Master's Research Report

Estimating CO_2 Emissions in Operational Processes of China's Express Delivery Sector: A Case Study of SF Express

by

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Certification Page

I, LIU Chaoying (Student ID 51220613) hereby declare that the contents of this Research Report are original and true, and have not been submitted at any other university or educational institution for the award of degree or diploma.

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Summary

China, the largest CO_2 emitter in the world, promised that its CO_2 emissions would peak by 2030 and that it would achieve carbon neutrality by 2060. China's express delivery volume has ranked first in the world for the past six consecutive years. The sector urgently need to make analysis of its present CO_2 emission situation and find solutions of emission reduction.

This article focuses on CO_2 emission in China's express delivery sector. In 2014, the State Post Bureau of P. R. China (SPB) published a guidance for GHG emission inventory calculation, however, this sector's emissions were not documented until January, 2021. Since the emission sources, emission factors and emissions in operational processes have not been listed, the document is not sufficient to serve as a guidance for CO_2 emission reduction for the staff of different operational processes. To fill this gap, this article will identify CO_2 emission sources and calculate emissions in the operational processes of this sector.

This article examined the operational processes of China's express delivery industry and classified them into three categories; outlets, transit centre and transportation. For each process, the author listed emission sources and gathered emission factors based on the knowledge of national and international standards, organisations, and other sources. The author also collected activity data of SF Express delivery, which is one of the largest delivery companies in China and calculated the CO_2 emissions in its operational processes.

The results show that the total CO_2 emissions of SF Express in 2020 was 5,292,109.59 tCO_2, among which, transportation accounts for 78%, outlet 17%, and transit centre 5% of total CO_2 emissions. In transportation, road accounts for 62.8%, aviation 37.2%. Railway is excluded for lack of activity data in the year 2020. In road transportation, diesel vehicles account for 94.10% of CO_2 emissions, followed by gasoline and electricity. In outlets, packaging is the major emission source, accounting for 73% of total emissions. In transit centres, due to data unavailability, emissions from water and paper use, and waste etc. are not calculated, and electricity is the only emission source accounted for.

Based on the results, this author has made several recommendations which include focusing on hybrid modes of transportation and alternative fuel vehicles. SF's measurement unit of activity data is difficult to use for carbon emission calculations and some improvements are needed. Whether or not to include indicators from international peers' practice, such as outsourcing and employee commuting, in national standards, should also be discussed.

By using SF Express as an example, this article provides a list of emission sources of the main operational processes, to provide a reference for the staff to reduce CO_2 emissions during their work, and to facilitate decision-makers to adopt more effective measures to reduce CO_2 in their organisations in a practical way.

Key words: *express delivery sector, CO_2 emission, operational process, SF Express, State Post Bureau of P. R. China (SPB)*

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1. Introduction

1.1 Background

The build-up of carbon dioxide and "greenhouse gases" in the atmosphere was first reported by a meeting of the World Meteorological Society, UN Environment Program and the International Council of Scientific Unions in 1985. It was a meeting on climate change, and they predicted global warming (International Institute for GHG countries to goals for greenhouse gas emission reductions and established the Clean Development Mechanism for developing countries (UNFCC, 1998). At the beginning of the new millennium, the 2000 UN Millennium Development Goals were developed by the United Nations. Within the eight millennium development goals, the seventh goal is to "ensure environmental sustainability". Every nation strives to ensure a sustainable future (IISD, 2012). In 2016, the Paris Agreement officially recognizes human influence on the climate and commits to "holding the increase in the global average temperature well below 2 ℃; pursue efforts to limit the temperature increase to 1.5℃" (UNFCC, 2006). Currently, many countries have committed to GHG reductions and acted toward the direction of reducing emissions.

While it ranks only 78th in per capita emissions, China overtook the United States as the world's largest emitter of GHGs in 2009 (IISD, 2012). The main GHG gas in the atmosphere is carbon dioxide (CO_2), which accounts for approximately 26%, excluding vapor (H_2O, which accounts for approximately 60%-70%), followed by O_3, CH_4, N_2O, PFCs, HFCs, HCFCs and SF6, etc. (SPB, 2014). Therefore, this article will focus on CO_2. According to the International Energy Agency's CO_2 emissions data, China's CO_2 emissions accounted for approximately 29% of the world's CO_2 emissions in 2019,

ranking first among all countries. They are followed by the United States (15%), the European Union (10%), India (7%), Russia (4%), and Japan (3%) (IEA, 2020). Due to China's methods of energy consumptions and CO_2 emissions issues, the nation is now drawing more attention and facing more pressure both domestically and internationally. It is struggling to develop a low carbon economy to mitigate global climate change (Wang, 2017). In 2011, China began shifting to a "green economy". China's 12th Five Year Plan for economic development is based on sustainable development goals, including substantial reductions in pollution and carbon intensities. The plan is backed by nearly half a trillion USD in proposed expenditure for environmental protection (IISD, 2012). China promised that its carbon dioxide emissions would peak by 2030 and it would strive to achieve carbon neutrality by 2060 (Xinhua News Agency, 2019). Therefore, China only has 9.5 years to achieve the peak of carbon dioxide emissions. Hence, it urgently needs to identify CO_2 sources. In March 2021, the National People's Congress of China approved The 14th Five-Year Plan for National Economic and Social Development and Long-Term Goals for 2035 (National People's Congress of China, 2021). The Five-Year Plan restated and approved the commitments by legislative procedure. Table 1 shows China's Commitments to CO_2 Reduction.

Table 1: China's Commitments to CO_2 Reduction

Date	Event	Commitment to CO_2 reduction	Source
1998.5	China signs the Kyoto Protocol	Developed countries began to undertake the obligation to reduce carbon emissions in 2005, while developing countries began to undertake the obligation to reduce carbon emissions in 2012.	UNFCC, 1998
2016.4	China signs the Paris Agreement	Long-term goals: it is expected that the world will be carbon neutral between 2051 and 2100; the global average temperature rise will be controlled above the pre-industrial level and below two degrees Celsius, and efforts will be made to control the temperature rise to within 1.5 degrees Celsius of the pre-industrial level.	UNFCC, 2016
2020.9	General Debate of the Seventy-fifth United Nations General Assembly	China will increase its national independent contribution, adopt more powerful policies and measures, and its carbon dioxide emissions will reach their peak before 2030. China strives to achieve carbon neutrality by 2060.	Xinhua News Agency, 2019
2020.12	2020 Climate Ambition Summit	By 2030, China's carbon dioxide emissions per unit of GDP will be reduced by more than 65% compared to 2005, non-fossil energy will account for approximately 25% of primary energy consumption, and forest reserves will increase by six billion cubic meters compared with 2005. The total installed capacity of wind power and solar power will exceed 1.2 billion kilowatts.	Xinhua News Agency, 2020
2021.3	The 14th Five-Year Plan for National Economic and Social Development and Long-Term Goals for 2035	Reduce the intensity of carbon emissions, support businesses where conditions permit, take the lead in reaching the peak carbon emissions, and formulate a carbon peak plan by 2030.	National People's Congress of China，2021

Source: compiled by the author, 2021

China's express delivery volume has ranked first in the world for the past six years (The State Post Bureau, 2020). According to Measures for the Administration of Express Delivery Market of the People's Republic of China, the term "express delivery" refers to "the posting and delivery activities that are completed quickly within a promised time limit" and the term "posting and delivery" refers to "the activities of delivering articles, such as letters, parcels, printed matter, to a specific individual or entity according to the name and address on the package" (Ministry of Transport of the People's Republic of China, 2008) . And according to the Postal Law of the People's Republic of China, "Mail delivery services within the scope prescribed by the State Council shall be exclusively operated by postal enterprises" (Standing Committee of the National People's Congress, 2015). Therefore, express delivery companies in China provide express delivery services, excluding mail delivery services and official

document delivery services of state organs, which are exclusively operated by designated postal operators. In December, 2020, it was reported that China's business volume of express deliveries exceeded 80 billion pieces for the first time (China Post and Express News, 2020). On June 1st, 2021, it was reported that the express delivery business volume exceeded 40 billion pieces, which broke the record again. The State Post Bureau predicted that the express delivery business volume in 2021 will exceed 95 billion pieces (BJNEWS, 2021). However, the energy consumption and GHG emissions of the express delivery sector have increased synchronously in the process of packaging, collecting, delivering, transportation, sorting and distribution. For example, in the process of packaging, the usage of tape for each parcel is 0.8 meters, and based on 80 billion express deliveries, the annual usage of tape exceeds 64 billion meters, which can circle the earth's equator nearly 1,600 times (Yang, 2020). It is estimated that "the total volume of express delivery will increase to approximately 220 billion in 2035" and "the GHG emissions of express deliveries are expected to reach approximately 75 $MtCO_2e$-1 by 2035, an amount equal to the GHG emissions from fuel combustion in many countries such as Israel and Austria in 2016" (Peng et al., 2021.1).

To curb the GHG emission surge in express delivery sector, many measures related to reducing, reusing, and recycling were taken, such as tape reduction, buffer reduction, simplifying packaging, recycling, new energy vehicles, hybrid modes of transportation, smart warehouses and so on. However, the pollution and emissions of China's express delivery sector are extremely high. To achieve the "carbon peak" and "carbon neutrality", the primary and basic task for the sector is carbon calculation. China's express delivery sector has attached great importance to environmental protection for

many years and has adopted various measures to reduce its impact on the environment, however, it had never calculated its carbon emissions until January, 2021.

