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Optimising cold chain asset locations with real-estate considerations: A China perspective

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I hereby declare that this Doctor of Business Administration dissertation is my original work and it has been written by me in its entirety.

I have duly acknowledged all the sources of information which have been used in this dissertation.

This Doctor of Business Administration dissertation has also not been submitted for any degree in any university previously.

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ABSTRACT

Optimizing Cold Chain Asset Locations with Real Estate Considerations: A China Perspective

Koh Chaik Ming

This study explores the logistics costs optimization of a cold chain logistics network with a real estate perspective. This research seeks to optimise the logistics costs (warehouse costs plus transportation costs) of a cold chain network, where there are import shipments transported to multiple cold chain warehouses from a single port. In addition to the existing cold chain warehouses that the company has been using, this study expands the solution space by exploring the addition of a potential user-developed warehouse. The user invests and builds the warehouse. When the warehouse is completed, it will undergo a sale-and-leaseback transaction. The user will sell the asset and simultaneously undertake to lease it back for a few years. By doing so, the user can monetize the asset and use the real estate gains to offset the sale-and-leaseback commitment as well as the logistics cost, thus achieving the economic benefits for the user-developer.

This study draws on the situation faced by a large cold chain player in China in deciding if the user should consider developing its own warehouse when it is a major user of the many third-party warehouses. This study attempts to optimise the trade-offs systematically and quantitatively for this consideration. By modelling the problem as a combination of logistics network optimisation problem and a real estate development economics problem, the model attempts to search for the most optimal warehouse capacity as well as the

quality level of the warehouse to build, based on the different parameters of rent spreads, warehouse construction cost, maximum allowable warehouse capacity, capitalisation rates and rent net operating income margins. This model can effectively optimize the use of the assets, considering the real estate economic benefits by using the user-developed warehouse optimally while taking advantage of the cost competitiveness of the existing warehouses, so as to achieve the best economic outcome for the user.

The study also shows that with better planning and using deterministic optimization for the existing warehouse network, the model can potentially reduce the total logistics costs for Q4 2020 deliveries by 30.9%, from 5,572,208 RMB to 3,851,743 RMB. By further extending the experiments, the model was able to provide insights that allows this model to be applied to different situations. With a smaller rent spread, the model recommends building a warehouse with a lower quality of warehouse, compared to the recommendation of building a higher quality warehouse when the rent spread was larger. For unit warehouse construction costs, the economic benefits become insignificant when the unit costs exceed 6,854 RMB in the current parameters and the model recommends not to develop the warehouse when unit costs exceed this threshold. In terms of transportation costs that corresponds to the chosen location of the user developed warehouse, the model recommends building the warehouse even in far locations as the economic benefits of the real estate outweighs the operating costs and rental commitment. As the relative size of the user-developed warehouse increases in comparison to the existing network warehouse, the model continues to prioritise the user-developed warehouse and concurrently reduce the use of the existing network warehouses, to maximise the economics benefits. In terms of capitalisation rates, the model predicts significant non-linear increase in economic benefits with lower capitalisation rates but recommends not to build a warehouse at capitalisation rates above 8% for this model. Finally, the decrease in the rent net operating income margin leads to a linear increase of the economics benefits to the user. The study found that the real estate economic benefits (development profit less sale-and-leaseback commitment) can be substantially higher than the total logistics cost over the sale-and-leaseback commitment period (transportation costs and storage costs), accounting for a mean and median of 3.8 times and 2.9 times of the total logistics costs across the scenario variations of this study.

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plans again and I look forward to having an opportunity to support her on her journey.

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1 INTRODUCTION

This research explores the situation encountered by a leading frozen product import platform in China, where more than two million tons of products (equivalent to about 60,000 refrigerated containers) are brought into China from more than 2000 factories globally. These products are shipped in refrigerated containers (frozen at sub-zero temperature) and arrives in the major ports in China. This study focuses on the import port of Tianjin, which is the largest frozen products import location for this company as well as for China.

When the containers arrive at the port, the company will clear customs and haul the containers to one of the twenty-three cold chain warehouses that it has a lease arrangement in Tianjin city. The cost of container haulage or transportation differs for each of the warehouses due to the differences in the distance between the port and the warehouse. The total storage cost of each container shipment differs depending on the weight of the shipment (different meat products have different densities), the design and quality of the facility (modern warehouse versus multi-storey cargo lift warehouses, old versus new facilities) as well as the number of days the shipment will stay in the warehouse (dependent on the offtake and ordering behaviour of the customer).

The planners of this company select the warehouse to send each container shipment based on the availability and the perceived lowest total logistics costs (sum of total storage costs and transportation cost for each container) based on his or her judgement and experience. The company is looking to build its own cold chain warehouse in Tianjin and accessing whether the new facility is economically desirable and can lead to a more optimal logistics cost structure for its import operations.

2 PURPOSE OF THE STUDY

This research explores the facility location problem of a cold chain logistics asset network with a real estate perspective. This research seeks to understand the trade-offs of owning an asset while optimising the logistics costs (warehouse costs plus transportation costs) of using an existing cold chain network. In this facility location problem, the research seeks to add in a new dimension where the user has an alternative option to purchase land and develop it into a cold chain warehouse at their desired location. When completed, the user can store its products into this new facility or in the other twenty-three third party warehouses. The user can also choose to recycle its invested capital in the completed asset by selling it to long-term capital investors (such as pension funds, insurance funds or sovereign wealth funds) on a “sale and leaseback” basis. By doing so, the user can monetize the asset, achieve real estate development profits (asset price less total development costs) to offset the sale-and-leaseback commitment (based on the number of years of leaseback rental commitment of the entire warehouse) and the logistics cost (including the use of other warehouses in the existing network if it is deemed to be more beneficial). This study attempts to seek the optimal warehouse capacity and the level of the warehouse quality to build, to achieve the best economic outcome and the most optimal logistics cost structure for the company.

3 SIGNIFICANCE OF THE STUDY

3.1 IMPORTANCE OF COLD CHAIN RESEARCH

Cold supply chain research has received strong interest in recent research work. In addition to regular transportation cost, cold supply chain consumes more cost for cooling and needs to adapt to the increasing needs of fresh, refrigerated and frozen food. Perishable foods also have limited shelf-lives and the quality deteriorates continuously and significantly throughout the stages of supply chain. This could be due to temperature, humidity, possible interactions between various foods as well as shock during transportation (Al Theeb et al., 2020). In China, about 15% of all perishable products are transported in refrigerated vehicles, resulting in a loss up to US$8.9b annually in fruit and vegetable distribution (Bolton & Liu, 2006).

The Covid-19 outbreak has a significant impact on the cold chain logistics and cold storage warehousing market in Asia Pacific. Due to the pandemic, online shopping exploded when people under lockdowns had to shop online from their homes for fresh food items. In addition, the need for vaccine cold storage is also contributing to the demand for cold chain in the region. According to Allied Market Research, the size of the Asia Pacific cold chain logistics market was valued at US$61.1 billion in 2018 and will growth at compound annual growth rate of 13.2% to reach US$162.7 billion by 2026. Post-Covid, factors such as the increase in consumer demand for perishable foods and more advanced pharmaceutical treatment will continue to sustain the high pace of growth (Cushman & Wakefield, 2020).

In the medium and long term, the increasing affluence of the middle class in the Asia Pacific region, fuelled by the rapid economic development will underpin the strong growth in cold chain market. According to Ernst & Young, the middle class will reach 3.3 billion in 2030 or two-thirds of the global middle class, up from just one-third in 2009. This economic expansion which includes China, India and Southeast Asia, will continue to increase the disposable income of the middle class and allows them to purchase more higher quality, fresh produce and organic products. This in turn will drive a surge in cold chain investments in the Asia Pacific region (Cushman & Wakefield, 2020).

3.2 IMPACT OF AMBIENT LOGISTICS REAL ESTATE DEVELOPMENT ON COLD CHAIN

The development of cold chain real estate in China draws a lot of similarity with the ambient logistics real estate sector in China. Over the last two decades, capital markets have taken a strong interest in the logistics real estate asset class in China. Long-term yield-focused investors such as pension funds and sovereign wealth funds, have been deploying large amount of capital in the logistics real estate class, due to its attractive yield, stable cashflow and robust exposure to new growth sectors such as ecommerce. Many of the global investors have acquired ambient warehouses in China for yield and that have given rise to logistics-focused developers such as Global Logistics Properties (GLP), Prologis, ESR, Logos and New Ease. This has in turn created new avenues of capital recycling for logistics assets where developers can quickly monetise the assets after constructing and stabilising the rental income (i.e. fully tenanting the facilities).

This development has also partly been driven by the support of the Chinese government, both locally and nationally. Unlike sensitive real estate asset classes such as residential where the government is concerned about soaring housing prices, logistics real estate is seen as a critical building block for the logistics infrastructure that contributes to the long-term competitiveness of the city and nation's supply chain. In the recent push to promote "dual circulation", the Chinese government has prioritised the strengthening of the domestic supply chain. It has announced the addition of 22 cities to the lists of logistics hubs in 2020, adding to the existing list of 23 cities that was announced in 2019. The National Development and Reform Commission (NDRC) aspires to have 150 logistics hubs and aims to reduce China's total logistics costs as a proportion of GDP from 15% in 2019 to 12% by 2021 (CBRE, 2021).

The logistics real estate sector has seen another boost in its development over the last five to ten years due to the rapid rise of ecommerce in China. According to Alibaba, although the number of orders on the Double 11 shopping festival in 2020 was 33 times that of 2012, the time required for delivering the orders in 2020 was just one-fifth of that in 2012. These lightning fast deliveries was possible for the ecommerce giants such as Cainiao and JD Logistics because of the pre-selling strategies as well as storing inventory in warehouses close to city centres (CBRE, 2021). These trends continue to fuel development of city distribution hubs and last mile warehouses.

China's ecommerce market is now bigger than the markets in the US and Europe combined. Logistics and delivery performance is now intertwined with the online shopping boom in the world's second largest economy. Service levels have now evolved from the same-day delivery to a two-hour delivery standard in China. For leading logistics real estate developers such as ESR, ecommerce firms make up 43% of customer leasing demand across its 9 million square metres of warehouse footprint. If ESR accounts for third-party logistics providers serving ecommerce as well, the proportion is more than 50% (Caillavet, 2021).

One significant change has also emerged in the ecommerce sector around real estate. While JD is one of the top tenants of leading logistics real estate developers like ESR, it has also been busy developing its own warehouses under its infrastructure arm, JD Property. JD Property has enjoyed strong financial backing from US private equity major, Warburg Pincus and is providing competition for the traditional developers like ESR and GLP, particularly when pitching local governments for allocation of land (Caillavet, 2021). Cainiao Network, the logistics arm of ecommerce giant Alibaba Group, has also setup an 8.5 billion yuan (US$1.24 billion) fund with China's largest insurer China Life Insurance, to finance the expansion of its storage facilities across China. It is also expected to transfer ownership of its existing logistics centres to the fund in exchange for cash (Jing, 2017).

According to Darren Xia, Head of International Capital at JLL China, logistics is now seen as a core business for many tech and ecommerce firms. Warehouses are assets that these ecommerce firms are aggressively investing so that they can adopt the sale-and-leaseback model. JD and Singapore's sovereign wealth fund GIC have cooperated and established two funds focused on China logistics properties with respective capital commitment of US$756 million and US$725 million respectively. Increasingly, logistics warehouses are a real estate sector that is linked to the successes of these tech-based ecommerce companies and it is not just about renting more warehouse space. These firms are looking to be involved in operating these platforms (JLL, 2020).

3.3 DEVELOPMENT OF COLD CHAIN LOGISTICS REAL ESTATE IN CHINA

Cold chain facilities, particularly in China continues to be in short supply despite its strong growth. In 2016, the per capita of cold chain warehouse space in China stands at 0.14 square metres per capita, well below the global average of 0.2 square metres per capita. In comparison, China's cold storage per capita is only half of Korea and one-third of United States (JLL China, 2019). China's fledging cold chain logistics market is expected to reach 470 billion yuan (US$66.5 billion) by 2020, with a compound annual growth rate of more than 20 percent, according to China Federation of Logistics and Purchasing (China.org.cn, 2020).

