers

1.2.1. Problem and objective

1.2.1.1. Definition of e-commerce

E-commerce originated in the 1960s (Zheng et al., 2014). At the time, business organizations used electronic data interchange (EDI) as a tool for exchanging data. In 1979, companies universally established electronic networks to share files. In 1991, the

Internet was open for business. E-commerce was first proposed by IBM in 1995, and in 1997, the online market platform eBay triggered an Internet boom.

E-commerce has been around for many years; however, owing to the business model complexity of e-commerce, general standards and a widely recognized definition for it has not yet been established. The lack of a common definition leads to different researchers paying attention to divergent research themes. E-commerce can be defined in different dimensions, including competition, information sharing, use of technology and buy-sell transaction (Goyal et al., 2019).

From the perspective of competition, e-commerce involves the ethical mode of online commerce as well as the deployment of resources to achieve and maintain a competitive advantage in virtual markets (Gajendra & Wang, 2014).

From the perspective of information sharing, e-commerce is the use of information and communication technology to electronically capture, process, store, communicate and deliver information (Lin et al., 2019; Babenko et al., 2019; Alshibly & Chiong, 2015).

From the perspective of the use of technology, e-commerce is defined as the communication, delivery and buy-sell of products, services and information over a computer network, including the Internet (Kunesova & Micik, 2015).

From the most popular perspective of buying and selling transactions, e-commerce is defined as the sale or purchase of goods or services conducted over computer networks by methods specifically designed for the purpose of receiving or placing of orders (Babenko et al., 2019; Kant et al., 2015; Bălășoiu, 2015; WTO, 2013; Wittmann & Stahl, 2012; Wigand, 1997).

Although these definitions are not identical, they all highlight two crucial elements: economic activity and the Internet. According to the definitions mentioned, the difference between e-commerce and traditional business is the way in which orders are placed. E-commerce is carried out only via the Internet. The communication channels include the Internet, extranets and electronic information exchange. Mail ordering or fax ordering are not considered as tools of e-commerce. On the other hand, e-commerce payments do not need to be made electronically, since e-commerce buyers can select either online payment or traditional offline payment methods, such as invoicing or even payment by cash. An economic transaction generally consists of five phases: initiation, agreement, exchange, inspection/control and adjustment/service (see Figure 2).

Figure 2: Phases of an economic transaction (Delfmann et al., 2002)

The most fundamental transaction phases of e-commerce are those of initiation and agreement. The electronic initiation of transaction is treated as an essential component of e-commerce, while the electronic exchange of goods or services is not a necessary condition for e-commerce. This narrow approach would thus only comprise digital products. For the same reason, the electronic control and adjustment/service phases are also considered as being non-necessary conditions.

E-commerce, then, consists of a large number of online business activities involving products and services. Based on the category of buyers and sellers, e-commerce can be divided into six types (Merz, 2001): (1) Business-to-consumer (B2C): e-commerce in this model is related to the transactions and relationships between companies and end consumers. Goods and services are sold directly by the producer or supplier to the consumer; (2) Business-to-business (B2B): e-commerce transactions occur between companies. For example, conventional wholesalers and producers deal with retailers; (3) Consumer-to-Consumer (C2C): This is simply commerce between private individuals or consumers; (4) Consumer-to-business (C2B): This model is very relevant for crowdsourcing-based projects. In this case, individuals can sell their products or services to companies; (5) Business-to-administration (B2A): This can also be referred to as business-to-government (B2G) commerce. This kind of e-commerce refers to all online transactions between companies and bodies of public administration and involves a large variety of services, especially in the areas of social security, fiscal measures, legal documents, employment and registration; and (6) Consumer-to-administration (C2A) or consumer-to-government (C2G): In this type of e-commerce, electronic transactions are carried out between individuals and bodies of public administration. C2A commerce helps individuals post various kinds of feedback regarding the public sector directly to the relevant government authorities or request information from such administration. Therefore, C2A can provide a simple and immediate solution or way of establishing communication between consumers and government. Some examples of this are information dissemination, distance learning, health/medical payments, tax return filing and so on. Both the B2A and C2A types of e-commerce can be referred to as government e-commerce, the main objective of which is to increase flexibility, efficiency, and transparency in public administration. The main benefits of government e-commerce services include reduced waiting times and faster access to government services.

Thanks to the development of electronic commerce, the most basic of economic transactions continue to undergo change. E-commerce enables faster times to market, better asset utilization, more efficiency improvements, a reduction in total order fulfillment times, and enhanced customer service. Accordingly, most companies are changing their business patterns significantly. E-commerce has led to new business relationships and initiated new markets and new marketing paradigms. Thus, it has had a large economic impact on pricing, product availability, transportation patterns and consumer behavior worldwide.

The business concept of e-commerce has been developing for several years, it encompasses all previous business management and economic concepts and as such, e-commerce influences many management areas of business according to Shahjee (2016):

- Human Resources

  Human resources are the driving force and source of any enterprise's core competitive advantage (Rezwan, 2021). Both Amazon and Alibaba regard human resource management as a key success factor. In 2021, Amazon has approximately 1,298,000 employees (Amazon, 2021). These employees are working hard to serve customers around the clock, from order processing, packaging, transportation and delivery to the customers' designated addresses. How e-commerce giants manage labor forces composed of so many employees is a difficult problem. Moreover, e-commerce requires employees to have a wide range of digital skills. Due to highly seasonal demand and an increased use of automation, workforce planning must be set up to be more flexible. Online recruitment and home office opportunities can especially be implemented to this end.

- Payments

Offering the right payment methods for online customers is a key element of e-commerce success. The most common online payment methods are the following five meta-categories (Fatonah et al., 2018):

- Debit/credit cards: cards represent the most popular worldwide payment method in Europe, North America and East Asia.

  Bank transfers: This payment does not involve any sort of physical card. It is used by customers who have Internet or online banking accounts. Bank transfer payments, unlike card payments, cannot be reversed.

- E-wallets: an e-wallet is a type of electronic card used for e-commerce transactions. Its utility is the same as that of a credit or debit card. An e-wallet needs to be linked to an individual's bank account in order for payments to be made. This type of payment method (as seen in the services provided by Paypal and AliPay, is becoming a more popular payment method around the world.

- Cash: in many countries, even for e-commerce transactions, cash remains king. Offering a cash-on-delivery service is a surefire way to cover more markets.

- Cryptocurrencies: a cryptocurrency is a digital currency that uses cryptography to secure financial transactions. The first blockchain-based cryptocurrency was Bitcoin.

Furthermore, the impact of exchange rates is significant for international sales online. E-commerce involves a greater use of multi-currency transactions than traditional commerce. To minimize payment defaults, online retailers typically work with service providers to eliminate/minimize such risk. For example, during the order process, a customer's solvency is checked in the background before possible payment options are displayed.

- Marketing

Compared to traditional business, customers exhibit many special behaviors in online shopping (Rashad et al., 2012). E-commerce enables customers to perform transactions round the clock and in any part of the world, providing consumers with a variety of options. With e-commerce, consumers can easily get detailed and relevant information about the commodity they want to purchase while also being able to communicate with other consumers and share/compare their experiences. E-commerce services also help marketing professionals to collect and manage valuable customer-related information, including consumer ordering patterns, so as to build comprehensive databases. These in turn help hone the companies' marketing and promotion strategies. Marketers have to develop marketing strategies for customer service, online advertising, order making processes, dynamic pricing, localization, multiple distribution channels, wider product range, product life cycles etc.

- Production and Operations Management

In the era of e-commerce, manufacturers are rapidly turning to multi-channel business models to sell products to different markets and gain competitive advantages. Even without considering higher profit margins, businesses will interact with customers so as to understand them better and fine-tune their products. Manufacturers can use the e-commerce model to provide their new products directly on virtual digital marketplaces and experiment with new products without the risk of significant investment. Improved research and development environments can shorten product life cycles.

There are periods of time during the year when businesses receive higher and lower volumes of customer orders. Retailers have to deal with this deceptively simple concept: seasonality (Graves, 2012). E-commerce sales are highly seasonal, especially in the lead-up to important holidays worldwide such as Christmas, Eid, Diwali and Lunar New Year. During these times, companies must place great emphasis on the strong operations of production management, inventory control and logistics.

- Logistics

Ever since e-commerce has been experiencing rapid growth, it has also become a major factor behind the changing shape of the logistics industry (Delfmann et al., 2002). In order to fulfill e-commerce tasks, the coordination and cooperation of facilities (both existing warehouses as well as in-store sites) have been seen as strategic decisions requiring special consideration and arrangement. Since an efficient supply chain will allow a high level of service to be provided across all channels, logistics is already regarded as a crucial piece of a successful e-commerce business plan.

In the classical supply chain, the retailer was the only consumer interface. Traditionally, last-mile logistics were carried out by the consumers themselves. Instead of this model, e-commerce has providers handle order fulfillment. Customers thus have expectations regarding delivery and may consider the speed and convenience of delivery to be as important as product price and quality. Mountains of packages in smaller sizes thus need to be picked, packed and delivered within a specific or narrow delivery timeframe. Furthermore, e-commerce also needs to manage a corresponding volume of returned, exchanged and/or damaged goods, which can increase the delivery and operational costs of e-commerce logistics. This is further exacerbated by the difficult task of last-mile delivery. However, in e-commerce decentralized logistics activities are transformed into potentially bundled goods flows. The supplier side has room to plan and design effective logistics systems. In this case, the retailer stage is bypassed and producers can offer their goods directly to consumers.

A lack of planning for handling increased market demand could result in a huge pile-up of shipments, thus extending the post-peak season recovery period. In order to attain high capacity before the onset of peak handling season, companies need detailed data analytics to forecast customer demand and trends. Companies can then adjust purchasing and production plans in time to avoid wasting time and resources, losses which might be directly reflected in a company's overall bottom line.

The role of third-party logistics firms here cannot be disputed, since their use is intended to provide customers with higher-quality logistics services. Due to the limited number of supply and the increase of demand, acquiring the right distribution center in close proximity to as many major population centers as possible is also an increasingly difficult task for retailers. Thus, numerous retailers choose third-party logistics firms that can supply such necessary distribution centers. The delivery process itself has also become an increasingly difficult task, as the delivery location of the warehouse is no longer limited to retail stores, but can also be directly to customers at work or home. Having quality logistics services will be seen as a competitive advantage as consumers begin to value time over reliability. In this case, choosing the right third-party logistics firm is becoming more and more important.

In short, e-commerce promotes the importance of logistics and leads to different logistics tasks. Companies must find new logistics solutions to meet the new challenges and opportunities of e-commerce.

1.2.1.2. E-commerce logistics in China

Germany is dependent on foreign trade like few other countries in the world. Therefore, the country is committed to promoting the sustainable development of the global trading system and to developing new markets. In 2020, Germany exported goods in the value of 1,205 billion euros and imported goods in the value of 1,025 billion euros (Statistisches Bundesamt, 2021a), making it the world's third largest exporter of goods behind China and the USA. In 2020, China was Germany's most important trading partner (ahead of the Netherlands and the USA) (Statistisches Bundesamt, 2021b). German companies are also becoming increasingly active in China.

Around 80% of German e-commerce companies sell goods to foreign customers (Paul et al., 2019). While economic growth rates in western countries remain stagnant, e-commerce in emerging markets has grown rapidly. In particular, China is considered as the most attractive growth market for e-commerce, having already surpassed the USA as the largest e-commerce market. In 2017, China's e-commerce retail sales (B2C) were 897 billion euros, accounting for 40% of the total e-commerce market (China Electronic Commerce Research Center, 2018). By 2020, the Chinese e-commerce market is projected to generate sales in the USA, UK, Japan, Germany and France (The Economist, 2013). The annual growth rate of GDP in China is 6–7% (Trading Economics, 2018), and the concomitant rise in disposable income in China has led to a trend toward consumption upgrades (see Figure 3) focusing on quality and fashion, especially for cosmetics, clothing and food. Brands need to offer more than just low prices to draw consumers. Middle- to high-end consumers are increasingly demanding goods that are not available domestically. International high-end and niche brands are becoming more and more popular. Therefore, cross-border e-commerce and logistics have become one of the most important development factors in the consumption upgrade movement.

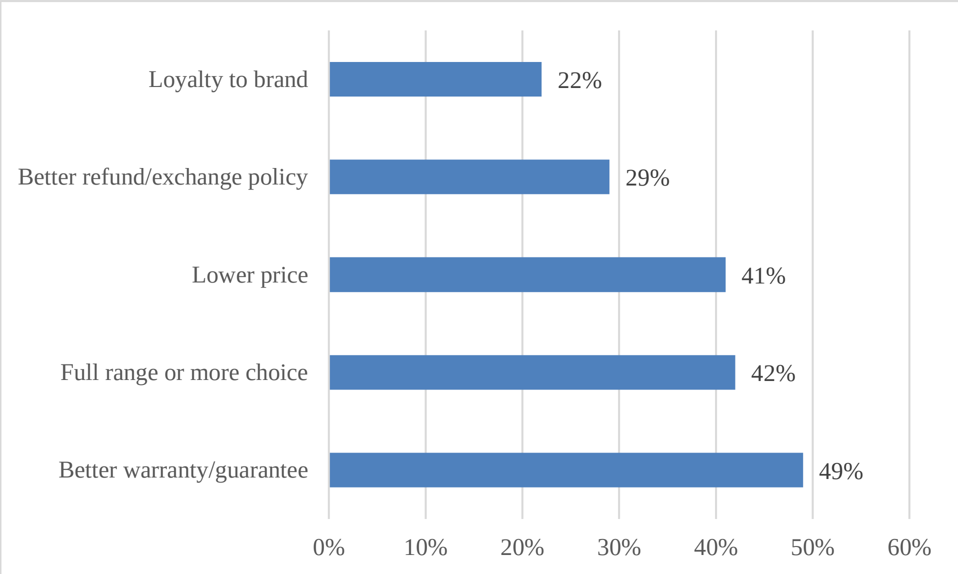


Figure 3: Factors behind deciding to purchase from a brand's official Chinese website versus via third-party platforms (PricewaterhouseCoopers, 2018)

The Chinese e-commerce market provides an attractive business opportunity for many merchants. However, China should still be regarded as a developing country. There are still many challenges for foreign companies which might wish to enter the Chinese e-commerce market effectively. From the viewpoint of German retailers, there still exists many difficulties in the Chinese e-commerce market, such as customer trust (Shao & Yin, 2019; Zhang, Bian & Zhu, 2013; Teo & Liu, 2007), the investment environment (Fan, 2019; Wang, 2012), and specific buying behavior (Yan et al., 2017; Yoon, 2009; Efendioglu & Yip, 2004). One of the most discussed issues related to e-commerce is the development of logistics (Zheng et al., 2020; Yu et al., 2017; Ke & Jiang, 2014; Yang & Ma, 2013). The success of e-commerce thus essentially depends on the efficiency of the logistics systems (Riehm et al., 2003). In 2013, total logistics sales in China totaled 23.3 trillion euros (National Development and Reform Commission et al., 2014). China's logistics industry has developed rapidly in recent years. The trade volume of Chinese logistics increased over sixfold (6.3x) between 2001 and 2010, while the average annual growth rate during this period was 22%. Due to its enormous rate of economic development, China has continuously improved its logistical infrastructure, which is one of the most important foundations for e-commerce growth. Nevertheless, today's logistics industry cannot adequately satisfy the demands of e-commerce. The main reason for this is that logistics cannot keep up with the evolution of e-commerce, and this relatively weaker logistics development has slowed e-commerce growth in China.

On the basis of the research literature, some problem areas for logistics in Chinese e-commerce markets have been identified. The concept of logistics was introduced by Europe and the United States in the early 1980s (Wang, 2006). The focus of Chinese research on logistics is still limited to the physical transportation of goods, while Western scientists have focused on supply-chain management (Mahpula et al., 2013). Supply-chain management considers all internal and network-related activities such as supply, disposal and recycling, including the accompanying cash flow and information flow (Werner, 2008). In the following, the logistics problems with regard to e-commerce, such as covered in the literature, are described in detail.

Infrastructure

In terms of infrastructure, the length of motorways and railways per inhabitant in China is below average compared to other developed countries. In fact, China's outdated and inadequate infrastructure still causes significant problems in terms of punctuality and reliability. Furthermore, there are still large regional differences in Chinese infrastructure (Fang, 2012; Wang, 2014): infrastructure in the east of the country is much better developed than in the west. Even in rural areas, there is still a lot of catching up to do in terms of logistics infrastructure compared to larger cities. However, significant progress can be expected in the near future. The construction of highways, high-speed railways, airports and ports will continue to be strengthened. How long and to what extent will the inadequacy and imbalance of infrastructure exist in the future? As the geographical population distribution in China is also uneven, e-commerce companies should rationally allocate logistics resources.

Legal framework conditions

Regarding the legal situation, various departments of the Chinese government are responsible for the regulation of the various modes of transportation, such as highway, rail, water and air traffic. These offices regularly work separately and thus rarely cooperate and coordinate with each other. As a result, the adopted laws of the individual offices concerning logistics are not coordinated. Additionally, many laws regarding logistics are outdated. Thus, the legal basis for an efficient logistics network is not available (Qin, 2013). The Chinese government has started to create a series of legal frameworks regarding the current situation in logistics. How should practitioners be prepared for avoiding potential legal risks? This unavoidable question must be actively addressed by e-commerce companies, especially foreign companies.

Fees and taxes

Furthermore, fees (e.g., toll/administrative/certificate fees, etc.) and taxes (e.g., trade/traffic/corporate taxes, etc.) account for about one third of the total cost of logistics for companies in China (Chen & Hao, 2013). Due to rising raw material and land prices, not to mention increased personnel and capital costs, the average return on sales of logistics companies in China has fallen from 30% in 2005 to 5% in 2013 (Zhou, 2013). Because of their low profitability, it is difficult for logistics companies in China to attract investment. The cost of logistics in China is also affected by the legal framework. Therefore, the Chinese government is planning to reduce the previously mentioned logistics-related expenses and taxes. Companies need to continue to pay attention to relevant policies to adjust their management in a timely manner.

Information and communication technology

With regard to information and communication technology, China still needs to catch up to already developed countries (Ma & Xun, 2012). Information management systems include electronic order systems, warehouse management systems, transport management systems, procurement management systems, online payment systems, customer management systems and object tracking. There are currently no standards or uniform formats for information transmission in the Chinese market. Thus, digital communication and information integration between different participants is very difficult. In response to this problem, first the cause of this defect must be found out. For example, lack of funds, technical support, technical infrastructure or human resources. What solutions do currently exist on the market? With reference to these existing methods, e-commerce companies can make appropriate improvements.

Human resources

Additionally, both practice and science have identified a shortage of qualified human resources in logistics for several years. However, there is no accurate determination of the need for logistics professionals. The numerical demand is estimated between 6 million and 600 thousand (Li, 2013). This is due to the inconsistent definition of logistics professionals in Chinese science and practice, and also proves that there are still research gaps in the theory of Chinese logistics. Insufficient research leads to unclear supply-demand relations. It is challenging to hire enough professional logistics staff in China. How and where should e-commerce companies find suitable professionals? This problem is particularly fatal for e-commerce companies that need to build their own logistics channels.

Competition and cooperation

Regarding point competition and cooperation, Chinese logistics represent a polypol market: There are many small logistics companies operating regionally. The four largest logistics companies in the B2C segment in China generated about 50% of the total turnover in the industry in 2012. By comparison, the four largest logistics companies in the USA had a market share of 95% in 2012 (Mo, 2014). Due to the fierce competition in the logistics industry in China, successful cooperation between the individual logistics companies is hard to achieve (Fang, 2012). Thus, composite effects cannot be realized. To know one's own strength and the enemy's is the sure way to victory. Understanding the competitiveness and profitability trends of logistics companies is conducive to the future decisions of all logistics-related companies, not just e-commerce.

Logistics service providers

In terms of logistics service providers, China's e-commerce market players – especially in B2C – can be classified into three types: state-owned logistics companies, foreign logistics companies and private Chinese logistics companies. Chinese logistics companies have significantly higher market share compared to foreign logistics providers (Mahpula et al., 2013). Private Chinese logistics companies are most popular in China because of their flexibility and low cost. Most Chinese logistics service providers are small companies and therefore generally do not have the most up-to-date information and communication technology. Thus, customers often experience problems with collections, requests, returns, and tracking (Chen & Lin, 2013). This affects the image of e-commerce companies. Most e-commerce companies do not need to build their own logistics channels, they must choose logistics service providers to cooperate. Which logistics service providers are currently active in the Chinese market? What are the characteristics of these logistics service providers, involving safety, accuracy, timeliness, coverage, and price? E-commerce companies need to figure out the necessary market information.

Against this backdrop, this article focuses on Chinese e-commerce logistics and aims at answering the following research question: How can German merchants position themselves in the Chinese e-commerce market with regard to logistics? The aim of this thesis is to present e-commerce growth on the basis of logistical development in China.

Here, existing problems will be analyzed and solved from a variety of perspectives. After synthesizing the analysis, action options with regard to logistics for German merchants in the Chinese e-commerce market will be presented.

1.2.2. Research method

As a first step, the current literature on Chinese e-commerce logistics should be evaluated. Next, one can identify the development, problems and solutions of e-commerce logistics in China through case studies. Afterwards, the results will be discussed and action options for German merchants will be derived.

For this article, case study research (Yin, 2009) will be used as the research method. According to Yin, "A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context may not be clearly evident." Case study research is particularly suitable for answering the research questions of "how" and "why" as well as for investigating current phenomena. Furthermore, the case study method has the advantage of being able to react flexibly to unexpected findings during the investigation.

The research question should be answered on the basis of two subquestions:

1. How do logistics problems affect e-commerce in China?

2. What are the solutions to existing logistical problems for e-commerce in China?

These two research subquestions concern the current phenomenon of e-commerce logistics in China. To answer these questions in the case study, no prediction from experts is needed. The action options for the final research question can be deduced from the results of the first two research questions. This is why this paper uses case studies instead of the Delphi study (Rowe & Wright, 2001) as a method. The latter is a qualitative estimation method based on expert surveys, in which a group of experts is presented with a questionnaire about a complex problem. Respondents have the opportunity to assess the theses in several rounds. The main difference between case study research and the Delphi study method is the requirements for respondents' responses. In the case study method, respondents should objectively relate and discuss current phenomena. By contrast, the Delphi study is considered to be a subjective-intuitive prognostic instrument allowing statistical fuzzy-like results and suitable for assessing future events, trends and technical developments.

For the case study, data will be collected through telephone interviews as well as through evaluating secondary sources such as websites, annual reports and other publications. Since the subject of investigation (Chinese e-commerce logistics) will remain the same across the case studies to be conducted, the holistic multiple-case design should be implemented as the case study type (Yin, 2009). Twelve experts are selected for the interviews, which can be divided into the organizational groups of research, practice and Chinese government, with each group being analyzed as a single case study. In the research group, four experts from the Southwestern University of Finance and Economics (SWUFE) and two experts from the China E-Commerce Research Center (CECRC) will be interviewed. Three senior employees of logistics companies will be interviewed in the company group. For the category of Chinese government, three officials from the state logistics park will be interviewed. By selecting different groups, regional differences and subjective views of individual groups should be excluded. In choosing the case study organizations, in addition to the argument of information accessibility and staff willingness to participate in the investigation, the desire to involve as many different groups as possible is also crucial. After conducting the case studies, cross-case conclusions will be drawn based on the case-by-case reports, and these will be used to modify or expand the current theoretical state of e-commerce logistics in China. Based on the adapted theory, options for action will be derived for German merchants wishing to be active in the Chinese e-commerce market.

1.3. Analysis of Logistics Efficiency in E-Commerce: Online vs. Multichannel

1.3.1. Problem and objective

Hitherto, traditional retailers have maintained a single mode of offering sales and services, such as a physical store. Online pure players, by contrast, only offer their products and services online. Multichannel retailers offer more than one way to purchase products and services. Due to advances in technology and changes in buying behavior, e-commerce has naturally taken on a multichannel character. Multichannel commerce (Levy & Weitz, 2008), as the name suggests, means a model with different distribution and promotional channels, such as retail storefront, website, mail-order, catalog ordering, telephone ordering, television shopping and comparison-shopping sites. A multichannel retailing strategy maximizes loyalty and increases revenue by providing customers better convenience and choice, and multichannel retailing is an ever evolving concept.

One of the obvious advantages of multichannel commerce is the ability to reach a larger market and more customers (Thelen & Berman, 2004). A physical store is limited by geographical area, and it is difficult for buyers and sellers to find each other in the physical world. By contrast, e-commerce is not restricted to geographical boundaries. Through the Internet, customers can search for any desired product and can purchase it from anywhere in the world, finding every type of products without any hassle. In theory, all e-commerce businesses can become virtual multinational corporations. Online sellers have access to people all around the world and can expand into new facets of their business. In effect, the entire world is a playground for e-commerce. Furthermore, multichannel retailing helps ensure the following benefits (Shahjee, 2016):

- Customer satisfaction (e.g., purchase and payment flexibility for consumers, 24-hour service)

  One of the most important benefits of e-commerce is unlimited store hours (24/7/365). With these operational hours, sales can be increased by boosting the number of orders without any additional cost. It is also beneficial for customers as they can purchase products whenever they want. Customers can get product information at any time, even if they do not end up buy a given product at the time. E-commerce not only enables shopping from home at any time of day or night; it also provides purchasing options that are quick, convenient and user-friendly, including the ability to transfer funds online. Because of this convenience and ease, consumers can save much time in product searching, purchasing and transportation back to a given destination.

- Easier access to market information

  Online sellers can easily gain access to customer data for analysis, such as mailing addresses, e-mail addresses and phone numbers, providing at least three different ways to communicate and build a relationship with customers. Through big data collection and analysis, online retailers can even keep a constant eye on consumers' interests and consumption habits to provide tailor-made products and services. Adequate information can help to launch a complete range of consumer and market evaluation campaigns with the aim of analyzing and calculating customer effectiveness, sales effectiveness, product mix, customer engagement, marketing campaigns and more. On the other hand, consumers themselves can also obtain a vast amount of information not normally possible in a physical store, including price comparisons, product descriptions with warranty information, other customers' evaluations and recommendations, etc. E-commerce websites can offer additional information without any hassle, so that customers can easily decide whether to purchase the product or service in question or not.

- Ability to process a high number of orders

  Due to their limited operating area and processing time, retail stores can experience long line ups, which in turn can deter people from shopping. With e-commerce, customers can place orders on schedule with no delay. Sellers can then unhurriedly handle a high number of orders in the background.

- Scalability

  With the help of e-commerce, traditional enterprises can grow and scale easily to diversify sales channels and reach new market segments.

- Product and process digitization

  In particular, software and music/video products can be sold directly to customers via the Internet in digital or electronic format.

Customers want convenience and want transactions to be completed immediately. Today, most companies try to provide customers with several ways to shop. Multichannel sellers, however, also face risks and challenges in their striving to find more sales opportunities. Sellers are often too eager to establish multiple channels, which may overload their current management or logistics systems. For example, the design of a retail distribution center supporting an offline store is different from that of a similar distribution center supporting an online channel. For offline physical stores, merchandise can be evenly loaded into cartons for transportation. Generally, such cartons do not stay in distribution centers for more than one day. By contrast, merchandising cartons for online sales should be broken down into individual items, which after repicking and repacking will be sent to the end customers. Different channels may have different target markets and require unique organization. Therefore, many multichannel retailers have separate management systems for each channel. In addition, embarking on or developing the wrong type of channel can cause serious damage to a company. For example, luxury fashion brands may not be suitable for sale on ordinary e-commerce platforms. This risk can be minimized by prior experimentation and market evaluation.

Multichannel operations blend both marketing and retailing strategies, and require significant investment and reorganization to be implemented in the logistics system (de Carvalho & Campomar, 2014). In order to acquire a greater market share, a growing number of traditional brick-and-mortar retailers have been using the Internet as a complementary business channel and boast of more experience and knowledge in handling logistics issues as a result (Maltz et al., 2004). By contrast, online pure players only sell products online and are usually more flexible and responsive. The logistics activities of online pure players are often outsourced; this external provision of logistics services is commonly known as third-party logistics.

The alternative retail channels possess some distinct differences with regard to structural organization, environmental costs, logistics, etc. The major differences in the field of logistics between the traditional retail model and the e-commerce model depend on the respective transportation networks. Retail stores need several warehouses and require that customers come and pick up the goods. Before arriving at the store, customers are unable to obtain any information about these goods. An online shop, on the other hand, does not need multiple levels of warehouses and can even ask the manufacturer to deliver the product/service to the customer directly.

There are several studies in the relevant literature comparing multichannel retailers and online pure players. Xing & Grant, (2006) have introduced an e-physical distribution service quality framework to investigate which of the two e-retailing systems (online pure player and multichannel retailer) performs better. With this framework, providers can clarify consumers' expectations and understand the advantages and disadvantages of their home delivery structure, retailers and their logistics service, and then can better collaborate to offer superior services to consumers.

On account of prior comparative research, Weber and his colleagues (Weber et al., 2009) conducted a streamlined life cycle assessment (LCA) to quantitatively analyze variations in energy use and carbon dioxide emissions for these alternative systems. Their report provided conclusions and offered recommendations to decrease logistical LCA uncertainties. As a result, prior findings were confirmed that the energy consumption and carbon dioxide emissions from delivery accomplished wholly via e-commerce were approximately 30% lower compared to traditional retail.

Based on experience and enterprise examples, Żuchowski (2016) proved the uncertainty that the introduction of e-commerce in a warehouse would necessarily be a revolution for the employees in question; rather, this depends on the customers the company serves and the corresponding market.

Retail systems have been significantly changed by online retail. Hübner, Wollenburg & Holzapfel (2016) declared that operations and logistics integration require more in-depth consideration. Through an exploratory survey with active experts and retailers, German multichannel and omnichannel retail market are described. The authors then offer advice about omnichannel fulfillment and distribution structures as well as on designing a framework for transitioning from multichannel to omnichannel. The main results of their research can be summarized as follows: Expanding the delivery model and improving the delivery speed service levels are the key themes for the excellence of omnichannel forward and backward distribution (Hübner, Holzapfel & Kuhn, 2016).

As mentioned earlier, the efficiency of logistics is a key determinant of e-commerce success. So far, no research has been conducted about the quantitative comparison and analysis of the efficiency of multichannel retailer and online pure player. Therefore, this paper focuses on the quantitative comparison of logistics efficiency between these two firm structures and investigates the relationship between logistics and e-commerce to see which corporate structure – multichannel retailer or online pure player – is more efficient in terms of logistics.

1.3.2. Research method

The goal of this research is to investigate the efficiency of logistics within the performance of the two firm structures outlined above. As previously mentioned, logistics can secure sustained competitive advantages for many e-commerce companies over traditional retail competitors. It has been confirmed that there exists a positive relationship between logistics capability and its performance in the e-commerce market. Furthermore, e-commerce delivery consumes less energy than traditional retail. Most market participants have estimated that the introduction of e-commerce will have an overall positive effect on logistics. Therefore, it is hypothesized that there is a positive relationship between the efficiency of logistics and the share of total company revenue deriving from e-commerce.

Several items were used to make the comparison of the logistics efficiency between multichannel retailers and online pure players:

- Share of e-commerce revenue on total revenue (independent variable X) and logistics efficiency (dependent variable Y).

- Share of e-commerce (X) is equal to online sales divided by total turnover. Theoretically, a value of $X = 0$ represents a traditional retailer (100% offline), a value of $0 < X < 1$ represents a multichannel retailer, while a value of $X = 1$ would indicate an online pure player. In order to give an answer about the rationality of organizing a logistics center, Brdulak & Zakrzewski (2013) introduced Return on Investment (ROI) to calculate logistics efficiency. According to similar ideas, logistics efficiency (Y) in this study is defined as the total turnover divided by the logistics costs of a firm, indicating the amount of turnover produced by investing one unit of logistics costs. The latter include storage costs, transport costs, packaging and material handling costs, information costs and costs for logistics outsourcing.