There were many studies on GHG emissions in China over the last 10 years, from city level studies to key economic sector studies, such as “Detailed method is based on the research of challenges in developing an inventory of greenhouse gas emissions of Chinese cities: A case study of Beijing”（Li et al., 2017), “Carbon dioxide mitigation target of China in 2020 and key economic sectors” (Wang, 2013) and so on. Currently, sectoral reduction of CO_2 emissions is the focus (UNFCCC, 2007). According to Colli, “Calculation standards and tools help us analyse our sector, and effectively support a zero-carbon society” (Colli, 2020). The carbon emissions of the express delivery sector, the achievements of carbon-reduction in recent years, and the huge room for improvement in the future have not been reflected upon.

The transition from carbon emissions peak to carbon neutralization will take approximately 60 years for the European Union, 45 years for the United States, and 30 years for China, which means the speed and intensity of China's energy consumption, economic transformation, and greenhouse gas emission reduction are much faster than that of developed countries (21st Century Business Herald, 2021). The express delivery sector is one of the sectors which has severe GHG emission problems in China.

1.2 Research Question and Objectives

Are there any universally accepted guidelines and indicators to reduce CO_2 emissions in the express delivery sector? China’s express delivery sector has taken

various measures to curb its CO_2 emissions and control pollution. Are these measures to curb CO_2 emissions and control pollutions effective or not? Is there any room for improvement? Can it be improved in several different perspectives? To tackle the above problems, my research question "What are CO_2 emission sources in the operational process of China's express delivery sector?" should be answered first. This article is designed to identify CO_2 emission sources and calculate emissions in different operational processes of this sector. Only after obtaining the results can we "establish a reduction target, track emissions and trends, and manage inventory quality" (Innovation Centre for U.S., 2019).

The main objective of the research is to investigate CO_2 emission sources in the operational processes of China's express delivery sector. This article also investigates CO_2 emission sources and emissions calculations for each process of China's express delivery sector. The objectives are as follows:

1. To identify carbon dioxide emission sources in the operational process of China's express delivery sector.
2. To calculate emissions in different operational process.
3. To provide suggestions for stakeholders of the related operational process.

1.3 Significance of the Study

There are many studies focused on CO_2 emissions at the national level, regional levels with several provinces, and at individual province or large city level (Wang & Liang, 2013; Liu et al., 2011; Li et al., 2017). However, none of the methods used were

designed for estimating the CO_2 emissions of China's express delivery sector. SPB published a guidance of GHG emission inventory calculation without any data accumulation until January 2021. Since the emissions sources, emission factors and emissions of operational process in the express delivery sector were not listed, the document is not sufficient to serve as a guidance of CO_2 emissions reduction for the staff of different operational processes. To fill this gap, this article will identify CO_2 emission sources and calculate the emissions of different operational process in this sector.

With the CO_2 emissions results of different operational processes, we can determine which process generated the most CO_2, and what specific measures can be taken by different staff who work in different operational positions. If emission reduction measures have been taken, the research can help to calculate the emission reduction and truly calculate the emission reduction contributions. If emission reduction measures have not been taken, the article can propose targeted emission reduction measures in operational processes.

It provides SF Express, as well as the express delivery sector, with a list of emission sources and calculation methods for different operational processes. It provides references for SF staff to reduce CO_2 emissions in outlets, transit centres and transportation. It facilitates SF decision-makers to adopt more effective measures to reduce CO_2 in their organisations in a practical way. With a further understanding of SF express, the sector can further understand CO_2 emissions and reduction measures. It also provides governmental organisations with references to make a feasible policy based on

clear figure. In addition, it helps to identify all stakeholders to reduce the emissions of outsourcing, express delivery companies, and staff.

1.4 Structure of the Study

Section 1 introduces the background information of this topic, the article's research question and objectives, and the significance and structure of the study. Section 2 focuses on CO_2 emission estimations in the express delivery sector in China and around the world. The article compares the two major methods and concludes with their strengths and shortcomings. In this section, the most up-to-date research findings on CO_2 emissions in China's express delivery sector will be introduced. Section 3 is about the methodology adopted by the research. This chapter articulates the calculation formula of CO_2 emissions, analyses the flow chart of operational processes in China's express delivery sector, lists emission sources and emission factors, and introduces SF Express as a case study. Section 4 presents the lists of emission sources and activity data of SF Express in different operational processes, specifically outlets, transit centres and transportation in 2020. Section 5 provides CO_2 emission calculation results for outlets, transit centres, and transportation, by aggregating the activity data of SF Express. It also shows the results of the CO_2 emission calculation involved in all operational processes. Section 6 analyses the results, and gives recommendations from the perspective of operational processes, calculation method, express delivery industry and different stake-holders in China's express delivery sector. Section 7 is the conclusion, which provides a summary of this article, it contributions, and the limitations of the research.

2. Current Status of CO_2 Emission Estimation in Express Delivery Sector

The express delivery sector in different countries has its own unique circumstances and situations, however, they all urgently need to analyse their present situation and find methods to improve their CO2 emissions reduction and accelerate the realization of low-carbon environmental protection to facilitate sustainable development. Carefully crafted policies can help industries remain competitive while working towards carbon neutrality (Zusman et al., 2019). Currently, there are two main guidelines for GHG gas emissions inventory. According to a survey by World Resources Institute, among the top 500 global companies that conduct organizational carbon inventories,66% adopt GHG Protocol. However due to the highly recognition of the ISO brand, most sectors in China adopt ISO 14064 (Zhao,2011). United States Postal Service, Deutsche Post DHL Group, Royal Mail Group, Le Groupe La Poste and a total 19 participant countries have joined the International Post Corporation. They adopted the IPC method, which is based on the GHG Protocol. Otherwise, China adopted the State Post Bureau of P. R. of China adopted the SPB method based on ISO 14064-1.

2.1 International Practice

The International Post Corporation (IPC) is “a global initiative, consisting of 19 participants, whose mail volume account for 80% of the world, including Swiss post, United States Postal Service, Australia Postal Corp, and Deutsche Post DHL Group”

(IPC， 2019). The IPC has worked together with its member posts to develop dedicated and efficient services with global reach (Winklbauer,2020). “IPC’s Environment Measurement and Monitoring System program (EMMS), a sector-wide initiative to mitigate the postal sector’s contribution to global warming, was developed in 2008 in response to stakeholders’ requests for the postal sector to minimise its carbon footprint” (IPC, 2019).

The Greenhouse Gas Protocol adopted by the IPC develops standards and tools that help countries and cities track progress towards their climate goals (GHG Protocol, 2001). It was developed by the World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI) in 2004. The IPC uses the World Resources Institute Greenhouse Gas (GHG) Protocol, which is divided into scope 1, scope 2, and scope 3.

According to Table 2, scope 1 includes direct GHG emissions from operations that are owned or controlled by the company, including transport (vehicles, aviation, rail) and building-related (heating, gas, heating, fuel, oil, steam) emissions. Scope 2 includes indirect GHG emissions from the generation of purchased electricity, heat, steam, or the cooling consumed by the company. Electric vehicles are also included in this scope. Scope 3 includes other indirect emissions from sources within the company's value chain, including transport-related activities by vehicles not owned or controlled by the reporting entity, outsourced activities, etc. Business travel and employee commuting are calculated in scope 3. The members of the IPC from different countries account for and report emissions from scope 1, 2 and 3 separately.

2.2 China’s Practice

China's express delivery volume accounts for 60% of the world’s total and has ranked first in the world for the past six years. The energy consumption and emissions of the sector have increased synchronously (State Post Bureau of P. R. of China, 2019). Sustainable development research on China’s express delivery sector has only started in recent years. ISO 14064 was adopted in 2014 in China’s express delivery sector. The International Organisation for Standardisation (ISO) is an independent, non-governmental international organisation. The ISO 14064 series is GHG program neutral (ISO, 2020). The practice of GHG emissions accounting in China has not been closely integrated into the IPC-led GHG Protocol guidance in other countries of the express delivery sector.

According to Table 2, GHG emissions can be divided into three categories by the SPB method. Category 1 is direct greenhouse gas emissions, including vehicles, aviation kerosene, gasoline, diesel in the process of collection, delivery, and transportation. Category 2 is indirect greenhouse gas emissions, including electric vehicles, non-motor vehicles in the process of collection, delivery, and transportation, heating equipment, and power-consuming equipment in the process of comprehensive management. Scope 3 is other indirect greenhouse gas emissions including outsourced contract in the process of collection, delivery, and transportation, and express packaging supplies, including waybill, express envelope, plastic packaging bags, plastic woven fabric packaging bags, express packaging boxes, and tape.