Cold chain facilities are specialised assets and require substantially higher investment to build. Due to this phenomenon, unlike ambient warehouses, the traditional supply of such assets was often built-to-suit and therefore always trail behind the demand in the market. Developers in emerging markets therefore do not tend to build cold chain facilities "speculatively" while end users are worried about the length of time working capital is being tied up if they build their own facilities. According to the JLL report, China's cold chain logistics market remains immature with facility standards that are lower than the global average (JLL China, 2019). Over the past ten years, the cold chain utilisation rate of perishable food has increased from 15% to over 30% while the cargo damage rate of fresh products has decreased from 30% to 20%. Since 2008, the cold storage per capita in China has increased 14 times (JLL China, 2019).

Logistics-focused developers rely on the end-users for rent commitment and stabilisation. China over the last two decades has experienced a boom in industrialisation and warehouse demand has experienced a phenomenal growth. As ambient warehouse design is relatively generic and the end-user base is huge (almost all industries can use a generically designed modern warehouse, particularly those are designed for palletised storage), logistics developers face little or no stabilisation risk (risk of not being fully tenanted) if the location is confined to key cities with strong economic growth.

For cold chain logistics facilities, due to the specialised nature of its use (only users that require temperature control for the storage of their products), the tenancy risk is perceived to be much higher. Thus, logistics developers have traditionally shy away from these developments, unless it is built-to-suit for a specific user who is willing to sign a long-term lease (typically fifteen to twenty years) despite cold chain rental rates are typically two to three times the rental rates of ambient warehouse and the rental yields are significantly higher than its ambient peers.

Over the last few years, more sophisticated and experienced cold chain logistics developers are designing more generic cold chain logistics warehouses that can satisfy most temperature-control storage requirements for a broad range of users. According to JLL, China cold chain users can choose from built-to-suit (BTS) facilities or standardized cold storage facilities. These two asset types offer differing propositions for different users (JLL China, 2019). Cold chain warehouses are now moving towards the trend of standardization, like what its ambient counterparts have experienced over the last two decades, which will substantially lower the risk of rent stabilisation of cold chain assets. With this development, more capital will be accessible to provide capital recycling for these cold chain assets, driving future growth like what their ambient counterparts have experienced.

End users require cold chain warehouses to provide the storage and distribution services for its customers. Users typically lease cold chain facilities from the asset owners for temporary storage, either based on size (rental area of number of square metres at an agreed rent per square metre per day rate) or throughput (rental rate based on number of tons or pallets stored per day multiplied by the agreed rent per ton or pallet per day rate). According to Warehouse in Cloud (WIC), total cold storage logistics warehouse stock in China exceeded 6.65 million square metres in 2019, accounting for 2.2% of the total logistics warehouse market. Due to the strong demand, the national average vacancy rate in China stands at 10.9% with an average rental rate of RMB 91.2 (US$ 14.3) per square metre per month or RMB 3.04 (US$0.48) per square metre per day. However, the vacancy and rental rate can vary significantly between different cities. For example, cities such as Chengdu, Shanghai and

Beijing have average vacancies of less than 5% while Xian and Nanjing are at 10% and 15.5% respectively. With these vacancy rates, Beijing and Shanghai can command average rental rates in excess of RMB 110 (US$17.2) per square metre per month or RMB 3.7 (US$0.58) per square metre per day while cities such as Jinan and Qingdao would command rental rates in the RMB 60 (US$9.4) to RMB 80 (US$12.5) per square metre per month range (Cushman & Wakefield, 2020). Within the city, depending on the location, the rental rates can also vary. For Beijing and Shanghai, the throughout-based rental rates can vary from RMB 3.5 (US$0.55) per pallet per day to RMB 6 (US$0.94) per pallet per day (JLL China, 2019).

In addition to traditional cold chain storage services, the coronavirus pandemic has accelerated the shift to ecommerce for fresh produce. Chinese companies have been investing heavily in cold chain warehouses and logistics infrastructure to handle the boom in online groceries, fuelled by the rise of community group buying which spurred the need for cold chin logistics to deliver fresh fruits, vegetables and meat (Chan, Cathy ; Baigorri, 2021). China ecommerce giant JD established its cold chain logistics network in 2014 which was in response to the increasing demand for fresh food. During the pandemic, JD was ensuring livelihood through fresh produce delivery and transporting medical supplies that have specific temperature requirements. JD data showed its cold chain orders in the first quarter of 2020 increased 200 percent year-on-year. It has since operated over 20 cold chain warehouses for fresh food (China.org.cn, 2020).

3.4 ASSET HEAVY VERSUS ASSET LIGHT STRATEGY

Companies pursue their strategies with the lowest possible level of asset ownership but determining of the optimal asset level is often challenging. Asset-heavy, vertically integrated models have superior control, but often ties up significant amount of financial capital and is less flexible in a fast-changing environment. On the other hand, asset-light business models have greater flexibility, lower profit volatility but is tougher to manage. Boston Consulting Group's study of 2,687 companies across 24 industry sectors showed that asset-light companies on average generated higher returns on assets than their peers while industries that have lower levels of assets also generate a better return on the assets they hold (Kachaner, Nicolas; Whybrew, 2014).

In choosing between the asset-heavy and asset-light strategy, considerations on whether the asset is strategic or in short supply needs to be considered. If a particular asset, such as a cold chain warehouse, is integral to the company's competitive position, then ownership is usually a good option. It is also wise to own scarce assets for companies so that it can act faster and more decisively than its rivals (Kachaner, Nicolas; Whybrew, 2014). Asset-light strategy also involves transferring capabilities to "better owners" to enable companies to transition fixed costs to a variable cost structure, enhance agility and facilitate a shift of resources that focuses on core capabilities. Right partnership models that can transition into an asset-light model after capability-level analysis includes joint-venture, spin-off, partnership and sale-and-leaseback (Varadarajan, Giri ; Schlosser, Jeff; Ahuja, 2021).

4 LITERATURE REVIEW

Cold chain logistics network related studies have become an emerging area of research. The literature review will explore several domains of research that has touched on the related studies including facility location optimization problems, application of finance in operations research, real estate finance, cold chain logistics and warehouse management.

4.1 MATHEMATICAL MODELLING AND OPTIMIZATION RESEARCH IN PLANT LOCATION AND SUPPLY CHAIN MANAGEMENT

In the field of operations research, early studies have incorporated mathematical modelling to tackle and optimise the plant-location problem. Wendell & Hurter (1973) has been early in examining the nature of optimal solutions to a plant-location problem on a plane under generalised distance measures. It is based on a generalised Kuhn's characterisation of a convex hull by dominance and shown to be sufficiently optimal solutions when the "Manhattan" norm is employed. Numerical optimization techniques such as robust optimization are also used to optimize cost for replenishment of supply chains.

Lim, Jiu & Ang (2020) studied an online retailer that was selling multiple products to multiple locations over a multiple period horizon. By using a two-phase approach robust optimization with binary and continuous decisions, they were able to potentially achieve cumulative cost reduction of 30%. The two-phase approach's average cost was also within a 7% gap from the benchmark with perfect information.

In another study, Ang, Lim & Sim (2012) examined the decisions of assigning to and retrieving them from a unit-load warehouse in minimizing the operating costs. By assuming a factor-based demand model and introducing a robust optimization model, they found that the Restricted Linear Decision Rule, achieves close to the expected cost under perfect condition and significantly yields better cost outcome than existing heuristics in the literature such as class-based turnover policy and class-based duration of stay policy.

Al Theeb et al., (2020) investigated the use of a comprehensive mixed integer optimization model to combine vehicle routing problem and inventory allocation problem in a cold supply chain. To solve the problem in a reasonable time frame and computational effort, a NP-hard multi-phase approach is proposed which provided solutions with low gaps for different scale of data sets. Using a real case study of a logistics provider in Jordan, the proposed model was able to achieve a savings of 9.25% of total distribution cost compared to the current costs incurred by the organization.

Yu & Solvang (2018) conducted a study on the process of value recovery of the end of life and end of use products and its impact on sustainable development. The study was particularly focused on the challenge of the reverse logistics process, where the stochastic reverse product flow, unstable quality of used product and the fluctuating price of remanufactured and recycled products made the process a complex one. Utilizing a two-stage stochastic bi-objective mixed integer model, they were able to compare the differences between the use of efficiency-focused non-flexible capacity and effectiveness-focused flexible capacity on profitability and environmental performance. The study found that increasing flexibility may yield positive impact on economic and environmental performance when efficiency loss is kept at a reasonable level.

4.2 APPLICATION OF FINANCE IN SUPPLY CHAIN NETWORK DESIGN AND OPERATIONS RESEARCH

There has also been strong research interest in the application of finance in operations research, particularly on the optimisation of financial performance of the supply chain.

Jahani, Abbasi & Talluri (2019) investigated the use of Supply Chain Network Design (SCND) as a strategic tool for firms. Although SCND has attracted strong research interest, much of the research have been focused on profit maximization or cost minimization While operation managers take the owners and shareholder's viewpoint and focus on three other main goals such as investment, financing, and dividends. Their study revised the main objective function of a previous study by Jahani to a financial objective and financial statement limitations in related constraints to avoid a suboptimal solution. The study, which used real operational and financial data from the case study company on the Australian Stock Exchange, the resultant ratios from the model was very similar to the real ratios in every period. In addition, when the models are deliberated on a financial performance instead of profit as a target, though the proposed network may be the same, the factories' production, facilities' inventory and flow of new products are different. The study concludes that as long as the supply chain network is not obliged to satisfy all the demand, the manager can maximize each financial performance, with its corresponding constraints and improve the defined measure of the company more efficiently.

Hodder (1984) examined the use of financial market approaches for facility location problems that includes uncertainty and risks. By using financial market approaches such as Capital Asset Pricing Model (CAPM) rather than a mean-variance approach, there is increased modeling and computational flexibility. The shortcoming for this approach is the assumption that the owners can fully diversify their personal portfolios easily and cost effectively. This approach also does not consider the probability of financial distress or bankruptcy.

Li & Wang (2018) investigated the use of contextual information such as time, position and user devices in proposing a Multidimensional Context-Aware Recommendation Algorithm (MCARA) for a cold chain network. MCARA compares historical and current contextual information and selects out the data with the same cluster from historical data set. It then uses user-based collaborative filtering algorithm to provide recommendations. The study has shown that MCARA is able to improve the accuracy of the forecast of cold chain logistics distribution, with about 10% improvement over eight other approaches.

4.3 REAL ESTATE FINANCE AND SALE-AND-LEASEBACK TRANSACTIONS

Furthermore, in real estate finance, studies of sale-and-leaseback transactions and their impact on shareholder value creation have been abundant.

Studies have found that sale-and-leaseback transactions are value creating and leads to a more optimized network solution.

Longinidis & Georgiadis (2013) researched a Supply Chain Network (SCN) design model that incorporates the Sale & Leaseback (SLB), a method that releases value in real estate, achieves better balance sheet and increases tax benefits. Longinidis & Georgiadis found that a SCN design which incorporates financial matters are in its infancy and there is an increased need by SCN managers to have a holistic decision support tool that can quantify the financial impact of the production and distribution decisions. Sale and leaseback transactions involve the sale of the property by the owner (seller-lessor), who simultaneously leases it back from the new owner (buyer-lessor). The interest rate implicit in the lease is the discount rate that the aggregate present value of the minimum lease payment at the commencement of the lease is equal to the sum of the fair value of the leased asset. By modelling a four-echelon SCN where multiple plants were producing multiple products, moving through various distribution centres, the study was seeking to maximize the expected value of NOPAT (net operating profit after tax) and UPSLB (unrealized profit on sale and leaseback). The model was able to arrive at an optimal configuration where the warehouse and distribution centres were at proximate areas, taking advantage of potential transportation cost savings while executing a sale and leaseback deal for one of its warehouses during one of the periods.

Slovin, Sushka & Polonchek (1990) also investigated if sale-and-leasebacks are value enhancing for shareholders by examining the market valuation effects of corporate sale-and-leasebacks of major office buildings and related structures between 1975-1986. They specifically examined the net benefits and whether these benefits are accrued to the lessors or lessees by evaluating the impact of the firm's share price when the announcement was made. The study found that the impact of the announcements of the sale-and-leaseback transactions on the seller-lessee shareholder wealth to be both positive and statistically significant. In addition to being able to deduct rental payments from taxes that are equivalent to the full market value of the building and land, if the real estate has appreciated in value, the lessee can in effect deduct the payments based on the payments based on the appreciated real estate value rather than the historical cost. Slovin et al concluded that given the existence of positive gains upon the announcements of sale-and-leaseback transactions indicates that these are value-increasing transactions.