- Ordinary least squares (OLS) regression analysis was employed to test the hypotheses.
  P-value method was introduced to examine the regression result. As a generalized linear modeling technique, OLS can be used to estimate the relationship between the two variables.

Due to the probabilistic nature of theories and measurement errors, relationships between variables in economics are not normally exact. Regression analysis (Fahrmeir et al., 2013) can find average relationships between the data which look independent. If the relationship of two variables is linear, it may be appropriately represented mathematically using the straight-line equation

$$Y = a + bX.$$

The relationship between the variables X and Y is described using the linear equation. a indicates the value of Y when X is equal to zero (the intercept) and b indicates the rake ratio of the line (regression coefficient). The regression coefficient b describes the change in Y by one unit changed in X.

The study is implemented in Germany via online survey. All possible industries were covered: car and motorcycle accessories, clothing, books, office supplies, computer/hardware accessories, decoration, drugstore, electronics and telecommunications, house and home textiles, household goods and appliances, lamps/lights, food, medicines, furniture, jewelry, shoes, toys, animal requirements and watches.

1.4. A Review and Comparison of Genetic Algorithms for the 0–1 Multidimensional Knapsack Problem

1.4.1. Problem and objective

The 0–1 multidimensional knapsack problem is one of the best-known integer programming problems. In a given group of projects, each project has an objective profit and resource consumption (for instance, storage space or required machine minutes). Any number of projects can be freely chosen. The only restriction is that resources are limited. In other words, when resource capacity is reached, the addition of projects must be stopped. The ultimate goal is to find the subset of all projects that maximizes overall profit. This kind of non-deterministic polynomial-time-hard 0–1 multidimensional knapsack problem can be represented as follows (Kellerer et al., 2004):

$$\begin{aligned} \text{maximize} \quad & \textstyle\sum_{i=1}^{n} c_i x_i \\ \text{subject to} \quad & \textstyle\sum_{i=1}^{n} a_{ij} x_i \le b_j, \forall j \\ & x_i \in \{0,1\}, \forall i \end{aligned}$$

(projects i, resources j, profit c_i, resource consumption values a_{ij}, decision variable x_i, resource capacities b_j)

A detailed description and application of the knapsack problem and examples will be explained in the next section. The focus of this section is on the genetic algorithms used to solve the knapsack problem.

In the relevant literature, two types of general approaches have been used to solve the 0–1 multidimensional knapsack problem during the past decades: exact methods and heuristics. Compared to exact methods, heuristics such as greedy algorithms (Senju &

Toyoda, 1968), simulated annealing (Drexl, 1988), or genetic algorithms are especially competitive at solving such large problems (Fréville, 2004). In particular, genetic algorithms have been very well suited for solving knapsack problems (Lin, 2008), 0–1 multidimensional knapsack problems (Raidl, 1998, 1999) and are often applied to various types of general optimization problems (Pal & Chakraborti, 2013). Therefore, this article focuses on the performance of genetic algorithms. The original intention of this article was merely to select the appropriate genetic algorithms for the software design of the next article. But scientists who are trying to further improve the current best approaches are also the addressees of this article's research.

A genetic algorithm is an optimization method inspired by Charles Darwin's theory of natural evolution (Sivanandam & Deepa, 2008). However, it has only recently become popular in operations research. According to Darwin's theory of natural selection, the fittest individuals are selected for reproduction in order to produce offspring of the next generation. The chromosomes in a genetic algorithm correspond to the solutions in an optimization problem. Chromosome pairs are selected to produce new chromosomes: this is precisely the primary mechanism by which solutions are developed. To promote genetic diversity, mutations are used. Iterations and recurrent exchanges rule out bad chromosomes and record good chromosomes.

A genetic algorithm is constructed from a number of distinct components. These standard components can be modified and refactored to generate many different genetic algorithms. The main components are initial population, selection, recombination and termination (evolution scheme).

Setting a population is the first step in a genetic algorithm (Katoch et al., 2021). A population here refers to a set of solutions to a particular problem. Chromosomes are string representations of solutions. A chromosome can be thought of as a string of letters from the alphabet {A, B, C, D, E}. A particular locus in a chromosome is referred to as a gene. In other words, genes are joined into a string to form a chromosome (i.e., solution). The classical genetic algorithm uses a bit-string representation to encode solutions. Bit-string chromosomes consist of binary values (a string of 0s and 1s). Any particular representation for a given problem is called the encoding of the problem.

Projects	Profit	Resource		Project Selection				
	in EURO	Equipment in min	Storage Area in m²	C1	C2	C3	C4	C5
		Capacity: 1000 min	Capacity: 170 m²					
Product 1	7000	600	80	1	0	0	0	1
Product 2	4000	300	50	0	1	0	1	1
Product 3	6000	300	10	0	1	0	1	0
Product 4	5000	100	40	0	1	1	0	1
Product 5	6500	400	90	1	0	1	1	0
			Total Profit	13500	15000	11500	16500	16000

Table 1: An example of a genetic algorithm

As shown in Table 1 above, C1 or C2 is a chromosome, 0 or 1 in C1 is a gene of C1. C1, C2, C3, C4 and C5 together form the population of a genetic algorithm.

The fitness value is an indicator evaluating the ability of a chromosome to compete with other chromosomes. The probability that a chromosome will be selected for reproduction and replacement is based on its fitness value. Thus, the value must be calculated for each chromosome in the first step. In this case, the fitness value is the profit of the project.

The next phase, selection, is about selecting the chromosomes and having them use their genes to reproduce the next generation. In general, a genetic algorithm uses fitness values as a discriminator to select chromosomes. Those chromosomes with better fitness values should have a greater chance of being selected.

In the next phase, recombination, the chromosomes selected from a source population are recombined to form new offspring. There are two main components of recombination: the crossover operator and the mutation operator. The genes from two selected parent chromosomes will be mixed by the crossover operator to produce child chromosomes. Crossover operators come in many forms. One typical crossover operator is the so-called one-point crossover. A crossover point is chosen at random from within the genes. Child chromosomes are then produced from the genes of the first parent chromosome before the crossover point and the genes of the second parent chromosome after the crossover point. This process is illustrated as follows (Figure 4):

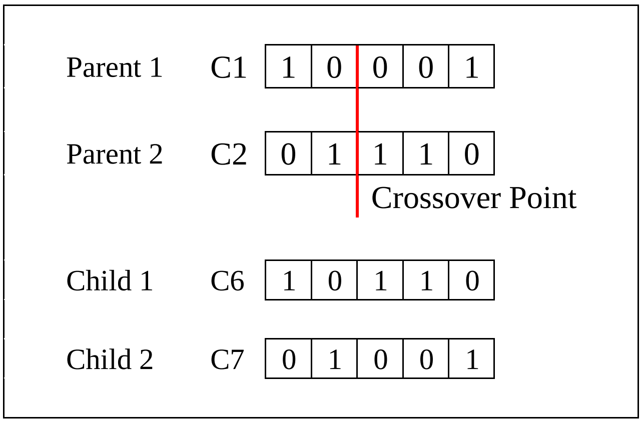


Figure 4: Selection

A mutation operator, on the other hand, will possibly change one or more genes with a certain mutation rate. The normal mutation (Figure 5) can occur in each position of the chromosome. The role of a mutation operator is to maintain population diversity so as to prevent premature convergence.

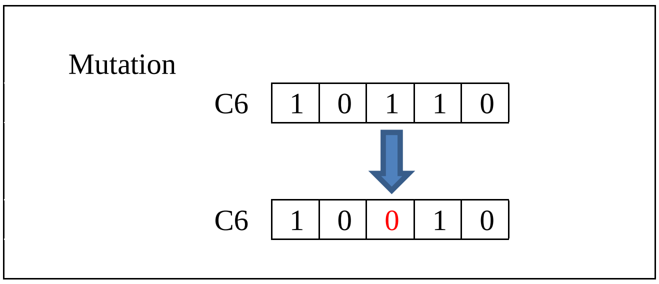


Figure 5: Mutation

After mutation, the resultant chromosomes are passed into the successor population in the termination phase. The steps of selection and recombination are then iterated until the termination condition is reached, i.e., until it does not produce better offspring than the previous generation.

In addition to the general components (i.e., population, crossover and mutation), design also has important and decisive significance for the effectiveness and efficiency of a genetic algorithm. There are many choices that have to be made in designing a genetic algorithm for a given application, such as the choice of encoding (bit-string or non-bit-string representation), the quality of chromosomes in the initial population, the choice of offspring, or the termination conditions. A typical design for a classical genetic algorithm with standard genetic operators might be as follows:

1. Randomly generate an initial population with P chromosomes (P is population size).
2. Calculate the fitness value F(c) of each chromosome c in the initial population.
3. Using proportional fitness selection, select two chromosomes, c1 and c2, from the initial population.
4. Apply one-point crossover to c1 and c2 with crossover rate to obtain two children chromosome ch1 and ch2.
5. Apply uniform mutation to ch1 and ch2 with mutation rate to produce ch1' and ch2'.
6. Add ch1' and ch2' to the initial population, expel the two worst chromosomes, have initial population become successor population.

If termination criteria have not been met, return to Step 2.

1.4.2. Research method

Due to the diversity of component settings and design, there are many different genetic algorithms in the literature. Therefore, this article focuses on the performance of genetic algorithms and strives to answer the following research question: Which genetic algorithm should be applied to solve the 0–1 multidimensional knapsack problem? For this purpose, a systematic evaluation of carefully chosen genetic algorithms will be implemented. Next, these genetic algorithms will be tested in the simulation's procedure using all 270 standard problems by Chu & Beasley (1997, 1998). Two criteria are set as prerequisites for selection. First, genetic algorithms must be specifically designed for solving the 0–1 multidimensional knapsack problem. Second, genetic algorithms have to show significant progress compared with previous algorithms. Eleven genetic algorithms have been selected: the genetic algorithms by Khuri et al. (1994), Thiel & Voss (1994), Rudolph & Sprave (1995), Hoff et al. (1996), Chu & Beasley (1998), Raidl (1998), Raidl (1999), Gottlieb (2000) (two algorithms), and Levenhagen et al. (2001) two algorithms). Each algorithm has its own special characteristics.

The specialty of Khuri et al. (1994) is the utilization of penalty terms and the allowance of a non-feasible chromosome in the population, which represents a solution with exceeded capacity. The individual's fitness value is decreased by a penalty term dependent on the number of overfilled knapsacks multiplied by the maximum profit of all individuals. Due to potential negative fitness values, linear dynamic scaling is applied to the proportional parent selection. Thiel & Voss (1994) integrate a taboo search into the mutation operator, in order to avoid the local optimality dilemma. Mutation per individual is applied while observing the taboo list. Rudolph & Sprave's algorithm (1995) incorporates two special features: first, the parent chromosomes are proportionally selected within a varying limiting neighborhood; second, they use a customized generational approach in the replacement phase. Offspring are then only considered for the new population if their fitness value is above a defined threshold, itself dependent on a set number of past offspring. The genetic algorithm by Hoff et al. (1996) was the first to implement the steady-state replacement approach. The approach by Chu & Beasley (1998), in turn, was the first to use tournament parent selection. Furthermore, a specific add-and-drop repair algorithm is incorporated. The projects' sorting is based on a quotient using the chromosomes' fitness values, shadow prices, as well as rates of resource consumptions. Shadow prices equal the difference between the fitness value of a portfolio with original resource capacities and that of a portfolio with a slightly increased resource quantity. Raidl (1998) incorporates the LP-relaxed MKP into the initial population. Each gene of a chromosome is set to 1 with the probability of the relaxed LP solution. Furthermore, the LP-relaxed vector is applied in the add-and-drop repair step. The second algorithm by Raidl (1999) presents different weight-coding variants. In each iteration, the fitness values of the initial population are temporarily modified by a biasing factor. The genetic algorithms are then run with the new permutation. Gottlieb (2000) develops the algorithms of Chu & Beasley (1998) and Raidl (1998), adding a boundary function to both algorithms to ensure that no additional allative projects can be added to the solutions without violating the constraints. Levenhagen et al. (2001) extend Gottlieb's modification by adding a path-tracing component. To enforce boundary solutions, an additional "embedded local search" optimization procedure is randomly applied to the chromosomes on the path between two individuals. If a newly obtained local optimum dominates the respective chromosome on the path and is neither a duplicate nor on the taboo list, the latter is replaced and the process is iterated. Finally, the worst initial population member is replaced by the improved solution. The algorithm terminates if either the path chromosome differs from the target individual by only one bit or no valid local optimal is found anymore.

The publicly available standard test data proposed by Chu & Beasley (1998) were used to compare the eleven genetic algorithms. These data include randomly generated test problems with a different number of constraints ($m \in \{5, 10, 30\}$), variables ($n \in \{100, 250, 500\}$), and tightness ratios ($\alpha \in \{0.25, 0.5, 0.75\}$). For each instance with a differing value for m, n, and α, 10 test cases are provided, resulting in 9 sets of 30 problems each, totaling 270 cases. All comparisons were carried out in identical experimental conditions: standard parameter settings with a population size of 100, a bit string encoding, a mutation rate of $1/n$, and a crossover rate of 0.9.

The 270 problems were solved three times for each setup with a differing number of iterations (10^1, 10^2, 10^3, 10^4). The final solutions' fitness values and the overall computation times were recorded. In the evaluation phase, the results were analyzed using the solution quality and time.

1.5. Knapsack problems in practice - quick decisions made with difficulty

1.5.1. Problem and objective

1.5.1.1. Knapsack problem and an example

Companies, whether online or offline, often have to face the knapsack problem, a difficult one to solve via simple common mathematical methods. The knapsack problem is a combinatorial optimization problem in which one has to maximize the profit of objects (products) in the knapsacks without exceeding the latter's capacity. Involved are several knapsacks having positive capacity. There are many distinct items that could potentially be placed in the knapsack. The goal is to maximize the total value of distinct items which will be loaded into the knapsack, while each weight or volume is simultaneously less than or equal to a given limit.

A large variety of resource allocation problems can be cast in the framework of a knapsack problem. The capacity of the knapsack can be considered as the available amount of a resource, and the item types as activities to which this resource can be allocated. A typical example is the allocation of a research and design budget to the promotion of individual products.

The following example shows that even a small knapsack problem is not easy to solve for practitioners on the market. A company produces clothing and sells it through multiple channels. In addition to the production facility, the company also operates both physical and online stores. Often, the company is particularly concerned with the question of which products should be manufactured and sold within a certain period of time. Before or during holiday periods, unexpected increases in order volume often lead to the elementary production factors being insufficient. The previous selection of action alternatives was mostly based on the experience of managers in accordance with the decreasing profitability of given alternatives. Due to the large number of alternatives and limited resources, a selection based on the overall profitability of the complete project portfolio was only carried out in exceptional cases and with great manual effort. Here is a simple illustration of this problem:

Projects	Profit	Resource		Project selection	
	in EURO	Equipment in min	Storage Area in m²	Decreasing Profitability	Overall Profitability
		Capacity: 1000 min	Capacity: 170 m²		
Product 1	7000	600	80	1	0
Product 2	4000	300	50	0	0
Product 3	6000	300	10	0	1
Product 4	5000	100	40	0	1
Product 5	6500	400	90	1	1
			Total Profit	13,500	17,500

Table 2: An example for knapsack problem

As shown in Table 2, five clothing alternatives can be selected for production. The equipment operating time is limited to 1,000 minutes and the storage area to only 170 square meters. A value of 1 means that the corresponding project is picked, while one of 0 means the item is discarded.

Based on decreasing profitability, the clothes items 1 and 5 will be selected. Products are selected based on profit, going from large to small, until the constraints are met. This is a simple empirical solution, and it is difficult to get a satisfactory answer. In this case, total profit is 13,500. In order to find the optimal solution, all 31 possible solutions must be calculated and compared. Furthermore, feasible solutions with exceeded capacity should be excluded. In the case of overall profitability, the combination of clothes items 3, 4 and 5 is the best solution with a total profit of 17,500. The essence of overall profitability is enumeration, which lists all the possibilities in a collection (Jech, 2003). This example shows that the traditional method with decreasing profitability is very unsatisfactory, while the enumeration method is too time-consuming. If the number of products and resource constraints increases, the difficulty of using this method to solve the knapsack problem will increase exponentially. Therefore, the enumeration method is in no way applicable. Companies definitely need a simple and quick solution.

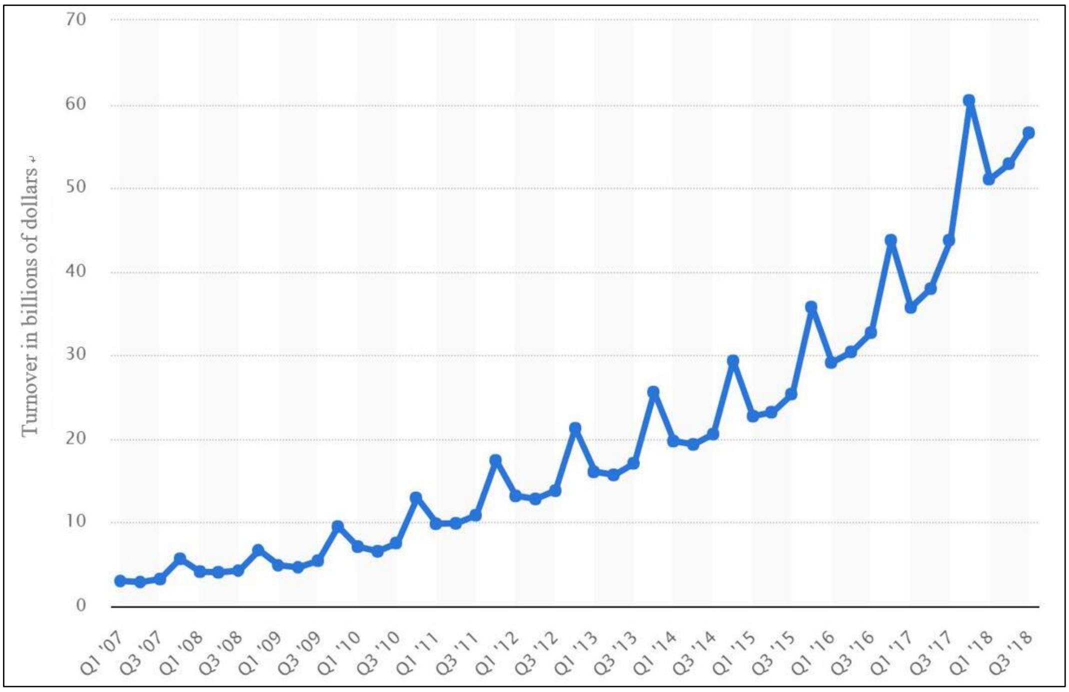


Figure 6: Amazon sales worldwide from Q1 2007 to Q3 2018 in billion US Dollars (Statista, 2018)

Compared to the above example, more complex cases are the majority in actual production activities. E-commerce companies often encounter similar problems. One of the characteristic features of the e-commerce market is the significant irregularity of sales related to seasonality (Graves, 2012), particularly during certain holiday periods. Severe fluctuations in sales across the four seasons of the year are a challenge for nearly all companies, including those that correctly predict their goods flows. The data published by amazon.com illustrates this problem (see Figure 6). In the case of poor forecasting, out-of-stock situations can quickly destroy a store's e-commerce rating and lead to a decline in sales. In the e-commerce market, not only the shopping process but also an aggregation of negative feedback can be completed in an instant. On the other hand, however, too much inventory can seriously decrease a company's cash flow and reduce flexibility. "In terms of e-commerce, unpredictability is a constant factor" (Graves, 2012). Even in the case of correct forecasting in e-commerce, it is necessary to adjust company organization and technology for sales in the high season, including a rational allocation of resources (such as employee and technological equipment, etc.) (Żuchowski, 2016). Moreover, the best predictions are never completely correct. Enterprises, especially in the e-commerce sector, should always maintain flexibility, balancing in timely manner the competing demands of resources, production and sales strategies. Given limited resources, knowing how to make right decisions quickly is the key to business success.

1.5.1.2. Solving the knapsack problem

The knapsack problem has been thoroughly studied in the last few decades and several algorithms for its solution can be found in the literature. Algorithms for solving the 0–1 knapsack problem can be divided into two general categories: those of exact methods and those of heuristics. Exact methods demonstrably determine the exact optimum of the decision problem: this includes such algorithms as the branch-and-bound algorithm, core algorithm, dynamic programming algorithm and tighter bounds. Exact methods (Martello et al., 1999, Martello et al., 2000) have made significant progress in recent years (Kellner et al., 2012), but are still not satisfactory when dealing with large problems.

Heuristic methods are not only numerous in the literature, but also very divergent in content. The word “heuristic” is derived from Greek and means “suitable for finding.” In the field of operations research in Germany, Streim (1975) has presented the notion of heuristic solution methods for optimization problems. Heuristic solution methods generally assume a solution of the model and, in the course of the procedure, search the solution set for “better” solutions. The best-known heuristics are the add approach of Kuehn and Hamburger (1963) and the drop approach of Feldman, Lehrer and Ray (1966). Both methods are a form of greedy heuristics. Due to the add or drop method, the solution can be improved with perturbation. A typical method for this is called “interchange heuristic” (Jacobson 1983; Khumawala 1974).

Although heuristics cannot guarantee an optimal solution vector in the strict sense, they are nevertheless good methods for providing very good or optimal results even for larger problems (Fréville, 2004). Heuristics can be further divided into several subcategories, such as greedy algorithms (Senju and Toyoda, 1968), meta-heuristics with taboo search (Dammeyer and Voss, 1991), simulated annealing (Drexl, 1988) or genetic algorithms.

In practice, decision makers at a company usually require complex optimization software in order to make quick decisions about multiple action alternatives. Based on these approaches mentioned above, many types of software were developed as decision support for knapsack problems. Existing software types have different characteristics in terms of cost, user-friendliness, installability and solution efficiency. Costs here refers to fees for using the software, while user-friendliness refers to the operability for the overwhelming majority of employees in an enterprise, which in turn affects the training costs for employees. Due to the widespread application of Microsoft Excel® in companies, the user-friendliness of Excel integration is considered as already established. Installability here includes the usability on the computer of an employee without administrator rights. Solution efficiency is described by the solution quality or solution efficiency and the required computation time, especially for large problems.

In general, optimization software can be divided into commercial and free software options. Commercial software, such as IBM ILOG CPLEX® or LINDO LINGO®, is more suitable for advanced operations research users, since one has to learn a lot of software-specific syntax. Although there are also several applications which experienced users can use in the Excel interface, the relatively high license costs per user hinder widespread use in companies. An expensive price tag for this type of software and the concomitant complex installation requirements might be acceptable for large companies, but are harder to bear for small ones. In 2016, the share of micro-enterprises and small enterprises in Germany was 96% (Statista, 2017). A study 2017 from ibi research (Zeng & Bolz, 2017) shows that 42% of online pure players started their businesses after 2010. These young small enterprises usually have only a few employees and lack the capital to operate complex optimization software. In addition, currently existing optimization software is typically used by operations research experts within larger corporations, but the application of these software products is restricted. Such software entails large costs in terms of staff training. Furthermore, the lack of technical feasibility can also be an important reason behind companies using it. License regulations and restrictive IT policies regularly prohibit the installation or the data connection of software which has not been verified by the internal IT department. Verifying optimization software is often out of the question for the employee because of how long verification can often take in a given IT department.

Among the free options for optimization software, one can mention LP_Solve, COIN-OR, and GLPK. But as is the case with commercial software, these all require local installation on the respective user's computer. Some kinds, such as the COIN-OR / OpenSolver, can also perform a pure Microsoft Excel® integration, but then they usually try to establish a data connection in order to download the required algorithms for the 0-1 problem, which installation (as mentioned above) is regularly prevented by IT security measures. Beside software, some Internet services provide free optimization alternatives. However, their user-friendliness is very limited, since integration with Microsoft Excel® is usually not possible. Thus, the employee only has the option of using the Excel Solver, which is integrated by default in Microsoft Excel® and can be activated by the user. However, in practice the Excel Solver often proves ill-suited for knapsack problems due to a lack of solution competence; even minor problems of this type cannot be solved using it. Because of the shortcomings of existing programs, small enterprises – especially in the field of e-commerce – require a new solution.

This paper will present a new software, SolveGA, for decision support, developed using genetic algorithms and technically programed into Microsoft Excel®, since genetic algorithms are particularly suitable for solving 0–1 decision problems (Raidl 1998, Raidl 1999).

1.5.2. Research method

SolveGA is programmed in Microsoft Excel 2007® / VBA and contains several different genetic algorithms. This software is free of charge and can be installed and used at one's own risk according to MIT license (http://opensource.org/licenses/mit-license.php). User-friendliness is achieved through direct Excel integration with a simple graphical interface. Administrator rights are not required in order to use SolveGA; installability is thus not an issue. With regard to the solution quality of SolveGA, the user has the option of four levels of quality and speed. At level 1, only the method of Raidl (1998) is used; level 2 also applies the method of Chu and Beasley (1998); level 3 incorporates the algorithm from Gottlieb (2000); while level 4 adds the algorithm from Levenhagen et al. (2001) based on the first three levels. For each method, 500 iterations are performed each time. The user has the possibility in the program's advanced mode of modifying the number of iterations.

SolveGA's graphical user interface consists of four input fields (see Figure 7). To fill these four input fields, first select the input field and then mark the corresponding area on the Excel sheet. "Alternative Value" includes the range of the target function coefficients or the profits of the action alternatives. "Available Resources" is the area of available resources. Alternative Consumption is the area of resource consumption through action alternatives. "Output Range" contains the area where the result vector is to be copied. In addition to these four input fields, the user has the option to select one of the four quality and speed levels.

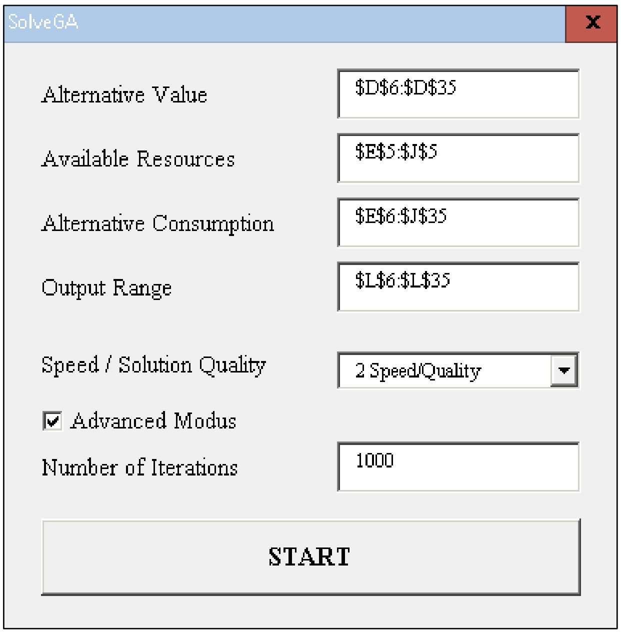


Figure 7: Graphical user interface of SolveGA

1.6. List of Publications

Paper 1:

Zeng, L. (2014). “E-Commerce-Logistik in China: Status quo und Handlungsoptionen für deutsche Online-Händler.” Banking and Information Technology, 15(2), 33–44.

Paper 2:

Zeng, L. & Bolz, T. (2017). “Analysis of the Logistics Efficiency in E-Commerce: Online vs. Multichannel.” Banking and Information Technology, 18(1), 62–68.

Paper 3:

Lienland, B. & Zeng, L. (2015). “A Review and Comparison of Genetic Algorithms for the 0–1 Multidimensional Knapsack Problem.” International Journal of Operations Research and Information Systems, 6(2), 21–31.

Paper 4:

Zeng, L., Lienland, B. & Kellner F. (2016). “Rucksackprobleme in der Praxis – schnelle Entscheidungen schwer gemacht.” HMD Praxis der Wirtschaftsinformatik, 53(3), 310–322.

2. E-Commerce-Logistik in China: Status quo und Handlungsoptionen für deutsche Online-Händler[1]

Li Zeng

2.1. Einleitung

Der Umsatz des E-Commerce in Deutschland gemäß den Daten des Bundesverband des Deutschen Versandhandels wächst seit Jahren stetig an und betrug für das Jahr 2013 39,1 Milliarden Euro (BVH, 2014). Etwa 80 % der deutschen E-Commerce-Unternehmen verkaufen auch an ausländische Kunden und etwa 17 % davon generieren damit mehr als 10 % des gesamten Umsatzes (Wittmann & Stahl, 2012). Während sich die wirtschaftlichen Wachstumsraten in den westlichen Ländern etwas abschwächen, kommt der E-Commerce in den Schwellenländern in Schwung. Insbesondere China gilt als attraktivster Wachstumsmarkt für E-Commerce-Aktivitäten. Nach Angaben des China Internet Network Information Center (CNNIC) hatte China 591 Millionen Internetnutzer im Jahr 2013, davon sollen 312 Millionen im selben Jahr mindestens einmal online eingekauft haben (CNNIC, 2013; Cao, 2014). Der chinesische E-Commerce-Markt ist im Jahr 2013 um ca. 30 % gewachsen und das gesamte Handelsvolumen einschließlich Customer to Customer (C2C), Business to Customer (B2C) und Business to Business (B2B) beträgt etwa 1.200 Milliarden Euro (Cao, 2014). Davon beträgt der Umsatz des Einzelhandel im E-Commerce ca. 220 Miliarden Euro (Ministry of Commerce of the people's Republic of China, 2014). Der Umsatz im B2C-Segment wird vor allem über Online-Marktplätze generiert. Über die fünf größten Online-Marktplätze in China Tmall (50,1 %), 360Buy (22,4 %), Suning (4,9 %), Tencent (3,1 %) und Amazon (China) (2,7 %) wird 83,2 % des gesamten B2C-Umsatzes im E-Commerce generiert (Cao, 2014). Zudem wird der Online-Einkauf direkt aus dem Ausland in China immer beliebter. Der Umsatz mit den aus dem Ausland online gekauften Waren erreichte 2013 etwa 9 Milliarden Euro und ist damit im Vergleich zum Vorjahr um 58,8 % gestiegen (Mo, 2014). Diese Entwicklung ist auch für deutsche Online-Händler interessant, denn das Interesse der chinesischen Endverbraucher an deutschen Marken ist sehr hoch.

Gemäß der Statistik von National Bureau of Statistics of China (NBS) beträgt der Umsatz des gesamten chinesischen Einzelhandels 2,76 Billionen Euro im Jahr 2013 (NBS, 2014). Der Umsatzanteil des E-Commerce am gesamten Einzelhandel beträgt in China somit etwa 8 %. Damit hat China bereits die USA als größten E-Commerce-Markt überholt. Der Economist (2013) prognozietiert sogar, dass der chinesische E-Commerce Markt bis 2020 den Umsatz der USA, UK, Japan, Deutschland und Frankreich zusammen generieren wird.