Table 2: The Main Categories and Indicators of the IPC Method and SPB Method

Scope	**International Postal Corporation based on GHG Protocol (IPC Method)**	**Categories based on ISO 14064-1 (SPB Method)**	**Indicators (IPC Method)**	**Indicators (SPB Method)**
Scope 1 /Category 1	All direct GHG emissions from operations that are owned or controlled by the company, including buildings and transport.	Direct greenhouse gas emissions	Transport (Vehicles, aviation, rail); Heating (Gas, fuel, oil, steam); Other Scope 1	Collection, delivery, and transportation (Vehicles, aviation kerosene, gasoline, diesel); Logistics (boiler, stove)
Scope 2 /Category 2	Indirect GHG emissions from the generation of purchased electricity, heat, steam, or the cooling consumed by the company.	Indirect greenhouse gas emissions	Electricity (Including electric vehicles); Other Scope 2	Collection, delivery, and transportation (Electric vehicles, non-motor vehicles); Comprehensive management (Heating equipment, power-consuming equipment)
Scope 3 /Category 3	Other indirect emissions from sources within the company's value chain, including transport-related activities by the vehicles not owned or controlled by the reporting entity, business travel and employee commuting, outsourced activities, etc.	Other indirect greenhouse gas emissions	Scope 3a: outsourced road and transport; Scope 3b: Employee commuting and business travel	Collection, delivery, and transportation by outsourced contracts; Express packaging supplies 1. Waybill (5 sheets of waybill/E-waybill; ink) 2. Express envelopes 3. Plastic packaging bags (Degradable and Non-degradable) 4. Plastic woven fabric packaging bag (Recyclable/ Not recyclable) 5. Express packaging box （Polyethylene plastic, double corrugated cardboard, single corrugated cardboard, calcium plastic cardboard） 6. Tape (60mm/45mm)
Source	Adapted from the IPC Annul Report, 2019	Adapted from the Measurement Methods of Greenhouse Gas Emissions for Express Delivery, 2014	Adapted from the IPC Annul Report, 2019	Adapted from the Measurement Methods of Greenhouse Gas Emissions for Express Delivery, 2014

Source: Adapted from the IPC Annul Report,2019
and the Measurement Methods of Greenhouse Gas Emissions for Express Delivery, 2014.
Compiled by the author, 2021.

2.3 The Shortcomings of The Two Approaches

The IPC's CO_2 emission calculation method and the SPB CO_2 emission calculation method set up two specific methods for CO_2 emissions calculation in the express delivery sector. Both methods divide carbon dioxide emissions into three scopes. The content of the three scopes is roughly the same, however, the specific details are slightly different, and the key emission sources emphasised are also different. For example, the two methods have a different emphasis on emissions. The IPC's calculations focus on data collection and result analysis and omits the huge amount of packaging material. The SPB's calculations focus on packaging material and omit outsourcing, commuting, and travelling. Both methods have their own advantages and shortcomings in practice.

The strengths of IPC method are as follows: accumulating data on GHG emissions since the EMMS program was introduced in 2008; discusses and analyses the results from different perspectives for different countries; analyses the trend of GHG emission and recommends some effective measures to some areas and procedures. There are also some limitations to the IPC method. The major limitation is that the IPC confined their calculation method to members only.

The strengths of the SPB method in China are as follows: it lists most of the emission factors according to Chinese national conditions. For example, list the plastic bag emissions of China's express delivery sector; list the petroleum emission factor according to its own petroleum production standard. However, this method also has some limitations. For example, the emission factors vary according to the quality of the sources, however, there is only one other option for every emission source; leave

commuting and business travel unmentioned. The major limitation of the SPB method is that until the method was approved and published in 2014, there was no documentation of emission calculations in the express delivery sector in China. In January, 2021, an article named Low-carbon Pathways for the Booming Express Delivery Sector in China was published. The main results of the research include: a total of 8.8 Mt CO_2e of scrap packaging materials were generated by the express delivery sector in China in 2018; and its transportation related GHG emissions surged from 0.3 Mt in 2007 to 13.7 Mt CO_2e in 2018, with an average of 0.27 kgCO_2e, GHG emissions per delivery piece (Peng et al., 2021.1). The research mentioned that "GHG emissions varied with parcel size and packaging materials, ranging from 10 to 2800 kilo tonnes (kt) of CO_2e", which provides a rough estimate of the GHG emissions of the sector.

The IPC method does not provide a specific calculation method, it is only mentioned in the annual report for reference and is confined to the member countries. The SPB has formulated a national standard and issued it nationwide. The standard mainly refers to ISO 14064-1"Greenhouse Gas Part 1: Regulations and Guidelines for the Organisational Level of Greenhouse Gas Emissions and Clear Quantification and Reporting." The emission factors are based on authoritative international and domestic reference materials for greenhouse gas emission measurement, for example the "2006 IPCC Greenhouse Gas Inventory Guidelines" issued by the United Nations Intergovernmental Panel on Climate Change (IPCC), the IPCC Fourth Assessment Report, Swiss Ecoinvent 2.1 database, eBalance China Life Periodic database, etc. The IPCC inventory guidelines are compatible with the guidelines of the United States and the European Union in terms of emission source determination rules, quantity, and quality. The US Energy Information Administration (EIA), International Energy

Agency (IEA) and World Resources Institute (WRI) and other government departments and research institutions also use the IPCC's accounting methods when calculating international greenhouse gas emissions data. The emission factors and calculation guidance under the framework of SPB method are universal practice.

This article is based on the SPB method and incorporates the IPC calculation indicators that are not included in the SPB, such as employee commuting and other indicators. As the GHG emissions of the express delivery sector in China (within China's territory) and the average GHG emission per delivery have been calculated, the gap between the method and reality is that the emission sources in different operational processes have not been identified and total emissions in individual processes have not been calculated.

3. Methodology

This article studies CO_2 emissions in the express delivery sector by identifying the sources of emissions, using calculation formulation, collecting SF express's activity data, analysing the results, and drawing conclusions from different perspectives.

3.1 Formula of CO_2 Emission Calculation

The main GHG emission of the express delivery sector is CO_2. Although emissions of O_3, CH_4, N_2O, PFCs, HFCs, HCFCs and SF6 can be calculated by the formula (SPB, 2014), this article will focus on CO_2.

The research attempts to calculate the CO_2 emissions of the express delivery sector by using the methods of the State Post Bureau and following the guidance of the Measurement Methods of Greenhouse Gas Emissions for Express Delivery（YZ/T 0135-2014). All CO_2 emissions were calculated according to this formula (SPB, 2014):

AE=AD✕EF

Where AE is the emission of Greenhouse gases from greenhouse activities, in carbon dioxide equivalent（t CO_2e）

AD：the amount of activity, measured in tons (t).

EF：emission factor (t CO_2e/t)

3.2 Chart Flow of Operational Processes

According to Postal Law of the People's Republic of China, the whole process of China's express delivery sector includes sending, transportation, storage, and delivery (Standing Committee of the National People's Congress, 2015). The delivery routes can be divided into intracity routes and intraprovince routes within the territory of P. R. of China. Judging by the delivery distances and the number of outlets and transfer centres involved, the delivery routes can be illustrated as follows:

Route 1（Intracity）:

A sender wants to send an item. They can make a phone call or send a message on an APP. The delivery man at the outlet rides a tricycle to their location, packs their items in packing materials, scans the QR code by facilitated equipment, and delivers the item to his outlet. If the receiver's address is in the vicinity of outlet 1's business area, the outlet will assign another delivery man to send it by tricycle. It is the nearest route for a delivery.

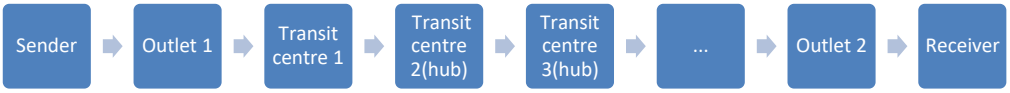
Route 2 (Intracity):

If the receiver' s address is not in the business scope of outlet 1, the item will be delivered directly to transit centre 1. If the address is in the business area of outlet 2, which also in the business area of transit centre 1, parcel will be delivered to outlet 2, then to the receiver by a delivery man of outlet 2.

Route 3 (Intracity):

Normally, for the intracity route, one main transit centre (hub) is sufficient for delivery in a small city or even in a metropolitan like Shanghai or Beijing, or any other large cities in China.

Route 4 (Interprovincial):



For the interprovincial route in China, two main transit centres (hub) in the delivery route are normally enough for a delivery. In the most remote and mountainous areas of China, three main transit centres (hub) are enough for a delivery.

As shown in the above intracity and interprovincial routes, the whole operational process of China's express delivery sector can be illustrated by a flow chart:

We can see from the operational process of a parcel delivery that the route of a parcel includes the sender, outlet 1 nearby, transit centre 1 which collect nearby outlets' items, transfer 0-2 times to another transit centre whose outlet is close to the receiver and, finally, delivery from the nearby outlet to the receivers. The outbound and inbound items are all processed in a similar way within China's territory. However, the activity data of outbound and inbound items outside China's territory cannot be easily collected. The flow chart of all the delivery routes shows that sending and dispatching are handled

by outlets, storage and transferring are handled in transit centres, and the whole operational process is connected via transportation.

The delivery route runs from the outlets, the transit centres and to other outlets by transportation. Therefore, by listing the emission sources, analysing them and calculating the emissions of outlets, transit centres and transportation, we can determine which emission sources and operational processes emit the most, and what kinds of measures we can focus on in several important processes. The analysis and calculation of emission sources in outlets, transit centres and transportation help us to know which is the key CO_2 emission process and sources of China's operational processes.

Based on the CO_2 emission results of different operational process, we can take specific measures to control CO_2 emissions in key operational processes and the major emission sources of China's express delivery sector.

3.3 Emission Sources

The article tries to collect as many emission sources in the processes of express delivery sector as many as possible, and categorise them into outlets, transit centres and transportation. In different operational processes, the article further classified emission sources into several categories, such as equipment, building-related, aviation, road, ship, railway, etc.