Fisher (2004) also investigated the use of sale-and-leaseback as one of the ways for firms to use financial contracts to reorganize their organizational architecture. Using a sample of 71 sale-and-leaseback transactions from the 1990s, the study found that relatively short lease terms of less than 15 years documented an abnormal return of 1.3% for shareholders of seller-lessee firms when these wealth gains are attributable to reallocation of tax benefits from the ownership of a durable asset to another firm that values the benefits more than the seller. The choice of the lease period is endogenous to the sale-and-leaseback decision and the optimal choice is a function of the relative importance of each party in the joint wealth production process. This study further supports previous research in that firms should own real estate in which they would make highly specialized investments. More generic real estate should be owned by investors who are not end users of the assets.

Barris (2002) examined the trend of real estate sale-and-leasebacks transactions in the various European jurisdiction in the late 1990s. By examining the process from the perspectives of the buyers and sellers, Barris was able to investigate the motivations of the sellers, both public and private sector as well as the buyers to give insights on key issues that arises in these transactions as well as how they affect the pricing, financing and structuring of these transactions. He noted that the motivations of the sellers include the need for fund raising for reinvestment, both off-balance sheet and off-budget as well as the need to diversity the funding sources. In addition, improving the efficiency of the property managers and enhancing tenant occupancy flexibility were also cited as strong drivers for these transactions. The ability to dispose low-yield assets to increase key performance indicators such as ROCE (Return on Capital Employed) and ROE (Return on Equity) numbers are also particularly attractive propositions to companies with strong shareholder pressure to improve returns on capitals. If the property can be sold at a yield below that of the existing ROCE of the company, the ROCE is automatically enhanced. From the buyer's perspective, the motivation is to achieve a larger portfolio, in which value can then be achieved through active management and financial engineering. These transactions, however, are not without limitations, some of the challenges include portfolio quality and the challenge in deconsolidation, both which are caused by "non-generic" asset type properties. "Non-generic" assets are essentially assets that suit "owner-occupier" more than the general market. Such assets' specificity can arise from its technical specifications or location or its position in the local market, making it difficult to value, structure leases and finance, which places the pressure of financing risk fully on the credit risk of the occupier. Other impeding factors include the lack of information completeness, taxes, restriction on disposal or use of assets due to strategic or regulatory concerns and employees. Barris concludes that given these motivations to achieve financial and operational flexibility, efficiency, and shareholder value creation, he expects that the trend of sale-and-leaseback to continue.

4.4 VALUATION AND APPRAISAL OF ASSETS IN REAL ESTATE FINANCE

Appraisal and valuation of real estate is another active area of research in real estate finance. In appraising real estate, two methods are commonly used. These are income capitalisation method and the use of hedonic model.

Lisi (2019) developed an integrated approach to incorporate these two methods. Although it is preferable to estimate the capitalisation rate by using comparable transactional data, this method proves to be useful when rental data are either missing or not reliable. The study introduces the standard hedonic price function into the basic model of income capitalization which allows the developed method to estimate the capitalization using only selling prices information. In doing this, it helps to account for hedonic variables that are linked to the intrinsic characteristics of housing but also factors that are different from housing characteristics, such as bargaining power of the parties. Studies on the determinants of industrial properties have also shown to be correlated to physical characteristics and other factors.

Lockwood & Rutherford (1996) examined the determinants of industrial value by using the factor-analytic Linear Structural Relations (LISREL) model to conduct simultaneous test of the possible effects. Lockwood & Rutherford used a simplified LISREL model to estimate the linear relationship between the industrial property prices and the factors, which included physical characteristics, national market factors, regional market factors, interest rates and location. One key advantage in using the LISREL model is to reduce the errors-in-variables problems, often encountered by standard regression tests. Physical characteristics include total industrial area, total office area and total land area of the property. National market factors included US Employment Rate, US National Income and the US Gross National Product while regional market factors include local Employment Rate, local Income and local State Product. Interest rate factors include Long Term Treasury Yield, Industrial Conventional Loan Rate and Moody's AAA Industrial Yield. Lastly, the location factor is expressed in the property's distance to the Central Business District, distance to the local airport, distance to a major road and access to rail. Using a data set of sales of 308 industrial buildings over the period of 1987-1991 in the Dallas/Fort Worth area, the study was able to find that the property prices are correlated to physical characteristics, local market factors and location factors. Similar findings were also observed in another study.

Fehribach, Rutherford & Eakin (1993) investigated the relationship between physical, location, financial and economic variables, and their influence on the sales price of an industrial property. The study was based on the sales of 228 industrial buildings in Dallas and Tarrant County. This research provides an initial framework for appraisers to value industrial properties and attempts to take a first step towards developing an industrial property index. Physical variables that were used in this study included building size, office size, dock doors, rail siding, ceiling height and age of property. Financial variables included industrial capitalization rate and prime rate of banks. Location variables include whether the location was in Dallas or Tarrant County and the distance of the property from Dallas/Fort Worth Airport. Economic variables used in the model included local indicators of economic activity including indices on employment, consumer price and industrial production. Date of sale of the property was also added where the observations occurred between January 1987 to May 1991. The study using ordinary least squares regression (OLS) analysis, concluded that seven variables, Building Size, Office Space, Dock Doors, Ceiling Height, County, Distance from the Dallas/Fort Worth Airport and Type of Tenant is statistically significant in explaining the sale price of industrial buildings at 5%. Using weighted least squares regression (WLS) analysis, three more variables Age, Industrial Cap Rate and Prime Rate are now statistically significant in explaining the sales price of industrial buildings at 5%. Similar observations are found when industrial warehouse rents determinants are studied.

Buttimer, Rutherford and Witten (1997) conducted the first empirical analysis of the determinants of pool variation in industrial warehouse rents. Using quoted rents for 848 industrial warehouses in the metroplex, the study indicated that rents are significantly impacted by physical characteristics, location and general market variables. Under a two-way random effects model, real rents are positively correlated to changes in prior year's net employment and the number of grade high doors while negatively impacted by the age of the building, ceiling height, percent of office space and the presence of a sprinkler system. In addition, there is evidence in the study that shows that the physical characteristics and rents have non-linear relationships.

5 THEORY AND MODEL CONSTRUCTION

This research contributes to the body of knowledge by combining real estate finance and operations research to optimise the logistics network for a cold chain logistics network, minimising the total of storage and transportation costs.

In a classical facility location problem, the total logistics cost is optimised by selecting the existing available facilities to send each container over each time frame based on its storage duration and transportation cost. By adding a new potential facility (user-developed facility), this study hypothesize that the user-developer can generate economic benefits (real estate development profits minus the sale-and-leaseback commitment minus total logistics costs) and the economic benefits can be maximised by selecting an optimal warehouse capacity and its optimal warehouse quality index.

5.1 PROBLEM DESCRIPTION

Due to the different locations and quality of the warehouses, the transportation costs to the warehouses in the existing network and the cost of storage per day per ton differs. The current allocation of the warehouse upon arrival of the container is based on the company planner's personal preference and experience, with an objective to minimise the total logistics cost. The length of stay of the products in the warehouse is not known at the time when the container arrives at the port. In practice, the planner can estimate the length of stay based on historical data.

There are currently a total of twenty-three warehouses where the planner can choose to send to, each with a transportation cost to the warehouse and the rental rate per ton per day of storage.

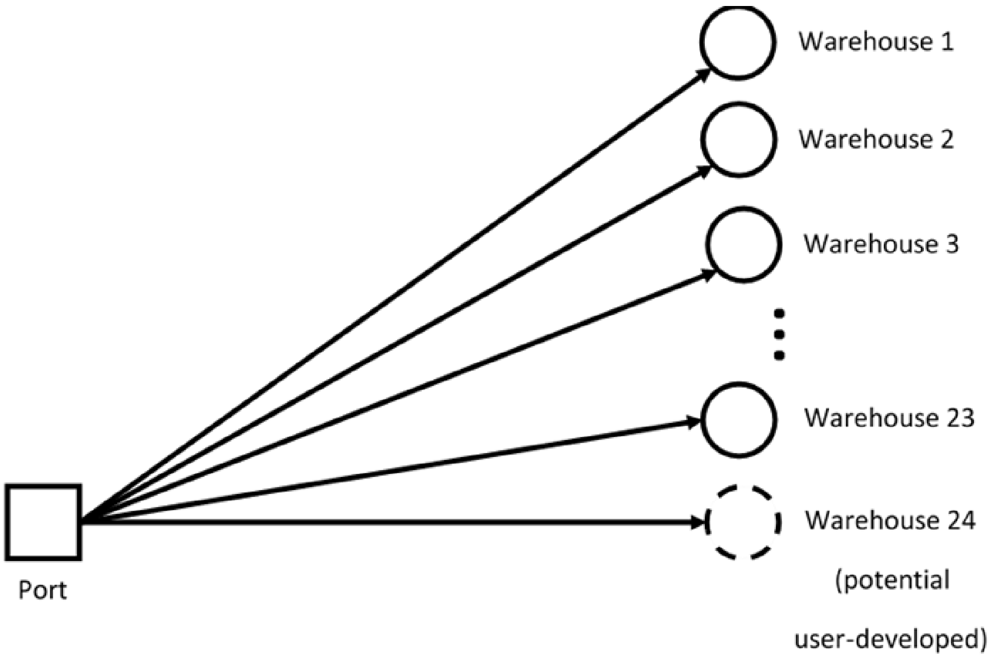

Figure 1: Network of Cold Chain Warehouses in the Model

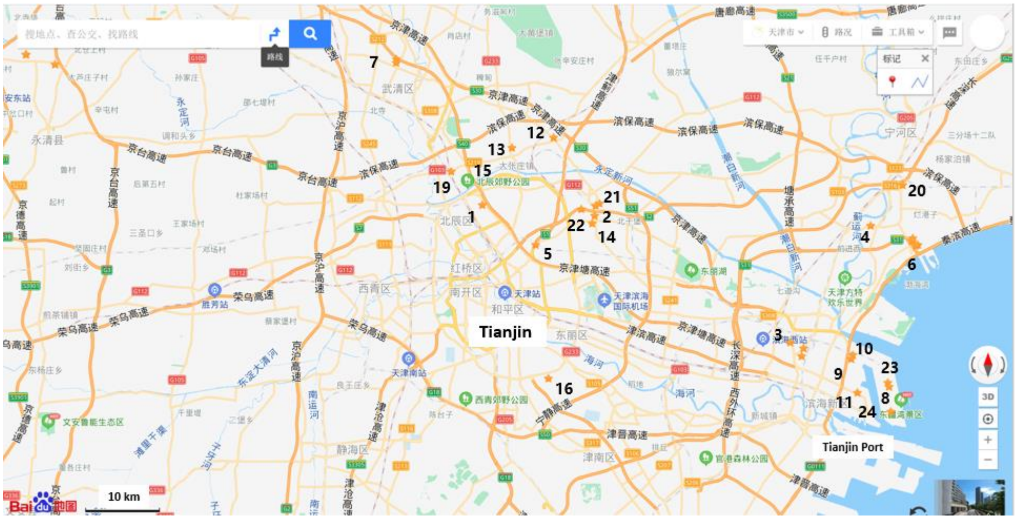

Figure 2: Location of Warehouses in Tianjin City, China

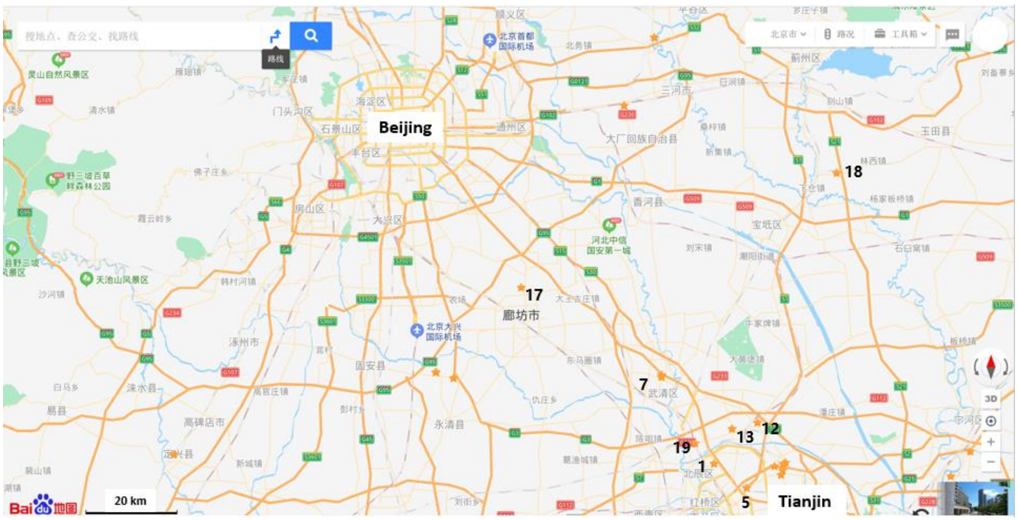

Figure 3: Location of Warehouses Between Tianjin and Beijing

Data has been constructed for the full year of 2020 which included the date of arrival of each container, the warehouse that the container has been sent to, the inbound date into the warehouse and the outbound date out of the warehouse. The total weight of each container shipment is also tracked. In addition, the transportation cost of sending each container to each warehouse is also collected (the transportation rate is per container shipment per trip and differs depending on the location of the warehouse). The storage rental rates per ton per day for each warehouse is also collected and remains constant for the year due to the annual contract arrangement of the lease. Thus, the total logistics cost is the sum of the storage cost (number of tons for each container shipment, multiplied by the storage rate per ton per day, multiplied by the number of days the products are stored in the specific warehouse) and the transportation cost (transportation cost of each container shipment going to the specific warehouse).