China ist noch als ein Entwicklungsland anzusehen. Der chinesische E-Commerce-Markt stellt deswegen für viele Händler eine attraktive Geschäftsmöglichkeit dar. Für ausländische Unternehmen, die im chinesichen E-Commerce aktiv werden wollen, sehen sich aber noch vielen Herausforderungen gegenüber. Der chinesische E-Commerce Markt

[1] Zeng, L. (2014). "E-Commerce-Logistik in China: Status quo und Handlungsoptionen für deutsche Online-Händler." Banking and Information Technology, 15(2), 33–44.

ist jedoch in vielen Bereichen aus der Sicht eines deutschen Händlers als problematisch anzusehen, z. B. hinsichtlich des Vertrauens (Teo & Liu, 2007; Zhang, Bian, & Zhu, 2013), der Rahmenbedingungen für Investitionen (Wang X., 2012) und des spezifischen Kaufverhaltens (Efendioglu & Yip, 2004; Yoon, 2009). Eines der am meisten diskutierten Probleme im Zusammenhang mit dem E-Commerce ist die Entwicklung der Logistik (Yang & Ma, 2013; Ke & Jiang, 2014). Im Jahr 2013 betrug der Gesamtlogistikumsatz in China 23,3 Billionen Euro und für 2014 wird ein Wachstum von 9 % erwartet (National Development and Reform Commission et al., 2014). Die relativ langsame Logistikentwicklung hat das E-Commerce-Wachstum in China abgeschwächt (siehe Abbildung 1).

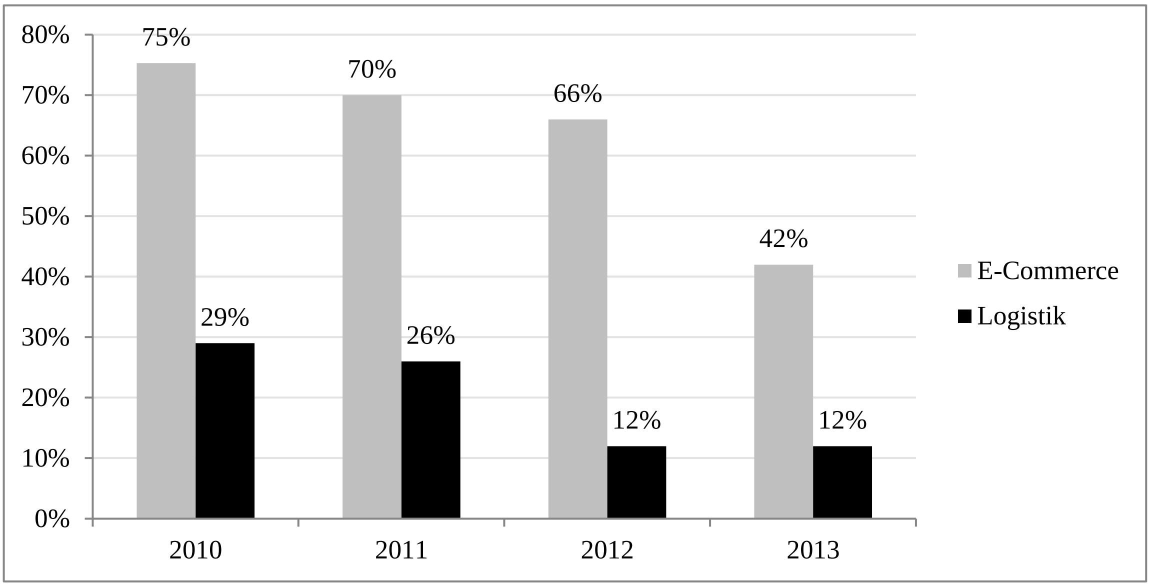


Abbildung 1: Wachstumsrate des Umsatzes des E-Commerce (Einzelhandel) und der Logistik in China 2010-2013 (iResearch, 2014; National Development and Reform Commission et al., 2011-2014)

Wittmann & Stahl (2012) definieren den E-Commerce als der Verkauf von Waren und Dienstleistungen über das Internet. Die logistische Abwicklung ist dabei als Teilprozess in der Prozesskette von E-Commerce-Aktivitäten zu sehen. Der Erfolg des E-Commerce ist damit wesentlich von der Effizienz der Logistiksysteme abhängig (Riehm et al., 2003).

Vor diesem Hintergrund fokussiert sich dieser Artikel auf die chinesische E-Commerce-Logistik. Folgende Forschungsleitfrage soll beantwortet werden: Wie können sich deutsche Händler hinsichtlich der Logistik auf dem chinesischen E-Commerce-Markt positionieren? Das Ziel der vorliegenden Arbeit ist die Darstellung des E-Commerce-Wachstums vor dem Hintergrund der logistischen Entwicklung in China. Hierbei sollen bestehende Probleme analysiert und Lösungsansätze mit möglichen Perspektiven aufgezeigt werden. Auf Basis der daraus generierten Erkenntnisse sollen Handlungsoptionen für deutsche Händler auf dem chinesischen E-Commerce-Markt vor allem hinsichtlich der Logistik unterbreitet werden.

Zu diesem Zweck erfolgt zuerst eine Auswertung der aktuellen Literatur zur chinesischen E-Commerce-Logistik. Zum Zweiten werden die Entwicklung, Probleme und Lösungsmöglichkeiten der Logistik für E-Commerce in China im Rahmen von

Fallstudien ermittelt. Im Anschluss werden die Ergebnisse diskutiert und Handlungsoptionen für deutsche Händler abgeleitet.

2.2. Literaturauswertung

Im Rahmen dieses Artikels wurde eine umfassende Literaturrecherche zur E-Commerce-Logistik in China durchgeführt. Zum einen wurde die Literatur in der Datenbank von China National Wissensinfrastruktur (CNKI) ausgewertet. CNKI ist die größte und wichtigste Quelle für Informationsressourcen über China (CNKI, 2014). Die Datenbank enthält wissenschaftliche Publikationen in den Bereichen Politik, Wirtschaft, Sozialwissenschaft, Naturwissenschaft und Technik in China. Zudem wurde in den Datenbanken von ScienceDirect und EBSCOhost nach relevanten Artikeln gesucht. Aufgrund der dynamischen Entwicklung sowohl im E-Commerce als auch im Logistikbereich wurde der Betrachtungszeitraum für Veröffentlichungen ab dem Jahr 2012 ausgewählt.

Als Fazit der Literaturrecherche kann festgehalten werden, dass die meisten Artikel sich mit einem konkreten Problem für eine bestimmte Branche oder für eine bestimmte Region beschäftigen (Sun, 2012; Yang, 2013; Yang J., Yang C., & Yao, 2014). Nur wenige wissenschaftliche Arbeiten analysieren den gesamten chinesischen E-Commerce-Markt vor dem Hintergrund der logistischen Entwicklung. So sind Fang (2012) und Wang J. (2014) der Meinung, dass die Infrastruktur die größte Wachtumsbremse für den chinesischen E-Commerce ist. Qin (2013) behauptet, das die rechtlichen Rahmenbedingung für die Logistik in China nicht zeitgemäß sind und deswegen zu Problemen führen. Chen L.& Hao (2013) und Xie & Yan (2012) schreiben, dass die Logistikkosten in China aufgrund von verschiedenen Gebühren und der niedrigen Effizienz zu hoch sind. Ma & Xun (2012) zeigen, dass die Digitalisierung bei chinesischen Unternehmen im Bereich der Logistik noch in der Anfangsphase ist. Li (2013) beschreibt den Mangel an logistischem Fachpersonal bei chinesischen Unternehmen. Fang (2012) führen an, dass es zu viele kleine Logistikunternehmen (inklusive Spedition, Lagerhäuser und Logistikdienstleister) auf dem chinesischem Markt gibt und somit kein effektives Logistiknetzwerk vorhanden ist. Chen X. & Lin (2013) sind der Meinung, dass die Qualität der Logistikdienstleister in China für den E-Commerce nicht ausreicht.

2.3. Methode

Für diesen Artikel wurde die Fallstudienforschung nach (Yin, 2009) als Forschungsmethode angewendet. Nach Yin (2009) ist die Fallstudienforschung vor allem zur Beantwortung der Forschungsfragen „wie“ und „warum“ und zur Untersuchung aktueller Phänomene geeignet, besonders wenn kein direkter Einfluss auf den Untersuchungsgegenstand ausgeübt werden kann. Weiterhin bietet die Fallstudienmethodik den Vorteil, dass sie auch während der Untersuchung noch flexibel genug gestaltet werden kann, um auf unerwartete Aspekte und Erkenntnisse reagieren zu können. Die Forschungsleitfrage soll dabei auf Basis von zwei Forschungsunterfragen beantwortet werden:

1. Wie beeinflussen logistische Probleme den E-Commerce in China?

2. Wie sehen die Lösungsansätze für bestehende logistische Probleme im E-Commerce in China aus?

Die Datenerhebung erfolgte sowohl durch Telefoninterviews, als auch durch Auswertung von Sekundärquellen wie Webseiten, Geschäftsberichte und andere Schriften. Da der Untersuchungsgegenstand, die chinesische E-Commerce-Logistik, immer der gleiche ist und mehrere Fallstudien durchgeführt wurden, liegt das holistische Multiple-Case Design als Fallstudientyp vor (Yin, 2009). Für die Interviews werden zwölf Experten selektiert, die in die Organisationsgruppen Forschung, Praxis und chinesische Regierung eingeteilt werden können. Jede Gruppe wird dabei als einzelne Fallstudie analysiert. In der Gruppe Forschung wurden vier Experten von der Southwestern University of Finance and Economics (SWUFE) und zwei Experten vom China E-Commerce Research Center (CECRC) befragt. In der Unternehmens-Gruppe wurden drei leitende Angestellte von Logistikunternehmen zur Befragung herangezogen. Aus der Kategorie chinesische Regierung wurden drei Beamte vom staatlichen Logistikpark befragt. Durch die Auswahl von verschiedenen Gruppen sollten regionale Unterschiede und subjektive Sichtweisen einzelner Gruppen ausgeschlossen werden. Bei der Wahl der Fallstudien-Organisationen war neben dem Argument der Zugänglichkeit zu Informationen und der Bereitschaft der Mitarbeiter in der Untersuchung mitzuarbeiten auch das Bestreben, möglichst unterschiedliche Organisationsgruppen mit einzubeziehen entscheidend. Nach der Durchführung der Fallstudien wurde auf Basis der Einzelfallberichte fallübergreifende Schlüsse gezogen und mit diesen der aktuelle theoretische Stand zur E-Commerce-Logistik in China modifiziert bzw. erweitert. Auf Grundlage der angepassten Theorie wurden Handlungsoptionen für die deutsche Händler abgeleitet, die auf dem chinesischen E-Commerce-Markt aktiv sein wollen.

2.4. Logistik in China

Chinas Logistikindustrie hat sich in den letzten Jahren rapide entwickelt. Das Handelsvolumen der chinesischen Logistik hat sich von 2001 bis 2010 um das 6,3-fache erhöht. Die durchschnittliche jährliche Wachstumsrate in diesem Zeitraum betrug 22 %. Aufgrund der wirtschaftlichen Entwicklung hat China die logistische Infrastruktur kontinuierlich verbessert und damit die Grundlage für den E-Commerce-Wachstum gelegt. Dennoch kann die heutige Logistikindustrie die Ansprüche des E-Commerce nicht hinreichend befriedigen. Der Hauptgrund dafür ist, dass die Logistik der Entwicklung des E-Commerce nicht nachkommt (siehe Abbildung 1).

Auf Basis der durchgeführten Literaturrecherche wurden einige Problembereiche zur Logistik im E-Commerce identifiziert, wie in Tabelle 1 dargestellt wird.

	Problemfelder	Kriterien	Beschreibung	Quelle
1	Infrastruktur	Verfügbarkeit, Qualität und Zuverlässigkeit	Straßen, Eisenbahnen, Wasserstraßen und Flughafen	veraltete und unzureichende Infrastruktur (Fang, 2012; Wang J., 2014)
2	Rechtliches Umfeld	Verfügbarkeit und Systematik	Gesetze, Regel und staatliche Politik	keine systematischen Gesetze, schlechte Exekutive (Qin, 2013)
3	Kosten	Preis und Art	Gebühren und Steuern	vielfältige Gebühren und Steuern, niderige Rentabilität (Chen L.& Hao, 2013; Xie & Yan, 2012)
4	Informations- und Kommunikations-technik	Verfügbarkeit, Qualität und Durchdringung	Kommunikation und Informationsintegration	geringer Stand der Digitalisierung (Ma & Xun, 2012)
5	Humankapital	Verfügbarkeit und Qualifikation	Fachpersonal	Mangel an Fachpersonal (Li, 2013)
6	Konkurrenz und Kooperation	Anzahl und Qualität	Anzahl und Ausmaß der Logistikunternehmen	zu viele kleine Logistikunternehmen (Fang, 2012)
7	Logistikdienstleister	Verfügbarkeit, Qualität und Zuverlässigkeit	Firmenexterne Logistikdienstleister (Third Party Logistics)	nicht genug qualifizierte Logistikdienstleister (Chen X. & Lin, 2013)

Tabelle 1: Logistikprobleme in China

Das Konzept der Logistik wurde von Europa und den USA am Anfang der 1980er Jahre eingeführt, nachdem die Auswirkungen der Logistik auf die Geographie untersucht wurde (Wang C. J., 2006). Der Fokus der chinesischen Forschung zur Logistik beschränkt sich noch auf den physischen Transport von Waren, während sich die westlichen Wissenschaftlicher auf Supply Chain Management konzentrieren (Mahpula et al., 2013). Im Rahmen des Supply Chain Management werden alle internen und netzwerkgerichteten Unternehmungsaktivitäten wie Versorgung, Entsorgung und Recycling, inklusive den begleitenden Geld- und Informationsflüssen, berücksichtigt (Werner, 2008). Im Folgenden werden die in der bestehenden Theorie identifizierten Problembereiche der Logistik im Hinblick auf den E-Commerce detailliert beschrieben.

Infrastruktur

Im Jahr 2012 hatte China das zweitgrößte Eisenbahnnetz der Welt mit mehr als 100.000 km Eisenbahnen (Bai, Tang, & Cai, 2013) und das größte Straßennetz weltweit mit 4.240.000 km. Weiterhin besitzt China den größten Binnenwassertransport mit 125.000 km schiffbaren Wasserstraßen (Sun Y., 2013). Der Gesamtfrachtverkehr durch Transport auf Straßen, Eisenbahnen, Wasser und Luft betrug 406,67 Millionen Tonnen im Jahr 2013 (Wei, 2013). Etwa 79 % des Warentransports wurde mit Lastwagen, 9,6 % mit Zugverbindungen und 11,2 % per Schifftransport durchgeführt. Berechnet man jedoch diese Werte pro Einwohner, so ergeben sich im Vergleich zu entwickelten Ländern unterdurchschnittliche Werte. Die veraltete und unzureichende Infrastruktur in China führt immer noch zu erheblichen Problemen z. B. bei Pünktlichkeit und Zuverlässigkeit. Weiterhin gibt es in China noch große regionale Unterschiede hinsichtlich der

Infrastruktur (Fang, 2012; Wang J., 2014). So ist die Infrastruktur im Osten des Landes deutlich besser entwickelt als im Westen. Auch in ländlichen Gebieten gibt es noch enormen Nachholbedarf hinsichtlich der logistischen Infrastruktur im Vergleich zu größeren Städten.

Rechtliche Rahmenbedingung

Für die Regelung der verschiedenen Transportarten wie Autobahn, Eisenbahn, Wasserverkehr und Luftverkehr sind verschiedene Abteilungen der chinesischen Regierung verantwortlich. In der Regel arbeiten diese Ämter getrennt voneinander und haben damit nur geringe Möglichkeiten zum Koordinieren. Somit sind auch die verabschiedeten Gesetze der einzelnen Ämter, die die Logistik betreffen, nicht aufeinander abgestimmt. Zudem sind viele rechtliche Rahmenbedingungen hinsichtlich der Logistik nicht mehr zeitgemäß. Die gesetzliche Grundlage für ein effizientes Logistiknetzwerk ist damit nicht vorhanden (Qin, 2013).

Kosten

Die Logistikkosten in China betrugen durchschnittlich zwischen 2002 und 2012 gemessen am Bruttoinlandsprodukt etwa 18 %. Im Vergleich dazu betrug dieser Wert in den USA nur etwa 10 % (Chen L.& Hao, 2013; He, 2013). Zudem war im Jahr 2012 der Anteil der Verwaltungskosten an den gesamten Logistikkosten in China 12,3 %. In den USA lag dieser Wert bei 2,3 %. Der Transportkostenanteil an den Logistikkosten betrug in 2012 in China 52,5 % (USA 63 %). Allgemein gilt, je niedriger der Anteil der Verwaltungskosten und je höher der Anteil der Transportkosten an den gesamten Logistikkosten, desto effizienter die Logistik (Chen L.& Hao, 2013). Gebühren (z. B. Mautgebühr, Verwaltungsgebühr, Zertifikatsgebühr, etc.) und Steuern (z. B. Gewerbesteuer, Verkehrsteuer, Körperschaftssteuer, etc.) machen etwa ein Drittel der Gesamtkosten der Logistikunternehmen aus (Chen L.& Hao, 2013). Aufgrund der steigenden Preise für Rohstoffe und Grundstücke, und den gestiegen Personal- und Kapitalkosten ist die durchschnittliche Umsatzrendite der Logistikunternehmen in China von 30 % im Jahr 2005 auf 5 % im Jahr 2013 gesunken (Zhou, 2013). Wegen der geringen Rentabilität von Logistikunternehmen in China werden kaum Investitionen durchgeführt.

Informations- und Kommunikationstechnik

Um die Zusammenarbeit innerhalb eines Unternehmens oder zwischen verschiedenen Unternehmen zu unterstützen und zu intensivieren, ist eine effektive Informations- und Kommunikationsinfrastruktur notwendig (Muckstadt et al., 2001). Dabei spielt die Informationsintegration eine wichtige Rolle. Unter Informationsintegration versteht man die gemeinsame Benutzung von Informationen zwischen den Teilnehmern einer Lieferkette (Lee & Whang, 2001). Hierbei sind sämtliche Daten relevant, von denen die Handlungen und Leistungen eines Kettengliedes abhängig sind, z. B. Nachfragedaten, Lagerbestandsdaten, Kapazitätsdaten, Produktionspläne, Lieferdaten und Pläne zur Gestaltung von Rabattaktionen (Lee & Whang, 2001).

Laut dem Bericht „Logistics Informatization Investigation Report 2010“ von China Federation of Logistics & Purchasing (CFLP) haben 61 % der Logistikunternehmen eine eigene Webseite, 78 % haben eine eigenständige IT-Abteilung, 80 % der Unternehmen haben Angestellte, die für Informationssysteme zuständig sind und 70 % der befragten Unternehmen haben ein Informationsmanagementsystem aufgebaut. Das Informationsmanagementsystem umfasst hierbei das Electronic Order System, Warehouse Management System, Transport Management System, Procurement Management System, Online Payment System, Customer Management System und Object Tracking. 40,2 % der Unternehmen haben das Informationsmanagementsystem selbst entwickelt. Hinsichtlich der neuen Technologien nutzen 40,3 % der Unternehmen die Strichcodetechnik, 33,8 % nutzen GPS bzw. GIS und 23,6 % RFID oder RF 23,6 %. Im Vergleich zu bereits entwickelten Ländern besteht hinsichtlich der eingesetzten Technologien noch großer Nachholbedarf (Ma & Xun, 2012). Bei der Informationsübertragung gibt es auf dem chinesischen Markt kaum Standards bzw. einheitliche Formate. Somit gestaltet sich die digitale Kommunikation und die Informationsintegration zwischen verschiedenen Teilnehmern sehr schwierig.

Fachpersonal

Seit einigen Jahren hat sowohl die Praxis als auch die Wissenschaft einen Mangel an qualifiziertem Fachpersonal in der Logistik identifiziert. Eine eindeutige Meinung hinsichtlicht des Bedarfs an Fachleuten im Logistikbereich existiert jedoch nicht (Li, 2013). Der zahlenmäßige Mangel wird zwischen 6 Millionen und 600 Tausend beziffert (Li, 2013). Dies ist auf die uneinheitliche Definition des Begriffes logistisches Fachpersonal in der chinesischen Wissenschaft und Praxis zurückzuführen. Aus diesem Grund ist der exakte Mangel an Quantität und Qualität von logistischem Fachpersonal nicht eindeutig festzustellen. Damit wird auch belegt, dass noch Forschungslücken in der Theorie zur chinesischen Logistik vorhanden sind.

Konkurrenz und Kooperation

Die chinesische Logistik ist durch eine polypolistische Marktsituation gekennzeichnet: Es gibt viele kleine Logistikunternehmen, die regional agieren. Eine genaue Anzahl der chinesischen Logistikunternehmen ist nicht vorhanden. In der Provinz Sichuan sind mehr als 10.000 Logistikunternehmen eingetragen (Duan & Liu, 2013). Auf Basis dieser Daten wird die Anzahl der Logistikunternehmen in China auf etwa 700.000 geschätzt. Die vier größten Logistikunternehmen im B2C-Segment in China generierten 2012 etwa 50 % des gesamten Umsatzes in der Logistikbranche. Im Vergleich dazu sind in den USA ca. 6.000 Logistikunternehmen am Markt tätig und die größten vier Logistikunternehmen hatten in 2012 einen Marktanteil von 95 % (Mo, 2014). Aufgrund der starken Wettbewerbssituation in der Logistikbranche in China sind erfolgreiche Kooperationen zwischen den einzelnen Logistikunternehmen eher selten (Fang, 2012). Somit können Verbundeffekte nicht genutzt werden.

Logistikdienstleister

Chinas Marktteilnehmer für E-Commerce, insbesondere für B2C, können hinsichtlich ihrer Struktur in drei Typen eingeteilt werden. Zum einen staatliche Logistikdienstleister, die zurzeit große Marktanteile haben, wie z.B. Express Mail Service (EMS), China Air Express (CAE) und China Railway Express (CRE). Zudem kann nach ausländischen Logistikunternehmen, die in China für ihre multinationalen Kunden agieren, unterteilt werden. Dazu gehören z.B. TNT, UPS, DHL und FedEx. Die letzte Gruppe stellen private chinesische Logistikunternehmen, wie z.B. Shunfeng Express, STO, YTO und Yunda, dar.

Chinesische Logistikunternehmen haben im Vergleich zu ausländischen Logistikanbieter deutlich höhere Marktanteile (Mahpula u. a., 2013). Diese ergeben sich vor allem aufgrund des Marktschutzes der chinesischen Regierung und der vielen inländischen Konkurrenten, was eine Markteindringung für ausländischen Anbieter erschweren. So verließ z. B. DHL 2011 den chinesischen Binnenmarkt wegen anhaltender Verluste. Im Jahr 2013 verkaufte TNT das chinesische Tochterunternehmen Tiandihuayu und hatte damit einen Buchwertverlust in Höhe von 217,6 Millionen Euro.

Private chinesische Logistikunternehmen werden in China aufgrund ihrer Flexibilität und den geringen Kosten am häufigsten als Logistikdienstleister eingesetzt. Gemäß den Daten der Ministry of Commerce of the people’s Republic of China wurden in 2012 nicht mehr als 25% des Rohmaterials und der Fertigprodukte von Logistikdienstleistern geliefert (Ministry of Commerce of the people’s Republic of China, 2013). Der Transport des restlichen Rohmaterials bzw. der Fertigprodukte wurde von den Unternehmen selber durchgeführt. Die meisten chinesischen Logistikdienstleister sind Kleinunternehmen und daher in der Regel nicht auf dem aktuellsten Stand der Informations- und Kommunikationstechnologie. Dies äußert sich unter anderem in einem unbefriedigenden Kundenservice. So haben Kunden oftmals Probleme z. B. bei Abholungen, Anfragen, Rückgaben und Sendungsnachverfolgungen (Chen X. & Lin, 2013). Dies wirkt sich auf das Image von E-Commerce-Unternehmen aus. Laut einer Studie aus dem Jahr 2012 sind nur 40 % der Kunden mit der Lieferung zufrieden, wenn sie bei E-Commerce-Unternehmen online bestellen (Online Shopping Express Satisfaction Monitoring, 2012).

2.5. Diskussion

Die Auswirkungen der beschriebenen logistischen Probleme in China auf den E-Commerce und mögliche Lösungsansätze dazu wurden, wie bereits erläutert, im Rahmen von Fallstudien mit Experten untersucht.

Hinsichtlich der Infrastruktur geht aus den Fallstudien hervor, dass die aktuellen Kapazitäten nicht die Nachfrage befriedigen können. Jedoch ist ein deutlicher Fortschritt in der nahen Zukunft zu erwarten. So werden z. B. bis 2020 die Eisenbahnstrecken um 20 % vergrößert und bis 2030 soll die Kapazität für den Frachtverkehr auf Straßen verdoppelt werden. Unter Logistikpark kann ein Gebiet verstanden werden, in der sich verschiedene Logistikunternehmen mit einer entsprechenden Infrastruktur (z. B. Eisenbahn, Flughafen, Versandzentren) befinden. Neben den aktuell 348 vorhandenen Logistikparks sind aktuell noch 241 weitere im Aufbau und zusätzliche 165 sind noch geplant. Das starke Ungleichgewicht der logistischen Infrastruktur zwischen Ost- und Westchina wird auch in Zukunft weiterhin bestehen. Dies wird jedoch nicht als ein großes Problem angesehen, da die Nachfrage nach mehr logistischer Infrastruktur für den E-Commerce vor allem aus dem Osten kommt. Die umsatzstärksten chinesischen E-Commerce-Unternehmen, wie beispielsweise Alibaba oder 360Buy, haben ihren Sitz in der Regel in der Mitte und im Osten des Landes, wo auch etwa 66 % der chinesischen Bevölkerung leben.

Bezüglich der rechtlichen Rahmenbedingungen ist aus den Fallstudien zu entnehmen, dass es sich um ein typisches Wachstumsproblem handelt, bei dem der Gesetzgeber erst auf die Entwicklungen der Praxis reagieren kann. Die chinesische Regierung hat damit angefangen, eine Reihe von gesetzlichen Rahmenbedingungen hinsichtlich der aktuellen Situation in der Logistik zu erstellen. So versucht die Regierung z. B. die Kooperation von Logistikunternehmen mit politischen Maßnahmen in den Bereichen Investition, Finanzierung und Steuern zu fördern. Die Anpassung der rechtlichen Rahmenbedingungen wird jedoch iterativ durchgeführt und wird auf längere Sicht erfolgen.

Die Kostensituation in der chinesischen Logistik wird insbesondere durch die gesetzlichen Rahmenbedingungen beeinflusst. Die chinesische Regierung plant vor allem eine Reduktion der erläuterten Gebühren und Steuern, die die Logistik betreffen. Weiterhin sollten chinesische Logistikunternehmen ihre Technik verbessern, um die Kosten zu senken und damit ihre Effizienz zu steigern. Auch die Qualität des Managements im Bereich des Controllings wird von den Fallstudienpartnern als unzureichend gesehen.

Hinsichtlich der Informations- und Kommunikationstechnik resultiert aus den Fallstudien, dass der Grad der Digitalisierung insbesondere bei kleinen und mittleren Logistikunternehmen sehr niedrig ist. Die Mehrheit der Logistikunternehmen können als KMU kategorisiert werden. Die Logistikunternehmen, bei denen die Digitalisierung fortgeschritten ist, ist oftmals die Anpassung der Software an die unternehmensspezifischen Besonderheiten problematisch. Die Ursache für den geringen Grad der Digitalisierung liegt vor allem auch am mangelnden Fachpersonal.

Bezüglich des Fachpersonals ist aus den Fallstudien zu entnehmen, dass die Nachfrage nach qualifizierten Fachkräften aus dem Logistikbereich deutlich größer ist als das Angebot. Insbesondere sind erfahrene Manager im Logistikbereich in China nur sehr schwer zu finden. Die chinesischen Hochschulen und Berufsschulen können sowohl qualitativ als auch quantitativ die Nachfrage nach neuen Fachkräften nicht nachkommen. Oftmals ist den Hochschulen der Mangel an logistischem Fachpersonal gar nicht bewusst und die Ausbildung zu praxisfern. Auch in naher Zukunft sind hier keine Lösungsansätze zu erkennen. Aus diesem Grund müssen sich Logistikunternehmen um die Aus- und Fortbildung ihres Personals selber kümmern.

Weiterhin geht aus den Fallstudien hervor, dass die starke Konkurrenzsituation bei Logistikunternehmen sich in Zukunft verringern wird. Aufgrund der geringen Margen und der polypolistischen Marktsituation soll es in naher Zukunft eine Marktbereinigung geben. Nicht konkurrenzfähige Logistikunternehmen werden vom Markt verschwinden. Dies wird voraussichtlich vor allem auf kleine, regional begrenzte Logistikanbieter zutreffen. Dadurch werden sich die Marktanteile für die verbleibenden Anbieter vergrößern und diese können ihre zusätzlichen Einnahmen für das weitere Wachstum nutzen.

Bezüglich der Logistikdienstleister wurde in den Fallstudien untersucht, welche Vor- und Nachteile die größten Anbieter aufweisen. Die Logistikdienstleister wurden nach den Kriterien geographische Abdeckung, Servicequalität und Preis beurteilt. Weiterhin werden die Logistikdienstleister in die bereits erläuterten drei Gruppen staatliche Logistikdienstleister, private chinesische Logistikdienstleister und ausländische

Logistikdienstleister kategorisiert. Hinsichtlich der geographischen Abdeckung hat der größte staatliche Logistikdienstleiter EMS das weitreichendste Netzwerk in China. EMS hat in China über 45.000 Filialen und deckt alle Städte in 31 chinesischen Provinzen ab. Die restlichen staatlichen Logistikunternehmen spielen aufgrund der geringen Anzahl ihrer Filialen im Vergleich zu EMS eine eher unbedeutende Rolle. Private chinesische Logistikunternehmen, wie z. B. Shunfeng, STO, YTO, Yunda, ZJS und TTK, können die meisten Gebiete in China abdecken. Jedoch können sie in der Regel ländliche Gebiete und kleine Städte nicht beliefern. Ausländische Logistikdienstleister müssen sich eine Genehmigung der chinesischen Regierung für den Aufbau eines Liefernetzwerks in einem bestimmten Gebiet einholen. So darf z. B. der amerikanische Logistikanbieter FedEx nur in den Gebieten der acht Städte Shenzhen, Guangzhou, Hangzhou, Shanghai, Tianjin, Dalian, Zhengzhou und Chengdu beliefern und UPS hat nur die Genehmigung für die Gebiete um Shenzhen, Guangzhou, Xi’an, Shanghai und Tianjin. Bezüglich des Angebots von Service-Dienstleistungen geht aus den Fallstudien hervor, dass die staatlichen Logistikdienstleister im Vergleich zu den privaten und ausländischen Unternehmen deutlich schlechter sind. Das größte staatliche Logistikunternehmen EMS ist z. B. für verspätete Lieferungen und die Unfreundlichkeit seiner Mitarbeiter bekannt. Der Service von privaten chinesischen Unternehmen gestaltet sich sehr unterschiedlich, da größere private Logistikdienstleister ihre Filialen oftmals an kleine regionale Logistikunternehmen auslagern. Eine Ausnahme stellt hier vor allem der Anbieter Shunfeng Express dar, dessen Kernkompetenz die Servicequalität (Zuverlässigkeit, Versanddauer und Pünktlichkeit) darstellt. Dieses private Logistikunternehmen verwaltet alle Filialen selber und hat ein ausgezeichnetes Qualitätsmanagement. Ausländische Logistikdienstleister bieten ebenfalls einen überdurchschnittlich guten Service an. Aufgrund der relativ guten Managementqualität und dem Knowhow aus anderen Ländern haben sie im Vergleich zu den chinesischen Anbietern eine höhere Zufriedenheitsrate bei Kunden. Bei den Preisen kann festgestellt werden, dass die ausländischen Logistikanbieter um einiges teurer sind als die chinesischen Dienstleister. Die staatlichen Unternehmen sind wiederum teurer als private chinesische Logistikanbieter.