However, some emission sources maybe not included. Some new technologies and applications may be applied in the sector in the future. However, with the emission sources of fuels and electricity as information and guidance, by choosing the emission factor of the new application and collecting the activity data, we can determine the CO_2 emissions of this new application.

3.4 Emission Factors

The emission factors are collected from the Measurement Methods of Greenhouse Gas Emissions for Express Delivery（YZ/T 0135-2014) (SPB,2014). While there are many emission factors for different emission sources, the article will apply emission factors on the basis of the Measurement Methods of Greenhouse Gas Emissions for Express Delivery（YZ/T 0135-2014) (SPB,2014), which are suitable for China's national conditions. Most of SPB's emission factors are from the 2006 IPCC National Greenhouse Gas Inventory Guidelines. Some of them are from the Ecoinvent2.1 Database, CLCD Public, Ecoinvent2.1, EBalance and China Life Cycle Database, because they are more suited to China's national conditions and express delivery situation. Below is the CO_2 emission factor of different emission sources. Some emission factors, such as commuting, water, gasoline and diesel related to aviation are not listed in SPB Measurement Methods. Table 3 shows the emission factors involved in China's express delivery sector.

Table 3: Emission Factors Involved in China's Express Delivery Sector

NO.	Emission Sources	CO_2 Emission Factor	Unit	Source
1	Road transportation (gasoline)	2.985	tCO_2/t	2006 IPCC National
2	Road transportation (Diesel)	3.161	tCO_2/t	Greenhouse Gas Inventory
3	Road transportation (liquefied petroleum gas)	3.166	tCO_2/t	Guidelines
4	Road transportation (natural gas)	2.184	tCO_2/t	2006 IPCC
5	Railway (diesel)	3.161	tCO_2/t	2006 IPCC
6	Aviation (gasoline)	2.985	tCO_2/t	2006 IPCC
7	Aviation (kerosene)	3.050	tCO_2/t	2006 IPCC
8	Ship (gasoline)	2.985	tCO_2/t	2006 IPCC
9	Ship (kerosene)	3.097	tCO_2/t	2006 IPCC
10	Ship(diesel)	3.161	tCO_2/t	2006 IPCC
11	Ship (liquefied petroleum gas)	3.166	tCO_2/t	2006 IPCC
12	Ship(gasoline)	2.184	tCO_2/t	2006 IPCC
13	Waybill	1.872	$kgCO_2e/kg$	Ecoinvent2.1 Database
14	Express envelope	2.528	$kgCO_2e/kg$	Ecoinvent2.1 Database
15	Express packaging box	1.137	$kgCO_2e/kg$	Ecoinvent2.1 Database
16	Plastic packaging bag	3.240	$kgCO_2e/kg$	CLCD Public
17	Plastic woven fabric packaging bag	2.507	$kgCO_2e/kg$	Ecoinvent2.1
18	Tape	2.765	$kgCO_2e/kg$	Ecoinvent2.1
19	Electricity (thermal power)	0.960	tCO_2e/MWh	EBalance
20	Heat (coal)	0.408	tCO_2e/t	China Life Cycle Database Ecoinvent2.1 Database
21	Water	-	-	
22	Gas	-	-	
23	Paper	-	-	
24	Waste		-	
25	Commute	-	-	
…	…			

Source: compiled by the author, 2021

3.5 Case Study: SF Express

Founded in Guangdong in 1993, SF Express has become a leading express and logistics service provider in China. It provides delivery services and solutions suitable for customers, continuously optimises the service quality, and adopts innovative technologies. It is believed that SF Express integrates their responsibility for sustainable environmental and social development with their business objectives and long-term visions. This research utilises a case study of SF Express. The activity data is collected

from the 2020 S.F. Holding Co., Ltd. Sustainability Report. There are three main reasons to choose SF Express as a case study for this research.

First, SF Express is one of the top express delivery companies in China. China's express delivery sector gained legal status in 2009, when the Standing Committee of National People's Congress amended the Postal Law of the People's Republic of China. Since 2009, private express delivery companies have taken off and the express delivery sector has experienced rapid growth. As of June, 2021, there are eight listed express delivery companies in China, including SF Express, STO, Yunda, ZTO, YTO, JD.COM, Best Logistics, and Deppon Express. Table 4 presents detailed information about the eight listed companies, including number of franchisee, outlets, deliverymen, and coverage rate. According to the updated statistics provided by SPB, SF has the most deliverymen (390,000) among the eight companies without any franchisees (Fan, 2021). Due to SF Express' business model, which is to directly manage itself without franchisees, SF Express can mobilise the company and enjoy a relatively better reputation among the eight listed delivery companies. With 634,328 staff (2020 SF Sustainability Report, 2021), 39,000 delivery men, 19,000 outlets, 87.4% town coverage (Fan,2021) and without franchisee outsourcing, SF Express collects activity data generated by itself.

Table 4: Major Express Delivery Companies in China

No.	Company	Franchisee	Outlets	Deliverymen	Coverage
1	SF Express	/	19000	390,000	87.4% Town-Level
2	STO	4340	/	134,000	87.0% Town-Level
3	Yunda	3875	32624	196,000	97.7% Town-Level
4	ZTO	5350	30000	/	92.0% Town-Level
5	YTO	4650	38375	/	97.3% County-Level
6	JD.COM	/	15280	190,000	444 Cities
7	Best Logistics	9888	/	/	97.2% County-Level
8	Deppon Express	/	9877	67,800	93.5% Town-Level
Total		28,103	145,156	977,800	

Source: adapted from SPB newsletter, 2021

Second, SF Express is the only express delivery company in China that has been collecting and releasing CO_2 related data in their annual report since 2019. It is the first company in China to have sustainable awareness and accumulate CO_2 relevant data. The activity data recorded by SF Express helps to calculate CO_2 emissions in the express delivery sector in China, including transit centres, outlets and transportation. The 2020 S.F. Holding Co., Ltd. Sustainability Report stated that "In 2020, under the background of striving for reaching CO2 emissions peak before 2030 and achieve carbon neutrality before 2060, it continued to increase energy conservation and emission reduction, deepened the green enterprise transformation, actively established the sector benchmark, and contributed to the achievement of the carbon neutral goal" (SF Express, 2021). It is the first express delivery company in China to integrate national carbon goals with the enterprise's daily operation.

Third, this article hopes to use SF Express' example to develop a further understanding of China's express delivery sector. As my research question is "What are CO_2 emission sources in every operational process of China's express delivery sector?" I will analyse the operational process of SF Express, then list the emission sources in SF Express' outlets, transit centres and transportation in detail. The analysis and results will help to provide the express delivery sector with a list of emission sources of the main operational processes and calculation methods for outlets, transit centres and transportation, to provide references for staff to reduce CO_2 in different operational processes, and to facilitate decision-makers to adopt more effective measures to reduce CO_2 in their organisations. As the operational process of China's express delivery services are similar, with a further understanding of SF express, the article will have a further understanding of CO_2 emissions and reduction in China's express delivery sector.

4. Emission Sources of Operational Processes of SF Express

As all the handlings are dealt with in outlets, transit centres and transportation. The article will list emission sources and activity data in outlets, transit centres and transportation, respectively. Activity data is collected from SF Express' 2020 Annual Report.

4.1 Emissions Source Involved in Outlets

Emission sources in outlets include the equipment of the outlets and delivery men (barcode data collector, APPs), packaging (waybill, express envelope, plastic packaging bag, plastic woven fabric packaging bag, express packaging box, and tape), commuting and building-related emissions (air conditioner, cooling, paper, lighting, water). The vehicles of outlets and delivery men are classified as transportation, which will be discussed later.

The activity data collected by SF Express includes electricity, packaging (waybill, express envelope plastic packaging bag, express packaging box and tape. Plastic woven fabric packaging bag is excluded). The activity data of water, paper and waste are also collected by SF. The activity data of electricity, including equipment and building-related emissions, is collected as well. Table 5 lists the emission sources in the outlets and the activity data of SF express.

Table 5: Emissions Sources Involved in Outlets

Category	Emission Source	Activity Data (SF Express)
Equipment	Electricity (barcode data collector, APP, et.)	Electricity (barcode data collector, APP, building-related electricity...): 252,084,789.6kW•h
Packaging	Waybill	22,287,605.8kg
	Express envelope	75,051,139.1kg
	Plastic packaging bag	26,761,002.0kg
	Plastic woven fabric packaging bag	/
	Express packaging box	231,477,671.1kg
	Tape	26,316,984.3kg
Building-related	Electricity (air-conditioner, cooling, lighting)	/
		43,600.3t
	Water	/
	Gas	31,961.5kg
	Paper	4,098,124.8kg
	Waste	
Commute	motorbike, tricycle, car	/
	bus, metro, walk, bicycle	

Source: emission sources were compiled by the author, 2021;
activity data was collected from the SF Express Sustainability Report, 2020.

4.2 Emissions Source Involved in Transit Centres

Emission sources in transit centres include equipment (RFID, sorting robots, double-layer sorting machines, cold chain preservation, forklifts, drones, storage et.), building-related (air-conditioner, cooling, lighting, water, gas, paper waste, et.) and commuting. Vehicles in the transit centre are classified as transportation, which will be discussed later.