Due to the extraordinary circumstances in 2020 due to the Covid-19 situation, the supply chain globally was very erratic in the earlier months of the year. After the initial lockdown in China for the first half of the year, China was able to normalise its import port operations for cold chain in the second half of the year. This study uses the last three months of data in Q4 2020 where the cold chain import shipments has returned to normal.

5.2 MODEL OF PLANT LOCATION AND REAL ESTATE FOR TOTAL LOGISTICS COST MINIMIZATION

The model has been designed to include two components, namely the plant location model and the real estate model. The plant location model is used to compute the total logistics costs (i.e., transportation cost of sending the containers to the respective warehouse and the storage costs for each container) of the existing network of twenty-three warehouses. The real estate model is constructed to determine the economic benefits of constructing a new warehouse based on the selection of the size of the warehouse (i.e., capacity of the warehouse) and the quality of the warehouse that is to be constructed. By combining the two models, the study will be able to compute the optimal warehouse capacity and the quality of the warehouse to achieve the highest economic benefits and the optimal logistics cost structure for the company.

THE LOGISTICS COMPONENT

In this section, we first provide the description for the model. The model utilises a multiple-period plant location problem with an objective that is a function of aggregate total logistics costs. There are *I* shipments, indexed by *i*, with *J* warehouses, indexed by *j*.

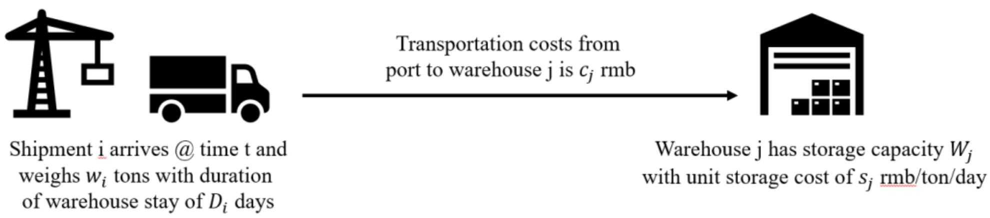

Figure 4 : Plant Location Model

The total logistics costs consist of transportation cost and warehouse storage cost. Let x_{ij} (a zero-one variable) be the decision variable in the model to indicate whether the shipment i goes to warehouse j. Let s_j denote the unit storage cost of warehouse j in rmb/day.ton and let w_i be the quantity of the shipment *i* in tons. The duration of the stay (or storage) of shipment *i* is denoted by D_i in days. Let c_j denote the transportation cost to warehouse *j* in rmb/trip.

Inventory stored in warehouse j at time period t is denoted by I_{jt} and is equivalent to the sum of inventory in warehouse j at time period (t-1) denoted by $I_{j,t-1}$, shipment arrivals into warehouse j at time period t denoted by a_{jt}, less the shipment departures from warehouse j at time period t denoted by d_t. Capacity of warehouse j is denoted by W_j.

Sets and indices

i	Product index
j	Warehouse index
t	Time index
c_j	Transportation cost to warehouse j
w_i	Weight of product i
s_j	Unit storage cost of warehouse j
W_j	Capacity of warehouse j
D_i	Duration of stay of product i
I_{jt}	Inventory in warehouse j at time t

In this model, the decision maker needs to decide on the warehouse to store the shipment upon arrival. Hence, we let the decision variables, x_{ij} denote that the shipment i going to warehouse j if it is 1. Otherwise, x_{ij} is zero. Hence,

$x_{ij} = \{0,1\}$

The objective of the function is to minimize the total logistics costs π across all time periods *t*, which is the sum of the cost of transportation to warehouses *j* and the cost of storage for each shipment *i* inside each warehouse *j* for every duration of stay.

$$\text{Min } \pi = \sum_j \sum_i \left(c_j \, x_{ij} + s_j \, w_i \, D_i \, x_{ij} \right)$$

The model is subjected to the following constraints. At any time period *t*, the inventory in warehouse *j* is to be less than or equal to the capacity of warehouse *j*, W_j.

$$I_{jt} \leq W_j \qquad \text{for all } j \text{ and } t$$

The inventory of warehouse *j* at time period *t* must be equal to the inventory of warehouse *j* at time period *(t-1)*, plus any arrivals into warehouse *j* at time period *t*, less any departures out of warehouse *j* at time period *t*.

$$I_{jt} = I_{j,t-1} + \sum_i a_{ijt} - \sum_i d_{ijt} \qquad \text{for all j and t}$$

In addition, the arrivals a_{ijt} and departures d_{ijt} into warehouse *j* at time period *t* must be equal to the weight of the shipment *i*, w_{jt}. From the data, we can decide on the arrival and departure times of product *i*. We denote these timings as *u(i)* and *v(i)* respectively.

$$a_{ij,u(i)} = w_i x_{ij}$$

$$d_{ij,v(i)} = w_i x_{ij} \qquad \text{for all i and j}$$

The last constraint states that at any time period *t*, the shipment must be stored in a warehouse.

$$\sum_j x_{ij} = 1 \qquad \text{for all i}$$

THE REAL ESTATE COMPONENT

We next describe the model for the real estate development. For the potential user-developed warehouse, an additional warehouse 24 (denoted by *J*) is to be added to the current solution set. The model can select the most optimal location of the warehouse by modelling the location using the transportation cost from the port.

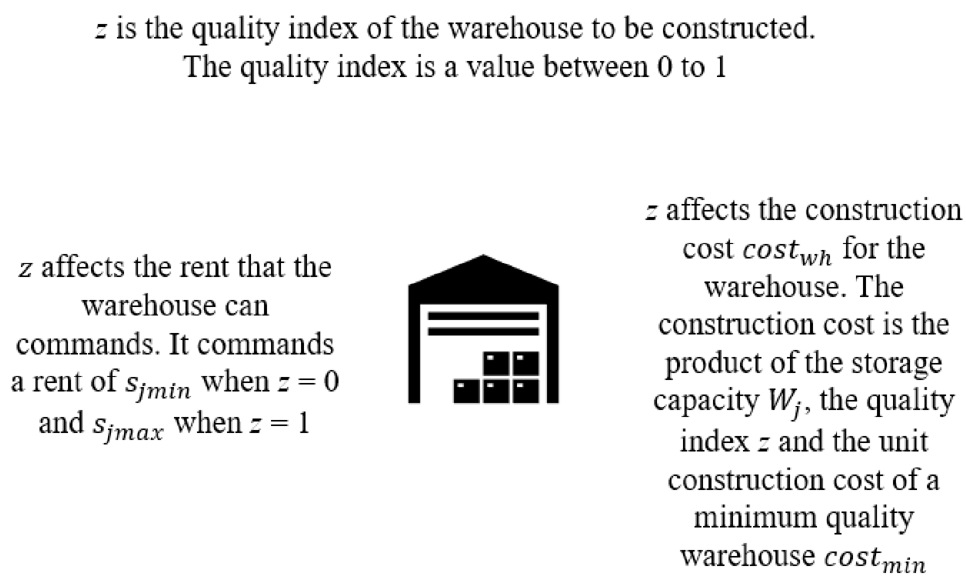

Figure 5: Real Estate Model

The rental rate and construction cost of the new user-developed warehouse is determined by the quality of the warehouse that is to be built. This is represented by a warehouse quality index z and ranges from 0 to 1.

Warehouse 24 can command a unit storage cost of s_{jmin} if it is built at the minimum warehouse quality index z_{min} or 0 while it can command a unit storage cost of s_{jmax} if it is built at the maximum warehouse quality index z_{max} or 1.

The unit construction cost will also increase if warehouse 24 is constructed at a higher warehouse quality index. The unit construction cost of warehouse 24 will be $cost_{min}$ if it is constructed at the lowest warehouse quality index z_{min} or 0 while the unit construction cost will be 50% higher than $cost_{min}$ if it is constructed at the highest warehouse quality z_{max} or 1.

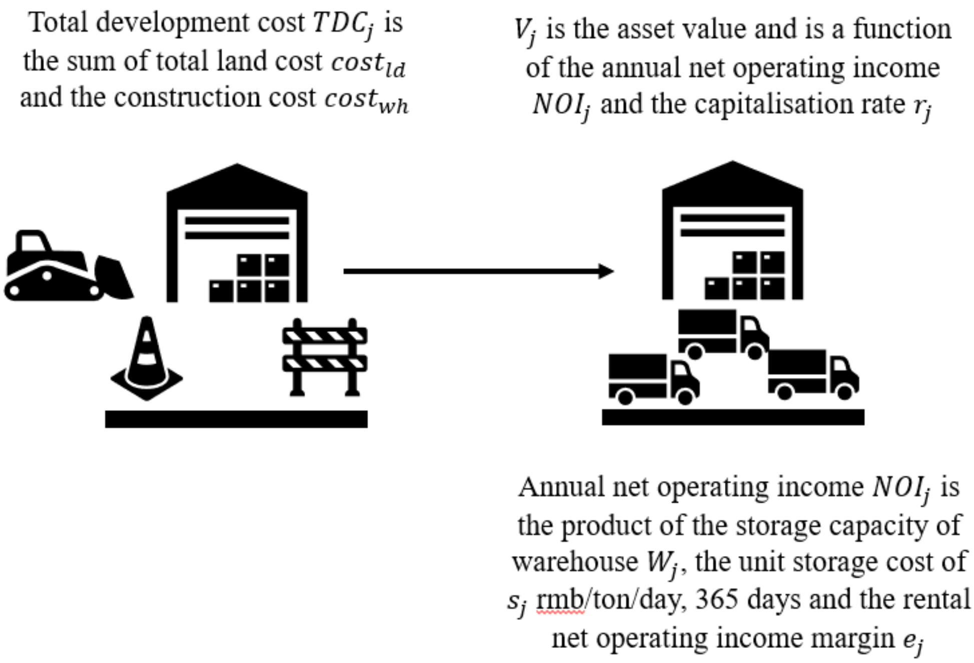

Figure 6: Value of Asset and Development Cost Model

The total cost to develop the warehouse j is the total development cost TDC_j, which is the sum of the warehouse construction cost $cost_{wh}$ and the land cost $cost_{ld}$. The construction cost $cost_{wh}$ is the product of the storage capacity W_j, the unit construction cost $cost_{min}$ and the warehouse quality index z.

VALUING THE ASSET AFTER CONSTRUCTION COMPLETION USING INCOME CAPITALISATION METHOD

Upon completion of the development, the value of the warehouse asset can be computed using the Income Capitalisation Method, which capitalises the future rental income stream that the asset is able to generate. Capitalization rate is one of the most important variables of real estate as it allows the conversion of an owned property into a market rent and vice versa (Lisi, 2019).

Properties that are capable of generating rental income and which an investor represents the likely purchaser, warrants the use of income capitalization approach as the principal valuation model for determining market value (Sevelka, 2004). Net operating income NOI, calculated from the percentage of property leased, rent rates and expenses of the building provided a high correlation coefficient and explained an industrial building's value better than any other single variable (Fehribach et al., 1993).