	Staatliche Logistikdienstleister	**Private Logistikdienstleister**	**Ausländische Logistikdienstleister**
Geographische Abdeckung	Lieferung in alle Gebiete möglich	In der Regel keine Lieferung in ländliche Gebiete und kleine Städte	Nur in bestimmte Städte nach Genehmigung der chinesischen Regierung
Servicequalität	Verspätete Lieferungen und unfreundliche Mitarbeiter	Je nach Anbieter unterschiedlich	Überdurchschnittlich gute Servicequalität und in der Regel pünktliche Lieferung
Preis	Durchschnittliches Preisniveau	Niedriges Preisniveau	Hohes Preisniveau

Tabelle 2: Klassifizierung der firmenexternen Logistikdienstleiter für E-Commerce in China

Obwohl Logistikdienstleister sich in den letzten Jahren auf dem chinesischen Markt gut entwickelt haben, können sie die qualitativen und quantitativen Anforderungen von E-Commerce-Unternehmen noch nicht vollständig erfüllen. Aus diesem Grund haben einige große Online-Marktplätze, wie z. B. 360Buy, ihren eigenen Logistikversand aufgebaut und nachhaltig in diesen investiert. Mit dem eigenen Logistiknetzwerk kann der Versand besser kontrolliert und koordiniert werden. Dies resultiert in der Regel in einem besseren Kundenservice und in einer höheren Kundenzufriedenheit. So haben z. B. Logistikdienstleister am Frühlingsfest aufgrund des Personalmangels Lieferungsprobleme von bis zu vier Wochen. Zudem kann mit einer internen Logistik zusätzliche Services für Kunden angeboten werden. Zusammenfassend geht aus den Fallstudien hervor, dass der Versand einen der wichtigsten Erfolgsfaktoren für den E-Commerce in China darstellt.

2.6. Fazit

Die aktuellen Probleme in der chinesischen Logistik haben eine starke Auswirkung auf die Entwicklung des E-Commerce in China. Die Infrastruktur wird in Zukunft durch weitere Investitionen der chinesischen Regierung stark ausgebaut. Das starke Ungleichgewicht der Infrastruktur zwischen Ost- und Westchina wird auch in Zukunft weiterhin bestehen. Auch die rechtlichen Rahmenbedingungen werden von der chinesischen Regierung sukzessive an die aktuellen Anforderungen des E-Commerce angepasst. Diese Rahmenbedingungen beeinflussen auch die Kostensituation in der chinesischen Logistik. Auch hier wird eine Anpassung seitens des Gesetzgebers erfolgen, um Gebühren und Steuern, die im logistischen Bereich entstehen, zu senken. Nichtsdestotrotz ist eine Effizienzsteigerung bei den Logistikdienstleistern notwendig, um bei den Kosten auf internationalem Niveau mithalten zu können. Als Ursache für den geringen Grad der Digitalisierung konnte in den Fallstudien der Mangel am Fachpersonal identifiziert werden. In naher Zukunft sind hier keine Lösungsansätze zu erkennen, denn eine Besserung hinsichtlich der logistischen Bildung ist aufgrund vielfältiger anderer Probleme an den chinesischen Universitäten nicht zu erwarten. Aus diesem Grund müssen sich Logistikunternehmen um die Aus- und Fortbildung ihres Personals selber kümmern. Aufgrund der geringen Margen und der polypolistischen Marktsituation soll es in naher Zukunft eine Marktbereinigung geben, die insbesondere kleine Logistikunternehmen mit geringer Profitabilität treffen wird. Dadurch werden sich die Marktanteile für die verbleibenden Anbieter vergrößern, was wiederum in einem besseren Kundenservice und einer erweiterten geographischen Abdeckung resultieren kann. Hinsichtlich der in China vorhandenen Logistikdienstleister geht aus den Fallstudien hervor, dass es keine optimale Gruppe von Logistikdienstleistern gibt. Zwar können staatliche Anbieter landesweit liefern, jedoch besteht großer Handlungsbedarf hinsichtlich Service und den hohen Preisen. Private chinesische Logistikanbieter haben zwar geringe Preise und in der Regel einen durchschnittlichen Service, jedoch decken sie nur Gebiete um Großstädte ab. Ausländische Anbieter haben zwar einen überdurchschnittlich guten Service, verlangen jedoch hohe Preise und liefern nur in die von der chinesischen Regierung genehmigten Gebiete. Zusammenfassend kann festgehalten werden, dass für viele Problembereiche der chinesischen Logistik bereits Lösungsansätze existieren. Der Mangel an Fachpersonal wird auch weiterhin als ein wesentliches Problem der Logistik und damit auch des E-Commerce angesehen. Trotzdem kann davon ausgegangen werden, dass die aufgezählten Lösungsansätze eine gute Basis für die weitere Entwicklung des E-Commerce in China sind.

Für deutsche Händler, die auf dem chinesischen E-Commerce-Markt aktiv sein wollen, gibt es Einiges zu beachten. In China wird mehr als 85 % des Umsatzes im B2C-E-Commerce über Online-Marktplätze generiert. Dementsprechend stellt der Verkauf auf chinesischen Online-Marktplätze eine gute Startmöglichkeit für deutsche Händler dar.

Zudem bieten einige große chinesische Online-Marktplätze die Durchführung des Versandes an, der in der Regel zuverlässig ist und eine landesweite Lieferung garantiert. Trotz der hohen Umsätze über Online-Marktplätze kann auch ein eigener Online-Shop in China sinnvoll sein. Denn ausländische Marken haben in China in der Regel eine höhere Loyalitätsbindung bei Kunden. Einige internationale Marken verkaufen bereits erfolgreich auf ihren eigenen Online-Shops. Oftmals werden Standardprodukte mit entsprechend geringeren Margen über Online-Marktplätze verkauft, während das gesamte Produktsortiment und speziell reduzierte Waren nur im eigenen Online-Shop angeboten werden. Bei der Auswahl des Logistikdienstleisters für den eigenen Online-Shop bzw. bei Marktplätzen ohne Versanddienstleistung spielt vor allem das gewünschte Absatzgebiet eine Rolle. Händler, die in China landesweit versenden möchten, ohne den Versand von Online-Marktplätzen zu nutzen, sind derzeit noch auf staatliche Logistikdienstleister angewiesen. Diese können zwar landesweit liefern, dies ist jedoch mit einem schlechten Kundenservice und langer Lieferdauer verbunden. Dies kann sich langfristig negativ auf die Kundenzufriedenheit auswirken. Händler, die auf guten Kundenservice und zuverlässige Lieferungen Wert legen, sollten entweder mit bekannten ausländischen oder privaten chinesischen Logistikdienstleistern versenden. Dies ist jedoch mit höheren Kosten und begrenztem Liefergebiet verbunden.

Literatur

Bai, Y., Tang, R., & Cai, J. (2013). Railway in China exceeds 100.000 kilometers. In: Peoplerail. http://szb.peoplerail.com/shtml/rmtdb/20131229/103945.shtml (Abruf am 23.03.2014).

BVH. (2014). E-Commerce legt 2013 über 40 % zu. http://www.buchreport.de/nachrichten/online/online_nachricht/datum/2014/02/19/mobil-ist-die-neue-e-commerce-macht.htm (Abruf am 31.05.2014).

Cao, L. (2014). China e-business market data monitoring report 2013. China e-Business Research Center. http://www.100ec.cn/zt/upload_data/down/2013ndbgqw.pdf (Abruf am 29.03.2014).

Chen, L., & Hao, Z. (2013). Why are the logistics costs in China so high? In: China Economic Report, 6, 64–66.

Chen, X., & Lin, H. (2013). Research on E-Commerce logistics system informationization in chain. In: Procedia - Social and Behavioral Sciences, 96, 838–843.

China Federation of Logistics & Purchasing. (2012). Logistics informatization investigation report 2010. http://www.chinawuliu.com.cn/zhuanti/201202/17/178306.shtml (Abruf am 07.03.2014).

China Internet Network Information Center. (2013). China Internet development statistical report. http://www.cnnic.cn/hlwfzyj/hlwxzbg/hlwtjbg/201307/P020130717505343100851.pdf (Abruf am 12.03.2014)

China National Knowledge Infrastructure. (2014). http://oversea.cnki.net/kns55/support/en/about_cnki.aspx (Abruf am 05.04.2014).

Duan, Y., & Liu, C. (2013). The total number of logistics enterprises in our province is more than 10.000. In: Sichuan Daliy. Chengdu. http://sichuandaily.scol.com.cn/2013/09/24/20130924714134479659.htm (Abruf am 08.03.2014).

Efendioglu, A. M., & Yip, V. F. (2004). Chinese culture and e-commerce: an exploratory study. In: Interacting with Computers, 16(1), 45–62.

Fang, D. (2012). Review of the development of China's e-commerce logistics. In: Logistics & Material Handling, 9, 59–64.

He, L. (2013). China logistics yearbook 2012. Beijing: China supplies Press.

iResearch. (2014). China annual e-commerce monitoring report 2013.

Ke, J., & Jiang, W. (2014). The analysis of the development of China's express industry under the electronic commerce. In: Logistics Sci-Tech, 3, 124–126.

Lee, H. L., & Whang, S. (2001). E-business and supply-chain integration. In: Stanford Global Supply Chain Management Forum, SGSCMF-W2-2001.

Li, Y. (2013). Review on logistics talent demand research of China. In: Journal of Zhejiang University of Science and Technology, 25(4), 289–294.

Ma, Y., & Xun, Y. (2012). China's logistics enterprise information technology development and innovation. In: Logistics Engineering and Management, 1(34), 27–31.

Mahpula, A., Yang, D., Kurban, A., & Witlox, F. (2013). An overview of 20 years of Chinese logistics research using a content-based analysis. In: Journal of Transport Geography, 31, 30–34.

Ministry of Commerce of the people's Republic of China. (2013). The third party logistics occupies less than 25% of the logistics market. In: Guangzhou Daily. http://gzdaily.dayoo.com/html/2013-11/28/content_2465264.htm (Abruf am 2014.03.16)

Ministry of Commerce of the people's Republic of China. (2014). China E-commerce report. Proceedings of China-Beijing E-Commerce Conference. http://ec.iresearch.cn/oec/20140528/231832.shtml (Abruf am 04.06.2014).

Mo, D. (2014). China online retail market data monitoring report 2013. China e-Business Research Center. http://www.100ec.cn/zt/upload_data/down/20140304.pdf (Abruf am 20.03.2014).

Muckstadt, J. A., Murray, D. H., Rappold, J. A., & Collins, D. E. (2001). Guidelines for collaborative supply chain system design and operation. In: Information Systems Frontiers, 3(4), 427–453.

National Bureau of Statistics of China. (2014). Total retail sales of social consumer goods increased 13.6% in December 2013. http://www.stats.gov.cn/tjsj/zxfb/201401/t20140120_502174.html (Abruf am 24.03.2014).

National Development and Reform Commission, National Bureau of Statistics of China, & China Federation of Logistics & Purchasing. (2011). The logistics operation in China report 2010. http://www.chinawuliu.com.cn/xsyj/201103/01/144033.shtml (Abruf am 20.05.2014).

National Development and Reform Commission, National Bureau of Statistics of China, & China Federation of Logistics & Purchasing. (2012). The logistics operation in China report 2011. http://www.chinawuliu.com.cn/xsyj/201202/13/179239.shtml (Abruf am 20.05.2014).

National Development and Reform Commission, National Bureau of Statistics of China, & China Federation of Logistics & Purchasing. (2013). The logistics operation in China report 2012. http://www.chinawuliu.com.cn/lhhkx/201302/26/210410.shtml (Abruf am 20.05.2014).

National Development and Reform Commission, National Bureau of Statistics of China, & China Federation of Logistics & Purchasing. (2014). The logistics operation in China report 2013. Abgerufen von http://www.stats.gov.cn/tjsj/zxfb/201403/t20140306_520357.html (Abruf am 20.05.2014).

Online Shopping Express Satisfaction Monitoring. (2012). Proceedings of the Transformation of Traditional Retail and the Innovation of Express Service Forum. Guangzhou.

Qin, Z. (2013). The study on logistics and transport regulation system of China. In: Logistics Engineering and Management, 5 (35), 26–27.

Riehm, U., Petermann, T., Orwat, C., Coenen, C., Revermann, C., Scherz, C., & Wingert, B. (2003). E-Commerce in Deutschland: Eine kritische Bestandsaufnahme zum elektronischen Handel. Berlin: edition sigma.

Sun, X. (2012). An analysis on E-business self-built logistics current situation and countermeasures. In: Commercial Times, 8, 78–82.

Sun, Y. (2013). Development report of highway and waterway transportation. In: China Communications News. http://www.moc.gov.cn/zhuzhan/jiaotonggaikuang/fazhanzongshu/hangyefazhan_ZS/201309/t20130927_1489440.html (Abruf am 03.04.2014).

Teo, T. S. H., & Liu, J. (2007). Consumer trust in e-commerce in the United States, Singapore and China. In: Omega, 35 (1), 22–38.

The Economist. (2013). The Alibaba phenomenon. In: The Economist. http://www.economist.com/news/leaders/21573981-chinas-e-commerce-giant-could-generate-enormous-wealthprovided-countrys-rulers-leave-it (Abruf am 31.03.2014).

Wang, C. (2006). Geographical study on modern logistics and its development trend. In: Human Geography, 21 (6), 22–26.

Wang, J. (2014). The analysis of logistics development in E-commerce era. In: China Business and Market, 3, 54–59.

Wang, X. (2012). Foreign direct investment and innovation in China's e-commerce sector. In: Journal of Asian Economics, 23 (3), 288–301.

Wei, J. (2013). The medium and long-term development trend of Chinese logistics industry. Proceedings of the 10th China Logistics Conference, Changsha.

Werner, H. (2008). Supply Chain Management: Grundlagen, Strategien, Instrumente und Controlling. (3. Aufl.). Springer Verlag.

Wittmann, G., & Stahl, E. (2012). E-Commerce-Leitfaden: Noch erfolgreicher im elektronischen Handel (3. Aufl.). Regensburg: Universitätsverlag Regensburg.

Xie, N., & Yan, J.-Y. (2012). Analysis of SME logistics cost management and countermeasures. In: Logistics Engineering and Management, 1 (34), 65–67.

Yang, J. (2013). Foreground and background logistics: new understanding of the E-commerce log. In: Logistics Sci-Tech, 5, 3–5.

Yang, J., & Ma, P. (2013). The Construction Strategy of China's E-Commerce-Logistics. In: Economic Vision, 1, 13–16.

Yang, J., Yang, C., & Yao, X. (2014). Research on the „last-mile" issue in the E-commerce logistics system. In: Journal of Business Economics, 270 (4), 16–22.

Yin, R. K. (2009). Case study research: design and methods. Thousand Oaks: SAGE.

Yoon, C. (2009). The effects of national culture values on consumer acceptance of e-commerce: Online shoppers in China. In: Information & Management, 46(5), 294–301.

Zhang, Y., Bian, J., & Zhu, W. (2013). Trust fraud: A crucial challenge for China's e-commerce market. In: Electronic Commerce Research and Applications, 12 (5), 299–308.

Zhou, Y. (2013). E-commerce in China’s countryside. In: China Youth Daily. http://zqb.cyol.com/html/2013-08/29/nw.D110000zgqnb_20130829_1-07.htm (Abruf am 03.03.2014).

3. Analysis of the Logistics Efficiency in E-Commerce: Online vs. Multichannel[2]

Li Zeng
Thomas Bolz

3.1. Introduction

E-commerce is becoming one of the most topical subjects in business area. Meier & Stormer (2012) define e-commerce as the sale of goods and services via the internet. The internet has become a dynamic medium for channeling transactions between customers and firms. The share of online sales in total sales in the retail sector continues to grow. From 2000 to 2016 e-commerce has grown in Germany from less than 1% of retail sales to 13% (Handelsverband Deutschland 2017; Statista 2017). The sales volume of e-commerce in Germany according to the report of the Bundesverband des Deutschen Versandhandels has been growing steadily and amounted 52.79 billion euros in 2015 (Figure 1).

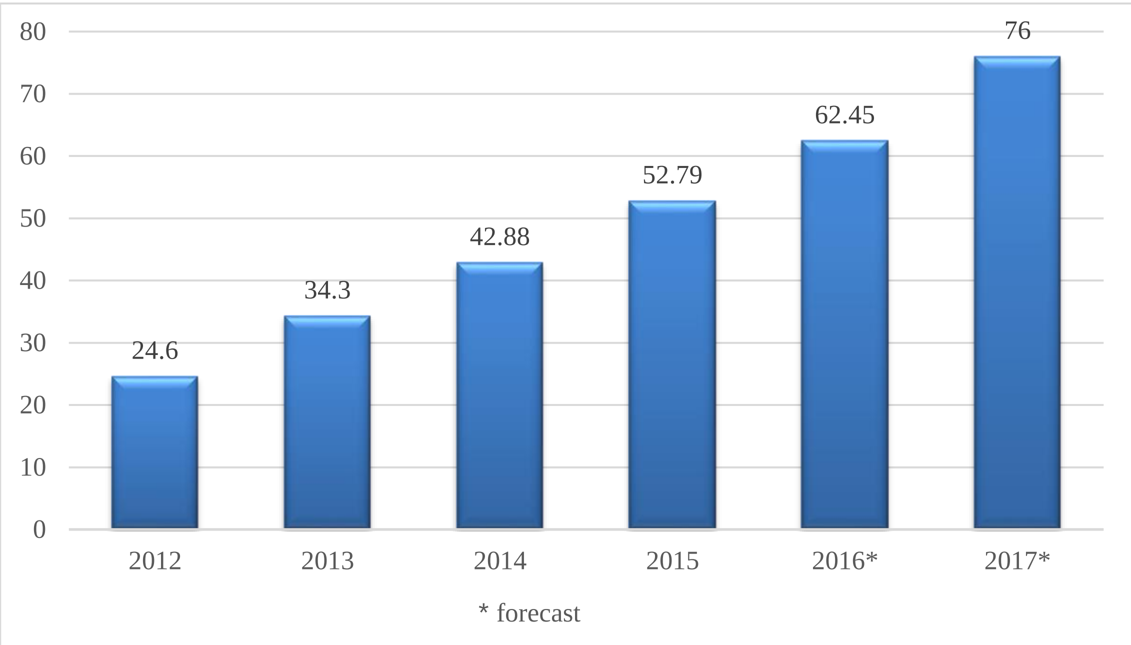


Figure 1: E-commerce turnover in Germany in 2012 to 2015 as well as a forecast to 2016 and 2017 (Statista 2017)

The logistical processing is one of the most important parts of the process in the e-commerce activities. The success of e-commerce is dependent among others on the efficiency of logistics systems (Riehm et al., 2003).

In order to get more market share a growing number of traditional brick and mortar retailers use the internet as a complementary business channel and boast of more experience and knowledge in handling logistics issues (Maltz et al., 2004). In contrast, online pure players only sell products online. They are usually more flexible and

[2] Zeng, L. & Bolz, T. (2017). "Analysis of the Logistics Efficiency in E-Commerce: Online vs. Multichannel." Banking and Information Technology, 18(1), 62–68.

responsive. The logistics activities of online pure players are often being outsourced. The external provision of logistics services are commonly known as third-party logistics (3PL).

A quantitative comparison and analysis of the efficiency of the two firm structures about logistics is still open to debate. This paper investigates the relationship between logistics and e-commerce and determines which corporate structure (multichannel retailer vs online pure player) is more efficient in logistics.

3.2. Literature Review

3.2.1. Relationship of E-Commerce and Logistics

According to the definition of Meier & Stormer (2012), e-commerce includes all business activities with the objective of selling products via internet. E-commerce provides provision of information about the offered products in electronic catalogues, the possibility for the customers to order these products online, accounting, marketing and customer services.

Logistics is defined as science of planning, implementing, and controlling the efficient, cost effective flow and storage of raw materials, in-process inventory, finished goods and related information from point of origin to point of consumption for the purpose of meeting customer requirements (Pfohl, 2013). Taking a more macro view, the task of logistics management is to provide the right goods in the right quantity and quality at the right time in the right place at the right cost. In addition to frequent changes in quantities and varieties of goods, the complexity of logistics extends to information, material flows, transport, transshipment, storage, packaging and signing processes. Logistics includes all physical, administrative and dispositive activities (including related information). Physical activities contain the transport, storage, transshipment, picking and packing of goods.

Why is the logistics determining success factor to e-commerce growth? The market answer of this question is customer behavior. Over 80% of British (89%), French (84%) and German (83%) customers prefer a seller with better delivery service of an order (Delivery Globetrotters, 2014). For the question why a customer does not order abroad, there are three most frequently cited reasons according to study of Pitney Bowes (2014): high delivery costs (68%), additional delivery costs e.g., customs and tax (58%) and long delivery times (42%). Uncertainty of the return procedure and the related costs are also the obstacles. In contrast, retailers can significantly increase their sales by implementing a tailor-made delivery and return system for each target market. If these processes run smoothly, the confidence and satisfaction of customer will rise. Thereby mainstream customers can be consolidated.

On the other hand e-commerce is reconstructing a new logistics approach. Various order size, increased daily order volumes, small parcel shipments, fast delivery, flexible time windows and high transparency are becoming increasingly important to customers, but also more complex for firms and logistician. Klumpp & Jasper (2008) have discussed the critical success factors in retail e-logistics in an e-commerce-environment. E-logistics is a specialized part of retail logistics and can be defined as the strategic planning and control of all logistics systems and processes which are necessary for electronic transaction processing as well as their administrative and operational physical form (Krampe et al., 2012). This analysis of e-commerce-logistics showed, e-logistics and e-commerce should be developed together in retail companies in order to achieve a successful supply chain and business model. Success of logistics depends on e.g. attractive and online presentable products as well as low return ratios of the product sold online.

Cho, Ozment and Sink (2008) examined the impact of logistics capability and logistics outsourcing on firm performance in an e-commerce market environment and revealed logistics capability to be positively related to firm performance in the e-commerce market. However, positive associations between logistics outsourcing and firm performance were not found. The association between logistics capability and outsourcing was not confirmed. Finally, positive indirect effects of logistics outsourcing on the relationship between logistics capability and firm performance was not supported.

Using data from online customer ratings Ramanathan (2010) explored how the relationships between logistics performance and customer loyalty are affected by risk characteristics of products and efficiencies of the websites. They proved that efficiencies of websites, but not risk characteristics of products, is a significant moderator of the impact of logistics performance on customer loyalty. Efficient e-commerce websites are able to better convert their logistics performance into customer loyalty. Subsequently Ramanathan (2011) provided a risk perspective to analyse the relationships between performance of companies in handling product returns and customer loyalty are affected by risk characteristics of products. As a result, handling product returns plays an important role in shaping customer loyalty for low-risk products and for high-risk products but not for products with medium levels of risk.

Żurek (2015) presented an assessment of the proficiency level of the changes in logistics processes on the local and international market as well as of the trends for these changes has been made. The development of e-commerce has impelled a new logistics chain management strategy, which covered both the process of handling the online and offline sales channel. New tasks of logistics include: streamlining flow processes, improving the efficiency of logistics processes as well as adjusting them to market requirements.

3.2.2. Differences of Multichannel Retailer and Online Pure Player in Logistics

Traditional retailer maintained a single mode like the physical store to offer sales and services. Multichannel retailers offer more than one way to purchase products and services. A multichannel strategy could include selling through a store, a website, mail orders, apps, chats, social networks, telephone ordering, interactive television and catalog ordering. Multichannel retailing is a good way to maximize revenue and loyalty by offering your customers choice and convenience. Online pure players offer its products and services only online.

The alternative retail channels have some distinct differences on structure organization, environmental costs, logistics etc. The major differences in the field of logistics between the traditional retail model and the e-commerce model base on the network of transportation. Retail stores need several warehouses and ask customer to come and pick up goods (Figure 2). Before arriving at the store customers cannot get any information about the goods. Online Shop does not need multiple levels of warehouses and can even ask the manufacturer to deliver directly (Figure 3).

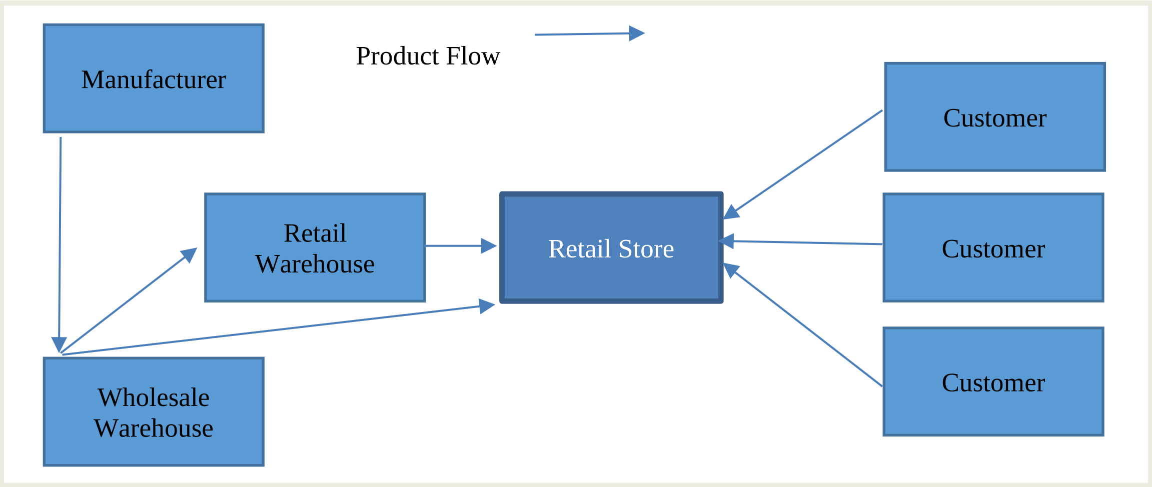


Figure 2: Traditional retail product flow network

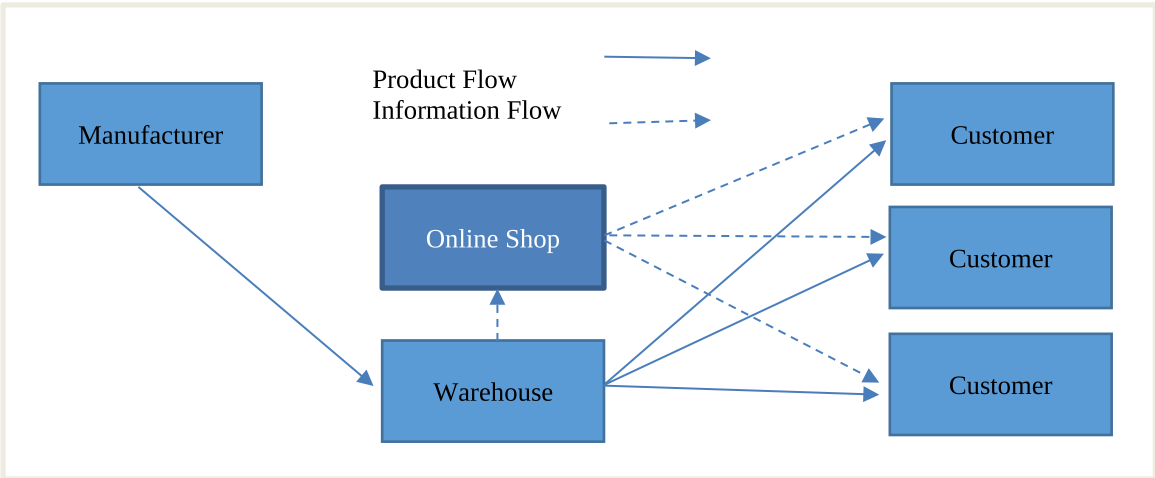


Figure 3: Online shop product flow network

There are several studies in the literature comparing multichannel retailer and online pure players. Xing & Grant (2006) have introduced an e-physical distribution service quality framework to investigate which of two e-retailing systems (online pure player and multichannel retailer) exhibits better. With this framework providers can clarify consumers' expectations and understand the advantages and disadvantages of their home delivery structure, retailers and their logistics service, and then can better collaborate to offer more superior services to consumers.
Due to the prior comparative research Weber et al. (2009) conducted a streamlined life cycle assessment (LCA) to quantify variations in energy use and carbon dioxide (CO2) emissions for the alternative systems using data received from the e-commerce industry for an electronic product. Their report provided conclusions and offered recommendations to decrease logistics LCA uncertainties. As a result, prior findings were

confirmed that on the whole e-commerce delivery uses about 30% lower energy consumption and CO_2 emissions compared to traditional retail.

On the basis of experiences and on examples of enterprises Żuchowski (2016) proved the uncertainty that the introduction of e-commerce in the warehouse is a revolution for its employees and managers. It depends on the markets in which the company operates, and on corresponding customers.

So far no research has been conducted about the efficiency of multichannel retailer and online pure player. Therefore this paper focuses on the quantitative comparison of the logistics efficiency of this two firm structures.

3.3. Research Method

The goal of this research is to investigate the efficiency of logistics in the performance of the two firm structures. As previously mentioned, logistics can make sustained competitive advantage for many e-commerce companies. It is confirmed that there is a positive relationship between the logistics capability and its performance in the e-commerce market. In addition e-commerce delivery uses lower energy consumption than traditional retail. Most market participants estimated that introduction of e-commerce brings an overall positive effect on logistics. Therefore, it is hypothesized that there is a positive relationship between the efficiency of logistics and share of e-commerce revenue on total revenue.

A couple of items in this paper were used to achieve the comparison: share of e-commerce revenue on total revenue (independent variable X) and efficiency of logistics (dependent variable Y). Share of e-commerce (X) is equal to online sales divided by total turnover. Theoretically, $X = 0$ represents traditional retailer (100% offline), $0 < X < 1$ is multichannel retailer, $X = 1$ is for online pure player. Efficiency of logistics (Y) was defined as total turnover divided by logistics costs of a firm. This item indicates the amount of turnover which produced by investing one unit of logistics costs. Logistics costs include storage costs, transport costs, packaging and material handling costs, information costs and costs for logistics outsourcing.
Ordinary least squares (OLS) regression analysis was employed to test the hypotheses. P-value method was introduced to examine the regression result. OLS is a generalized linear modelling technique that may be used to estimate the relationship between two variables.

Due to the probabilistic nature of theories and measurement errors, normally relationships between variables in economics are not exact. Regression analysis can find average relationships between the data which looks like independent. If a relationship of two variable is linear, it may be appropriately represented mathematically using the straight line equation

$$Y = a + bX.$$

The relationship between variables Y and X is described using the equation of the line. a indicates the value of Y when X is equal to zero (the intercept) and b indicates the rake ratio of the line (regression coefficient). The regression coefficient b describes the change in Y by one unit changed in X.

The study was implemented in Germany by an online survey in 2016. All possible industries were covered: car and motorcycle/accessories, clothing, books, office supplies, computer/hardware/ accessories, decoration, drugstore, electronics and telecommunications, house and home textiles, household goods and appliances, lamps/lights, food, medicines, furniture, jewelry, shoes, toys, animal requirements and watches.

3.4. Results

An online survey was conducted with 209 retailers. 11 participants were eliminated because of misdate. The remaining 198 companies were used in the final analysis. 81% of all respondents have at least one online shop and 41% have at least one local retail stores. 31% put their products on marketplace, e.g. Amazon and eBay. In this study the firms with a share of e-commerce with at least 95% are considered as online pure player. The firms with a share lower than 95% are considered as multichannel retailer. Thus 59% of our sample are online pure player and 41% are multichannel retailer. Figure 4 shows the sales channels of the interviewed retailer.