SF Express collected activity data on the electricity use of equipment and building-related emissions, as well as renewable energy generation. Consumption data regarding water and paper are also collected by SF Express. Table 6 lists the emission sources in the transit centre and activity data of SF express.

Table 6: Emission Sources in Transit Centres

Category	Emission Source	Activity Data (SF Express)
Equipment	Electricity (RFID, Sorting robots, double-layer sorting machines, cold chain preservation, forklifts, drones, storage, etc.)	Electricity (Equipment, building-related electricity...): 299,143,742.31 kW•h (Renewable energy generation 1,577,170.5 kW•h)
Building-related	Electricity (air-conditioner, cooling, lighting) Water Gas Paper Waste	/ 620,251.7t / 16,703,832.4kg /
Commute	Walk, bicycle motorbike, tricycle, car Bus, metro	/

Source: emission sources were compiled by the author 2021;
activity data was collected from the SF Express Sustainability Report, 2020.

4.3 Emissions Source Involved in Transportation

Emission sources in transportation include routes from customers to outlets, outlets to customers, outlets and transit centres, transit centres to outlets, and original transit centre to destination transit centre. In this part, outlet vehicles account for a huge amount of emissions through scooters, non-motor vehicles, tricycles, tractors, buses, motorcycles, cars, vans, electric locomotive and so on. The vehicles of outlets (including first-mile and last-mile delivery) and between outlets and transit centres are also classified as transportation. From the original transit centre to the destination transit centre, road, aviation, ship and railway are part of a hybrid way of transportation.

SF Express collected data on road and aviation, but have not collected data on ships and water. For road transportation, SF Express classified vehicles as electric, gasoline, and diesel. For aviation, SF Express collected data on kerosene, as well as water, electricity, gasoline, and diesel. Table 7 lists the emission sources in transportation and the activity data of SF express.

Table 7: Emission Sources in Transportation

Transportation	Emission Source	Activity Data (SF Express)
Customers ⇋ Outlet	Vehicles (electric, gasoline, diesel): cars, vans, trucks， tractors, buses, motorcycles, tricycle， electric locomotives, e-bicycles, non-motor vehicle, scooters, trolleys, walk-buggies	Road: Electricity 117,337,376.5 kW•h Gasoline 69,067,775.7L Diesel 913,116,365.4L
Outlet ⇋ Transit centre	Vehicles (electricity, gasoline, diesel): Trucks, vans, cars	Aviation: Kerosene 500,657.7t Aviation related: Water 39,116.0t; Electricity 7,731,677.5 kW•h; Gasoline 81,891.6L; Diesel 1,149,079.0L.
Transit centre ⇋ Transit centre	Road Aviation Ship Railway	Ship:/ Railway:/

Source: emission sources were compiled by the author in 2021;
activity data was collected from the SF Express Sustainability Report, 2020.

5. CO_2 Emission Calculation in Each Process of SF Express

This article divides the operational processes into outlets, transit centres, and transportation. For each operational process, the article lists the emission sources, emission factors, collects activity data (SF Express, 2021), and calculates the annual CO_2 emissions (tCO_2) of SF Express in 2020.

5.1 Emissions Calculation Involved in Outlets

The CO_2 emissions of outlets are calculated through the following steps, and the results are shown in Table 8.

Step 1: the article lists emission sources in the outlet. The list of emission sources in outlets includes packing materials including waybills, express envelops, express packaging boxes, plastic packaging bags, plastic woven bags and tape, which are mostly used in outlets.

Step 2: the article lists emission factors according to the emission sources in outlets. There is insufficient data on several emission factors, including water, paper, waste, commuting, business travel and outsourcing. Water, paper, and waste have not been listed in relation to the situation of China's express delivery sector or China's national condition. Commuting and business travel are not listed in SPB's method. While

outsourcing is listed in the SPB method, there are different kinds of outsourcing and the emission sources vary. In practice, it has not been documented until now.

Step 3: the article collects activity data on SF express in 2020.

Step 4: according to the data on annual CO_2 emissions in outlets: packaging materials emit the majority of CO_2, the normally used express packaging box and express envelop are the two major emission sources, with a total of 658,257.88 tCO_2, accounting for 73% of total emissions in outlets. Electricity is the second largest emitter in outlets, with emissions of 242,001.40 tCO_2 accounting for 27% of the total emissions in outlets.

Table 8: Emission Calculation for Outlets

Operational Process	Emission Source	Emission Factor	Activity Data (unit)	Annual CO_2 emissions (tCO_2)
Outlets	Waybill	1.872 $kgCO_2e/kg$	22,287,605.8 kg	41,722.40
	Express envelope	2.528 $kgCO_2e/kg$	75,051,139.1kg	189,729.28
	Express packaging box	1.137 $kgCO_2e/kg$	235,122,326.8 kg	267,334.09
	Plastic packaging bag	3.240 $kgCO_2e/kg$	26,761,002.0 kg	86,705.65
	Plastic woven fabric packaging bag	2.507 $kgCO_2e/kg$	/	/
	Tape	2.765 $kgCO_2e/kg$	26,316,984.3 kg	72,766.46
	Packaging materials Total CO_2 emissions			**658,257.88**
	Electricity	0.960tCO_2e/MWh	252,084,789.6 kW•h	242,001.40
	Heat (coal)	0.408 tCO_2e/t	-	-
	Renewable energy generation	--	-	--
	Water	--	43,600.3 t	--
	Paper	--	31,961.5kg	--
	Waste	--	4,098,124.8 kg	--
	Commuting	--		--
	Business travel	--	-	--
	Outsource	--	-	--
Total CO_2 emissions (Outlets)				**900,259.28**

Source: emission sources and emission factors were compiled by the author, 2021; activity data was collected from SF Express Sustainability Report, 2020.

5.2 Emissions Calculation Involved in Transit Centre

CO_2 emissions in transit centres are calculated through the following steps, and the results are shown in Table 9.

Step 1: the article lists the emission sources in transit centres, of which electricity emits the most CO_2. The usage of RFID, sorting robots, double-layer sorting machines, cold chain preservation, forklifts, drones, and storage all consume electricity. Another important phenomenon is that companies are starting to generate renewable energy.

Step 2: this article lists the emission factors related to transit centres. There is insufficient data on several emission factors, for example, water, paper, and waste were not listed as emission factors, however, SF Express consumes 620,251.7 t/year of water and 16,703,832.4 kg/year of paper. The CO_2 emissions of commuting and business travel are also not included.

Step 3: this article collected the activity data of SF group in 2020. Electricity and renewable electricity emissions account for the majority of CO_2 emissions in the transit centres. There is no mention of the emission factor and government reward policy for renewable energy generation.

Step 4: the data and results regarding the annual CO_2 emissions of the transit centre show that electricity emits the majority of CO_2 in the transit centre. However, with data on the heat, water, paper, waste consumption of SF Express, there is no evidence of emission factors. For commuting and business travel, there are neither emission factors nor activity data. The emission calculations for the transit centre are illustrated below:

Table 9: Emission Calculation Involved in Transit Centre

Operational Process	Emission Source	Emission Factor	Activity Data (unit)	Annual CO_2 emissions (tCO_2)
Transit Centre	Electricity	0.960tCO_2/MWh	299,143,742.31kW•h	287,178.00
	Heat (coal)	0.408 tCO_2e/t	-	
	Renewable energy generation	--	1,577,170.5 W•h	--
	Water	--	620,251.7 t	--
	Paper	--	16,703,832.4 kg	--
	Waste	--	-	--
	Commuting	--	-	--
	Business travel	--	-	--
Total CO_2 emissions (Transit Centre)				**287,178.00**

Source: emission sources and emission factors were compiled by the author, 2021; activity data was collected from the SF Express Sustainability Report, 2020.

5.3 Emissions Calculation Involved in Transport

CO_2 emissions related to transportation were calculated through following steps, and the results are shown in Table 10.

Step 1: this article will list the emission sources in transportation. There are four methods of transportation: land, aviation, railway, and ship. Aviation related water, electricity, gasoline, and diesel are not listed in the SPB method.

Step 2: this article lists the emission factors related to transportation. Insufficient data on the emission factors was found. According to the practice of SF Express, aviation related water, electricity, gasoline, and diesel consume a huge number of emissions, however the SPB method lacks the emission factor of the above emission sources. Therefore, a large amount of aviation related emission cannot be calculated.

Step 3: this article collects activity data related to the transportation of SF Express in 2020. According to SF Express' data, land transportation and aviation are the two main methods of delivery. However, ship and railway are also reasonable methods of long-distance transportation. 85%, 10%, and 5% of parcels were delivered via road, air, and railway transportation respectively (Peng et al., 2021.1). Railways are promoted for efficiency and low emissions, and SF has some railway-related transportation. However, currently, no data is collected in practice.

Step 4: this article will calculate the annual CO_2 emissions in transportation. Road transportation emits 2,577,666.32 tCO_2, accounting for 62.8% of transportation emissions. Aviation emits 1,527,005.99 tCO_2, accounting for 37.2% of transportation emissions. In road transportation, diesel vehicles emit 2,425,513.31 tCO_2, accounting for 94.10% of CO_2 emissions, followed by gasoline 5.90%, and electricity 4.37%. SF Express, as a pioneer delivery company in China, has several airplanes. However, the main emission source of aviation is kerosene, which consumes a lot of CO_2. SF collects data on aviation ground water, aviation round gasoline usage and etc, however SPB does not provide emission factors. SPB provides emission factors for railway and ship, however, SF does not have any activity data for railway and ship.