Value of a property investment V can be calculated by dividing the market rent *MR* by a suitable yield y. This suitable yield is also known as an all-risks yield (Wyatt, 2013).

$$V = \frac{MR}{y}$$

When comparable exchange prices are not available, valuers use initial yields as the basis of comparison for investment valuation. It is the rate at which rent (derived in the occupier market) is capitalised in the investor market (Ball et al., 1998). Baum & Crosby (1995) has also argued that the widespread use of initial yield as a market comparison metric because the market for a particular type of investment usually generates comparable price and income information.

The all-risks yield (ARY) is given as the unit of comparison used largely to value property investments and is usually derived by analysing initial yields from recent comparable property transactions. Adjustments in ARY are also made to reflect any differences between the recent comparable transactions and the property that is being valued. Yields tend to be comparable for similar properties in similar locality because of the similar income growth prospects and their associated risks to capital and income. Sources of data include databases of surveying firms, data publishers and the government. Property consultants such as Jones Lang Lasalle, CBRE, Cushman & Wakefield tend to share transaction information on an informal basis and this information provides a great deal of market knowledge on which to base valuation assumptions (Wyatt, 2013).

The value of the asset V_j is derived from the annual net operating income NOI_j that the warehouse asset can generate, divided by the capitalisation rate r_j. The annual net operating income NOI_j is computed as the product of the storage capacity of the warehouse W_j, the unit storage or rental cost s_j, the net operating income margin e_j, multiplied by 365 days. The net operating income margin e_j nets off the gross rental income by deducting operating expenses such as electricity costs and site management costs.

The asset value V_j is typically higher than the total development cost TDC_j and the difference is known as real estate development profits or gains. The real estate development profits or gains incentivise real estate developers to commence development projects

OBJECTIVE FUNCTION

Sets and indices

W_j	Capacity of warehouse *j*
z	Quality Index of Warehouse *j*
z_{max}	Maximum Quality Index of Warehouse *j*

z_{min} Minimum Quality Index of Warehouse *j*

s_j Unit storage cost of warehouse *j*

s_{jmin} Rent of Warehouse with Minimum Quality Index z_{jmin}

s_{jmax} Rent of Warehouse with Maximum Quality Index z_{jmax}

$cost_{min}$ Unit Construction Cost of Warehouse with Minimum Quality Index z_{jmin}

e_j Rental Net Operating Income Margin for Warehouse *j*

r_j Capitalisation Rate for City

$cost_{wh}$ Total Construction Cost for Warehouse *j*

$cost_{ld}$ Total Land Cost for Warehouse *j*

n_s Number of Years of Rent Commitment for the Sale-and-Leaseback agreement

Annual Net Operating Income = Warehouse Capacity × Unit Storage Cost × Net Operating Income Margin × 365 days/year

$$NOI_j = W_j \times s_j \times e_j \times 365$$

Asset Value = Annual Net Operating Income / Capitalisation Rate

$$V_j = \frac{NOI_j}{r_j} = \frac{(Q_j \times s_j \times e_j \times 365)}{r_j}$$

Unit Rental = Function of Warehouse Quality Index *z* where Unit Rental $s_j = s_{jmin}$ if z = 0 and $s_j = s_{jmax}$ if z = 1

$$s_J = f(z)$$

$$= s_{jmin} + (s_{jmax} - s_{jmin}) \times z$$

$$= s_{jmin} + z \times s_{jmax} - z \times s_{jmin}$$

Total Development Cost = Warehouse Construction Cost + Land Cost

$$TDC_j = cost_{wh} + cost_{ld}$$

$$= W_j \times (cost_{min} + 0.5 \times z \times cost_{min}) + cost_{ld}$$

Development Profit = Asset Value – Total Development Cost

$$= V_j - TDC_j$$

$$= \frac{(W_j \times s_j \times e_j \times 365)}{r_j} - W_j \times (cost_{min} + 0.5 \times z \times cost_{min}) - cost_{ld}$$

$$= W_j \times (s_{jmin} + z \times s_{jmax} - z \times s_{jmin}) \times e_j \times 365 \times (1/r_j) - W_j \times (cost_{min} + 0.5 \times z \times cost_{min}) - cost_{ld}$$

Cost of Sale-and-Leaseback Commitment = Number of Years of Rent Commitment × Annual Gross Rent

$= n_s \times 365 \times s_J \times W_J$

$= n_s \times 365 \times (s_{jmin} + z \times s_{jmax} - z \times s_{jmin}) \times W_j$

Objective Function = Development Profit – Cost of Sale-and-Leaseback Commitment – Transportation Cost for All 24 Warehouses – Storage Cost for 23 Existing Warehouses

$= W_j \times (s_{jmin} + z \times s_{jmax} - z \times s_{jmin}) \times e_j \times 365 \times (1/r_j) - W_j \times (cost_{min} + 0.5 \times z \times cost_{min}) - cost_{ld}$

$- n_s \times 365 \times (s_{jmin} + z \times s_{jmax} - z \times s_{jmin}) \times W_j$

$- \sum_j \sum_i (c_j \, x_{ij}) - \sum_{j \neq J} \sum_i (s_j \, w_i \, D_i \, x_{ij})$

The goal of the study is to maximise the objective function by seeking for the optimal Warehouse Quality Index z and Warehouse Capacity W_j for the user-developed warehouse 24.

To facilitate the coding of the optimization program, the coefficients of $z \times W_j$ and W_j are grouped as below:

Coefficient of $z \times W_j$ = (365× $s_{jmax} \times e_j/r_j$ - 365× $s_{jmin} \times e_j/r_j$

- 365× $n_s \times s_{jmax}$ + 365× $n_s \times s_{jmin}$ - 0.5 × $cost_{min}$)

Coefficient of W_j = $(365\times s_{jmin} \times e_j/r_j$ - $365\times n_s \times s_{jmin}$ - $cost_{min})$

The model attempts to solve for the warehouse quality index z_j and storage capacity W_j for warehouse 24 such that it maximises the economic benefit for the user. The economic benefit is the asset value minus the total development costs minus the sale-and-leaseback commitment for warehouse 24 minus all transportation costs going from the port to the 24 warehouses minus total storage costs of the products that are stored in the existing 23 warehouses.

The reason why the last term only accounts for the total storage costs of the products that are stored in the existing 23 warehouses is because the sale-and-leaseback commitment would have accounted for the storage costs for any shipments that has gone into warehouse 24, given that the commitment is considered a sunk cost.

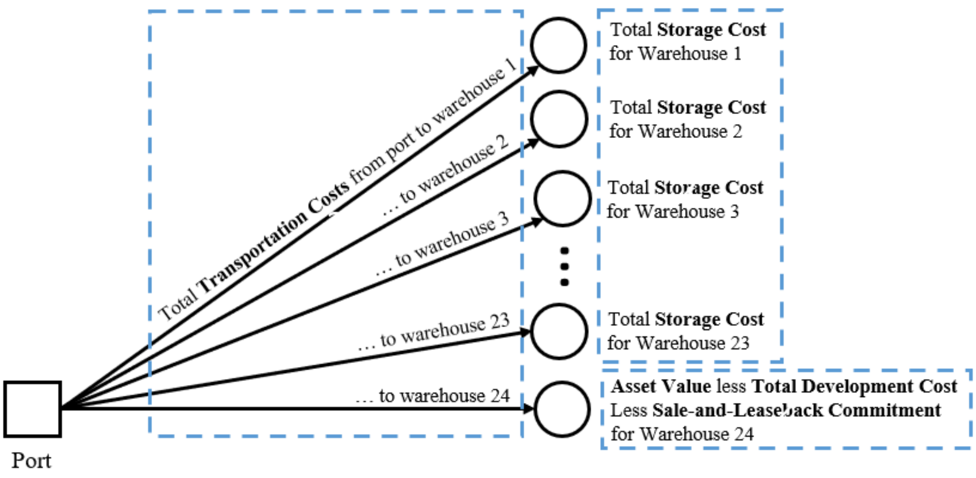

Figure 7: Objective Function for Optimization Model

THE COMPLETE MODEL

The complete model and its objective function and constraints are as follows: -

Objective Function = Development Profit – Cost of Sale-and-Leaseback Commitment – Transportation Cost for All 24 Warehouses – Storage Cost for 23 Existing Warehouses

= $W_j \times (s_{jmin} + z \times s_{jmax} - z \times s_{jmin}) \times e_j \times 365 \times (1/r_j)$ - $W_j \times (cost_{min} + 0.5 \times z \times cost_{min}) - cost_{ld}$

- $n_s \times 365 \times (s_{jmin} + z \times s_{jmax} - z \times s_{jmin}) \times W_j$

- $\sum_j \sum_i (c_j\, x_{ij})$ - $\sum_{j \neq J} \sum_i (s_j\, w_i\, D_i\, x_{ij})$

Subject to

$I_{jt} \leq W_j$	for all *j* and *t*
$I_{jt} = I_{j,t-1} + \sum_i a_{ijt} - \sum_i d_{ijt}$	for all j and t
$a_{ij,u(i)} = w_i x_{ij}$	
$d_{ij,v(i)} = w_i x_{ij}$	for all i and j
$\sum_j x_{ij} = 1$	for all i

6 DATA SET AND PARAMETERS

6.1 PARAMETERS OF THE SHIPMENTS

The data set of 1430 shipments over 90 time periods have an average and median duration of stay of 27 days and 19 days respectively, with the shortest duration of 1 day and the longest duration of stay at 117 days. The number of shipments per time period is not constant and the average number of shipments per time period is 16 shipments. The weight of the cargo shipments ranges from 12 tons to 28 tons per shipment, with a mean and median weight of 25 tons and 26 tons respectively.

	Duration of Stay	Shipment Weight
Mean	27	25
Median	19	26
Min	1	12
Max	117	28

Table 1: Statistics of the Shipment Data

6.2 DATA AND PARAMETERS OF THE EXISTING WAREHOUSE NETWORK

This study uses the Q4 2020 data of 1430 container shipments going to 23 different existing warehouse locations. Each of these 23 warehouses have a maximum capacity of 5,000 tons. The existing 23 warehouses have a transportation rate and unit storage cost as follows: -

Warehouse Index	Transportation Costs rmb/trip	Unit Storage Cost rmb/day.ton
1	1605	2
2	1800	3.5
3	1200	3.5
4	1085	3
5	1406	2.2
6	1600	3.5
7	1600	3.6
8	1050	3.5
9	1050	3.5
10	1050	3.5
11	1050	3.5
12	1800	3.5
13	1500	4
14	1400	2
15	1500	4.3
16	1650	3.3
17	1800	3
18	1800	3.5
19	1545	2
20	1854	3.5
21	1800	3.5
22	1854	2.8
23	1050	2.6

Table 2: Transportation Rates and Storage Rates for Existing Warehouses in the Network

6.3 PARAMETERS OF THE POTENTIAL USER-DEVELOPED WAREHOUSE

In addition, there is one warehouse that is currently being designed to be constructed by the user, which upon completion, will be sold to an investor and leased back by the user. This warehouse project has a maximum capacity W_J of 5,000 tons and will require an investment of 5,000,000 rmb for the cost of the land $cost_{ld}$. The warehouse can be constructed at warehouse quality index z ranging from 0 to 1. The unit construction cost of the minimum warehouse quality index of z=0, $cost_{min}$ is 4,500 rmb/ton capacity. The storage cost of the minimum warehouse quality index z =0 is 2 rmb/ton.day while the storage cost of the maximum warehouse quality index z =1 is 3.5 rmb/ton.day. The net operating income margin e_j is 65% and the capitalisation rate r_j for Tianjin is 6.5%. As part of the sale-and-leaseback agreement, the user is committing to 3 years of rental commitment n_s. In the study, given that the model used one quarter of operating data, the sale-and-leaseback was also scaled down proportionately. The corresponding sale-and-leaseback period is scaled to ¾ or 0.75 years.

6.4 STRUCTURE OF THE CODE

The model was programmed using ECLIPSE IDE Java for Developers 2020-12 and IBM ILOG CPLEX Studio IDE 20.1.0 and the computation was done on a Microsoft Surface Book 4 Intel i7-1065G7 CPU @1.30 GHz with 16Gb RAM. The program was setup with a main Java program module (main.java) that contains the core computational codes and an auxiliary module (WhMacro.java) that contained two main groups of parameters. These parameters are the program parameters (defining the number of warehouses, number of shipments and the number of periods for the runs) and the model parameters (rent at minimum and maximum quality, unit construction cost at minimum warehouse quality, net operating income margin, capitalisation rate, years of sale-and-leaseback commitment, cost of land and maximum allowable warehouse capacity). By keeping the program parameters in a separate module, it is relatively easy to vary the parameters across the different experiments.