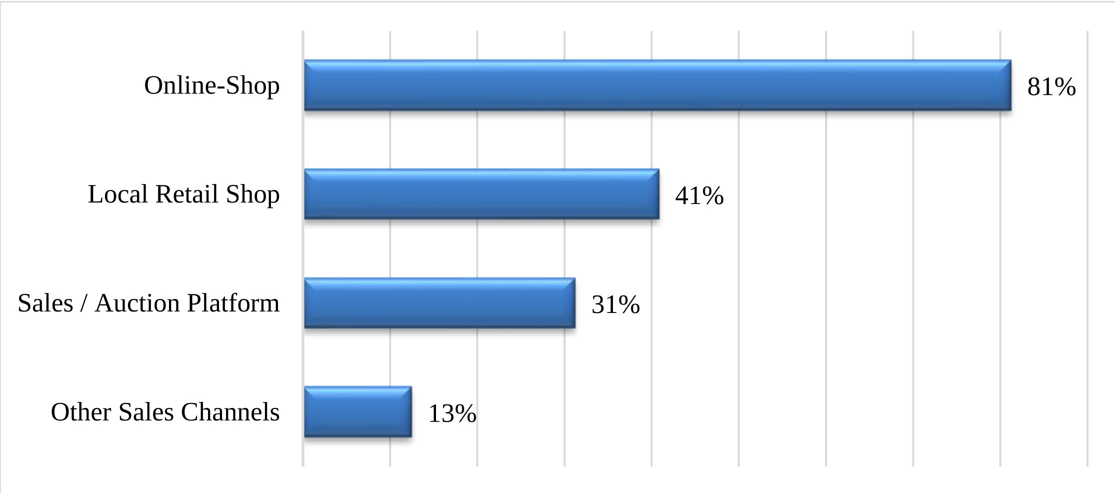


Figure 4: Sales channels of the interviewed retailer

The results of the OLS analysis are presented in table 1 and figure 5. Counter-intuitively, the results do not support the hypothesis in the direction initially theorized. The findings for all firms show a negative relationship between the efficiency of logistics and the share of e-commerce with a significant p-value. The average logistic efficiency for multichannel retailer is 11.19 and for online pure player 8.30. This means that multichannel retailer are more efficient in logistics than online pure player.

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Share of e-commerce	-2,7722	0,9717	-2,8529	0,005

Table 1: Regression results

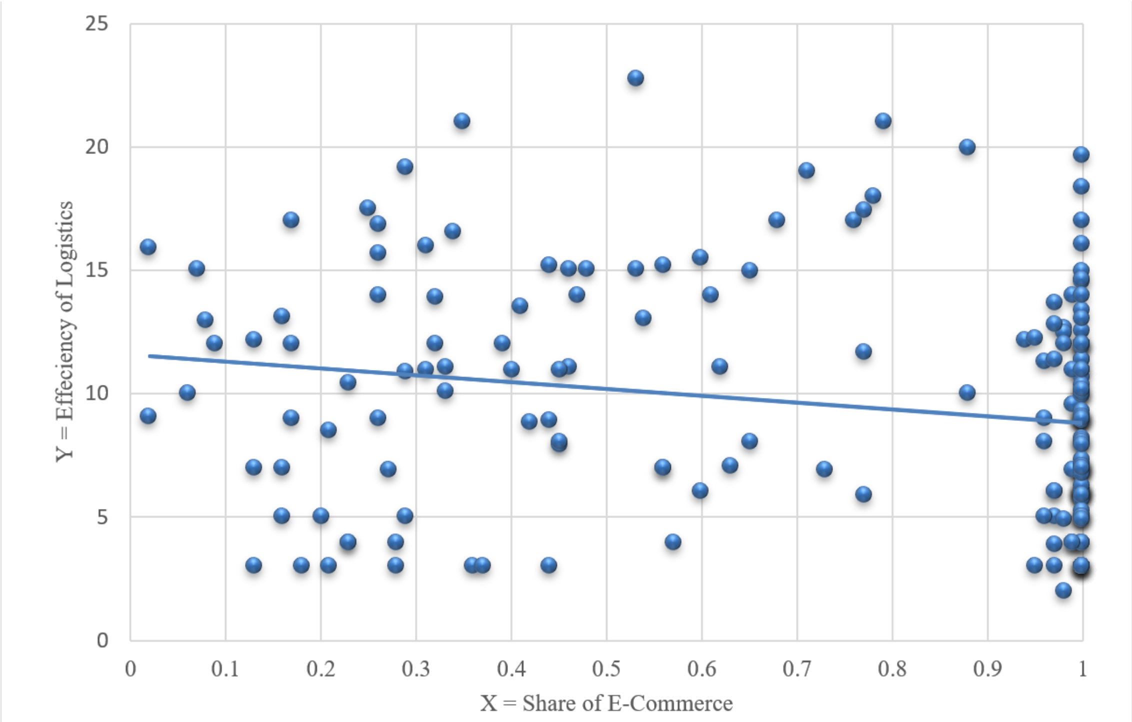


Figure 5: Distribution of observations

3.5. Discussions

Surprisingly, the hypothesis was not supported by our research. The results show that a higher share of online turnovers on total turnovers implicates a lower logistics efficiency for all firms. These results do not apply for the sample of multichannel retailer. Furthermore, the average logistic efficiency of multichannel retailer is significant higher compared to online pure player.

A possible reason for these results could be the relative high ratio of returns in e-commerce that leads to more costs and a lower logistics efficiency. According to a study from ibi research (Pur et al. 2013), 4 of 10 customers already calculate the return of the product at the online shopping. In the clothing sector, 4% of the returns cannot be sold again, in the remaining sectors it is 13%. The most important reasons of return are the article is not felled, the article does not fit and several variants ordered for selection. This is related to the basic properties of the e-commerce, and seems impossible to be improved in a short time. Furthermore, research findings are constrained, as the study was limited to the unbalanced proportion of respondents. In this study over 25% companies are engaged in clothes, shoes, cosmetics, living and furnishing. 36.1% of surveyed online merchants selling fashion and accessories stated the rate of returns was at 20 percent or higher in 2014 in Germany (Statista, 2014).

The second possible reason could be the lack of experience from online pure player in logistics. Commonly multichannel retailers have much more business experience compared to online pure player as of their traditional retail stores knowledge they have built up for decades. For example this could imply a more efficient warehousing and returns handling. In this study 42% of online pure player started their business after 2010.

Another possible reason for the higher logistic efficiency of multichannel retailer could be the economies of scale. Our sample for multichannel retailer has in average 22% more revenue compared to the sample of online pure player. Therefore, multichannel retailer could benefit from lower delivery charges or lower warehouse costs per square foot, which results in a higher logistic efficiency.

Moreover, multichannel retailer can use warehouses for several sales channels, therefore they have synergy effects among their channels which implies a higher logistics efficiency in compared to online pure player.

Bibliography

Delivery Globetrotters Infographic. 2014. RealWire RealResource. http://www.realwire.com/realResource.asp?ReleaseID=39730&d=w&name=Delivery-Globetrotters-International-Experience.jpg&title=Delivery+Globetrotters+Infographic (accessed on 01.02.2017).

Handelsverband Deutschland. 2017. Umsatzentwicklung im Einzelhandel. http://www.einzelhandel.de/index.php/presse/zahlenfaktengrafiken/item/110189-umsatzentwicklungimeinzelhandel (accessed on 09.02.2017).

Joong-Kun Cho Jay, John Ozment and Harry Sink. 2008. Logistics capability, logistics outsourcing and firm performance in an e-commerce market. International Journal of Physical Distribution & Logistics Management 38 (5): 336–59.

Klumpp, M. and A. Jasper. 2008. Success Factors for Retail Logistics in an E-Commerce-Environment. Sinoeuropean Engineering Research Journal 1: 63–68.

Krampe, Horst, Hans-Joachim Lucke and Michael Schenk. 2012. Grundlagen der Logistik: Theorie und Praxis logistischer Systeme. 4. Edition. München: Huss-Verlag.

Maltz, Arnold Bennett, Elliot Rabinovich and Raj Sinha Iv. 2004. Logistics: the key to e-retail success. Supply Chain Management Review 8 (3): 48–54.

Meier, Andreas and Henrik Stormer. 2012. eBusiness & eCommerce: Management der digitalen Wertschöpfungskette. Springer-Verlag.

Pfohl, Hans-Christian. 2013. Logistiksysteme: Betriebswirtschaftliche Grundlagen. Springer-Verlag.

Pitney Bowes. 2014. A Deep Dive Into the 2014 Pitney Bowes Global Online Shopping Study. Multichannel Merchant. http://multichannelmerchant.com/must-reads/deep-dive-2014-pitney-bowes-global-online-shopping-study-30102014/ (accessed on 01.02.2017).

Pur, Sabine, Ernst Stahl, Michael Wittmann, Georg Wittmann and Stefan Weinfurtner. 2013. Retourenmanagement im Onlin-Handel-Das Beste daraus machen. ibi

Research. http://www.ibi.de/aktuelle-meldungen/1176-neue-studie-erfolgsfaktor-retourenmanagement.html (accessed on 05.02.2017).

Ramanathan, Ramakrishnan. 2010. The moderating roles of risk and efficiency on the relationship between logistics performance and customer loyalty in e-commerce. Transportation Research Part E: Logistics and Transportation Review 46 (6): 950–62.

Ramanathan, Ramakrishnan. 2011. An empirical analysis on the influence of risk on relationships between handling of product returns and customer loyalty in E-commerce. International Journal of Production Economics 130 (2): 255–61.

Riehm, Ulrich, Thomas Petermann, Carsten Orwat, Christopher Coenen, Christoph Revermann, Constanze Scherz and Bernd Wingert. 2003. E-Commerce in Deutschland: Eine kritische Bestandsaufnahme zum elektronischen Handel. 1. Edition. Berlin: edition sigma.

Statista. 2014. Online shopping in Germany: return rate of online shops in 2014 | Statistic. https://www.statista.com/statistics/327314/share-of-returns-in-online-shopping-regarding-fashion-and-consumer-electronics/ (accessed on 01.02.2017).

Statista. 2017. Umsatz im Einzelhandel in Deutschland bis 2017 | Statistik. https://de.statista.com/statistik/daten/studie/70190/umfrage/umsatz-im-deutschen-einzelhandel-zeitreihe/ (accessed on 01.02.2017).

Weber, Christopher, Chris Hendrickson, Paulina Jaramillo, Scott Matthews, Amy Nagengast and Rachael Nealer. 2009. Life cycle comparison of traditional retail and e-commerce logistics for electronic products: A case study of buy.com. Conference: Sustainable Systems and Technology 2009.

Xing, Yuan and David B. Grant. 2006. Developing a framework for measuring physical distribution service quality of multi-channel and “pure player” internet retailers. International Journal of Retail & Distribution Management 34 (4/5): 278–89.

Żuchowski, W. 2016. The Impact of e-Commerce on Warehouse Operations. Scientific Journal of Logistics 12 (1): 95–101.

Żurek, Jadwiga. 2015. E-Commerce Influence on Changes in Logistics Processes. Scientific Journal of Logistics 11 (2): 129–38.

4. A Review and Comparison of Genetic Algorithms for the 0-1 Multidimensional Knapsack Problem[3]

Bernhard Lienland
Li Zeng

ABSTRACT

The 0-1 multidimensional knapsack problem (MKP) is a well-known combinatorial optimization problem with several real-life applications, for example, in project selection. Genetic algorithms (GA) are effective heuristics for solving the 0-1 MKP. Multiple individual GAs with specific characteristics have been proposed in literature. However, so far, these approaches have only been partially compared in multiple studies with unequal conditions. Therefore, to identify the "best" genetic algorithm, this article reviews and compares 11 existing GAs. Our tests provide detailed information on the GAs themselves as well as their performance. We validated fitness values and required computation times in varying problem types and environments. Results demonstrate the superiority of one GA.

Keywords: Multidimensional Knapsack Problem; Heuristic; Genetic Algorithm; Optimality Gap; Computation Speed

4.1. Introduction

Consider a situation with a multitude of projects i and resources j. Each project has an objective value c_i, for example, profit, and resource consumption values a_{ij}, for example, required machine minutes. Projects can either be carried out or not. A project's selection is determined through the decision variable x_i. Because of a limited resource capacities b_j, not all projects can be carried out, and one has to find the subset of all projects that maximizes the overall profit. Such a non-deterministic polynomial-time-hard 0-1 multidimensional knapsack problem (MKP) can be expressed as followed (Kellerer et al., 2004):

maximize	(1) $\sum_{i=1}^{n} c_i x_i$	(1)
subject to	(2) $\sum_{i=1}^{n} a_{ij} x_i \leq b_j, \forall j$	(2)
	(3) $x_i \in \{0,1\}, \forall i$	(3)

The 0-1 MKP is one of the best known integer programming problem. Two general approaches on solving the 0-1 MKP have emerged during the past decades: exact methods and heuristics. Even though exact methods (cf. Martello et al., 1999, 2000) have made improvements, large problems with an increased number of constraints remain a challenge. Heuristics like greedy algorithms (cf. Senju & Toyoda, 1968), mathematical

[3] Lienland, B. & Zeng, L. (2015). "A Review and Comparison of Genetic Algorithms for the 0–1 Multidimensional Knapsack Problem." International Journal of Operations Research and Information Systems, 6(2), 21–31.

programming, (cf. Hillier, 1969), or metaheuristics such as tabu search (cf. Dammeyer & Voss, 1991; Hanafi & Freville, 1998), simulated annealing (cf. Drexl, 1988), or genetic algorithms are competitive alternatives, especially at such large problems (Fréville, 2004). In particular, genetic algorithms (GA) have been very well suited for solving these 0-1 MKPs (cf. Raidl, 1998, 1999) and are often applied for solving various types of general optimization problems (cf. Pal & Chakraborti, 2013) and knapsack problems (cf. Lin, 2008). Therefore, this article focuses on the performance of genetic algorithms.

Apart from general parameters such as the population size or the crossover rate, a GA's effectiveness and efficiency are dependent on its design. Even though multiple individual GAs have been discussed in literature, a direct validation of the proposed algorithms' efficiencies has only sparsely been performed by Raidl & Gottlieb (2005). Rather than objective evaluations of the GAs in homogenous conditions, single approaches are primarily analyzed in the context of a new GA's exposure. Typically, the algorithms are contrasted to a very limited set of other alternative approaches (Hoff et al., 1996; Raidl, 1998; Gottlieb, 2000; Levenhagen et al., 2001). A combination of multiple such studies, however, is not possible due to diverging equipment characteristics, databases, and parameter settings. Consequently, one must be cautious to select the "best" GA (Chu & Beasley, 1998). For this purpose, we provide a systematic evaluation of 11 carefully chosen genetic algorithms using all 270 standard-problems by Chu & Beasley (1997, 1998) publicly available (Beasley, 1998). The selected GAs had to meet two selection criteria. First, GAs must be specifically designed for solving the 0-1 MKP. Second, GAs have to show significant progress compared with the previous algorithms. In other words, algorithms that only provide little benefit were not selected.

The addressees of our research are primarily practitioners requiring a suited algorithm for solving the 0-1 MKP but also scientists trying to further improve current best approaches. Consequently, the research question this article answers is: *Which GA should be applied to solve the 0-1 MKP*?

The remaining article is structured into the following sections. In the next section, we will provide a sound literature review on existing GA comparisons. GAs are furthermore described and their specialties identified. The literature survey is followed by a methods part, in which we will state the used data basis as well as the simulation's procedure. The results and the discussion are found in sections four and five.

4.2. Literature Overview

4.2.1. Comparisons

We divide our literature review into two parts. First, we provide an overview of existing GA comparisons. In these studies, newly proposed GAs are contrasted to a limited set of other approaches. We then refer to a study examining multiple GAs in identical experimental conditions.

The first GA comparison was performed by Hoff et al. (1996), who demonstrated the superiority of their algorithm to the one by Khuri et al. (1994) based on 57 test instances by Drexl. The GA by Khuri et al. (1994) yielded a similar solution quality compared with the approach by Thiel & Voss (1994). Raidl (1998) later proved the effectiveness of his GA by comparing it with the one by Hinterding (1994) and Chu & Beasley (1998). Test cases were taken from Chu & Beasley (1998). Gottlieb (2000) demonstrated that the algorithm by Raidl (1998) was superior to the one by Chu & Beasley (1998). The boundary proposed by Gottlieb (2000) improved the results of the GAs by Raidl (1998) and Chu & Beasley (1998), but it did not change the rank order of the GAs regarding their performance. Test data were again provided by Chu & Beasley (1998). Levenhagen et al. (2001) compared their algorithm with the ones by Chu & Beasley (1998) and Gottlieb (2000). Based on 90 problems provided by Chu & Beasley (1998), Levenhagen et al. (2001) identified their proposed algorithm to be beneficial only in the case of big valley problems.

Raidl & Gottlieb (2005) provided a comparison in which the authors evaluated five different GA representations (permutation, ordinal, random-key, weight-biased, direct) based on the specification of three variation operators (initialization, crossover, mutation). Their representations refer to the previous studies by Chu & Beasley (1998), Raidl (1998), Gottlieb (2000), and Levenhagen et al. (2001). Raidl & Gottlieb (2005) analyzed the GA representations regarding three features (heuristic bias, locality, heritability) to identify the ingredients, which are relevant to a GA's success or failure. However, their study is a conceptual article. Rather than comparing complete GA algorithms with their multiple specifications, Raidl & Gottlieb (2005) focused on the choice of the representation and variation operator. Furthermore, they only used a limited number of test instances from the Chu & Beasley database. In contrast, our study centers on the review and the comparison of already established GAs for solving the MKP. We support academics and practitioners in the selection of the "best" existing approach. Our computational study includes all of the proposed GAs' specialties and all of the problems in the Chu & Beasley database.

4.2.2. Genetic Algorithms

To explain the GAs examined in this comparison, we first provide information on the algorithms' general framework before we then examine individual specialties.

The general framework each GA is based on consists of 1) the initial population, 2) the reproduction, and 3) the replacement phase (see also Figure 1). The 1) initial population typically is a set of multiple randomly computed solution vectors with fitness values (FV) identical to the solutions of the objective function (cf. Khuri et al., 1994). To improve the individuals' FVs, projects can be added or dropped dependent on their sorting (cf. Thiel & Voss, 1994; Chu & Beasley, 1998; Gottlieb, 2000). The 2) reproduction phase is divided into a parent selection and a crossover stage as well as a mutation and a repair section. In early approaches, parent selection and crossover were performed through a proportional selection with a one-point crossover (cf. Khuri et al., 1994; Thiel & Voss, 1994; Rudolph & Sprave, 1995; Hoff et al., 1996). Proportional selection refers to the idea that individuals with a relatively high FV should have a greater chance to produce an offspring than should individuals with a lower FV. To select a parent, a cumulative probability distribution has to be derived. A random number within the range [0, 1] then represents the cumulative probability and refers to the respective vector. In the one-point crossover, a random bit position is determined. The offspring's bits are taken from the one parent up to this point, whereas the remaining chromosomes are copied from the other parent. More recent GAs, however, apply the tournament selection in combination with a uniform crossover (cf. Chu & Beasley, 1998; Raidl, 1998, 1999; Gottlieb, 2000; Levenhagen et al., 2001). The tournament selection forms two pools of individuals, each consisting of *k* individuals randomly drawn from the initial population. The pools' individual with the highest FV is chosen to be a parent. The uniform crossover then randomly copies the bit of one or the other parent into the offspring gene.

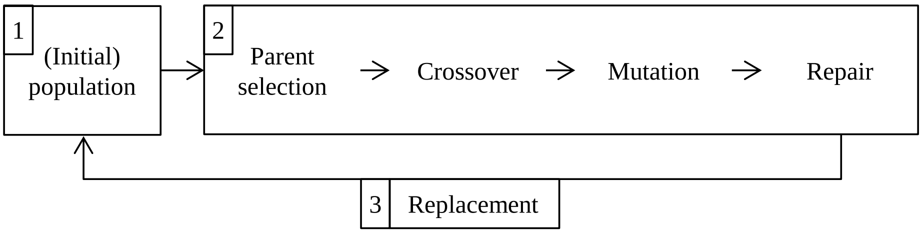
The subsequent mutation phase often consists of the mutation by bit (cf. Khuri et al., 1994), in which each of an individual's bit positions might possibly alter. In contrast, the mutation per individual allows only one random bit per individual to mutate (cf. Thiel & Voss, 1994). The subsequent repair phase typically uses the already described add or drop mechanisms.

A 3) GA's replacement phase typically incorporates either a generational or a steady state approach. In the former, the offspring replaces the entire population once the number of new offspring equals the population size (cf. Khuri et al., 1994; Thiel & Voss, 1994; Rudolph & Sprave, 1995). In the latter, the offspring directly replaces the individual with the lowest FV in the initial population (cf. Hoff et al., 1996; Chu & Beasley, 1998; Raidl, 1998, 1999; Gottlieb, 2000; Levenhagen et al., 2001). The whole process with the three steps is repeated until a defined criterion, for example, the number of iterations, is fulfilled. The best solution obtained thus far is then used.

After describing the general framework, we provide a more detailed view on the single available GAs. As the iterations are differently defined, the existing models are clustered into two sections: GAs allowing duplicates (Khuri et al., 1994; Thiel & Voss, 1994; Rudolph & Sprave, 1995; Hoff et al., 1996) in their population and GAs not allowing duplicates (Chu & Beasley, 1998; Raidl, 1998; 1999; Gottlieb, 2000; Levenhagen et al., 2001). In the second category, only the valid, non-duplicate children are counted as an iteration. The presented GAs are chronologically sorted within each section. All applied approaches are depicted in greater detail in Table 1.

The first section includes the GAs by Khuri et al. (1994), Thiel & Voss (1994), Rudolph & Sprave (1995), and Hoff et al. (1996). The specialty of Khuri et al. (1994) is the utilization of penalty terms and the allowance of a not feasible solution. The individual's fitness value is decreased by a penalty term dependent on the number of overfilled knapsacks multiplied by the maximum profit of all individuals. Due to potential negative fitness values, linear dynamic scaling is applied to the proportional parent selection. To avoid the local optimality dilemma, Thiel & Voss (1994) integrate a tabu search into the mutation operator. Mutation per individual is applied while observing the tabu list. Thiel & Voss (1994) tested several different forms of tabu search. We applied the one with the best performance. In detail, we included tabu search in combination with the residual cancellation sequence 2 (REM2) and long- and short-term memory (L+STM). The GA by Rudolph & Sprave (1995) incorporates two specialties. First, the parents are proportionally selected within a varying limiting neighborhood.

Figure 1 GA flow diagram



Second, they use a customized generational approach in the replacement phase. Offspring are only considered for the new population if their fitness value is above a defined threshold, itself dependent on a set number of past offspring. The GA by Hoff et al. (1996) first implemented the steady-state replacement approach.

GAs in the second category repeat an iteration in case a duplicate offspring is generated. Consequently, these algorithms generally compute more offspring, resulting not only in an increased solution quality, but also in an increased amount of computation time. The GAs by Chu & Beasley (1998), Raidl (1998), Cotta & Troya, (1998), Raidl (1999), Gottlieb (2000), and Levenhagen et al. (2001) are related to this category. The renowned approach by Chu & Beasley (1998) first uses the tournament parent selection. The authors furthermore incorporate a specific add and drop repair algorithm. The projects' sorting is based on a quotient using the projects' fitness values, shadow prices, as well as resource consumptions. Shadow prices equal the difference between the FV of a portfolio with the original resource capacities and the one of a portfolio with a slightly increased resource quantity. Raidl (1998) includes the LP-relaxed MKP into the initial population. Each bit of an individual is set to 1 with the probability of the relaxed LP solution. The LP-relaxed vector is furthermore applied in the add and drop repair step.

The algorithms by Cotta & Troya (1998) and Raidl (1999) both present different weight-coding variants. In each iteration, the fitness values of the initial population are temporarily modified by a biasing factor. The GAs are then run with the new permutation. Both GAs only differ with respect to their biasing factors. Since Raidl (1999) already implemented four different biasing methods and two different decoding heuristics without great performance variations, we solely implemented the GA by Raidl (1999). In detail, we applied his B4-biasing heuristic and his H1-decoding approach. Gottlieb (2000) extends the algorithms of Chu & Beasley (1998) and Raidl (1998). He adds a boundary function to both algorithms, ensuring that no additional projects can be added to the individuals without violating the constraints. Levenhagen et al. (2001) extend Gottlieb's modification by a path tracing component. To enforce boundary solutions, an additional "embedded local search" optimization procedure is randomly applied to the chromosomes on the path between two individuals. If a newly obtained local optima dominates the respective chromosome on the path and is neither a duplicate nor on the tabu list, the latter is replaced and the process iterated. Finally, the worst initial population member is replaced by the improved solution. The algorithm terminates if either the path chromosome differs from the target individual by only one bit or no valid local optimal is found anymore.

Table 1 Overview of compared GAs

	Duplicates allowed				Duplicates not allowed						
	Khuri et al. (1994)	**Thiel & Voss (1994)**	**Rudolph & Sprave (1995)**	**Hoff et al. (1996)**	**Chu & Beasley (1998)**	**Raidl (1998)**	**Raidl (1999)**	**Gottlieb (2000)**	**Gottlieb (2000)**	**Levenhagen et al. (2001)**	**Levenhagen et al. (2001)**
								Chu & Beasley (1998)	Raidl (1998)	Chu & Beasley (1998) and Gottlieb (2000)	Raidl (1998) and Gottlieb (2000)
1 Initial population	random penalty term	random drop	random drop	random drop	random add	add, based on solution of LP-relaxed MKP	biasing the original problem B4 bias strength=0.05 decoding heuristic (H1)	random add + boundary	add, based on solution of LP-relaxed MKP + boundary	random add + boundary	add, based on solution of LP-relaxed MKP + boundary
2 Reproduction											
Parent selection	PS	PS	PS in neighborhood neighborhood size = 50	PS	TS	TS	TS	TS	TS	TS	TS
Crossover	one-point	one-point	one-point	one-point	uniform	uniform	uniform	uniform	uniform	uniform PT (probability=0.05) probability of extrapolation = 0.2 ELS (probability=0.5)	uniform PT (probability=0.05) probability of extrapolation = 0.2 ELS (probability=0.5)
Mutation	mutation per bit	tabu search / REM2 / L+STM	mutation per bit	mutation per bit	mutation per bit	mutation per bit	random weights decoding heuristic (H1)	mutation per bit	mutation per bit	mutation per bit	mutation per bit
Repair	none penalty term	drop	drop	drop	drop+add pseudo utility ratio	drop+add LP-relaxed MKP		drop+add pseudo utility ratio	drop+add LP-relaxed MKP	drop+add pseudo utility ratio	drop+add LP-relaxed MKP
3 Replacement	GA	GA	GA threshold acceptance window size δ=1	SSA	SSA no duplicate	SSA no duplicate	SSA no duplicate	SSA no duplicate	SSA no duplicate	SSA no duplicate	SSA no duplicate

PS: proportional selection; TS: tournament selection; GA: generational approach; SSA: steady-state approach

4.3. Experimental Comparison

4.3.1. Material

To directly compare the eleven GAs, we used the publicly available standard test data proposed by Chu & Beasley (1998). These data include randomly generated test problems with a different number of constraints ($m \in \{5, 10, 30\}$), variables ($n \in \{100, 250, 500\}$), and tightness ratios ($\alpha \in \{0.25, 0.5, 0.75\}$). For each instance with a differing *m*, *n*, and *α*, 10 test cases are provided, resulting in 9 sets of 30 problems each, totaling 270 cases.

For the GAs, we used standard parameter settings with a population size of 100, a bit string encoding, a factor 2 in the tournament selection, a mutation rate of *1/n*, and a crossover rate of 0.9. The GA-specific factors we applied are also stated in Table 1. All GAs were run on an Intel U9600 1.6 GHz processor with 4 GB RAM.

4.3.2. Procedure

We divided our simulation into three phases: 1) a pre-processing, 2) a computation, and 3) an evaluation phase. In the pre-processing phase, we computed the shadow prices as well as the optimal and LP-relaxed solution vectors for each test instance. Due to technical limitations, a solution vector would be considered optimal if the gap between the upper and lower bound was less than 1% of the upper bound. We used CPLEX 12.4 with a set relative tolerance of 1% for all of these calculations. Therefore, it might have occurred that the FV of a heuristic was higher than was the solution vector. During the computation, the single GAs determined the respective solution vectors. In the seldom-found case that some of the GAs' ingredients were not clearly specified, we applied the then current standard components presented in the first part of section 0. The 270 problems were solved three times for each setup with a differing number of iterations (10^1, 10^2, 10^3, 10^4). The final solutions' fitness values and the overall computation times were recorded. When required, pre-processing times, for example, for the shadow price calculations were added. In the evaluation phase, we analyzed the results concerning the solution quality and time. Quality was measured through the relative gap to the optimum (relative gap = $(f_{opt}-f_{GA})/f_{opt}$). The average of the respective three repetitions was used. If, for example, problem sets were compared against each other, a set's relative gap was the average of all problems' gaps (cf. Chu & Beasley (1998)).

4.4. Results

Concerning the individual GAs, results demonstrated that algorithms not allowing duplicates typically outperformed other GAs regarding the relative gap to the optimum (see Table 2). Khuri et al. (1994), Thiel & Voss (1994), Rudolph & Sprave (1995), and Hoff et al. (1996) yield suboptimal solution vectors, independent of the number of iterations, tightness ratios, or problem sizes. The algorithm by Khuri et al. (1994) even computed invalid solutions, especially in case of low *α* and a high number of iterations. Even though the GAs not allowing duplicates generally dominated, the performance varied among these GAs. Whereas Raidl- (1998) based algorithms provided better results in a low number of iterations, Chu & Beasley- (1998) founded methods yielded improved outcomes in many repetitions. The extension of the Raidl (1998) as well as Chu & Beasley (1998) GAs by additional operators resulted in marginal improvements of the relative gap to the optimum. Raidl (1999) also computed solution vectors with relatively low gaps to the optimum but the algorithm required a substantial amount of computation time. No substantial benefit to the solution was provided. From a practical view, there is no reason to use this type of approach. Therefore, Table 2 does not provide results for Raidl (1999) at 10,000 iterations.

Related to the time used to complete the simulation, the GAs without duplicate detection required substantially less time than did GAs verifying doubles. In the latter, Raidl- (1998) based algorithms typically needed fewer seconds than did Chu & Beasley- (1998) based GAs. Additional operators such as ones introduced by Levenhagen et al. (2001) tended to prolong the computation.

Regarding the general aspects, which are independent from the GA applied, results showed the influence of the number of resources and the projects on the GAs' performance. Naturally, the higher *m* and *n* were, the more computation time was required (see Table 3).

Table 3 also demonstrates that the results of the Chu & Beasley- (1998) based GAs (cf. Chu & Beasley, 1998; Gottlieb, 2000; Levenhagen et al., 2001) were similar to each other. Yet, even though these Chu & Beasley- (1998) based GAs computed only slightly worse relative solution gaps than did CPLEX 12.4., these GAs required substantially more calculation time. In contrast, Raidl- (1998) based GAs (cf. Raidl, 1998; Gottlieb, 2000; Levenhagen et al., 2001), required, with the exception of Levenhagen et al., 2001, almost the same calculation times as did CPLEX 12.4, but outperformed CPLEX 12.4 on average.