Table 10: Emission Calculation for Transportation

Operational Process	Emission Source	Emission Factor	Activity Data (unit)	Annual CO_2 emissions (tCO_2)
Transportation	Road transportation (electricity)	0.960 tCO_2e/MWh	117,336,376.5kW•h	112,642.92
	Road transportation (gasoline)	2.985 tCO_2/t	50972.53t	152,153.00
	Road transportation (diesel)	3.161 tCO_2/t	767,324.68t	2,425,513.31
	Road transportation (liquefied petroleum gas)	3.166 tCO_2/t	-	
	Road transportation (natural gas)	2.184 tCO_2/t	-	
	Road transportation of Total CO_2 emissions			**2,577,666.32**
	Aviation (gasoline)	2.985 tCO_2/t		
	Aviation (diesel)			
	Aviation (kerosene)	3.050 tCO_2/t	500,657.7t	1,527,005.99
	Aviation ground water	--	39,116.0t	--
	Aviation ground electricity	--	7,731,677.5kW.h	--
	Aviation ground gasoline usage	--	81,891.6L	--
	Aviation ground diesel consumption	--	1,149,079.1L	--
	Aviation Total CO_2 emissions			**1,527,005.99**
	Railway (diesel)	3.161 tCO_2/t	-	-
	Ship (gasoline)	2.985 tCO_2/t	-	-
	Ship (kerosene)	3.097 tCO_2/t	-	-
	Ship(diesel)	3.161 tCO_2/t	-	-
	Ship (liquefied petroleum gas)	3.166 tCO_2/t	-	-
	Ship(gasoline)	2.184 tCO_2/t	-	-
	Outsource	--	-	--
Total CO_2 emissions (Transportation)				**4,104,672.31**

Source: emission sources and emission factors were compiled by the author, 2021; activity data was collected from the SF Express Sustainability Report, 2020.

5.4 Emissions Calculation Involved in All Operational Processes

Table 11 shows that the total CO_2 emissions of SF Express in 2020 is 5,292,109.59 tCO_2. Transportation (4,104,672.31 tCO_2) accounts for 78% of the total CO_2 emissions, outlets (900,259.28 tCO_2) 17%, and transit centres (287,178.00 tCO_2) 5%. Furthermore, the packaging materials (in outlets) (658,257.88 tCO_2) accounts for 12% of total CO_2 emissions, and electricity (both in outlets and transit centres) accounts for 10% of total CO_2 emissions. The outsources of transportation have not been calculated by SF Express or China's express delivery sector. However, outsourcing in

transportation and transit centres has a variety of activities in other express delivery companies. According to Table 4, SF is a directly owned company without franchisees, and the eight major express delivery companies have a total of 28,103 franchisees.

Table 11: Emission Sources and Calculation for All Operational Processes

Operational Process	Emission Source	Emission Factor	Activity Data (unit)	Annual CO_2 emissions (tCO_2)
Outlets	Waybill	1.872 $kgCO_2e/kg$	22,287,605.8 kg	41,722.40
	Express envelope	2.528 $kgCO_2e/kg$	75,051,139.1kg	189,729.28
	Express packaging box	1.137 $kgCO_2e/kg$	235,122,326.8 kg	267,334.09
	Plastic packaging bag	3.240 $kgCO_2e/kg$	26,761,002.0 kg	86,705.65
	Plastic woven fabric packaging bag	2.507 $kgCO_2e/kg$	/	/
	Tape	2.765 $kgCO_2e/kg$	26,316,984.3 kg	72,766.46
	Total CO_2 emissions of packaging material			**658,257.88**
	Electricity	0.960tCO_2e/MWh	252,084,789.6 kW•h	242,001.40
	Heat (coal)	0.408 tCO_2e/t	-	-
	Renewable energy generation	--	-	--
	Water	--	43,600.3 t	--
	Paper	--	31,961.5kg	--
	Waste	--	4,098,124.8 kg	--
	Commuting	--		--
	Business travel	--	-	--
	Outsource	--	-	--
Total CO_2 emissions (Outlets)				**900,259.28**
Transit Centre	Electricity	0.960tCO_2e/MWh	299,143,742.31kW•h	287,178.00
	Heat (coal)	0.408 tCO_2e/t	-	
	Renewable energy generation	--	1,577,170.5 W•h	--
	Water	--	620,251.7 t	--
	Paper	--	16,703,832.4 kg	--
	Waste	--	-	--
	Commuting	--	-	--
	Business travel	--	-	--
Total CO_2 emissions (Transit Centre)				**287,178.00**
Transportation	Road transportation (electricity)	0.960 tCO_2e/MWh	117,336,376.5kW•h	112,642.92
	Road transportation (gasoline)	2.985 tCO_2/t	50972.53t	152,153.00
	Road transportation (diesel)	3.161 tCO_2/t	767,324.68t	2,425,513.31
	Road transportation (liquefied petroleum gas)	3.166 tCO_2/t	-	
	Road transportation (natural gas)	2.184 tCO_2/t	-	
	Total CO_2 emissions of road transportation 2,577,666.32			
	Aviation (gasoline)	2.985 tCO_2/t		
	Aviation (diesel)			
	Aviation (kerosene)	3.050 tCO_2/t	500,657.7t	1,527,005.99
	Aviation ground water	--	39,116.0t	--
	Aviation ground electricity	--	7,731,677.5kW.h	--
	Aviation ground gasoline usage	--	81,891.6L	--
	Aviation ground diesel consumption	--	1,149,079.1L	--
	Total CO_2 emissions of aviation			**1,527,005.99**
	Railway (diesel)	3.161 tCO_2/t	-	-
	Ship (gasoline)	2.985 tCO_2/t	-	-
	Ship (kerosene)	3.097 tCO_2/t	-	-
	Ship(diesel)	3.161 tCO_2/t	-	-
	Ship (liquefied petroleum gas)	3.166 tCO_2/t	-	-
	Ship(gasoline)	2.184 tCO_2/t	-	-
	Outsource	--	-	--
Total CO_2 emissions (Transportation)				**4,104,672.31**
Total CO_2 emissions (SF Express)				**5,292,109.59**

Source: emission sources and emission factors were compiled by the author, 2021; activity data was collected from the SF Express Sustainability Report, 2020.

6. Discussion and Recommendations

This article calculates the CO_2 emissions of different operational processes of SF Express in China using limited data and emission factors. The total CO_2 emissions of SF Express in 2020 are 5,292,109.59 tCO_2, among which, transportation accounts for 78%, outlets 17%, and transit centres 5%. In transportation, road transportation accounts for 62.8% and aviation 37.2%. In road transportation, diesel vehicles account for 94.10% of CO_2 emissions, followed by gasoline and electricity. In outlets, packaging, which is the major emission source, accounts for 73% of emissions. In transit centres, due to the lack of data on some emission factors and activity data on water, paper, waste etc., electricity is the only emission source. Furthermore, packaging materials in outlets (658,257.88 tCO_2) account for 12% of total CO_2 emissions, and electricity in outlets and transit centres accounts for 10% of total CO_2 emissions. Based on the results, the following four sections will provide recommendations from different perspectives.

6.1 Recommendations for Each Operational Process

6.1.1 Recommendations for Transportation

At present, many companies are focusing on providing an efficient delivery service and better user experience at the expense of certain indicators of sustainable development. Express delivery companies urgently need to strike a balance between economic interests and sustainable interests.

(1) Road transportation, which emits 2,577,666.32 tCO_2, accounts for 62.8% of the emissions in transportation. Diesel vehicles emit 2,425,513.31 tCO_2, which accounts for 94.10% of transportation emissions, followed by gasoline vehicles 5.90%, and electric vehicles 4.37%. The above figures show that road transportation is the biggest source of CO_2 emissions in SF Express. In recent years, the sector has begun gradually transferring to alternative-fuel vehicles.

International delivery companies observed the phenomenon that road transportation emits larger amount of CO_2 than other category in express delivery sector and took a step further than China. Since 2012, the total number of IPC vehicles has increased by 88,000 (16%), while the total number of alternative-fuel vehicles has increased by an impressive 80,000 (116%) (IPC, 2019). The percentage of alternative-fuel vehicles in the fleet increased from 13% in 2012 (69000/538,000) to 24% in 2018 (148,000/626,000) (IPC, 2019). This data demonstrates the international participants' ongoing efforts to increase the proportion of alternative models within their vehicle fleets (IPC, 2019).

In China, to curb the GHG emission surge, alternative-fuel vehicles are promoted. 2018 figures from the Electric Vehicle World Sales Database shows "a doubling in overall sales from the previous year and even higher year-on-year growth, and EV sales have been growing at 40-50% every year" and "EV infrastructure is also increasing rapidly but a significant amount of additional investment will be required" (Dimsdale, 2019). On a national, provincial and city level, alternative-fuel vehicles are promoted vigorously.