The main program reads two text files, namely the shipment data (whstcost.txt, four columns of data, namely shipment number, day of arrival, duration of stay, shipment weight) and the warehouse transportation cost data (whdatatj.txt, three columns of data, namely warehouse index, transportation cost, unit storage cost). The main program subsequently sets up the variables after reading in the data and calls on Cplex module to do the optimisation. For most runs, the computation took approximately two to four minutes.

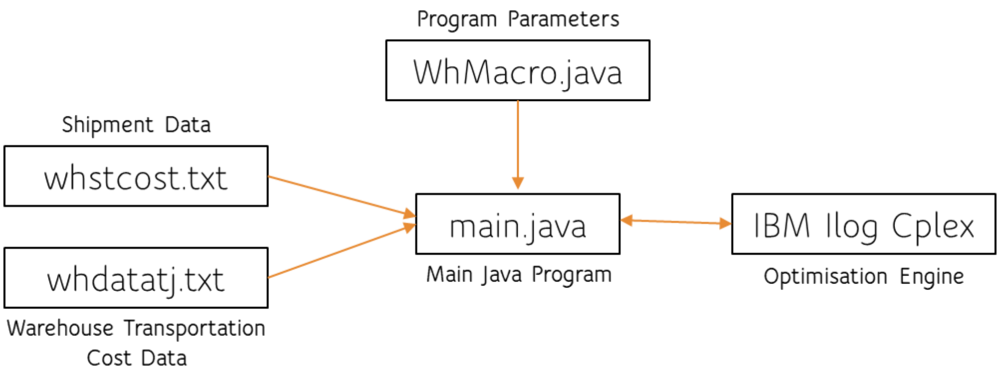

Figure 8: Setup of Optimization Program

7 NUMERICAL RESULTS

This study compares the three initial scenarios, namely (i) base case 0 of actual planning data, (ii) base case 1 for the deterministic optimized state and (iii) base case 2 for the final optimized state with a new user-developed warehouse.

7.1 BASE CASE 0 – CURRENT PRACTICE

In the base case actual state, the actual total logistics cost in Q4 of 2020 was computed by summing up the total logistic costs based on the actual locations of the warehouses each container was sent to and the number of days that the products were stored in the allocated warehouses. The total logistics costs are the sum of all the transportation costs from the port to the warehouse and the total storage cost incurred by storing the products over the duration of stay in the respective warehouses at the prevailing unit storage costs. The actual 2020 Q4 total logistics cost based on the actual planner's choice of warehouse was calculated to be 5,572,208 RMB.

7.2 BASE CASE 1 – OPTIMIZATION BASED ON THE EXISTING NETWORK OF WAREHOUSES

For the deterministic optimized state, the maximum allowable warehouse capacity for user-developed warehouse 24 was set to zero. With this, there was no maximization of the development profit, and the model will optimize for the lowest logistics costs of the existing network. Based on the actual shipment data (actual container arrival date, duration of stay and weight), the model will decide which warehouse to send each container to, such that the total logistics cost will be minimized. Based on this optimization, the total logistics cost for Q4 2020 became 3,851,743 RMB, a reduction of 30.9% against the base case 0 of actual planning data.

For this optimization, the model sent the shipments to six warehouses, namely warehouse 4, 5, 8, 14, 19 and 23. These warehouses can be grouped into two different types of competitiveness. Warehouses 4, 8, 23 are competitive from a transportation perspective and is cost efficient for shipments that stay for a short period of time (transportation rates at 1050 to 1080 RMB per trip). Warehouses 5, 14, 19 are competitive from a storage perspective and is cost effective for shipments that stay for a longer period of time (unit storage costs from 2 to 2.2 RMB per day per ton). These six warehouses recommendation coincides with the company's most frequently used warehouse for this network though the shipments were not as high as the model's prediction.

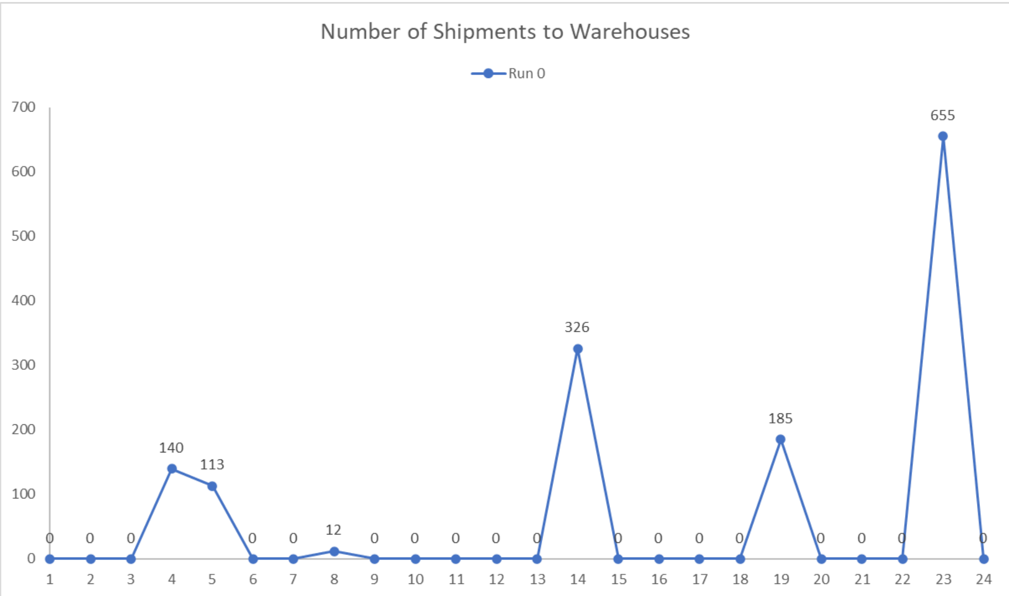

Figure 9 : Shipment Recommendation for Existing Warehouse Network

7.3 BASE CASE 2 – OPTIMIZATION CONSIDERING A NEW USER-DEVELOPED WAREHOUSE

In the third setting, the model attempts to compute if a new user-developed warehouse should be constructed. If the warehouse is to be constructed, the model attempts to optimize the storage capacity of this new warehouse (warehouse 24) and the quality of warehouse that it should construct such that the economics benefits to the user is maximised. The maximum allowable capacity of the warehouse based on the land size is 5,000 tons, like the rest of the warehouses in the existing network. The warehouse when completed, will undergo a sale-and-leaseback, in which the user will commit to lease the warehouse fully for 3 years.

In this setting, the model recommends constructing a warehouse with the maximum allowable capacity of 5,000 tons and at maximum warehouse quality z=1. With this, the model directs most of its shipments to the new warehouse 24 and reduces the shipments to the other warehouses, despite the rental costs of warehouse 24 being 3.5 RMB per day per ton which is corresponding to the upper end of the rental cost due to the selection of the higher end of the warehouse quality index. The shipments to warehouse 23 was reduced from 655 to 350. Nevertheless, due to the higher rent, the economic benefit (development profit less sale-and-leaseback commitment less operating cost) is still maximized at 17,655,410 RMB. If we compute the storage costs of warehouse 24 based on the number of days each container is being sent as part of the solution set, the total actual logistics costs of this solution increased 15.0% to 4,429,049 RMB from 3,851,743 RMB (increase of 577,306 RMB). This increase however is well offset by the increase in the development profit in the maximization.

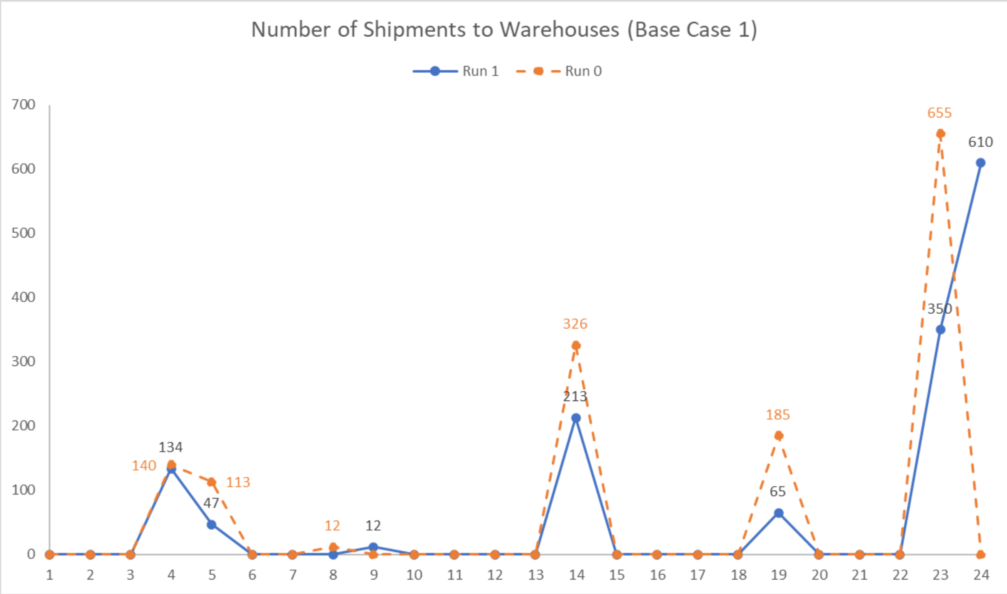

Figure 10 : Shipment Recommendation for Warehouse Network including New User Developed Warehouse

8 IMPACT OF DIFFERENT PARAMETERS

The base case scenarios have generated optimal solutions that consider the parameters that was provided. The optimal solutions demonstrated that the selection of warehouse capacity and warehouse quality allows for the solutions to take advantage of the current network cost advantages while considering the potential economic benefits of a new user-developed warehouse.

To further the insights of this study, this research attempts to vary six key parameters and summarise how these parameters changes the trade-offs. These six scenario variations are: -

1. Varying The Pay Off of Building a User-Developed Warehouse
2. Varying the Cost of Building a Minimum Quality Warehouse
3. Varying The Location of The User-Developed Warehouse
4. Varying The Capacity of the User-Developed Warehouse

5. Varying The City Location of The User-Developed Warehouse
6. Varying The Net Operating Income Margin of The User-Developed Warehouse

8.1 SCENARIO 1 – VARYING THE PAYOFF OF BUILDING A USER-DEVELOPED WAREHOUSE

One of the key parameters that vary with the quality index of the warehouse is the rent that the different quality warehouse can command. In general, a higher quality warehouse should command a higher rent. However, the rent spread (difference between the highest rent and the lowest rent) may differ for different geographies or cities.

The current base case assumes that the rent spread for quality index z from 0 to 1 is 1.5 RMB (2 RMB at the minimum-quality end and 3.5 RMB at the maximum-quality end). At the minimum-quality end, the construction cost is 4500 RMB per ton capacity while at the maximum-quality end, the construction cost is 50% higher, or 6750 RMB per ton capacity. The rent increase from 2 RMB to 3.5 RMB is 75%. Under this setting, the model recommends the building of a maximum quality warehouse (z=1) as economic benefit from getting the higher rent (+75%) outweighs the increase in construction cost (+50%).

The first variation attempts to look at the effect of changing the rent spread and moving the band of rent spread. The model is run for the rent pairs of (2.5 to 3), (3 to 3.5) and (3.5 to 4) which is +20%, +16.7% and +14.2%

respectively. The model is then run for the last rent pair of (2 to 4), which is a rent spread (+100%) that is wider than the base case.

	Run 1	Run 2	Run 3	Run 4	Run 5
Rent of Minimum Quality Warehouse	2	2.5	3	3.5	2
Rent of Maximum Quality Warehouse	3.5	3	3.5	4	4
Model Computed Quality Index to Build	1	0	0	0	1
Model Computed Capacity to Build	5,000	5,000	5,000	5,000	5,000
Economic Benefits	17.7m	12.0m	20.5m	28.9m	26.1m

Table 3 : Impact of Rent Spread on Warehouse Quality Recommendation

For the three rent pairs, the model recommends for the warehouse to be built to its largest allowable capacity but with the minimum quality index of z=0. This differs from the base case of z=1 despite the rent range being within the base case range. This shows that as long as the rent spread is lower than the 50% increase in the construction cost of a maximum quality warehouse, then the trade-off in building a maximum quality warehouse is not justifiable.