Table 2 Average performance of GAs depended on the number of iterations and test case characteristics (best relative solution gap marked)

Iteration	α		**CPLEX**	**Thiel & Voss (1994)**	**Rudolph & Sprave (1995)**	**Hoff et al. (1996)**	**Chu & Beasley (1998)**	**Raidl (1998)**	**Raidl (1999)**	**Gottlieb (2000)**		**Levenhagen et. al. (2001)**	
										Chu & Beasley (1998)	**Raidl (1998)**	**Chu & Beasley (1998), Gottlieb (2000)**	**Raidl (1998) and Gottlieb (2000)**
10	α=0.25	gap	0.00%	-21.68%	-21.81%	-21.59%	-18.01%	-0.63%	-2.87%	-17.36%	-0.53%	-17.07%	-0.52%
		sec	47.85	0.23	0.12	0.16	426.02	20.63	789.53	426.31	20.54	427.80	22.32
	α=0.50	gap	0.00%	-14.77%	-14.78%	-14.66%	-12.47%	-0.08%	-1.16%	-12.19%	-0.01%	-11.89%	0.00%
		sec	18.90	0.16	0.08	0.12	437.03	20.31	799.88	437.30	20.80	440.81	22.19
	α=0.75	gap	0.00%	-25.44%	-26.66%	-26.58%	-6.54%	0.02%	-0.53%	-6.25%	0.07%	-6.24%	0.05%
		sec	17.97	0.92	0.07	0.12	434.92	20.80	797.44	435.18	21.24	436.96	21.49
100	α=0.25	gap	0.00%	-21.16%	-21.61%	-21.33%	-11.07%	-0.28%	-2.33%	-10.92%	-0.26%	-9.74%	-0.27%
		sec	47.19	1.54	0.18	0.61	426.40	21.26	1119.93	426.71	21.45	437.47	39.87
	α=0.50	gap	0.00%	-14.21%	-14.60%	-14.43%	-8.50%	0.10%	-0.90%	-8.31%	0.10%	-7.47%	0.10%
		sec	18.88	2.09	0.14	0.57	437.40	20.93	1130.58	437.69	21.01	452.47	36.72
	α=0.75	gap	0.00%	-19.96%	-26.42%	-25.13%	-4.38%	0.12%	-0.39%	-4.30%	0.12%	-3.82%	0.13%
		sec	17.93	2.96	0.13	0.56	435.28	21.22	1135.34	435.56	21.03	446.17	37.14
1,000	α=0.25	gap	0.00%	-19.05%	-19.72%	-16.82%	-0.72%	-0.07%	-0.93%	-0.71%	-0.08%	-0.52%	-0.06%
		sec	47.91	21.40	0.73	4.98	430.55	29.92	4397.15	430.88	29.42	515.43	292.89
	α=0.50	gap	0.00%	-12.89%	-13.58%	-11.64%	-0.56%	0.19%	-0.20%	-0.56%	0.19%	-0.33%	0.20%
		sec	19.13	20.74	0.69	4.94	441.41	28.07	4461.03	441.70	28.10	524.89	245.47
	α=0.75	gap	0.00%	-7.91%	-21.17%	-13.68%	-0.12%	0.18%	0.01%	-0.12%	0.17%	-0.03%	0.18%
		sec	17.90	26.21	0.68	4.93	439.36	28.10	4650.66	439.66	27.92	513.99	258.59
10,000	α=0.25	gap	0.00%	-16.47%	-10.31%	-7.36%	0.04%	0.02%	-	0.06%	0.02%	0.04%	0.03%
		sec	47.70	191.37	6.22	48.83	488.13	94.20	-	488.57	93.91	1992.40	2542.88
	α=0.50	gap	0.00%	-11.34%	-7.79%	-5.34%	0.24%	0.24%	-	0.24%	0.24%	0.24%	0.24%
		sec	18.71	204.98	6.11	48.68	496.67	92.90	-	497.19	91.90	2092.66	2165.98
	α=0.75	gap	0.00%	-5.81%	-5.31%	-3.55%	0.22%	0.21%	-	0.22%	0.21%	0.22%	0.21%
		sec	17.60	223.41	6.12	48.74	495.74	87.68	-	496.24	86.49	1978.31	2624.64

Table 3 Average performance of GAs at 1,000 iterations depended on different problem sets (best relative solution gap marked)

Set	α		CPLEX	Thiel & Voss (1994)	Rudolph & Sprave (1995)	Hoff et al. (1996)	Chu & Beasley (1998)	Raidl (1998)	Raidl (1999)	Gottlieb (2000)		Levenhagen et. al. (2001)	
										Chu & Beasley (1998)	Raidl (1998)	Chu & Beasley (1998), Gottlieb (2000	Raidl (1998) and Gottlieb (2000)
set 1	α=0.25	gap	0.00%	-17.13%	-17.70%	-14.56%	-0.10%	-0.09%	-0.30%	-0.11%	-0.16%	-0.05%	-0.12%
m=5, n=100		sec	3.82	1.98	0.15	1.67	16.25	5.96	172.71	16.28	5.76	24.20	25.16
	α=0.50	gap	0.00%	-11.25%	-12.28%	-9.78%	0.12%	0.14%	-0.03%	0.15%	0.14%	0.16%	0.16%
		sec	3.21	2.26	0.14	1.66	17.80	6.04	159.66	17.81	5.78	24.14	23.67
	α=0.75	gap	0.00%	-5.51%	-13.61%	-6.90%	0.33%	0.32%	0.29%	0.35%	0.30%	0.34%	0.31%
		sec	3.00	2.73	0.14	1.66	15.62	5.76	177.52	15.63	5.57	21.59	20.47
set 2	α=0.25	gap	0.00%	-18.56%	-19.83%	-16.79%	0.21%	0.30%	0.00%	0.19%	0.30%	0.28%	0.31%
m=5, n=250		sec	6.86	11.99	0.35	4.09	39.67	15.00	1556.11	39.80	15.28	75.89	163.12
	α=0.50	gap	0.00%	-12.17%	-13.14%	-11.54%	0.06%	0.33%	0.07%	0.08%	0.33%	0.17%	0.33%
		sec	6.90	13.37	0.33	4.06	45.18	14.10	1455.94	45.32	13.81	74.45	107.48
	α=0.75	gap	0.00%	-6.27%	-22.60%	-13.37%	0.11%	0.20%	0.12%	0.13%	0.20%	0.16%	0.20%
		sec	6.91	17.40	0.33	4.07	45.56	13.78	1686.20	45.73	13.20	74.42	123.01
set 3	α=0.25	gap	0.00%	-20.29%	-21.38%	-19.36%	-0.80%	0.34%	-0.13%	-0.71%	0.34%	-0.17%	0.33%
m=5, n=500		sec	15.82	48.10	0.68	8.21	111.31	33.04	10213.89	112.09	31.45	283.93	513.45
	α=0.50	gap	0.00%	-13.14%	-13.96%	-12.57%	-1.33%	0.16%	-0.11%	-1.29%	0.15%	-0.76%	0.15%
		sec	15.07	48.00	0.65	8.20	111.89	32.41	10384.97	112.64	31.34	263.66	471.54
	α=0.75	gap	0.00%	-9.01%	-28.36%	-20.74%	-0.46%	0.09%	-0.01%	-0.47%	0.09%	-0.27%	0.09%
		sec	14.39	65.05	0.65	8.19	111.89	31.03	10851.20	112.67	30.40	250.61	461.87
set 4	α=0.25	gap	0.00%	-17.34%	-18.46%	-14.02%	-0.49%	-0.59%	-1.38%	-0.56%	-0.57%	-0.58%	-0.54%
m=10, n=100		sec	8.57	2.24	0.21	1.75	55.48	7.83	189.73	55.53	8.02	64.91	35.14
	α=0.50	gap	0.00%	-11.94%	-12.53%	-10.33%	-0.10%	-0.04%	-0.35%	-0.11%	-0.06%	-0.08%	-0.05%
		sec	4.78	2.28	0.20	1.75	56.97	6.99	189.56	56.99	7.20	64.03	24.77
	α=0.75	gap	0.00%	-6.02%	-12.74%	-7.31%	0.19%	0.24%	0.10%	0.18%	0.22%	0.21%	0.23%
		sec	4.87	2.83	0.20	1.71	57.35	7.50	203.97	57.38	7.37	63.99	26.51
set 5	α=0.25	gap	0.00%	-19.85%	-20.12%	-17.40%	-0.20%	0.06%	-0.57%	-0.16%	0.07%	-0.13%	0.10%
m=10, n=250		sec	10.64	11.34	0.50	4.22	133.67	19.14	1624.38	133.79	19.02	166.74	160.92
	α=0.50	gap	0.00%	-12.88%	-13.80%	-11.70%	0.03%	0.46%	0.13%	0.05%	0.48%	0.26%	0.50%
		sec	10.60	12.73	0.47	4.19	137.26	17.86	1648.67	137.40	17.90	172.30	140.06
	α=0.75	gap	0.00%	-8.63%	-22.71%	-13.44%	0.14%	0.28%	0.16%	0.13%	0.29%	0.20%	0.29%
		sec	10.70	15.85	0.47	4.20	140.26	17.46	1768.84	140.36	18.05	179.18	146.27
set 6	α=0.25	gap	0.00%	-19.60%	-20.65%	-18.39%	-1.17%	0.28%	-0.49%	-1.07%	0.28%	-0.68%	0.27%
m=10, n=500		sec	25.64	54.82	0.97	8.47	296.68	42.09	10681.21	297.39	42.49	479.68	545.77
	α=0.50	gap	0.00%	-13.64%	-14.13%	-12.63%	-1.35%	0.25%	-0.08%	-1.42%	0.25%	-0.93%	0.25%
		sec	23.60	48.25	0.93	8.44	292.22	40.44	10885.40	292.89	40.06	488.25	545.05
	α=0.75	gap	0.00%	-9.38%	-28.01%	-20.62%	-0.56%	0.11%	-0.04%	-0.56%	0.11%	-0.36%	0.11%
		sec	22.06	66.51	0.92	8.43	295.01	40.31	11316.82	295.70	41.63	457.25	518.58
set 7	α=0.25	gap	0.00%	-18.24%	-17.97%	-14.42%	-1.24%	-0.68%	-2.16%	-1.18%	-0.74%	-1.19%	-0.62%
m=30, n=100		sec	173.36	2.44	0.46	1.98	398.77	15.89	508.33	398.81	15.74	407.07	38.75
	α=0.50	gap	0.00%	-12.86%	-13.68%	-10.79%	-0.46%	-0.17%	-0.82%	-0.57%	-0.18%	-0.49%	-0.17%
		sec	16.21	2.35	0.44	1.94	414.35	15.72	529.19	414.44	16.30	423.29	40.66
	α=0.75	gap	0.00%	-6.88%	-12.66%	-7.66%	-0.13%	0.00%	-0.32%	-0.18%	-0.02%	-0.12%	-0.01%
		sec	11.54	2.82	0.42	1.92	429.89	15.57	551.47	429.95	15.48	438.97	39.95
set 8	α=0.25	gap	0.00%	-20.15%	-20.66%	-17.82%	-0.93%	-0.38%	-1.92%	-0.92%	-0.38%	-0.88%	-0.39%
m=30, n=250		sec	123.48	13.32	1.09	4.81	980.81	42.10	2357.02	981.00	41.55	1038.17	218.97
	α=0.50	gap	0.00%	-14.01%	-14.30%	-12.25%	-0.49%	0.14%	-0.52%	-0.41%	0.13%	-0.30%	0.13%
		sec	30.57	13.20	1.02	4.73	973.04	38.14	2367.78	973.15	38.81	1026.07	192.23
	α=0.75	gap	0.00%	-7.64%	-22.39%	-12.73%	-0.11%	0.15%	-0.16%	-0.13%	0.15%	-0.06%	0.16%
		sec	28.58	15.80	1.01	4.71	977.78	39.99	2448.15	977.86	39.06	1023.39	180.76
set 9	α=0.25	gap	0.00%	-20.29%	-20.76%	-18.59%	-1.78%	0.11%	-1.46%	-1.86%	0.12%	-1.24%	0.12%
m=30, n=500		sec	63.04	46.34	2.14	9.63	1842.36	88.27	12270.99	1843.24	85.43	2098.30	934.70
	α=0.50	gap	0.00%	-14.08%	-14.42%	-13.15%	-1.56%	0.48%	-0.15%	-1.52%	0.47%	-0.99%	0.47%
		sec	61.26	44.24	2.01	9.51	1923.95	80.90	12528.07	1924.69	81.70	2187.87	663.76
	α=0.75	gap	0.00%	-11.85%	-27.41%	-20.33%	-0.56%	0.24%	-0.02%	-0.53%	0.24%	-0.36%	0.24%
		sec	59.07	46.94	2.00	9.48	1880.90	81.50	12851.77	1881.61	80.49	2116.56	809.92
Average		**gap**	**0.00%**	**-13.28%**	**-18.16%**	**-14.04%**	**-0.47%**	**0.10%**	**-0.38%**	**-0.46%**	**0.09%**	**-0.29%**	**0.11%**
		sec	**28.32**	**22.79**	**0.70**	**4.95**	**437.11**	**28.70**	**4502.95**	**437.41**	**28.48**	**518.11**	**265.65**

4.5. Discussion

The research question this article is based on is which GA yields the best performance for the 0-1 multidimensional knapsack problem. Generally, GAs are very well suited for this problem type. In multiple cases, the GAs outperformed CPLEX 12.4. Even though the identification of the "best" GA can only be given depending on the specific requirements, we advocate the GA by Raidl (1998). Even at a low number of iterations, it yields good results, which are only yielded by other algorithms, such as the one by Chu & Beasley (1998), after substantially more repetitions. These results provide evidence for the solid initial population of the Raidl (1998) algorithm. Other Raidl- (1998) based GAs adding further specifications, for example, Levenhagen et al. (2001), reduce the gap to the optimum only marginally but require more computation time than does the original method. GAs based on the algorithm of Chu & Beasley (1998) substantially improve when increasing the number of iterations. This characteristic might be specifically due to the repair operator, whose initiation is dependent on the repetitions.

The performance of the other, non-Raidl- (1998) or non-Chu & Beasley- (1998) based algorithms is relatively low. The GA by Khuri et al. (1994) does not compute reliable vectors, and the GA by Raidl (1999) requires an inordinate amount of time for comparably higher gaps to the optimum solution. The remaining GAs by Thiel & Voss (1994), Rudolph & Sprave (1995), and Hoff et al. (1996), on the one hand, are faster due to the missing duplicate verification and the consequently fewer iterations. On the other hand, however, the remaining GAs do not reach the solution quality of, for example, Raidl (1998). Even increasing the time limit of these GAs to the required computation time of Raidl (1998) resulted in lower objective values than did Raidl (1998) in our additional tests.

Our results related to the general GAs' performance are consistent with prior research. Generally, GAs are very well suited for solving the 0-1 MKP (Raidl, 1998; Chu & Beasley, 1998; Raidl, 1999). Yet, with respect to the individual GAs, we concur only partly with the existing research. As Fréville (2004) has indicated, early GAs did not perform very well in our study, whereas later algorithms, starting with Chu & Beasley (1998), seemed to be extremely successful solving the 0-1 MKP. Regarding both the relative gap to the optimum and the required computation time to evaluate the GAs, we found that GAs extending the algorithms by Raidl (1998) and Chu & Beasley (1998) do not provide significant benefits to the applicant. In almost all problems, the only marginal improvement in solution quality did not compensate for the substantial increase in required computation time. As Levenhagen et al. (2001) have indicated, we do not see the need for algorithms like the one from Gottlieb (2000) and Levenhagen et al. (2001) to extend the GAs by Raidl (1998) and Chu & Beasley (1998).

Future research could focus on including additional, non-MKP-specific genetic algorithms in the analysis. For example, studies could incorporate algorithms of different heuristic types. These algorithms could then, for example, be evaluated by the achieved FV within a given and fixed computation time. Moreover, the specific characteristics of the most successful approaches could not only be identified but also might serve as the basis for the creation of a new, more efficient hybrid algorithm.

4.6. Conclusion

GAs are very well suited for solving the multidimensional knapsack problem (Raidl, 1998). Yet, severe differences regarding the solution quality and the computation time exist among the available GAs. Consequently, the selection of a GA has to be thoroughly considered. Results of this study are that GAs not allowing duplicates are generally better suited for the 0-1 MKP than are algorithms not verifying whether doubles occur. In detail, the GAs by Raidl (1998) and Chu & Beasley (1998) are well performing. Extensions, for example, related to the neighborhood search, do not provide any significant benefit. Finally, we propose the algorithm by Raidl (1998) as the best suited GA for the multidimensional knapsack problem. This GA constantly achieves good results even at a small number of iterations. The applicant is therefore able to quickly compute solution vectors with objective values relatively close to the optimum.

Bibliography

Beasley, J.E. (1998). OR-Library [WWW Document]. Retrieved August, 2012, from http://people.brunel.ac.uk/~mastjjb/jeb/orlib/mknapinfo.html

Chu, P.C., Beasley, J.E. (1997). A genetic algorithm for the generalised assignment problem. Computers & Operations Research, 24, 17–23.

Chu, P.C., Beasley, J.E. (1998). A genetic algorithm for the multidimensional knapsack problem. Journal of Heuristics, 4, 63–86.

Cotta, C., Troya, J.M. (1998). A hybrid genetic algorithm for the 0-1 multiple knapsack problem. In: Artificial Neural Nets and Genetic Algorithms, 251–255.

Dammeyer, F., Voss, S. (1991). Application of tabu search strategies for solving multiconstraint zero-one knapsack problems. Working paper, Technische Hochschule Darmstadt, Germany.

Drexl, A. (1988). A simulated annealing approach to the multiconstraint zero-one knapsack problem. Computing, 40, 1–8.

Fréville, A. (2004). The multidimensional 0-1 knapsack problem: An overview. European Journal of Operational Research, 155, 1–21.

Gottlieb, J. (2000). On the effectivity of evolutionary algorithms for the multidimensional knapsack problem. In: Fonlupt, C., Hao, J.-K., Lutton, E., Schoenauer, M., Ronald, E. (Eds.), Artificial evolution. Springer Berlin Heidelberg, Berlin, Heidelberg, 23–37.

Hanafi, S., Freville, A. (1998). An efficient tabu search approach for the 0-1 multidimensional knapsack problem. European Journal of Operational Research, 106, 659–675.

Hillier, F.S. (1969). Efficient heuristic procedures for integer linear programming with an interior. Operations Research, 17, 600–637.

Hinterding, R. (1994). Mapping, order-independent genes and the knapsack problem. In : Proceedings of the first IEEE conference on evolutionary computation, 1994. IEEE world congress on computational intelligence, 13–17.

Hoff, A., Løkketangen, A., Mittet, I. (1996). Genetic algorithms for 0/1 multidimensional knapsack problems. Proceedings norsk informatikk konferanse, NIK ’96.

Kellerer, H., Pferschy, U., Pisinger, D. (2004). Knapsack problems, 1st ed. Springer.

Khuri, S., Bäck, T., Heitkötter, J. (1994). The zero/one multiple knapsack problem and genetic algorithms. ACM Press, 188–193.

Levenhagen, J., Bortfeldt, A., Gehring, H. (2001). Path tracing in genetic algorithms applied to the multiconstrained knapsack problem, In: Boers, E.J.W. (Ed.), Applications of evolutionary computing. Springer Berlin Heidelberg, Berlin, Heidelberg, 40–49.

Lin, F.-T. (2008). Solving the knapsack problem with imprecise weight coefficients using genetic algorithms. European Journal of Operational Research, 185, 133–145.

Martello, S., Pisinger, D., Toth, P. (1999). Dynamic programming and strong bounds for the 0-1 knapsack problem. Management Science, 45, 414–424.

Martello, S., Pisinger, D., Toth, P. (2000). New trends in exact algorithms for the 0–1 knapsack problem. European Journal of Operational Research, 123, 325–332.

Pal, B.B., Chakraborti, D. (2013). Using genetic algorithm for solving quadratic bilevel programming problems via fuzzy goal programming. International Journal of Applied Management Science, 5, 172.

Raidl, G. R. (1998). An improved genetic algorithm for the multiconstrained 0-1 knapsack problem. In: The 1998 IEEE international conference on evolutionary computation proceedings, 207–211.

Raidl, G. R. (1999). Weight-codings in a genetic algorithm for the multi-constraint knapsack problem. In: Evolutionary computation, 1999. CEC 99. Proceedings of the 1999 congress on.

Raidl, G.R., Gottlieb, J. (2005). Empirical analysis of locality, heritability and heuristic bias in evolutionary algorithms: A case study for the multidimensional knapsack problem. Evolutionary Computation, 13, 441–475.

Rudolph, G., Sprave, J. (1995). A cellular genetic algorithm with self-adjusting acceptance threshold. In: Genetic algorithms in engineering systems: Innovations and applications, 1995. GALESIA. first international conference on (Conf. Publ. No. 414). Presented at the genetic algorithms in engineering systems: Innovations and applications, 1995. GALESIA. first international conference on (Conf. Publ. 414), IET, 365–372.

Senju, S., Toyoda, Y. (1968). An approach to linear programming with 0-1 variables. Management Science, 15(4), 196–207.

Thiel, J., Voss, S. (1994). Some experiences on solving multiconstraint zero-one knapsack problems with genetic algorithms. INFOR 32, 226–242.

5. Rucksackprobleme in der Praxis – schnelle Entscheidungen schwer gemacht[4]

Kolumnentitel: 0-1 Entscheidungsprobleme

Li Zeng
Bernhard Lienland
Florian Kellner

Unternehmen sind häufig mit Situationen konfrontiert, in denen schnell Entscheidungen bezüglich mehrerer Handlungsalternativen gefunden werden müssen. Mathematische Verfahren hierbei unterstützen, z.B. für die Ermittlung einer ersten Diskussionsbasis. Eine Einarbeitung in komplexe Optimierungssoftware ist für die teilweise sporadisch auftretenden Probleme in der Regel für Unternehmen jedoch nicht möglich, unter anderem auch unter Anbetracht der teilweise hohen Kosten der Standardsoftware und dem benötigten hohen Einarbeitungsaufwand. Gerade Problemstellungen in Fachbereichen, die nicht auf mathematische Problemlösung spezialisiert sind münden daher regelmäßig in Ineffizienzen. Basierend auf den in der Literatur diskutierten Lösungsansätzen wurde ein praxisorientierter Ansatz zur Entscheidungsunterstützung für Rucksackprobleme bzw. 0-1 Probleme mithilfe von Genetischen Algorithmen (GA) entwickelt und technisch in Microsoft Excel ® umgesetzt. Ein Praxistest bei einem chinesischen Textilunternehmen belegt erhöhte Effektivität und Effizienz aufgrund einer verbesserten Auswahl von Handlungsalternativen und einer verbesserten Kommunikation zwischen den Fachabteilungen.

5.1. 0–1 Entscheidungen als Basis für den Unternehmenserfolg

Das in der Literatur häufig auch als 0-1 Problem bezeichnete Rucksackproblem ist ein Optimierungsproblem bei dem mehrere Handlungsalternativen mit unterschiedlichen Nutzenniveaus, beispielsweise Stückdeckungsbeiträge, und Ressourcenverbräuchen begrenzten Ressourcen gegenüberstehen. Die Namensgebung des Rucksackproblems leitet sich von der Vorstellung ab, dass ein Rucksack mit bestimmten Gegenständen gepackt werden soll. Bestimmte Gegenstände – Handlungsalternativen – von definiertem Nutzen mit entsprechenden Volumen und Gewichten – Ressourcenverbräuche – sind in einem Rucksack mit begrenztem Volumen und Gewicht – begrenzente Ressourcen – zu verstauen. Ziel ist es die Gegenstände so zu kombinieren, dass der Nutzen maximiert wird, aber Volumen- und Gewichtsbegrenzungen des Rucksacks berücksichtigt werden (Zimmermann 2015). Es liegt eine 0-1 Entscheidung vor, da entschieden werden soll, welche Alternativen ausgewählt werden müssen („1“) und welche nicht („0“), sodass der Gesamtnutzen maximal wird.

So gut wie in jedem Funktionsbereich eines Unternehmens sind 0-1 Entscheidungen zu treffen. Knappe Entwicklungsbudgets sind zu allokieren, Projektportfolios zu optimieren, Produktionsanlagen bei begrenztem Budget zu bestellen und Kundenanfragen bei limitierten Produktionskapazitäten zu bestätigen. Gerade in Anbetracht der teilweise langen Projektlebenszyklen kann eine falsche Auswahl von Handlungsalternativen schnell zu schwerwiegenden Konsequenzen, wie z.B. verletzte Kapazitätsbudgets oder auch mangelnde Liquidität führen. Eine gute Auswahl der Handlungsalternativen ist daher unabdingbar zur Erhaltung der Wettbewerbsfähigkeit.

Eine Vielzahl von mathematischen Verfahren zur Lösung dieser 0–1 Probleme ist in der Literatur beschrieben und in kommerzielle als auch kostenfreie Standardsoftware implementiert. Solche Software wird typischerweise von ausgewiesenen Operations Research Experten in

[4] Zeng, L., Lienland, B. & Kellner F. (2016). “Rucksackprobleme in der Praxis – schnelle Entscheidungen schwer gemacht.” HMD Praxis der Wirtschaftsinformatik, 53(3), 310–322.

zumeist größeren Konzernen verwendet. Eine „breite“ Anwendung durch Mitarbeiter in mehreren Funktionsbereichen eines Unternehmens erfolgt in der Regel jedoch nicht bzw. nur sehr begrenzt. Gründe dafür sind die bei kommerziellen Lösungen teilweise hohen Anschaffungskosten der Software, ebenso wie die Kosten der Mitarbeiterschulungen – gerade bei Software-Lösungen ohne Microsoft Excel ®-Integration. Weiterhin verhindert auch das Fehlen einer technischen Umsetzbarkeit die breite Verwendung. Lizenz-Regularien und restriktive IT-Richtlinien untersagen regelmäßig die Installation oder den Datenverbindungsaufbau von nicht bereits durch die IT-Abteilung verifizierter Software. Eine Verifizierung der Optimierungssoftware kommt aufgrund des häufig recht kurzfristigen Problems des Anwenders und der langen Verifizierungszeiträume durch die IT-Abteilung für den Mitarbeiter zumeist nicht in Frage.

Somit bleibt dem Mitarbeiter lediglich die Option des Excel Solvers, der standardmäßig in Microsoft Excel ® integriert ist und aktiviert werden kann. In der Praxis erweist sich der Excel-Solver jedoch aufgrund der mangelnden Lösungskompetenz für 0-1 Probleme oft als untauglich. Schon kleinere Probleme lassen die Optimierung abbrechen.

Die Defizite der bestehenden Programme bedingen eine neue Lösung, die den Anforderungen der Unternehmen entspricht. Mit SolveGA ist eine verständliche, anwendbare und effiziente Softwarelösung erarbeitet und technisch umgesetzt worden. SolveGA ist bei Bedarf auf eigenes Risiko hin frei verfügbar nach MIT Lizenz (http://opensource.org/licenses/mit-license.php). SolveGA kann unter http://www.solvega.de/ heruntergeladen werden.

Der vorliegende Beitrag hat zum Ziel, die Funktionsweise und die Vorteile von SolveGA aufzuzeigen.

5.2. Bekannte Lösungsansätze

5.2.1. Exakte Verfahren und Heuristiken

Die in der Literatur beschriebenen Methoden zur Lösung des 0-1 Rucksackproblems können in zwei generelle Kategorien unterteilt werden: Die exakten Verfahren und die Heuristiken. Exakte Verfahren ermitteln nachweislich das exakte Optimum des Entscheidungsproblems. Obwohl die exakten Verfahren (vgl. Martello u. a. 1999; Martello u. a. 2000) in den letzten Jahren erhebliche Fortschritte gemacht haben (siehe z.B. Kellner u. a. 2012), stellen große Entscheidungsräume weithin ein Problem für die exakten Verfahren dar. Heuristiken können zwar keinen optimalen Lösungsvektor im engeren Sinne garantieren, sind aber dennoch gute Verfahren, um auch bei größeren Problemstellungen sehr gute oder optimale Ergebnisse zu liefern (Fréville 2004). Heuristiken können weiter in mehrere Unterkategorien, wie z. B. die Greedy Algorithmen (vgl. Senju und Toyoda 1968) oder die Meta-Heuristiken mit der Tabu-Search (vgl. Dammeyer und Voss 1991), dem Simulated Annealing (vgl. Drexl 1988) oder den Genetischen Algorithmen (GAs) klassifiziert werden.

5.2.2. Verfügbare Instrumente

Zur Lösung der 0-1 Optimierungsprobleme gibt es mehrere Softwarelösungen, die die theoretischen Erkenntnisse umsetzen. Die bestehenden Softwarelösungen weisen jeweils unterschiedliche Eigenschaften bzgl. der Kostenfreiheit, Anwendungsfreundlichkeit, Installierbarkeit und Lösungseffizienz auf. Unter Kostenfreiheit wird verstanden, dass keine Gebühr zur Verwendung der Software anfällt. Anwendungsfreundlichkeit bezieht sich auf die

Bedienbarkeit durch die breite Masse im Unternehmen. Anwendungsfreundlichkeit beeinflusst die Schulungskosten für Mitarbeiter. Aufgrund der vielfachen Anwendung von Microsoft Excel ® in Unternehmen, gilt die Anwendungsfreundlichkeit als gegeben, sobald eine einfach bedienbare Excel-Integration gegeben ist. Installierbarkeit umfasst die Verwendbarkeit auf dem Rechner eines Mitarbeiters ohne Administratorrechte. Lösungseffizienz ist beschrieben durch die Lösungsqualität bzw. Lösungseffektivität und die benötigte Rechenzeit gerade auch bei großen Problemen.

Generell kann bei Optimierungssoftware zwischen kommerzieller und kostenfreier Software unterschieden werden. Kommerzielle Software wie z.B. IBM ILOG CPLEX ® oder auch LINDO LINGO ® ist aufgrund der Vielzahl an Möglichkeiten und der zu erlernenden Software-eigenen Syntax eher für fortgeschrittene Operations Research Anwender geeignet. Zwar gibt es durch eine Excel-Schnittstelle auch Anwendungsmöglichkeiten für weniger erfahrene Benutzer, jedoch verhindern die relativ hohen Lizenzkosten mitunter eine breite Anwendung im Unternehmen.

Bei den kostenfrei verfügbaren Softwareangeboten (z.B. LP_Solve, COIN-OR, GLPK), ebenso wie auch bei den kommerziellen Optimierern, ist zu beachten, dass eine lokale Installation auf dem entsprechenden Rechner des Anwenders vorgenommen werden muss. In einigen Fällen wie dem COIN-OR / OpenSolver ist es zwar möglich auch eine reine Microsoft Excel ®-Integration durchzuführen, aber es wird dann in der Regel versucht eine Datenverbindung aufzubauen, um die für die 0-1 Problemstellung benötigten Algorithmen herunterzuladen. Die Installation von Fremdsoftware und auch unbekannte Datenverbindungen werden regelmäßig durch IT Sicherheitsstandards unterbunden. Neben der Software, sind noch Internetdienste als weitere kostenfreie Alternative zu nennen. Allerdings hält sich die Anwenderfreundlichkeit sehr in Grenzen. Eine Microsoft Excel ® Integration ist meist nicht möglich.

Dem Anwender bleibt daher häufig nur übrig, den Excel Solver zu verwenden, welcher jedoch bei komplexen Problemstellung keine Lösung generieren kann.

5.3. Die Lösung: SolveGA

Das in SolveGA zugrunde liegende 0-1 Optimierungsproblem entspricht folgender mathematischer Formulierung (Kellerer u. a. 2004):

Maximiere $$\sum_{i=1}^{n} c_i x_i \qquad (1)$$

u. d. Nb. $$\sum_{i=1}^{n} a_{ij} x_i \leq b_j \qquad \forall j \qquad (2)$$

$$x_i \in \{0,1\} \qquad \forall i \qquad (3)$$

mit

Indizes:

i	Handlungsalternative (1..n)
j	Restriktion (1..m)

Parameter:

c_i	Wert bzw. Nutzen von Handlungsalternative i

a_{ij}	Ressourcenverbrauch der Ressource j durch Handlungsalternative i
b_j	Kapazität der Ressource j

Entscheidungsvariablen:

x_i	1 wenn Handlungsalternative i ausgewählt ist, 0 wenn nicht

Die Zielfunktion in Formel 1 drückt den gesamten Nutzen der ausgewählten Handlungsalternativen aus. Bei den Nebenbedingungen beschreibt Formel 2 die Einhaltung der Ressourcenkapazität. Formel 3 zeigt auf, dass Handlungsalternativen nur ganz und nicht anteilig durchgeführt werden dürfen.