The promotion of alternative-fuel vehicles, especially electric vehicles, in China's express delivery sector is urgently required. With more than10 categories of alternative-fuels: CNG, LNG, LPG, E85, M85, Electronic, Hybrid, Hydrogen, Bioethanol (IPC, 2019), there are many different types of alternative-fuel vehicles, which include vans, tricycles, and motorbikes. In 2014, among the top 50 cities with the largest business volume in China, 40 cities promoted alternative-fuel vehicles (SPB, 2015). In 2019, SF Express deployed 10,651 new energy transportation vehicles in 41 regions of 22 provinces and cities, saving 24,000 tons of fuel per year (Development and Research Centre of the State Post Bureau, 2020). Electric vehicles are widely used in the field of short-distance express logistics, such as first-mile and last mile delivery. It is easier to integrate smaller alternative-fuel vehicles for first-mile, last-mile, and urban area routes. According to a survey, the average daily mileage of transportation and last-mile delivery vehicles at the outlets of most express companies does not exceed 150 kilometres. At present, most of the small electric vans launched on the market have a range of 150-250 kilometres (theoretical data) and are generally suitable for the express delivery sector (SPB, 2015).

There are few large alternative-fuel freight vehicles and long-distance transportation vehicles. However, there are insufficient charging points and incomplete rechargeable public supporting facilities. The supporting infrastructure for long-distance charging requires the planning and deployment of charging stations. The battery life is reduced in bad weather and it can easily fail in winter. The drivers dare not to turn on the air conditioner in the car in winter (Hua, 2021). When the air conditioner is turned on, the battery life is likely to be halved. Fuel efficiency, battery replacement and after-sales service are also a problem. It is necessary to open a public charging area and meet

the needs of night charging for express vehicles and supplementary charging during the day. The performance of new energy vehicles is unstable and the driving force for steep hills is insufficient. They are not suitable for driving in the vast mountainous areas in western China such as Chongqing and Sichuan, not even for last mile delivery. At present, alternative-fuel vehicles are in their infancy, many technologies have not been completely broken through, and the supporting facilities are not perfect.

(2) Although aviation emits 1,527,005.99 tCO_2, accounting for 37.2% of transportation emissions, express companies have purchased many airplanes to improve the efficiency of delivery. From 2011 to 2020， the number of cargo planes in this sector increased from 54 to 124 (Fu, 2021). Consequently, aviation and aviation-related emission have increased rapidly in recent years. As China's express delivery companies are experiencing a trend of rapid development, the countermeasures for CO_2 limitation should be implemented as soon as possible.

(3) There was no data collected on railway and water transportation for SF express in 2020. It is reported that "As of June 30, 2018, SF Express has opened 77 high-speed rail lines" (Logistics CTO, 2018). Railway is one of the most energy-efficient road vehicles. The energy consumption per unit cargo and the main pollutants emitted per unit volume of railway freight are only 1/7 and 1/13 of that of road freight, respectively (Chinabaogao.Co, 2018). Railway transportation is an energy-saving way to replace diesel truck freight. In practice, road-to-rail or hybrid transportation can be adopted to increase the proportion of railway transportation. SF Express can start data collection and accumulation on railway transportation.

The cost of replacing fuel and vehicles is much higher than that of simplifying express delivery packaging; however, the user experience and a reputation for high-efficiency and high-quality services is easily obtained by utilising sustainable express delivery packaging, which express delivery enterprises are eagerly pursuing. Therefore, regulators must push harder on transportation.

6.1.2 Recommendations for Packaging in Outlets

China's express delivery volume accounts for 60% of the global total, ranking first in the world for the past six years, while the energy consumption and emissions of the sector have increased synchronously (State Post Bureau of P. R. of China, 2019). As e-commerce continues to expand, growing demand for e-commerce delivery makes it more difficult to reduce carbon emissions due to the delivery methods. “Online retail sales grew 25% annually over the past decade” “the boom in China’s online retail business has been enabled by the rapid development of China’s express delivery…” “with around 80% of the deliveries due to online shopping” (Peng et al., 2021.1). Every item must be delivered with packaging. The online sellers send goods to the buyers and the sellers often pack layers of the express packaging for fear of damage. Excessive goods and packaging combined lead to packaging problems. Therefore, packaging materials are the major emitters in outlets.

Packaging materials emit the majority of CO_2, with a total of 658,257.88 tCO_2. The normally used express packaging box (267,334.09 tCO_2) and express envelope (189,729.28 tCO_2), accounting for 40.61% and 28.82% of packaging emissions

respectively, are the two major emission sources. We are delighted to see that China's express delivery sector has made great efforts in packaging. Even before the IPC included the CO_2 emissions of express packaging in the total emissions, China's express delivery sector has made corresponding arrangements. In terms of packaging reduction, China's express sector customises packaging, uses tape-free and water-soluble tape, uses QR codes instead of electronic waybills, simplifies packaging, reduced the number of layers of cartons, reuses transit bags, shares courier boxes, and sets up packaging recycling devices. In terms of recycling technology, China's express delivery companies have established their own packaging research laboratory, and integrated degradable technology.

If this article must make one or two suggestions on packaging, I will say that the companies' measurement unit is based on daily practices, and it is inconvenient to calculate the carbon emissions. The sector's calculation of CO_2 emissions is still in its infancy, and there are still some problems in the statistical units and specific calculations. For example, the Green Development Report of China Post Express Industry (2019-2020) stated that "In 2019, Y company invested in 5.8 million recyclable transit bags" "Saving about 570,000 tons of ink" and "61.7 billion sheets of paper" and so on (Development and Research Centre of the State Post Bureau, 2020). How can the outlets, transit centres and outsources of express delivery companies calculate carbon emissions? How can they link the daily CO_2 emissions with China's national CO_2 emissions peak and neutralisation commitments? If the standards are met, are there any rewards for outlets, transit centres and staff? If the standards are not met, are there any penalties? Furthermore, companies classify emission sources according to sector standards and collect statistics in accordance with the corresponding quantitative

units. When calculating emissions from transportation, it is necessary to count gasoline and other consumption. The usual unit of usage is litres, not mileage. It is inconvenient for outlets and transit centres to collect data and calculate their emissions properly. In the SPB standard, the emission factor standards for express packaging products are all calculated in kilograms, and it is convenient for manufacturing express packaging supplies to calculate emissions in kg. However, for outlets and transit centres in the actual operational process, emissions are not calculated in kg. It is recommended to change it into a unit such as an envelope, a packaging box, or a roll of plastic tape.

6.1.3 Recommendations for Electricity and Buildings

(1) Electricity accounts for 10% of total CO_2 emission in transit centres and outlets. The article must point out that, with the promotion electric vehicles, electric vehicles are charging with charging piles in the middle of the delivery routes and in transit centres and outlets. “In 2019, express companies shifted to 20,833 alternative vehicles”, “Among them, SF Express has launched 10,651 new energy vehicles” (Development and Research Centre of the State Post Bureau, 2020). How to decrease the consumption of electricity is an important issue.

(2) Photovoltaic-generated electricity has been used in SF. The sector’s related encouraging policies should keep pace with it.

(3) Building related emissions in transit centres and outlets, which can be calculated through emission factors and activities, have not been documented. SF

Express collects the activity data. However, waste and paper emission factors are not documented in the SPB method.

6.2 Recommendations Regarding the Calculation Method

China's express delivery sector has taken many measures to mitigate CO_2 and GHG emissions, however, it has not yet used international methods to calculate CO_2 emission. In addition to the measures currently used in outlets, transit centres and transportation, this article provides a new perspective for CO_2 emission reduction.

There are three factors which will influence the CO_2 emissions (as seen in 3.1), including emission source, emission factors, and activity data. To reduce CO_2 emissions, this article's recommendations are classified into these three categories.

6.2.1 Suggestions for CO_2 Mitigation Measures from the Perspective of Emission Source

It is recommended that environmentally-friendly and innovative technology be encouraged. 1,577,170.5 W•h of renewable energy was generated in outlets and transit centres in SF Express' photovoltaic industrial parks in 2020 (SF Express, 2021). Currently, there are no measures by the express delivery sector to encourage self-adopted sustainable strategies. SF Express is a pioneer of sustainability in the express sector as it is dedicated to using innovative technology to solve the CO_2 problem. The photovoltaic-generated electricity is a good way to solve the alternative-fuel vehicle

problems in outlets and transit centres. Therefore, it is better to differentiate renewable generated electricity with gross electricity production and adopt different emission factors and policies (Rupp et al., 2018).

6.2.2 Suggestions for CO_2 Mitigation Measures from the Perspective of the Emission Factors

(1) The emission factors are determined with reference to international methods and the actual situation in China. Even if the same mode of transportation is used, different fuels are burned, the emission factors are different, and the CO_2 emissions vary. For example, the emission factors of low-quality fuel and high-quality fuel of transportation vehicles are not consistent. Normally, gasoline fuel has a smaller emission factor than diesel fuel. In addition, fuel quality, vehicle age, and vehicle deceleration lead to different emissions. The emission factor is not static and can be reduced through scientific and technological means. Using the same fuel with a lower emission factor or switching to new fuel with a lower emission factor and higher energy are measures we can take.

(2) Due to the different packaging materials and quality of the same kind of express packaging, emission factors vary and total carbon emissions are different. For example, the emission factors of degradable and non-degradable plastic packaging bags are different; the emission factors of recyclable and not recyclable of plastic woven fabric packaging bags are different; the emission factors of polyethylene plastic, double corrugated cardboard, single corrugated cardboard, and calcium plastic cardboard are different; and the emission factors of five sheets of waybill and e-waybill are different.