With the last rent pair of (2 to 4), the model recommends the built to its largest allowable capacity and at the maximum quality index of z=1, similar to the base case (Run 1). This demonstrates that once the rent spread (in this case, +100%) is higher than the 50% increase in construction cost, the model will recommend for the maximum quality index to be built to maximise the economic benefit for the user.

8.2 SCENARIO 2 – VARYING THE COST OF BUILDING A MINIMUM-QUALITY WAREHOUSE

In addition to varying the warehouse quality index z to reflect the increase in construction cost, it is also possible that the construction cost can be varied by changing the unit construction cost of the minimum warehouse quality index of z=0. This would allow the model to simulate situations in different geographical locations within China. For example, top tier cities such as Shanghai, Beijing may have unit construction costs higher than that of the lower tier cities due to additional construction requirements and regulations, but the unit construction cost of a higher quality warehouse is still of the same magnitude when compared to the unit construction cost of a lower quality warehouse (in the base case, which is +50%).

	Run 6	Run 1	Run 7	Run 8	Run 9
Unit Construction Cost at Minimum Quality	4000	4500	5000	6000	9000
Model Computed Quality Index to Build	1	1	1	1	-
Model Computed Capacity to Build	5,000	5,000	5,000	5,000	0
Economic Benefits	21.4m	17.7m	13.9m	6.4m	-

Table 4 : Impact of Unit Construction Cost of Minimum Quality on Capacity Recommendation

This section varies the unit construction cost at z=0 from 4500 RMB to 4000 RMB (-11.1%), 5000 RMB (+11.1%), 6000 RMB (+33.3%) and 9000 (+100%) RMB respectively. At the unit construction costs of 4000 RMB, 5000

RMB and 6000 RMB, there is no change in the model's recommendation compared to the base case. The model recommends building the warehouse to the largest allowable capacity of 5,000 tons and to the highest quality index of 1.0. However, at 9,000 RMB construction costs, the model recommends for the user not to construct this warehouse. This change in the unit construction cost does not alter the shipment recommendation from the model.

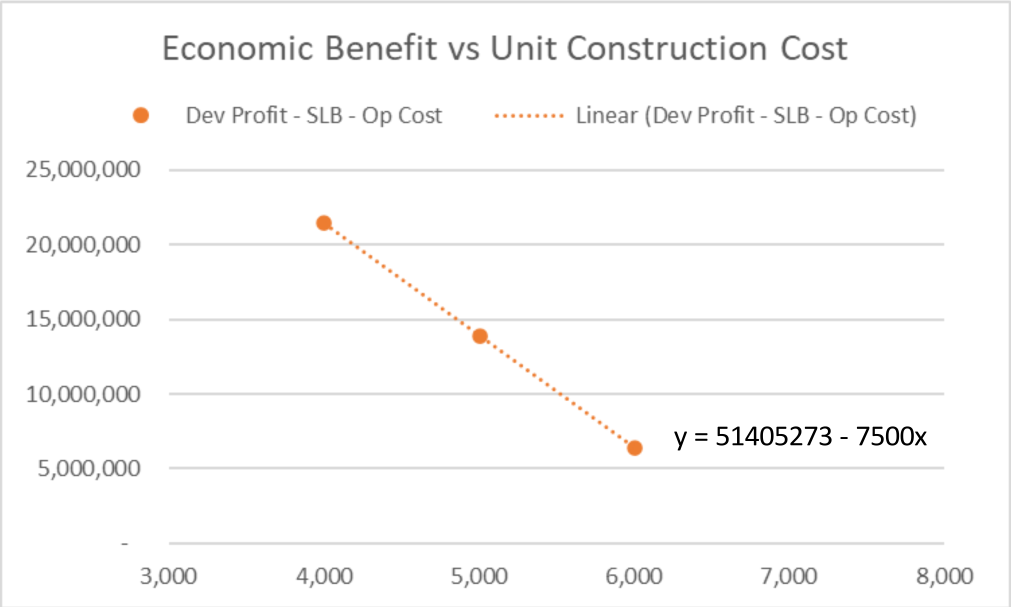

Figure 11 : Relationship Between Economic Benefits and Unit Construction Costs at Minimum Quality

By doing a linear regression on the best-fit line, the line will intersect the x-axis at 6,854. Hence, for this model, unit construction cost needs to be less than 6,854 RMB to generate economic benefits for the user.

8.3 SCENARIO 3 – VARYING THE LOCATION OF THE USER-DEVELOPED WAREHOUSE

The current model assumes that the location of the user-developed warehouse will be located around the same area as the existing warehouses that are closest to the port. Hence, the transportation rate of sending containers to warehouse 24 was assumed to be the lowest at 1050 RMB per trip. This section looks at varying the transportation costs to simulate the change in location. These variations include transportation costs at 1600 RMB per trip (median location of the existing warehouse network), 1854 RMB per trip (furthest warehouse in the existing warehouse network), 5000 RMB per trip (outside of Tianjin and Beijing) as well as 10000 RMB per trip (essentially locating far away from Tianjin as an extreme case).

	Run 1	Run 10	Run 11	Run 12	Run 13
Transportation Cost from Warehouse 24 to Port	1050	1600	1854	5000	10000
Model Computed Shipments to Warehouse 24	610	377	320	128	0
Model Computed Quality Index to Build	1	1	1	1	1
Model Computed Capacity to Build	5,000	5,000	5,000	5,000	5,000
Economic Benefits	17.7m	17.4m	17.3m	16.6m	16.6m

Table 5 : Impact of Transportation Costs to Warehouse 24 on Shipments Recommendations and Capacity to Build

In this variation, the model recommends in all four cases to build a warehouse to the largest allowable capacity of 5,000 tons and at the highest quality index of z=1. The economic benefits reduced slightly as the distance varied, with 17,394,057 RMB (-1.5%), 17,306,115 RMB (-2.0%), 16,588,346 RMB (-6.0%) and 16,482,820 RMB (-6.6%). The number of shipments sent to warehouse 24 also reduced as distance increased, with shipments dropping to 377 (-38.2%), 320 (-47.5%), 128 (-79%) and 0 (-100%).

This variation demonstrated an interesting scenario. Even if the new warehouse is located so far away from the port that it is not used for any of the shipments (in the last parameter change where transportation cost is 10000 RMB), the model will still recommend building the warehouse to achieve the economic benefits but will then not use this warehouse so as to optimise the operating costs. It should be noted that the economic benefit did not decrease dramatically even with large increases in the distances.

8.4 SCENARIO 4 – VARYING THE CAPACITY OF THE USER-DEVELOPED WAREHOUSE

This variation examines the impact of the capacity supply of the warehouse network, including the new user-developed warehouse. The section varied the maximum allowable capacity of the new warehouse from 5,000 tons to 4000 tons (-20%), 7500 tons (+50%), 10000 tons (+100%) and 20000 tons (+300%). These in turn changes the total installed capacity of the warehouse network by -0.9%, +2.2%, +4.3% and +13.0%. To model the additional land needed to construct a larger facility, the land cost is increased for larger facilities proportionately.

	Run 14	Run 1	Run 15	Run 16	Run 17
Maximum Allowable Capacity of Warehouse 24	4000	5000	7500	10000	20000
Land Cost of Maximum Allowable Warehouse 24	5m	5m	7.5m	10m	20m
Model Computed Shipments to Warehouse 24	548	610	776	926	1363
Model Computed Quality Index to Build	1	1	1	1	1
Model Computed Capacity to Build	4,000	5,000	7,500	10,000	20,000
Economic Benefits	12.4m	17.7m	28.2m	38.6m	79.8m

Table 6 : Impact of Maximum Allowable Capacity of Warehouse 24 on Shipment Recommendations and Capacity to Build

This variation saw the model recommending building the maximum allowable warehouse capacity of 4000 tons, 7500 tons, 10000 tons and 20000 tons at the maximum quality index of z=1. With the decrease of allowable capacity to 4000 tons, the shipments directed to warehouse 24 decreased from 610 shipments to 548 shipments. As the maximum capacity increased, the model directed more shipments towards warehouse 24, increasing from the base case of 610 shipments to 776 (for 7500 tons), 926 (for 10000 tons) and 1363 shipments (for 20000 tons) respectively. In the 20000 tons maximum allowable capacity run, the model directed shipments to only one warehouse in the existing network (warehouse 23). This variation showed that as long as the user-developed warehouse is transportation cost-competitive, the model will prioritise its shipment to this warehouse so as to achieve the highest economic benefits.

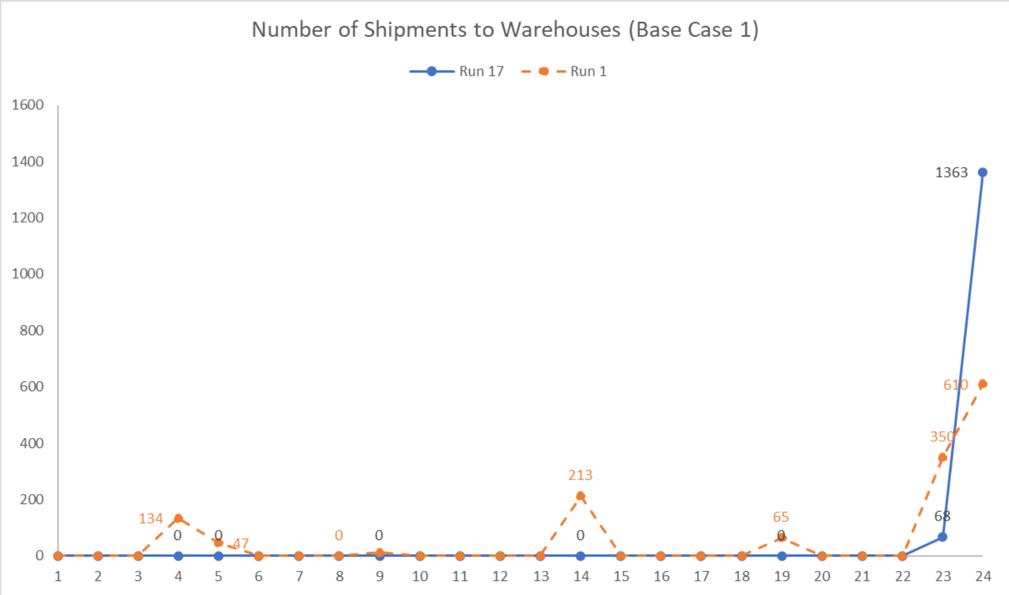

Figure 12: Shipment Recommendations for Run 17

8.5 SCENARIO 5 – VARYING THE CITY LOCATION OF THE USER-DEVELOPED WAREHOUSE

Different cities in China command a different asset capitalisation rate for the same asset class. In the base model with Tianjin, the historical capitalisation is estimated to be 6.5%. By varying the capitalisation rate, this variation can simulate the impact of building this warehouse in a different city. A lower capitalisation rate would simulate a city where logistics real estate is more valuable and scarcer (for example, 5.5% would be close to Shanghai capitalisation rate while 4% may be even good locations in Shenzhen) while a higher capitalisation rate would simulate a city which is less desirable (7.5% may refer to Wuhan while 9% may refer to third or fourth-tier cities or less developed provinces).

	Run 18	Run 19	Run 1	Run 20	Run 21
Warehouse 24 Capitalisation Rate	4%	5.5%	6.5%	7.5%	9%
Model Computed Quality Index to Build	1	1	1	1	-
Model Computed Capacity to Build	5,000	5,000	5,000	5,000	0
Economic Benefits	57.6m	29.3m	17.7m	9.1m	-

Table 7 : Impact of Capitalisation Rate on Computed Economic Benefits and Capacity to Build

For this variation, reduction in capitalisation rates leads to a hyperbolic increase in the economic benefits since the capitalisation rate is used in the denominator of the objective function. Compared to a base case of 6.5% capitalisation rate, the economic benefit increased from 17,655,410 RMB to 29,268,416 RMB (+65.8% at 5.5% cap rate, a 1% reduction) and 57,576,655 RMB (+226.1% at 4% cap rate, a 2.5% reduction). With an increase of capitalisation rate from 6.5% to 7.5%, the economic benefit is reduced to 9,139,586 RMB (-48.2%, a 1% reduction). At a capitalisation rate of 9%, the model recommends not to construct the current warehouse.

This variation demonstrates that the capitalisation rate is the most sensitive parameter in the maximization of the economics benefits. Thus, in most development projects, all things equal, the city location which then drives the commanding capitalisation rate, is a strong determinant of the economic benefits of the project.