5.3.1. Implementierte Methoden

Zur Lösung des mathematischen Optimierungsproblems verwendet SolveGA Algorithmen aus der Klasse der Genetischen Verfahren, da besonders die Genetischen Algorithmen sich zur Lösung von 0-1 Entscheidungsproblemen eignen (Raidl 1998; Raidl 1999).

Genetische Algorithmen funktionieren nach dem Grundprinzip, das aus zwei Lösungsvektoren – Eltern – ein neuer, besserer Lösungsvektor – Kind – erstellt werden soll, ähnlich dem Prinzip der biologischen Evolution. Der generelle Rahmen auf dem genetische Verfahren basieren, ist unterteilt in die 1) Initialpopulation-, 2) die Reproduktions- und 3) die Austauschphase (siehe Abbildung 1).

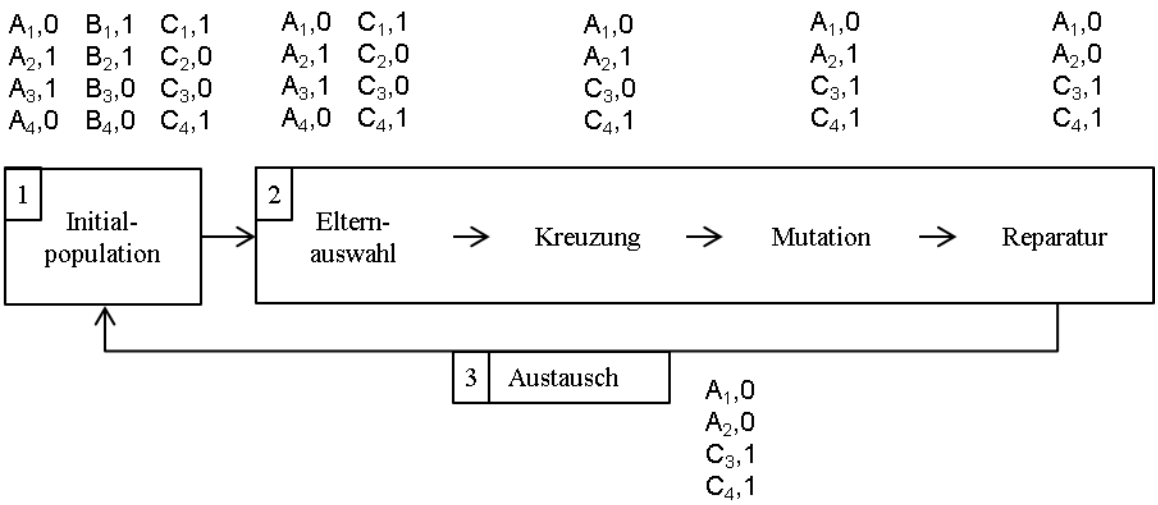


Abbildung 1: GA Prinzip

Die 1) Initialpopulation besteht in der Regel aus einer Reihe von zufällig ermittelten Lösungsvektoren. Dem Lösungsvektor ist ein spezifischer Fitness-Wert zugeordnet, der im einfachsten Fall dem Zielfunktionswert entspricht. Je nach Ausgestaltung des spezifischen GAs können die zufällig ermittelten Lösungsvektoren noch durch Hinzunahme oder durch Entfernen von Handlungsalternativen hinsichtlich einer Verbesserung des Fitness-Werts modifiziert werden. Bezogen auf das Rucksack-Beispiel beständen die Lösungsvektoren aus den zufällig ermittelten Gegenständen, die im Rucksack zu verstauen sind. Der Gesamtnutzen würde sich als Summe der Nutzen der einzelnen Gegenstände ergeben. Ein Gegenstand der in den Rucksack aufgenommen ist, entspricht einer 1 ($x_i = 1$), ein Gegenstand der nicht ausgewählt ist entspricht einer 0 ($x_i = 0$).

Die 2) Reproduktionsphase ist unterteilt in die Auswahl der Eltern und die Kreuzungsphase sowie eine darauffolgende Mutations- und Reparationsphase. Idee der Reproduktionsphase ist es zwei Lösungsvektoren der Initialpopulation zu einem Lösungsvektor zu kombinieren. Wohingegen in ersten Gentischen Algorithmen die „verhältnismäßige 1-Punkt-Kreuzung“ als Reproduktionsmethode verwendet wurde, wird in neueren Verfahren eine „Wettkampf Einheits-Kreuzung“ verwendet. Bei der „verhältnismäßigen 1-Punkt-Kreuzung“ steht die Idee im Vordergrund, dass ein Lösungsvektor mit einem hohen Fitness-Wert eine höhere Wahrscheinlichkeit hat für die Erstellung eines neuen Nachkommen in Erwägung gezogen zu werden, als ein Lösungsvektor mit einem niedrigen Fitness-Wert. Die Auswahl der Verfahren erfolgt über eine kumulative Wahrscheinlichkeitsfunktion. Nach Auswahl zweier Lösungsvektoren – Eltern – wird eine „Bruchposition“ zufällig ermittelt. Der Teil des einen Lösungsvektors bis zur Bruchposition wird dann mit dem Teil des anderen Lösungsvektors ab der Bruchposition kombiniert, so dass ein neuer Lösungsvektor – Kind – entsteht. Bei der „Wettkampf Einheits-Kreuzung“ als Reproduktionsmethode werden zwei neue zusätzliche Populationen erstellt, die aus zufällig ausgewählten Lösungsvektoren der Initialpopulation bestehen. Aus jeder der beiden zusätzlichen Populationen wird der Lösungsvektor – Eltern – ausgewählt, der den höchsten Fitnesswert aufweist. Der neue Lösungsvektor – Kind – wird ermittelt in dem für jedes Gen bzw. Position zufällig der Wert von dem einen oder dem anderen Elternpaar verwendet wird. Nach der Kreuzung findet typischerweise eine Mutation einzelner Gene bzw. Positionen innerhalb des Lösungsvektors statt. Die Mutation ist gefolgt von der Reparationsphase in der Gene bzw. Werte des Lösungsvektors auf 0 bzw. auf 1 gesetzt werden. In der Reparationsphase soll sichergestellt werden, dass nur Lösungsvektoren berücksichtigt werden, die einerseits die Nebenbedingungen nicht verletzen, aber andererseits auch keine Handlungsalternativen auslassen, die noch in den Lösungsvektor hätten aufgenommen werden könnten.

In der 3) Austauschphase werden die neuen Lösungsvektoren in die Initialpopulation integriert. Die Aufnahme der neuen Lösungsvektoren kann anhand des „Generations-Ansatzes“ oder anhand des „Bestand-Ansatzes“ erfolgen. Beim „Generations-Ansatz“ wird die komplette Initialpopulation mit neuen Lösungsvektoren ersetzt, sobald die benötigte Anzahl von neuen Lösungsvektoren erreicht ist. Beim „Bestand-Ansatz“ ersetzt der gerade neu ermittelte Lösungsvektor den Lösungsvektor in der Initialpopulation mit dem geringsten Fitness-Wert.
Der Genetische Algorithmus wird beendet sobald ein definiertes Abbruch-Kriterium erreicht ist, wie z.B. die vorgegebene Anzahl an Iterationen. Der bis dahin beste Lösungsvektor entspricht dann dem Ergebnis.

In der Literatur wird eine Vielzahl von GAs mit unterschiedlichen Ausprägungen beschrieben. Diese Vielzahl lässt sich auf die vier Verfahren von Raidl (1998), Chu und Beasley (1998), Gottlieb (2000), Levenhagen u. a. (2001) reduzieren, die besonders gut hinsichtlich Lösungsqualität und benötigter Lösungszeit abschneiden (Lienland und Zeng 2015). Der GA von Raidl (1998) hat die Besonderheit, dass die Initialpopulation basierend auf einem relaxierten Rucksackproblem ermittelt wird, d.h. die 0-1 Nebenbedingung wird hinsichtlich der Ganzzahligkeit vernachlässigt. Jedes Gen des Lösungsvektors wird mit der Wahrscheinlichkeit der Lösung des relaxierten Rucksackproblems auf 1 gesetzt. Diese Relaxierung findet auch in der Reproduktionsphase beim Reparaturabschnitt Anwendung. Chu und Beasley (1998) verwenden eine spezifische Form der „Wettkampf Einheits-Kreuzung“, bei der ein Quotient aus den Fitness-Werten, den Schattenpreisen und den Ressourcenverbräuchen des Lösungsvektors ermittelt wird. Die Schattenpreise entsprechen der Differenz zwischen dem Fitness-Wert des Lösungsvektors bei original gegebener Ressourcenausstattung und dem Fitness-Wert des Lösungsvektors bei leicht erhöhter Ressourcenausstattung. Gottlieb (2000) ergänzt die Verfahren von Raidl (1998) und Chu und Beasley (1998) um eine weitere Nebenbedingung, damit keine zusätzlichen Alternativen zu Vektoren hinzugefügt werden können, ohne die Ressourcengrenzen zu verletzen. Levenhagen u. a. (2001) ergänzen das Verfahren von Gottlieb (2000) um die Komponente der „Wegaufzeichnung“, bei der Zwischenlösungen zufällig Optimierungsmaßnahmen unterzogen werden.

5.3.2. Die technische Umsetzung

SolveGA wurde in Microsoft Excel 2007 ® / VBA programmiert und beinhaltet die beschriebenen GAs sowie einen für die GAs notwendigen Simplex-Algorithmus (vgl. Homburg 2000). *SolveGA* ist damit unabhängig von z.B. dem Excel Solver, der in der mit Microsoft Excel ® ausgelieferten Version gewissen Begrenzungen bei der Anzahl der Entscheidungsvariablen und der Nebenbedingungen unterliegt. Die einzelnen GAs und der Simplex-Algorithmus wurden als Module in Microsoft Excel ® konzipiert und können somit auch einfach anderweitig Anwendung finden.

SolveGA ist auf eigenes Risiko kostenfrei nach MIT Lizenz (http://opensource.org/licenses/mit-license.php) anwendbar. Die Anwenderfreundlichkeit wird über die direkte Excel-Integration mit einfacher grafischer Oberfläche erreicht. Administratorrechte werden für eine Anwendung von *SolveGA* nicht benötigt. Eine Installierbarkeit ist somit gegeben. Hinsichtlich der Lösungsqualität von *SolveGA* hat der Anwender die Möglichkeit eine von vier Qualitäts- bzw. Schnelligkeitsstufen auszuwählen. Bei Stufe 1 wird lediglich das Verfahren von Raidl (1998) eingesetzt; Stufe 2 wendet zusätzlich noch das Verfahren von Chu und Beasley (1998) an; Stufe 3 bedient sich zusätzlich noch dem GA nach Gottlieb (2000); Stufe 4 verwendet dann ebenso das Verfahren nach Levenhagen u. a. (2001). Für jedes Verfahren werden jeweils 500 Iterationen durchgeführt. Der Anwender hat die Möglichkeit im fortgeschrittenen Modus des Programms die Anzahl der Iteration zu modifizieren.

Die grafische Oberfläche von *SolveGA* besteht im Wesentlichen aus vier Eingabefeldern (siehe Abbildung 2). Zum Befüllen dieser vier Eingabefelder ist das Eingabefeld zuerst auszuwählen, um dann auf dem Excel-Blatt den entsprechenden Bereich zu markieren. „Alternative Value“ beinhaltet den Bereich mit den Zielfunktionskoeffizienten bzw. den Profiten der Handlungsalternativen. „Available Resources“ ist der Bereich mit den verfügbaren Ressourcen. „Alternative Consumption“ ist der Bereich mit den Ressourcenverbräuchen durch die Handlungsalternativen. „Output Range“ beinhaltet den Bereich, in den der Ergebnisvektor kopiert werden soll. Neben diesen vier Eingabefeldern hat der User die Möglichkeit eine der vier Qualitäts- bzw. Schnelligkeitsstufen auszuwählen. Im optionalen „Advanced Modus“ kann der Anwender spezifische Angaben zu der Anzahl der Iterationen machen, die ein GA durchlaufen soll. Der „Advanced Modus“ ist standardmäßig deaktiviert und die Iterationen sind auf 500 gesetzt.

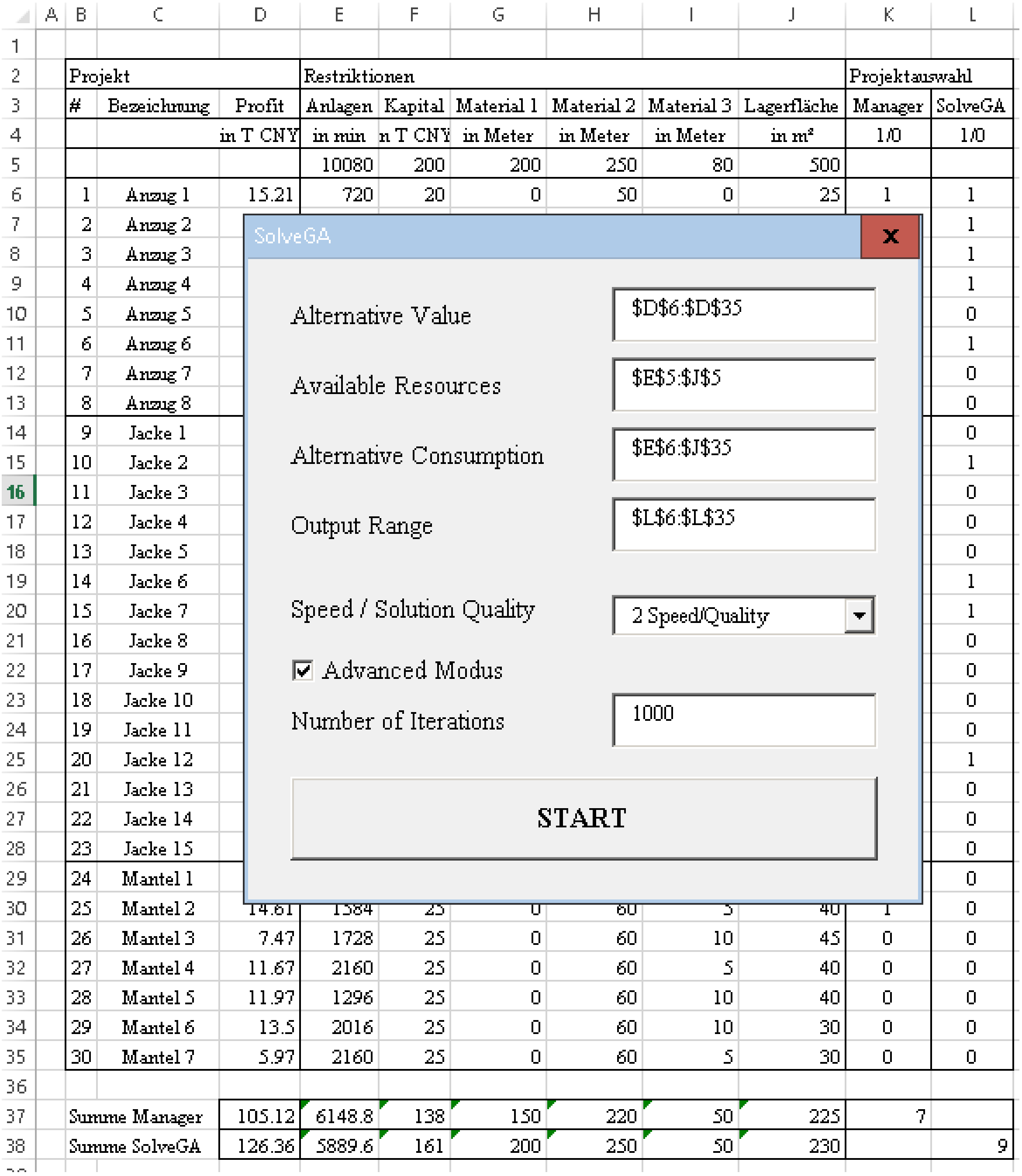


Abbildung 2: Grafische Benutzeroberfläche von *SolveGA*

5.4. Das Fallbeispiel

5.4.1. Das Unternehmen

Shaun Daun ist ein Hersteller und Multi-Kanal-Händler für Schuhe und Mode mit Sitz in China. Neben der Produktionsstätte umfasst das Unternehmen sieben stationäre Verkaufseinheiten und zwei Onlineshops. Das Unternehmen erzielte einen Umsatz von ca. 3 Millionen Euro in 2014, wozu der Online-Handel etwa 60% beitrug.

Aufgrund der Unternehmensstruktur mit der vertikalen Integration von Herstellung und Vertrieb aber auch aufgrund der erforderlichen hohen Reaktionsraten im Online-Handel ist Shaun Daun regelmäßig mit 0-1 Entscheidungsproblemen konfrontiert. Besonders häufig ist das Unternehmen mit der Frage beschäftigt, welche Produkte innerhalb eines Zeitraumes hergestellt und verkauft werden sollen. Gerade vor bzw. in Urlaubszeiten kommt es durch ein erhöhtes Bestellvolumen und durch bereits erfolgte Lieferzusagen regelmäßig zu Engpässen bei den elementaren Produktionsfaktoren Arbeitskraft und Betriebsmittel. Die bisherige Auswahl der Handlungsalternativen basierte meist auf der Erfahrung einzelner Manager und nach absteigender Profitabilität der einzelnen Alternativen. Eine Auswahl unter Berücksichtigung der Gesamtprofitabilität des vollständigen Projektportfolios wurde aufgrund der Vielzahl von Alternativen und Abhängigkeiten nur in Ausnahmefällen mit hohem manuellen Aufwand durchgeführt.

5.4.2. Der Praxistest

Die Anwendung von *SolveGA* im Rahmen eines Praxistests bestand aus drei Phasen. In der ersten Phase wurden Manager von Shaun Daun gebeten, die für sie wesentlichen restriktiven Ressourcen zu identifizieren. Aus der Erfahrung der Manager heraus wurden die Anlagenkapazität in Minuten, das Kapitalbudget in Euro, einige Produktionsmaterialien in Meter sowie die Kapazität des Ausgangslagers in m^2 als restriktive Ressourcen genannt. Das Kapitalbudget bezog sich hauptsächlich auf die finanziellen Mittel, die für den Akkordlohn der Angestellten vorgesehen waren.

In der zweiten Phase wurde eine Bestandsaufnahme der verfügbaren Ressourcen sowie der Projektanfragen der Kunden gemacht. Als Zeitraum für den Praxistest von *SolveGA* wurde eine Woche vor dem Beginn einer Chinesischen Feierlichkeit betrachtet. Neben den bereits zugesagten Liefer- und Produktionsaufträgen zeichnete sich diese Woche durch zusätzliche verbindliche Kundenanfragen zur Produktion von z.B. spezieller Festkleidung aus. Die für die Woche verfügbaren Ressourcen wurden unter Berücksichtigung der gesamt zur Verfügung stehenden Kapazität sowie bereits fix eingeplanter Produktionsaufträge ermittelt. Die Kundenanfragen entsprachen einer der drei Kategorien – „Anzüge“, „Jacken“, „Mäntel“, wobei jede Kundenanfrage aufgrund der erzielbaren Profitabilität sowie den speziellen Ressourcenverbräuchen individuell war.

In der dritten Phase wurde die bisherige Projektauswahl durch die Manager der Projektauswahl durch *SolveGA* gegenübergestellt. Nach Anwendung von *SolveGA* verdeutlichte sich, dass die bisherige Projektauswahl nach absteigender Projektprofitabilität suboptimal war. Die Portfolioermittlung mit *SolveGA* ergab, dass insgesamt mehr Projekte durchgeführt werden können, was zu einer Erhöhung der Gesamtprofitabilität um etwa 20% führt.

Tabelle 1 zeigt die Restriktionen mit den verfügbaren Ressourcen (z.B. verfügbare Anlagenkapazität der Woche von 10080 Minuten), die Projektdaten und die Projektauswahl der Manager sowie die Projektauswahl mit *SolveGA* in anonymisierter Form. Shaun Daun stellte das neue Projektportfolio den Fachabteilungen zur Diskussion. Es zeigte sich, dass die sonst teilweise von Eigeninteressen geprägten Gespräche, durch die neue Diskussionsgrundlage schnell zielgerichteter wurden und die Gesamtprofitabilität im Fokus stand. Vorschläge über die Aufnahme weiterer Restriktionen wurden seitens der Fachabteilungen gemacht. Basierend auf dem durch *SolveGA* vorgeschlagenen Portfolio und den weiterführenden Diskussionen wurde das Produktionsprogramm von Shaun Daun angepasst.

Projekte			**Restriktionen**						**Projektauswahl**	
#	Bezeichnung	Profit	Anlagen	Kapital	Material 1	Material 2	Material 3	Lagerfläche	Manager	*SolveGA*
		in T CNY	in min	in T CNY	in Meter	in Meter	in Meter	in m²	1/0	*1/0*
			10080	200	200	250	80	500		
1	Anzug 1	15,21	720,0	20	0	50	0	25	1	*1*
2	Anzug 2	13,74	763,2	20	0	50	0	25	1	*1*
3	Anzug 3	12,36	648,0	20	0	50	0	20	0	*1*
4	Anzug 4	10,50	676,8	20	0	50	0	10	0	*1*
5	Anzug 5	9,90	720,0	20	0	50	0	10	0	*0*
6	Anzug 6	13,50	705,6	18	0	50	0	15	0	*1*
7	Anzug 7	9,00	748,8	18	0	50	0	25	0	*0*
8	Anzug 8	6,42	633,6	18	0	50	0	20	0	*0*
9	Jacke 1	13,59	662,4	18	50	0	15	20	0	*0*
10	Jacke 2	15,03	705,6	18	50	0	10	30	1	*1*
11	Jacke 3	7,98	432,0	18	50	0	20	30	0	*0*
12	Jacke 4	4,62	504,0	18	50	0	10	20	0	*0*
13	Jacke 5	2,97	446,4	18	50	0	10	20	0	*0*
14	Jacke 6	14,55	460,8	15	50	0	15	20	0	*1*
15	Jacke 7	15,00	576,0	15	50	0	10	50	1	*1*
16	Jacke 8	13,47	504,0	15	50	0	10	45	0	*0*
17	Jacke 9	11,97	561,6	15	50	0	20	20	0	*0*
18	Jacke 10	8,67	590,4	15	50	0	20	45	0	*0*
19	Jacke 11	8,28	763,2	15	50	0	10	30	0	*0*
20	Jacke 12	16,47	633,6	15	50	0	15	35	1	*1*
21	Jacke 13	5,10	432,0	15	50	0	15	30	0	*0*
22	Jacke 14	5,10	432,0	15	50	0	15	25	0	*0*
23	Jacke 15	6,03	561,6	15	50	0	10	25	0	*0*
24	Mantel 1	15,06	1166,4	25	0	60	10	20	1	*0*
25	Mantel 2	14,61	1584,0	25	0	60	5	40	1	*0*
26	Mantel 3	7,47	1728,0	25	0	60	10	45	0	*0*
27	Mantel 4	11,67	2160,0	25	0	60	5	40	0	*0*
28	Mantel 5	11,97	1296,0	25	0	60	10	40	0	*0*
29	Mantel 6	13,50	2016,0	25	0	60	10	30	0	*0*
30	Mantel 7	5,97	2160,0	25	0	60	5	30	0	*0*

∑ Manager	105,12	6148,8	138	150	220	50	225	7	
∑ *SolveGA*	*126,36*	*5889,6*	*161*	*200*	*250*	*50*	*230*		*9*

Tabelle 1: Restriktionen, Projekte und Projektportfolios

5.5. Zusammenfassung

Die bisher zur Verfügung stehenden Softwarelösungen zur Entscheidungsunterstützung bei 0-1 Problemen sind für die breite Anwendung in Unternehmen hinsichtlich der Kriterien Kostenfreiheit, Anwenderfreundlichkeit, Installierbarkeit und Lösungseffizienz nicht ausreichend. Mit *SolveGA* steht Unternehmen eine effiziente Alternative zur Entscheidungsunterstützung zur Verfügung, die kostenfrei und ohne aufwändige Softwareinstallation als Addin in Microsoft Excel ® integrierbar ist und dem Anwender vier Qualitäts- bzw. Schnelligkeitsstufen zur Auswahl bietet. Ein Praxistest verdeutlicht Verbesserungen bei der Auswahl der Handlungsalternativen in komplexen Entscheidungssituationen und eine verbesserte Kommunikation zwischen den Fachabteilungen.

Literatur

Chu PC, Beasley JE (1998) A genetic algorithm for the multidimensional knapsack problem. Journal of Heuristics 4:63–86.

Dammeyer F, Voss S (1991) Application of tabu search strategies for solving multiconstraint zero-one knapsack problems. Working paper, Technische Hochschule Darmstadt, Germany.

Drexl A (1988) A simulated annealing approach to the multiconstraint zero-one knapsack problem. Computing 40:1–8.

Fréville A (2004) The multidimensional 0-1 knapsack problem: An overview. European Journal of Operational Research 155:1–21.

Gottlieb J (2000) On the Effectivity of Evolutionary Algorithms for the Multidimensional Knapsack Problem. In: Fonlupt C, Hao J-K, Lutton E, u. a. (Hrsg) Artificial Evolution. Springer Berlin Heidelberg, Berlin, Heidelberg, 23–37.

Homburg C (2000) Quantitative Betriebswirtschaftslehre: Entscheidungsunterstützung durch Modelle, 3., überarb. Aufl. 2000. Dr. Th. Gabler Verlag.

Kellerer H, Pferschy U, Pisinger D (2004) Knapsack Problems, 1. edn. Springer.

Kellner F, Otto A, Busch A (2012) Understanding the robustness of optimal FMCG distribution networks. Logist Res 6:173–185.

Levenhagen J, Bortfeldt A, Gehring H (2001) Path Tracing in Genetic Algorithms Applied to the Multiconstrained Knapsack Problem. In: Boers EJW (Hrsg) Applications of Evolutionary Computing. Springer Berlin Heidelberg, Berlin, Heidelberg, 40–49.

Lienland B, Zeng L (2015) A Review and Comparison of Genetic Algorithms for the 0-1 Multidimensional Knapsack Problem: International Journal of Operations Research and Information Systems 6:21–31.

Martello S, Pisinger D, Toth P (1999) Dynamic programming and strong bounds for the 0-1 knapsack problem. Management Science 45:414–424.

Martello S, Pisinger D, Toth P (2000) New trends in exact algorithms for the 0–1 knapsack problem. European Journal of Operational Research 123:325–332.

Raidl (1998) An improved genetic algorithm for the multiconstrained 0-1 knapsack problem. In: The 1998 IEEE International Conference on Evolutionary Computation Proceedings. 207–211.

Raidl (1999) Weight-codings in a genetic algorithm for the multi-constraint knapsack problem. In: Evolutionary Computation, 1999. CEC 99. Proceedings of the 1999 Congress on.

Senju S, Toyoda Y (1968) An Approach to Linear Programming with 0-1 Variables. Management Science 15:B–196–207..

Zimmermann H-J (2015) Operations Research: Methoden und Modelle. Für Wirtschaftsingenieure, Betriebswirte, Informatiker. Springer-Verlag.

6. Conclusion, Scientific and Practical Contribution and Need for Future Research

The research object of this dissertation has been e-commerce and the knapsack problem from the perspective of logistics and controlling and consists of two parts, each of which contains two papers. In the first part, through analysis of and research on two specific issues, this dissertation has contributed mainly to the interpretation of the relationship between logistics and e-commerce. The second part of this dissertation provides for companies a free, efficient and easy-to-use optimization software for solving knapsack problems and based on genetic algorithms.

6.1. E-commerce logistics in China

The first paper in this work refers to the restrictions impact of logistics on e-commerce and studies e-commerce logistics in China. As the largest e-commerce country in the world, China is one of the most attractive markets. China is also a developing country and has many challenges in the field of logistics. Studying the e-commerce logistics of this country can provide solutions to logistics problems for potential businesses. On the other hand, it can also summarize the experience of a developing country in solving e-commerce logistics problems, thus serving as a reference to other countries.

The effects of the described logistical problems with e-commerce in China and possible solutions are examined in case studies with experts (Zeng, 2014). First, existing conflicts between e-commerce and logistics in the Chinese market were analyzed and solutions with possible perspectives then presented. In terms of infrastructure, the case studies show that the current capacity cannot meet demand. However, significant progress is expected in the near future. China is building a large number of airports, railways and logistics centers. The strong imbalance in logistics infrastructure between eastern and western China will continue to exist in the future. However, this is not considered a major problem, as the demand for more logistical infrastructure for e-commerce comes mainly from the east, where about 66% of the Chinese population live.

The problem of the legal environment can be seen as a typical growth problem, in which legislators can only react to developments in practice. The Chinese government has begun to create a set of legal frameworks with regard to the current logistics situation, and the cost of Chinese logistics is influenced in particular by the local legal framework. The Chinese government has planned to reduce the mentioned fees and taxes affecting logistics. Furthermore, Chinese logistics companies should improve their technology in order to reduce costs and thus increase their efficiency.

Case studies show that the degree of digitization is very low, especially for small- and medium-sized logistics companies. The main reason for this problem is the lack of specialized personnel: the demand for qualified specialists for the logistics sector is significantly greater than the supply. In particular, experienced managers in logistics in China are very difficult to find. Chinese universities and vocational schools cannot meet the demand for new skilled workers, either qualitatively or quantitatively. For this reason, logistics companies have to take care of training and educating their own staff.

The logistics service providers were assessed according to geographical coverage, quality of service and price, and logistics service providers in China were categorized into three groups: state logistics companies, private Chinese logistics companies and foreign logistics companies. The state logistics service provider EMS has the widest network in China. Foreign logistics service providers must obtain approval from the Chinese government to build a supply network in a specific area. The service of private Chinese companies is very different, as larger private logistics service providers often outsource their branches to smaller regional logistics companies. In terms of price comparison, the foreign logistics providers are more expensive than Chinese service providers, and state-owned enterprises are more expensive than private ones in China.

Furthermore, the case studies show that the current level of strong competition among logistics companies will decrease in the future, and market adjustments are expected in the near future due to low margins and the polypolistic market situation. Non-competitive logistics companies will disappear from the market.

In summary, it can be stated that solutions already exist for many problem areas of Chinese logistics, such as infrastructure, the legal environment, costs, information and communication technology, competition and cooperation, and logistics service providers. The shortage of skilled personnel will continue to be a major problem for logistics and e-commerce in China. Based on the results of these studies, this paper has examined how logistics affects e-commerce in China and has suggested how foreign retailers might start their business in the Chinese e-commerce market. In China, more than 85% of B2C e-commerce revenue is generated through online marketplaces. In addition, some large Chinese online marketplaces carry out shipments, which generally guarantees reliable delivery nationwide. Accordingly, the Chinese online marketplace is a good starting point for foreign merchants. Because foreign brands as a rule, have higher customer loyalty in China, an independent online store is also a good choice. The selection of the logistics service provider depends on the desired sales area. If the target sales area is the entirety of China, then only Chinese state-owned logistics companies should be selected. If a company seeks better customer service and more reliable deliveries, it should select either a well-known foreign logistics service provider or a private Chinese logistics company. However, these options are associated with higher costs and limited delivery areas.

At present, many German companies have achieved great success in the Chinese e-commerce market. Tmall published a report showing the top 10 sales in various industries (Tmall, 2021). Among them, German companies performed well, such as Siemens (no. 4 in household appliances), MCM (no. 3 in luggage), Zwilling (no. 2 in household products), Aptamil (no. 2 in baby products), Kohler (no. 7 in kitchen and bathroom), VW (no. 1 in cars) and Continental (no. 1 in tires).

The perspective of this paper is that of the impact of logistics on e-commerce. Many of the problems mentioned in the paper come from the field of logistics itself. However, e-commerce has in fact been changing logistics in very significant ways, and future research could focus on the impact of e-commerce on logistics. The continuous improvement of logistics in China due to the development of e-commerce should be observed and studied. In addition to logistics, there are many other valuable topics in Chinese e-commerce. For example, due to consumption upgrades, the demand of Chinese customers for overseas goods is increasing. Cross-border e-commerce is becoming more and more popular, in which foreign merchants deliver products via cross-border logistics to complete transactions. Future research can observe the factors that influence cross-border e-commerce, such as social culture, marketing, payments and international logistics. Furthermore, China is now setting the benchmark for present and future global retailing, and innovation in China's e-commerce market is a moving target. Chinese Internet giants like Alibaba and JD are at the forefront of emerging technologies, and start-ups such as Xiaohongshu or Mogujie are pioneering new commerce experiences within lucrative niches. Research on these companies in logistics, innovation and business models, among other areas, can help predict future e-commerce trends.

6.2. E-commerce changes all retail systems

The second paper also examines the relationship between e-commerce and logistics. This paper investigated and compared the logistics services of multichannel retailers and online pure players. The advantages and disadvantages of their delivery structures were discussed and clarified (Zeng & Bolz, 2017). This paper provides useful insights into the ongoing development of Internet shopping. Before this research, most market participants estimated that the introduction of e-commerce would have an overall positive effect on logistics; in other words, the efficiency of the logistics of online pure players would be higher than that of multichannel retailers. Unexpectedly, this hypothesis was not borne out by this paper's research, which shows that the arithmetic average logistics efficiency of multichannel retailers is higher than that of online pure players. One of the possible reasons for these results could be the relative high ratio of returns in e-commerce, leading to higher costs and lower logistics efficiency. Another possible reason could be the lack of experience on the part of online pure players with logistics. In this study, 42% of online pure players started their businesses after 2010. The third possible reason could be economies of scale. In this research, multichannel retailers had on average 22% more revenue compared to online pure players. On the multichannel retailer side, the relatively low costs (such as lower delivery charges or lower warehouse costs per square foot) led to higher logistic efficiency. In addition, the role of synergic effects here cannot be ignored. While multichannel retailers can use warehouses for several sales channels, online pure players have almost only one way to outsource logistics to third parties.

For the above-mentioned factors, comparisons between the logistics services of multichannel retailers and online pure players should continue to be made in the future. It is particularly worth mentioning the impact of the growth of online pure players on logistics. This study covers a variety of industries and does not distinguish the sizes of the company. Especially considering the issue of return rates, future research could be carried out with a focus on a single industry, since the logistics requirements among various industries in the e-commerce sector differ greatly. For this same reason, a new study would equally be necessary under the same preconditions and the same level of enterprise scale. In this way, the effects of economies of scale could be reduced.

In the future, e-commerce logistics will continue to develop and change the world. The further evolution of e-commerce logistics is mainly due to increasing customer demand and technological advances. The trends listed below will have the greatest impact on retailers, distributors, manufacturers and consumers, and researchers and merchants alike must be focused on the challenges, opportunities and expectations that lie ahead.

Over the past year, 'omnichannel' has become something of a buzzword in the e-commerce space (de Carvalho & Campomar, 2014). E-commerce merchants really have to focus on providing consumers with a seamless shopping experience. Omnichannel is an integrated commerce approach providing shoppers with a consistent and personalized experience, from brick-and-mortar stores (offline channels) to e-commerce marketplaces, mobile-browsing and social media (online channels). The guiding principle of omnichannel is that it is shopper-based, not channel-based. In this sense, brick-and-mortar stores will be reborn. By contrast, every channel in the multichannel concept is separate and independent from others, operating as it were in a vacuum and having its own strategy and goals. The lack of integration within a multichannel is the main difference to an omnichannel. However, building an effective and efficient omnichannel distribution system will face multiple challenges (Hübner, Holzapfel & Kuhn, 2016), e.g., the execution of online orders, the organization of delivery and the return process implement, and the establishment of context-specific omnichannel distribution systems. Solving these tasks in retail research and practice requires a comprehensive understanding of the distribution concepts of direct-to-customer and store deliveries in omnichannel retail.

Convenience is always one of the tasks of e-commerce improvement and to which many new technologies have been applied. Mobile payments are gradually becoming the preferred payment method for retail. Google and Apple have applied fingerprint and facial recognition systems to this area and continue to make significant advancements in this technology. Voice technology and image-based product searches will essentially alter the very nature of online search. Consumers will be able to use pictures or voice input instead of manually entering a description and then searching for the target product or a similar one. The web browser will no longer be the only means for shopping digitally. New alternative technologies offer customers more choices, e.g. conversational AI, mobile devices, interconnected devices and augmented reality. One of the biggest shortcomings of e-commerce is the lack of a personal touch. Now, augmented reality (AR) technology can make up for this shortcoming to a certain extent and massively improve the customer experience. From furniture to household appliances, consumers will be able to see the 3D appearance of objects in their environment, including visualizing “plus-sized” items like cars or real estate. AR superimposes digital information onto the physical environment, thus opening up opportunities for novel consumer experiences. Thanks to AI technology, shopping will be customized to and optimized for every consumer. This new technology will further narrow the distance between customers and sellers. Online retailers continue to get better at leveraging consumer behavior-based analysis, data driven optimization and personalization, and e-commerce services will target potential customers much more specifically, even perhaps attaining to one-to-one (1:1) marketing. Therefore, in the future, e-commerce will definitely present higher and more precise requirements for logistics. At the same time, consumers also want shipping to be more flexible and faster. More new delivery models will be offered, such as delivery by drone, in the trunk of the car, same-day delivery, even up to a time window of 40 minutes, evening delivery with a precisely selected time window, delivery in a parcel box, which can be attached to the front door, the parcel shop, or the bakery next door.

6.3. Review and comparison of genetic methods for solving the knapsack problem

The third paper of this dissertation centered on the review and comparison of already established genetic methods for solving the multidimensional knapsack problem, and supports academics and practitioners in the selection of the “best” existing approach. Although genetic algorithms are suitable in theory for the 0–1 multidimensional knapsack problem, their performance in practice is quite different. This paper studied eleven different genetic algorithms designed specifically for the multidimensional knapsack problem, and the structural similarities and differences of these genetic algorithms were analyzed and demonstrated via a simulation using all 270 standard knapsack problems. The results, in terms of solution quality, show that algorithms not allowing duplicates typically outperformed other genetic algorithms. The algorithms proposed by Khuri et al. (1994), Thiel & Voss (1994), Rudolph & Sprave (1995), and Hoff et al. (1996) yielded suboptimal solution vectors. In the same number of iterations, those of Raidl (1998) and Chu & Beasley (1998) provided much better results.

In terms of computation time, the genetic algorithms without duplicate detection required less time than those of Raidl (1998) and Chu & Beasley (1998) with the same termination condition. The calculating speed of Raidl’s (1998) algorithm was typically faster than that of the algorithm of Chu & Beasley (1998).

Thus, the genetic algorithm by Raidl (1998) was recommended for use with the multidimensional knapsack problem, as it yielded good results even at a low number of iterations. The genetic algorithm by Chu & Beasley (1998) can provide competitive results, but requires more computation time. The other algorithms not based on Raidl (1998) or Chu & Beasley (1998) cannot attain the solution quality of Raidl (1998), even when increasing the time limit of these genetic algorithms to the required computation time of Raidl (1998).

For future research, genetic algorithms not specific to the multidimensional knapsack problem could be included in the analysis: for example, competing with algorithms of different heuristic types. The performance of these algorithms could be evaluated against the achieved fitness value within a given and fixed computation time. Furthermore, the specific characteristics of the most successful approaches could not only be identified but might also be used to create a new, more efficient hybrid algorithm.

6.4. Knapsack problems in practice

The fourth paper developed a new free practical optimization software for solving knapsack problems. Companies are often faced with the situation of having to make a decision with respect to several action alternatives with limited resource aimed at achieving the maximum possible profit. The software previously available for solving the 0–1 multidimensional knapsack problem was unable to meet the needs of small- and medium-sized enterprises, since they usually exhibit several shortcomings, such as high pricing, unfriendly application, installation restrictions and inefficient results. The result of this paper was the creation of a new software, SolveGA, which incorporates several genetic algorithms to solve the 0–1 multidimensional knapsack problem. Besides being free of charge and easy to install, this software has the great advantage of being very easy to understand and operate. Businesses no longer need to spend a lot of time and money on training employees to use such decision-aiding software. The user should be able to select the best project portfolio given the specific situation, and the 0–1 multidimensional knapsack problem can be solved more effectively and efficiently.

The premise of optimization software development is the research and update of algorithms. As new algorithms are constantly being introduced, optimization software should also be continuously improved. Newly developed heuristic algorithms could be integrated into the software, leading perhaps to quicker computation times, since heuristic algorithms often require less computation time than genetic algorithms when solving small and medium-sized knapsack problems.

All algorithms in this study are programmed in Microsoft Excel / VBA. In order to solve real-world problems, programming languages continue to develop and advance. In recent years, the programming languages Python and R have been increasingly recommended for data science tasks. Python was released in the early 1990s and is easy to learn (Python, 2021). Similar to VBA, Python is also a high-level interpreted language that is influenced by the C language, the difference being that VBA is a domain-specific language in the Windows environment while Python is a general-purpose language. Although VBA supports the construction of user-defined functions, its code usually cannot be run as a stand-alone program and is limited to implementation in Microsoft Office products. Python, by contrast, can run under all kinds of operating systems for a wide range of purposes. In Python the possibilities are endless: anyone can create and modify a library to help complete highly creative and complex tasks that are impossible or limited in VBA. In addition, as one of the most popular programming languages, Python has a huge user community. Active users continue to raise questions and solve problems in online forums, thereby expanding the knowledge base. It is generally believed that Python is more powerful than VBA, especially in solving complex problems. VBA is more suitable for solving repetitive tasks in Microsoft Office applications.

R is very similar to Python and also free to download (Ihaka & Gentleman, 1996). Different from the general language Python, R originates from statistical analysis. The use of these two programming languages for specific problems is becoming more and more effective and important. R was developed in 1992 and optimized for statistical analysis and data visualization, being characterized by a rich ecosystem mainly used for in-depth statistical analysis and ideal for visualizing data in vivid and beautiful graphics.

As a mature programming language, Python is generally used to integrate data analysis tasks into a production database or apps. Therefore, Python is a good tool for implementing algorithms in production and management. R, by contrast, is mainly used for independent calculation or data analysis tasks, and can simply realize the establishment of statistical models.

Bibliography

Alshibly, H., & Chiong, R. (2015). Customer empowerment: Does it influence electronic government success? A citizen-centric perspective. Electronic Commerce Research and Applications, 14(6), 393–404.

Amazon (2021). Number of Employees 2006-2021 | AMZN. https://www.macrotrends.net/stocks/charts/AMZN/amazon/number-of-employees/ (accessed on 11.07.2021).

Bălăşoiu, A.-E. (2015). Unfair Competition In Online Commerce. Romanian Economic Business Review, 10(2), 39–47.

Babenko, Vitalina, Zdzisław Kulczyk, Irina Perevosova, Olga Syniavska & Oksana Davydova, (2019). Factors of the Development of International E-Commerce under the Conditions of Globalization. In: SHS Web of Conferences 65: 04016.

Brdulak, J., & Zakrzewski, B. (2013). Methods for calculating the efficiency of logistics centres. Archives of Transport, 27-28(3–4), 25–43.

Chen, L. & Hao, Z. (2013). Why are the logistics costs in China so high? China Economic Report, 6, 64–66.

Chen, X. & Lin, H. (2013). Research on E-Commerce logistics system informationization in chain. In: Procedia – Social and Behavioral Sciences 96, 838–843.

Chevalier, S. (2021). Global retail e-commerce market size 2014-2023. Statista. https://www.statista.com/statistics/379046/worldwide-retail-e-commerce-sales/ (accessed on 11.07.2021).

China Electronic Commerce Research Center. (2018). China E-Commerce Annual Report 2017. http://www.100ec.cn/zt/17market_data_report/ (accessed on 01.09.2018).

Chu, P.C. & Beasley, J.E. (1997). A genetic algorithm for the generalised assignment problem. Computers & Operations Research, 24, 17–23.

Chu, P.C. & Beasley, J.E. (1998). A genetic algorithm for the multidimensional knapsack problem. Journal of Heuristics, 4, 63–86.

Dammeyer, F. & Voss, S. (1991). Application of tabu search strategies for solving multiconstraint zero-one knapsack problems. Working paper, Technische Hochschule Darmstadt, Germany.

de Carvalho, J. L. G., & Campomar, M. C. (2014). Multichannel at retail and omni-channel: Challenges for Marketing and Logistics. Business and Management Review, 4(3), 103–113.

Delfmann, W., Albers, S., & Gehring, M. (2002). The impact of electronic commerce on logistics service providers. International Journal of Physical Distribution & Logistics Management, 32(3), 203–222.

Drexl, A. (1988). A simulated annealing approach to the multiconstraint zero-one knapsack problem. Computing, 40(1), 1–8.

ecommerceDB. (2021). Top online stores in Germany by revenue. ecommerceDB.com. https://ecommercedb.com/en/ranking/de/all/ (accessed on 12.07.2021).

Efendioglu, A. M. & Yip, V. F. (2004). Chinese culture and e-commerce: an exploratory study. Interacting with Computers, 16(1), 45–62.

Fahrmeir, L., Kneib, T., Lang, S., & Marx, B. (2013). Regression: Models, Methods and Applications. Springer-Verlag.

Fan, Q. (2019). An Exploratory Study of Cross Border E-commerce (CBEC) in China: Opportunities and Challenges for Small to Medium Size Enterprises (SMEs). International Journal of E-Entrepreneurship and Innovation (IJEEI), 9(1), 23–29.

Fang, D. (2012). Review of the development of China’s e-commerce logistics. Logistics & Material Handling, 9, 59–64.

Fatonah, S., Yulandari, A., & Wibowo, F. W. (2018). A Review of E-Payment System in E-Commerce. Journal of Physics: Conference Series, 1140, 012033.

Feldman, E. F., Lehrer, A. & Ray, T. L. (1966). Warehouse location under continuous economies of scale. Management Science, 12(9), 670–684.

Fréville, A. (2004). The multidimensional 0–1 knapsack problem: An overview. European Journal of Operational Research, 155, 1–21.

Gajendra, S., & Wang, L. (2014). Ethical perspectives on e-commerce: An empirical investigation. Internet Research, 24(4), 414–435.

Gao, L. (2012). A Product Recommendation Algorithm Based on Knapsack Optimization. Eleventh Wuhan International Conference on e-Business. https://aisel.aisnet.org/whiceb2011/36/ (accessed on 12.07.2021).

Gottlieb, J. (2000). On the effectivity of evolutionary algorithms for the multidimensional knapsack problem. In: Fonlupt, C., Hao, J.-K., Lutton, E., Schoenauer, M., Ronald, E. (Eds.), Artificial evolution. Springer Berlin Heidelberg, Berlin, Heidelberg, 23–37.

Goyal, S., Sergi, B. S., & Esposito, M. (2019). Literature review of emerging trends and future directions of e-commerce in global business landscape. World Review of Entrepreneurship, Management and Sustainable Development, 15(1–2), 226–255.

Graves, J. B. (2012). Maximizing Productivity in E-commerce 3PLs, Inbound Logistics, 3PL Americas.

Hoff, A., Løkketangen, A. & Mittet, I. (1996). Genetic algorithms for 0/1 multidimensional knapsack problems. Proceedings norsk informatikk konferanse, NIK ’96.

Holland, J. H. (1975). Adaptation in natural and artificial systems: An introductory analysis with applications to biology, control, and artificial intelligence. University of Michigan Press.

Hübner, A., Holzapfel, A., & Kuhn, H. (2016). Distribution systems in omni-channel retailing. Business Research, 9(2), 255–296.

Hübner, A., Wollenburg, J., & Holzapfel, A. (2016). Retail logistics in the transition from multi-channel to omni-channel. International Journal of Physical Distribution & Logistics Management, 46(6/7), 562–583.

Ihaka, R., & Gentleman, R. (1996). R: A Language for Data Analysis and Graphics. Journal of Computational and Graphical Statistics, 5(3), 299–314.

J.P. Morgan. (2019). E-commerce payments trends: Germany. https://www.jpmorgan.com/merchant-services/insights/reports/germany/ (accessed on 12.07.2021).

J.P. Morgan. (2020). 2020 E-commerce payments trends report: China. https://www.jpmorgan.com/merchant-services/insights/reports/china-2020/ (accessed on 12.07.2021).

Jacobson, S. K. (1983). Heuristics for the capacitated plant location model. European Journal of Operational Research, 12(3), 253–261.

Jech, T. (2003). Set Theory: The Third Millennium Edition, revised and expanded. Springer-Verlag.

Johnson, J. (2021). Internet users in the world 2021. Statista. https://www.statista.com/statistics/617136/digital-population-worldwide/ (accessed on 11.07.2021).

Kant, K., Mairaj, H., & Kamna, S. (2015). E-commerce in India-Indian Journals. ACADEMICIA: An International Multidisciplinary Research Journal, 5(4), 399–408.

Katoch, S., Chauhan, S. S., & Kumar, V. (2021). A review on genetic algorithm: Past, present, and future. Multimedia Tools and Applications, 80(5), 8091–8126.

Ke, J. & Jiang, W. (2014). The analysis of the development of China's express industry under the electronic commerce. Logistics Sci-Tech, 3, 124–126.

Kellerer, H., Pferschy, U. & Pisinger, D. (2004). Knapsack problems, 1st ed. Springer Berlin Heidelberg, Berlin, Heidelberg.

Kellner, F., Otto, A. & Busch, A. (2012). Understanding the robustness of optimal FMCG distribution networks. Logistics Research, 6(4), 173–185.

Kelly, T. (2005). Generalized Knapsack Solvers for Multi-unit Combinatorial Auctions: Analysis and Application to Computational Resource Allocation. In: Faratin P. & Rodríguez-Aguilar J. A. (Eds.), Agent-Mediated Electronic Commerce VI. Theories for and Engineering of Distributed Mechanisms and Systems. Springer, Heidelberg, 73–86.

Khumawala, Basheer M. (1974). An efficient heuristic procedure for the capacitated warehouse location problem. Naval Research Logistics Quarterly, 21(4), 609–623.

Khuri, S., Bäck, T. & Heitkötter, J. (1994). The zero/one multiple knapsack problem and genetic algorithms. ACM Press, 188–193.

Koptyug, E. (2021). Internet user share in Germany 2001-2020. Statista. https://www.statista.com/statistics/380514/internet-usage-rate-germany/ (accessed on 13.07.2021)

Kuehn, Alfred A. & Hamburger, Michael J. (1963). A heuristic program for locating warehouses. Management Science, 9(4), 643–666.

Kunesova, H., & Micik, M. (2015). Development of B2C e-commerce in Czech Republic after 1990. Actual Problems of Economics, 167, 470–480.

Levenhagen, J., Bortfeldt, A. & Gehring, H. (2001). Path tracing in genetic algorithms applied to the multiconstrained knapsack problem. In: Boers, E.J.W. (Ed.), Applications of evolutionary computing. Springer Berlin Heidelberg, Berlin, Heidelberg, 40–49.

Levy, M., & Weitz, B. (2008). Retailing Management. McGraw-Hill Education.

Li, Y. (2013). Review on logistics talent demand research of China. Journal of Zhejiang University of Science and Technology, 25(4), 289–294.

Lin, F. T. (2008). Solving the knapsack problem with imprecise weight coefficients using genetic algorithms. European Journal of Operational Research, 185, 133–145.

Lin, X., Wang, X. & Hajli, N. (2019). Building E-Commerce Satisfaction and Boosting Sales: The Role of Social Commerce Trust and Its Antecedents. International Journal of Electronic Commerce, 23(3), 328–63.

Lynn, S. (2021). Launch of Regional Roundup 2021: Germany | emerchantpay. https://www.emerchantpay.com/insights/launch-of-regional-roundup-2021-germany/ (accessed on 13.07.2021).

Ma, Y. & Xun, Y. (2012). China’s logistics enterprise information technology development and innovation. Logistics Engineering and Management, 1(34), 27–31.

Mahpula, A., Yang, D., Kurban, A. & Witlox, F. (2013). An overview of 20 years of Chinese logistics research using a content-based analysis. Journal of Transport Geography, 31, 30–34.

Maltz, A. B., Rabinovich, E., & Sinha Iv, R. (2004). Logistics: The key to e-retail success. Supply Chain Management Review, 8(3), 48–54.

Martello, S., Pisinger, D. & Toth, P. (1999). Dynamic programming and strong bounds for the 0-1 knapsack problem. Management Science, 45(3), 414–424.

Martello, S., Pisinger, D. & Toth, P. (2000). New trends in exact algorithms for the 0–1 knapsack problem. European Journal of Operational Research, 123(2), 325–332.

Mathews, G. B. (1896). On the Partition of Numbers. Proceedings of the London Mathematical Society, 28(1), 486–490.

Merz, M. (2001). E-Commerce und E-Business: Marktmodelle, Anwendungen und Technologien (2. Auflage). dpunkt.

Mo, D. (2014). China online retail market data monitoring report 2013. China e-Business Research Center. http://www.100ec.cn/zt/upload_data/down/20140304.pdf (accessed on 20.03.2014).

National Development and Reform Commission, National Bureau of Statistics of China, & China Federation of Logistics & Purchasing (2014). The logistics operation in China report 2013. http://www.stats.gov.cn/tjsj/zxfb/201403/t20140306_520357.html (accessed on 20.05.2014).

Pal, B.B. & Chakraborti, D. (2013). Using genetic algorithm for solving quadratic bilevel programming problems via fuzzy goal programming. International Journal of Applied Management Science, 5, 172.

Paul, M., Seidenschwarz, H., & Wittmann, G. (2019). Internationaler E-Commerce – Chancen und Herausforderungen aus Händlersicht. ibi research. https://ibi.de/veroeffentlichungen/Erfolgsfaktoren-im-internationalen-E-Commerce/ (accessed on 12.07.2021).

PricewaterhouseCoopers. (2018). ECommerce in China – the future is already here. https://www.pwccn.com/en/industries/retail-and-consumer/publications/total-retail-survey-2017-china-cut.html (accessed on 08.11.2018).

Python. (2021). General Python FAQ – Python 3.9.6 documentation. https://docs.python.org/3/faq/general.html#what-is-python/ (accessed on 12.07.2021).

Qin, Z. (2013). The study on logistics and transport regulation system of China. In: Logistics Engineering and Management, 5(35), 26–27.

Raidl, G. R. (1998). An improved genetic algorithm for the multiconstrained 0-1 knapsack problem. In: The 1998 IEEE international conference on evolutionary computation proceedings, 207–211.

Raidl, G. R. (1999). Weight-codings in a genetic algorithm for the multi-constraint knapsack problem. In: Evolutionary computation, 1999. CEC 99. Proceedings of the 1999 congress on.

Rashad, Yazdanifard, Oluwasegun, & Samuel. (2012). The Influence of E-Commerce on Marketing Practitioners and Consumers. Undefined, 3, 279–282.

Rechenberg, I. (1973). Evolutionsstrategie–Optimierung technischer Systeme nach Prinzipien der biologischen Evolution. Frommann-Holzboog-Verlag.

Rezwan, R. B. (2021). Managing Human Resources in E-Commerce [Chapter]. Cross-Border E-Commerce Marketing and Management. IGI Global.

Riehm, U., Petermann, T., Orwat, C., Coenen, C., Revermann, C., Scherz, C. & Wingert, B. (2003). E-Commerce in Deutschland: Eine kritische Bestandsaufnahme zum elektronischen Handel. edition sigma, Berlin.

Rowe, G., & Wright, G. (2001). Expert Opinions in Forecasting: The Role of the Delphi Technique. In: Armstrong J. S. (Eds.), Principles of Forecasting: A Handbook for Researchers and Practitioners. Springer US, 125–144.

Rudolph, G. & Sprave, J. (1995). A cellular genetic algorithm with self-adjusting acceptance threshold. In: Genetic algorithms in engineering systems: Innovations and applications, 1995. GALESIA. first international conference on (Conf. Publ. No. 414). Presented at the genetic algorithms in engineering systems: Innovations and applications, 1995. GALESIA. first international conference on (Conf. Publ. 414), IET, 365–372.

Schwefel, H.-P. (1975). Evolutionsstrategie und numerische Optimierung [Dissertation]. TU Berlin.

Senju, S. & Toyoda, Y. (1968). An approach to linear programming with 0-1 variables. Management Science, 15(4), 196–207.

Shahjee, R. (2016). The impact of electronic commerce on business organization. Scholarly Research Journal for interdisciplinary studies, 4(27), 3130–3140.

Shao, Z., & Yin, H. (2019). Building customers' trust in the ridesharing platform with institutional mechanisms: An empirical study in China. Internet Research, 29(5), 1040–1063.

Sivanandam, S. N., & Deepa, S. N. (2008). Genetic Algorithms. In: Sivanandam S. N. & Deepa S. N. (Eds.), Introduction to Genetic Algorithms. Springer, Berlin, Heidelberg, 15–37.

Statista (2017). Unternehmen in Deutschland nach Unternehmensgröße 2016. https://de.statista.com/statistik/daten/studie/731859/umfrage/unternehmen-in-deutschland-nach-unternehmensgroesse/ (accessed on 11.11.2018).

Statista (2018). Amazon–Umsatz weltweit nach Quartalen 2018. https://de.statista.com/statistik/daten/studie/197099/umfrage/nettoumsatz-von-amazoncom-quartalszahlen/ (accessed on 07.01.2019).

Statista (2021a). ECommerce report 2021. Statista. https://www.statista.com/study/42335/ecommerce-report/ (accessed on 11.07.2021).

Statista (2021b). Umsatz durch E-Commerce (B2C) in Deutschland in den Jahren 1999 bis 2020. Statista. https://de.statista.com/statistik/daten/studie/3979/umfrage/e-commerce-umsatz-in-deutschland-seit-1999/ (accessed on 11.07.2021).

Statistisches Bundesamt (2021a). Overall developments. Federal Statistical Office. https://www.destatis.de/EN/Themes/Economy/Foreign-Trade/Tables/lrahl01.html (accessed on 12.07.2021).

Statistisches Bundesamt (2021b). The People's Republic of China is again Germany's main trading partner. Federal Statistical Office. https://www.destatis.de/EN/Themes/Economy/Foreign-Trade/trading-partners.html (accessed on 12.07.2021).

Streim, H. (1975). Heuristische Lösungsverfahren – Versuch einer Begriffserklärung. Zeitschrift für Operations Research, 19, 143–162.

Teo, T. S. H. & Liu, J. (2007). Consumer trust in e-commerce in the United States, Singapore and China. Omega, 35(1), 22–38.

The Economist (2013). The Alibaba phenomenon. The Economist. https://www.economist.com/leaders/2013/03/23/the-alibaba-phenomenon (accessed on 11.11.2018).

Thelen, S., & Berman, B. (2004). A guide to developing and managing a well-integrated multi-channel retail strategy. International Journal of Retail & Distribution Management, 32(3), 147–156.

Thiel, J. & Voss, S. (1994). Some experiences on solving multiconstraint zero-one knapsack problems with genetic algorithms. INFOR 32, 226–242.

Tmall (2021). Tmall Brand Ranking 2021. https://www.sohu.com/a/www.sohu.com/a/470507323_114930 (accessed on 17.07.2021).

Trading Economics (2018). China GDP Annual Growth Rate 1989-2018. https://tradingeconomics.com/china/gdp-growth-annual (accessed on 07.01.2019).

Wang, C. (2006). Geographical study on modern logistics and its development trend. Human Geography, 21(6), 22–26.

Wang, J. (2014). The analysis of logistics development in E-commerce era. China Business and Market, 3, 54–59.

Wang, X. (2012). Foreign direct investment and innovation in China's e-commerce sector. Journal of Asian Economics, 23(3), 288–301.

Weber, C., Hendrickson, C., Jaramillo, P., Matthews, S., Nagengast, A., & Nealer, R. (2009). Life cycle comparison of traditional retail and e-commerce logistics for electronic products: A case study of buy.com. Conference: Sustainable Systems and Technology 2009. https://www.researchgate.net/publication/224559288_Life_cycle_comparison_of_traditional_retail_and_e-commerce_logistics_for_electronic_products_A_case_study_of_buycom (accessed on 17.11.2018).

Werner, H. (2008). Supply Chain Management: Grundlagen, Strategien, Instrumente und Controlling (3. Auflage). Springer Gabler, Wiesbaden.

Wigand, R. T. (1997). Electronic Commerce: Definition, Theory, and Context. The Information Society, 13(1), 1–16.

Wittmann, G., & Stahl, E. (2012). E-Commerce-Leitfaden: Noch erfolgreicher im elektronischen Handel (3. Auflage). Universitätsverlag Regensburg. https://www.ecommerce-leitfaden.de/studien/item/e-commerce-leitfaden-3-auflage (accessed on 07.11.2018).

WTO. (2013). E-commerce in Developing Countries. World Trade Organization. https://www.wto.org/english/res_e/publications_e/ecom_devel_countries_e.htm (accessed on 07.11.2018).

Xing, Y., & Grant, D. B. (2006). Developing a framework for measuring physical distribution service quality of multi-channel and "pure player" internet retailers. International Journal of Retail & Distribution Management, 34(4/5), 278–289.

Yan, X.-X., Hu, Z.-Q., Xu, J., & Liu, J.-Y. (2017). Research on the Social E-commerce Marketing Model Based on SICAS Model in China. International Journal of Marketing Studies, 9(3), 113.

Yang, J. & Ma, P. (2013). The Construction Strategy of China’s E-Commerce-Logistics. Economic Vision, 1, 13–16.

Yin, R. K. (2009). Case study research: design and methods. SAGE, Thousand Oaks

Yoon, C. (2009). The effects of national culture values on consumer acceptance of e-commerce: Online shoppers in China. Information & Management, 46(5), 294–301.

Yu, Y., Wang, X., Zhong, R. Y., & Huang, G. Q. (2017). E-commerce logistics in supply chain management: Implementations and future perspective in furniture industry. Industrial Management & Data Systems, 117(10), 2263–2286.

Zeng, L. (2014). E-Commerce-Logistik in China: Status quo und Handlungsoptionen für deutsche Online-Händler. Banking and Information Technology, 15(2), 33–44.

Zeng, L., & Bolz, T. (2017). Analysis of the logistics efficiency in E-Commerce: Online vs. multichannel. Banking and Information Technology, 18(1), 62–68.

Zhang, Y., Bian, J. & Zhu, W. (2013). Trust fraud: A crucial challenge for China’s e-commerce market. Electronic Commerce Research and Applications, 12(5), 299–308.

Zheng, K., Zhang, Z., & Song, B. (2020). E-commerce logistics distribution mode in big-data context: A case analysis of JD.COM. Industrial Marketing Management, 86, 154–162.

Zheng, Q., Yang, C., Li, S., & Li, F. (2014). E-Commerce Strategy. Springer-Verlag.

Zhou, Y. (2013). E-commerce in China’s countryside. In: China Youth Daily. http://zqb.cyol.com/html/2013-08/29/nw.D110000zgqnb_20130829_1-07.htm (accessed on 03.03.2014).

Żuchowski, W. (2016). The Impact of e-Commerce on Warehouse Operations. Scientific Journal of Logisticx, 12(1), 95–101.