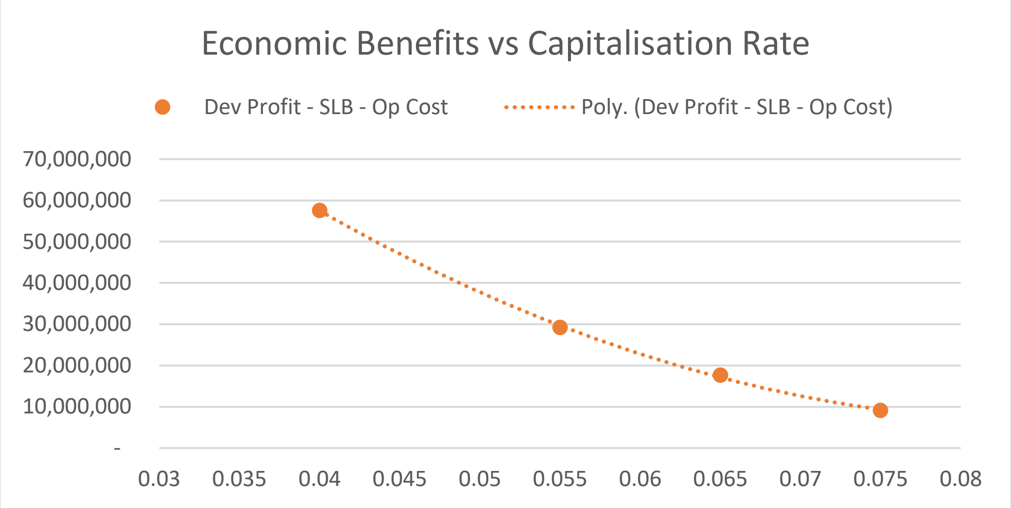

Figure 13 : Relationship Between Economic Benefits and Capitalisation Rate

8.6 SCENARIO 6 – VARYING THE NET OPERATING INCOME MARGIN OF THE USER-DEVELOPED WAREHOUSE

In the last variation, the model can simulate different types of warehouses by varying the rent net operating income margin. The base case of 65% rent net operating income margin is a typical net operating income margin for modern cold chain warehouse. For ambient warehouse, the rent net operating income margin is usually in the range of 75% to 85% due to the lower energy consumption. For similar assets such as cold chain warehouses, different net operating income margins can also be used to model different refrigeration systems designs and the impact of the differing energy consumption. For projects where there are both ambient and refrigerated warehouse space, the weighted average net income margin can be used to model the facility.

	Run 22	Run 1	Run 23	Run 24	Run 25
Warehouse 24 Expense Ratio	55%	65%	75%	85%	90%
Model Computed Quality Index to Build	1	1	1	1	1
Model Computed Capacity to Build	5,000	5,000	5,000	5,000	5,000
Economic Benefits	7.8m	17.7m	27.5m	37.3m	42.2m

Table 8 : Impact of Net Operating Income Margin on Computed Economic Benefits and Capacity to Build

For all parameters change to the net operating income margin to 55%, 75%, 85% and 90%, the model recommends building the warehouse to the maximum allowable capacity of 5000 tons and the maximum warehouse quality level of z=1. However, when the net operating income margin is reduced from 65% to 55% (15.4% reduction), the economic benefit decreased from 17,655,410 RMB to 7,829,157 RMB (-55.7%). Similarly, when the net operating income margin is increased to 75%, 85% and 90% (+15.4%, +30.8%, +38.5%), the economic benefit increased linearly to 27,481,703 RMB (+55.7%), 37,308,626 RMB (+111.3%) and 42,222,087 RMB (+139.1%).

9 SUMMARY OF RESULTS AND INSIGHTS

The study has shown that the use of user-developed real estate with sale-and-leaseback can lead to positive economic benefits for the user. In addition, coupled with the appropriate use of the existing network of warehouses, the economic benefits can be further optimized.

The three base cases and six scenarios outline the overall trade-off considerations for a user that is optimising across renting third party cold chain warehouses and building an own facility.

The base case scenarios 1 illustrate how deterministic optimization can reduce the total logistics costs by directing the shipments to the most competitive warehouses in the existing network. From an existing network perspective, using learnings from the deterministic model and better forecasting has the potential to help reduce operating costs by 30%.

The base case scenario 2 illustrates that the optimal solution for a potential user-developed warehouse is to build the warehouse and continue to use the existing network of warehouses, albeit at lower utilization. Based on the parameters used in the current model, the building of a cold chain warehouse by the user can generate positive economic benefits for the user. The development profit can offset the sale-and-leaseback commitment and the associated operating costs.

The remaining six scenario variations attempt to derive insights from varying various parameters in the model and understanding the sensitivities of these variations. These variations reflect trade-offs that are typically found in cold chain real estate projects when projects are evaluated in different cities (resulting in different rent spreads, unit construction costs), locality (resulting in different transportation costs) and competitive dynamics (resulting in different capacity, city selection and design choices).

Scenarios	Key Findings
Base Case 0 – Actual Planning Data	2020 Q4 actual total logistics costs was 5.6m RMB
Base Case 1 – Deterministic Optimization	Model was able to achieve a 30.9% reduction in total logistics costs, with shipments going to 6 selected warehouses
Base Case 2 – Final Optimized State with a User-Developed Warehouse	Model recommends building to the maximum allowable capacity at the maximum warehouse quality, achieving positive economic benefits of 17.7m RMB
Scenario 1 – Varying Payoff in Building a Higher Quality Warehouse	When the rent spread increase is larger than the unit construction cost increase, the model recommends building to the maximum quality.
Scenario 2 – Varying Cost of Building a Higher Quality Warehouse	Increase in unit construction cost leads to a linear decrease in economic benefits. The model will not recommend building when the construction costs is too high and does not generate positive economic benefits
Scenario Variation 3 – Varying the Location of the User-Developed Warehouse from the Port	Locating the warehouse further from the port has a marginal negative effect on the economic benefits. The model will still recommend building the warehouse that is further away but will use the user-developed warehouse less
Scenario Variation 4 – Varying the Relative Capacity Between the User-Developed Warehouse and Current Warehouses in the Network	The model will recommend building to the maximum allowable capacity. It will direct more shipments to the user-developed facility if the transportation cost is competitive
Scenario Variation 5 – Varying the City Location of the Warehouse Project	Lower capitalisation rate leads to a non-linear increase in economic benefits and is found to be one of the most sensitive parameters. The model will also recommend not building a warehouse if the capitalisation rate is too high and does not generate a positive benefit
Scenario Variation 6 – Varying The Net Operating Income Margin of The User-Developed Warehouse	Higher net operating income margin leads to a higher net operating income and economic benefits

Table 9 : Summary of Scenarios and Variation Findings

If the rent increase between the highest quality index and lowest quality index is larger than the construction costs increase, then the optimal recommendation is to build to the highest quality and at maximum capacity. Increase in the unit construction cost at minimum quality index level in turn leads to a linear decrease in economics benefit. Both these changes do not affect the shipment recommendations to the warehouses.

Locating the warehouse further away from the port decreases the economic benefits marginally as distance increases. The increase in distance also reduces the shipments sent to newly developed warehouse reflecting a reduction in competitiveness of new warehouse in comparison to the existing network warehouses. However, despite locating the warehouse far away from the port and becoming uncompetitive, the building of the warehouse is still recommended as the economics benefit outweighs the increase in operating costs.

When there is a possibility to build a larger warehouse on a bigger piece of land, the optimal recommendation is to build the warehouse to as large as the land can accommodate, despite a proportionate increase in the land cost because the economic benefits are still incremental. Lower capitalisation rates lead to a non-linear increase in the economic benefits and is one of the most sensitive parameters. Higher net operating income margins increase the net operating income of the asset and increases the value of the warehouse, leading to a higher economic benefit for the user.

The study also found that the real estate economic benefits (development profit less sale-and-leaseback commitment) can be substantially higher than the total logistics cost over the sale-and-leaseback commitment period (transportation costs and storage costs), accounting for a mean and median of 3.8 times and 2.9 times of the total logistics costs across the scenario variations of this study. This observation coincides well with the general observation in China where companies with strong operating businesses eventually pivoting to incorporate real estate development as one of their key pillars due to the strong economic returns of real estate development.

10 THEORETICAL CONTRIBUTIONS

This study brings together logistics network cost optimisation and real estate benefit considerations. By modelling the impact of these trade-offs and using an optimization model to seek for the optimal warehouse capacity and quality to build, the study presents a novel and quantitative way to objectively access the economic benefit in a holistic manner. In addition, the study also modelled the variations of six key parameters to further draw insights of how these parameters would affect the final shipment recommendation and the economics of the change.

This research adds to the body of knowledge by presenting a new way to combine operations research network optimization and real estate finance. While these two areas have been well-researched, the use of network optimization modelling techniques combined with real estate economic benefits model, has yet to be used.

The findings from this research enrich the repertoire of operations research literature by exploring holistic supply chain design methodology that encompass financial considerations. It also enriches the repertoire of real estate finance literature by exploring cold chain assets and adds to the understanding of cold chain operations considerations in China.

11 PRACTICAL IMPLICATIONS

With increasing industry concentration in sectors such as fresh produce & ecommerce, large users that use and rent real estate assets will become more and more prevalent. Users will continue to debate the pros and cons of an asset light (rent) and asset heavy (build) strategies. This study proposes a methodology and computation model that seeks for the highest level of economic benefits for the users, taking into consideration the lower operating cost of third-party facilities while considering the financial benefits of building, owning and monetizing the asset. This allows companies to consider the use of hybrid asset strategies, that initially builds the asset but then lightens up the balance sheet by incorporating financial manoeuvres such as sale-and-leaseback. By doing so, the company can enjoy the financial benefits of an asset heavy strategy while eventually enjoying the lower capital burden and flexibility of the asset light strategy.

Although this study is focused on cold chain warehouses, the methodology is applicable for other industries and real estate asset classes. This can include ambient logistics real estate, data centres, education agencies and other industrial use buildings. If the user can choose between renting or building the real estate and if there are established avenues for capital recycling (well-developed capital markets with REITs or real estate investment trusts and well-established real estate capital investors such as pension funds, insurance funds, sovereign wealth funds), the model can be easily adapted to help with the modelling of the trade-offs and the computation of the asset classes and the economic benefits.

12 LIMITATIONS

This study is not without its limitations despite its innovative approach in combining the realms of operations research and real estate finance. The current study and model are relatively simplistic and does not account for all the factors that make up a real estate consideration. Factors such as multiple land choices, differing designs, options to choose different cities, tax considerations are not scoped into this project. The study is based on China data and the findings may not be totally replicable especially for countries where the capital markets and investors are less sophisticated (thus, a less developed sale-and-leaseback market). This research was also limited to single-asset considerations, and it may not be applicable for situations where the user can choose from multiple cities from which to locate and build the facility. However, these limitations can be easily overcome by examining the parameter value and making appropriate changes to the makeup of the formulation. Additional limitations also include the single quarter time-period consideration and the sample size.

13 POTENTIAL AREAS OF FURTHER RESEARCH

The study is a first step in combining the considerations of two fields of research, namely operations research and real estate finance. The model is a good start to link the trade-offs and the parameters around rental rates and the financial value of the asset. Further research can be done to add in additional considerations such as corporate structures (offshore or onshore holding structures) and taxation considerations. Work can also be done to extend this study into other asset classes such as the ecommerce sectors and ambient warehouse. In the ecommerce study, research can also explore a network of self-developed warehouses (instead of a single warehouse in this study). Within the cold chain logistics sector, this study can be extended to study the possibility of developing multiple cold chain warehouses and across several cities. To extend the study further, the model can be adapted to a more complex distribution network with multiple nodes that can model the trade-offs further down the value chain. Lastly, the research can be extended and explored for other geographical locations outside of China.

14 CONCLUSION

This study adds to the body of knowledge of operations research by optimising the logistics costs with real estate consideration. By considering a potential user-developed warehouse with an existing warehouse network, this study opens new avenues of research in optimising between asset light and asset heavy strategies. This study is meaningful because it proposes a practical methodology and a quantitative computational model that can help users make the appropriate trade-offs while understanding the impact of the different variations of key parameters. By varying the parameters, this methodology can be adapted to model different asset classes, locations, commitment costs and other practical considerations for users who are considering the real estate aspects of the decision. This study highlights that there are often optimal solutions that provide economic benefits for the user that combines the economic benefits of developing real estate while taking advantage of the competitive cost structure of existing assets.

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