Furthermore, with the five sheets of waybill, the differing quality of paper and ink will lead to different levels of emissions. It is easily understood that “Among all the effective strategies, delivery companies are most motivated to optimise their logistics systems to reduce costs” (Peng et al., 2021.1). For express delivery companies, it is necessary to strike balance between ecological costs and economic costs; for regulators, it is necessary to consider how to use economic leverage to encourage express delivery companies to care more about ecological protection.

(3) In aviation transportation, in addition to aviation kerosene usage, aviation ground water usage is 39,116.0t, aviation ground electricity usage is 7,731,677.5kW.h, aviation ground gasoline usage is 94,105.8L, and aviation ground diesel usage is 753,549.7L. The usage of water, electricity, and gasoline seem huge and should be considered in the calculation of total carbon dioxide emissions. Water, paper, waste, and gasoline and diesel related to aviation are not listed in the SPB Measurement Methods, We are waiting for further clarification.

(4) Commuting and business travel also have not been listed in SPB’s method. Outsourcing is listed in the SPB method, however, there are different kinds of outsourcing and the emission sources vary. In practice, it has not been documented until now.

6.2.3 Suggestions for CO_2 Mitigation Measures from the Perspective of Activity Data

The main principle is to reduce the activity data but increase the energy efficiency. We can reduce the amount of activity data related to CO_2 emissions through scientific and technological methods. Some of the suggestions are as follows:

(1) Express packaging can be recycled several times or used in reduced quantities, and excessive packaging avoided. Switching from 60mm-width tape to 45mm-width tape will reduce the activity data by 25%. Research on tape-free packaging should also be conducted.

(2) Facilitate vehicle operation monitoring systems, such as GPS monitoring systems, which can optimise delivery routes to improve efficiency (Development and Research Centre of the State Post Bureau, 2020). Last-mile residential delivery optimization can increase the efficiency and lower the cost of residential deliveries as e-commerce continues to grow at an explosive rate (FedEx,2020; Lazarević et al., 2020). We can introduce eco-driving during driving training and emphasise the importance of fuel-efficient driving behaviour. With the helping of delivery route optimisation and driving behaviour analysis, APPs can help drivers to obtain the CO_2 emission figure for every delivery.

(3) Raise awareness of emission reduction in daily operations, by reducing activity data: avoid permanent lights in office buildings, save paper, water, and electricity, avoid leaving computers on standby for a long time, adjust the temperature of air conditioners, close doors and windows, check the air conditioner is turned off and so on.

All of the above uses the principle of reducing total emissions by reducing activity data. Only with a calculation method can specific reduction targets be set.

6.3 Recommendations for the Express Delivery Sector

6.3.1 Comparison of the CO_2 Emission Structure of SF and International Practice

In order to have a better understanding of the CO_2 emission structure, this article compare the results of SF Express with its counterpart, IPC members. As the IPC method is an international practice, it might give inspiration to SF Express and China's express delivery sector. However, the two methods achieve results through different calculation methods, indicators and categories. Moreover, the 2020 annual report of the IPC, issued in January, 2021, collects 19 participants' activity data in 2019. The rough comparison gives us have a clearer understanding of the CO_2 emission structure in the express delivery sector. Table 12 shows SF Express' CO_2 emission results in 2020 and Table 13 shows the group level CO_2 emission results of the IPC participants in 2019.

Table 12: Emission Calculation Result for SF, 2020

Indicator	2020	Percentage
Transportation	4,104,672.31	78%
Electricity	529,179.40	10%
Packaging materials	658,257.88	12%
Total	5,292,109.59	100%

Source: compiled by the author, 2021

Table 13: Emission Calculation Results for the IPC, 2019

Indicator	2019	Percentage
Scope 1		
Transport (vehicle, aviation, rail)	3,060,000	17.78%
Heating (gas, heating, fuel, oil, steam)	739,000	4.29%
Other scope 1	8,000	0.05%
Scope 2		
Electricity (including electric vehicles)	2,016,000	11.72%
Other scope 2	100,000	0.58%
Scope 3		
Outsourced Road and air transport	8,272,000	48.07%
Employee Commuting	3,013,000	17.51%
Total	17,208,000	100%

Source: adapted from Postal Sector Sustainability Results 2020 (IPC, 2020)

While we do not have the concrete method of calculating the CO_2 emissions of the IPC, and the indicators and emission sources differ from the SPB method, we can analyse and draw several conclusions by comparing both datasets as follows:

(1) Transportation accounts for 78% of the total CO_2 emissions in SF. As SF is a directly owned company, there are no outsource emissions. The transportation (17.78%) and outsourced road and air transport (48.07%) accounts for 65.86% of the total CO_2 emissions of the IPC. Therefore, we may say that transportation is the major CO_2 emission source in the express delivery sector.

(2) China has made great efforts to reduce the CO_2 emissions of packaging materials in recent years. As the IPC have not included packaging in their total emissions, SPB is better at identifying the emission source, defining the emission factor and collecting data on packaging in practice.

(3) The IPC's CO_2 emission indicator of employee commuting is a shocking indicator, which accounts for 17.51% of CO_2 emissions. As the express delivery sector

involves millions of drivers, deliverymen, and staff, the CO_2 emissions of commuting are huge. However, according to the 2020 SF Sustainability Report, there are 634,328 employees (SF Express, 2021) and it has not calculated the CO_2 emissions of commuting.

(4) The CO_2 emissions of electricity in SF Express is 10% and in the IPC it is 11.72%. The percentages of electricity are similar.

(5) The above tables shows that the IPC calculates CO_2 emissions of other scope 1 and scope 2 factors.

6.3.2 Recommendations for the Express Delivery Sector in China

(1) Clear CO_2 reduction targets were set by the IPC. For example, “to achieve a 20% reduction in collective Scope 1 & Scope 2 carbon emissions by 2020, compared to a 2008 base line” (IPC, 2020). The mid-term target of 2030 set further advancements on key KPIs (IPC, 2020). There are no short-term and long-term targets or goals related to CO_2 reduction of China’s express sector.

(2) The express sector has many outsourced activities, in the form of branches, companies, truck drivers with vehicles, lockers and pick-ups, personnel, and contracts. The State Post Bureau listed “the outsource emissions” in the SPB Method without detailed information. Different outsources may have different emission sources, emission factors, and activity data. In Table 12 (Emission Calculation Results for the IPC, 2019), outsourced road and transportation accounts for 48.07% of IPC members’

total emissions. However, the emissions of outsourcing in China are not calculated by any company. From a practical point of view, there are many outsourcing agencies, vehicles, and franchisees in China's express delivery sector. Table 4 shows that the eight major express delivery company has a total of 28,103 franchisees. The CO_2 emissions emitted by these institutions are not yet reflected in the results. If we used the same percentage as the IPC (48.07%), then China's express sector 's carbon dioxide emissions would be shocking. Carbon dioxide emissions reductions are urgently needed in China.

(3) The IPC's CO_2 emission indicator of employee commuting is a shocking indicator, which accounts for 17.51% of CO_2 emissions. As the express delivery sector involves millions of drivers, deliverymen, and staff, the CO_2 emission of commuting is huge. SF has 634,328 staff (2020 SF Sustainability Report, 2021) and 39,000 deliverymen (Fan, 2021), therefore, is better to calculate the CO_2 emissions of commuting and business travel. We cannot ignore such a big emission source.

(4) In 2020, SF Express first released the company's total GHG emissions, from which the CO2 emissions per delivery can be calculated. There are eight major listed delivery companies in China. The emissions of each company, transit centre, and outlet are different, and there is even a big gap between each other. How can the total emissions of various express companies, transit centres and outlets be calculated? How do you know that each express company, transfer centre, and branch have done a good job in sustainable development? It is possible to draw conclusions on the amount of emissions based on the list of carbon dioxide emission sources and calculation methods. SF Express began to accumulate data recently, therefore, SF Express's data was selected and analysed in this article. However, SF Express has developed relatively fast

compared to other Chinese express delivery companies, which suggests that the other companies need to catch up quickly.

(5) Compared with the IPC EMMS program since 2009, China only started to document GHG emissions in 2021. China's express delivery sector has just begun to calculate carbon dioxide emissions and lacks historical data. In China, there are eight major express delivery companies listed in the United States, Hongkong and the Mainland. SF is the only group to include a sustainability report and take steps to accumulate data related to sustainability management in 2020. While the data collected in 2019 (2019 S.F. Holding Co., Ltd. Sustainability Report) and in 2020 (2020 S.F. Holding Co., Ltd. Sustainability Report) is incomplete, compared with the 2019 annual report collected in 2020, the 2020 data is more comprehensive. Data insufficiency remains a problem in SF and other express delivery companies. It seems a little late, therefore, there is an urgent need to speed up. The accumulation and analysis of several years of data will tell us more about the trends of this sector. Through the accumulation of data over the years, the emission trend can be identified, the logical links can be detected, and the emissions can be reduced.

(6) Quantification and monitoring can follow up with the practice of emission measurement. On a monthly or annual basis, a system of monitoring, reporting, verification and adjusting can be set up. Continuous observation and monitoring of CO2 emissions by the relevant departments can keep a record of energy consumption of the key energy-consuming equipment for follow-up adjustments. With the SPB calculation method, sustainability performance can be measured by indicators and emissions. Therefore, rewards and punishments can be achieved by mechanisms and regulations.

(7) The IPC set the Carbon Management Proficiency (CMP) as an indicator to assess four core management pillars including strategy and policy, embedding, measurement and evaluation, disclosure and reporting with a 150+ question survey as part of a qualitative method (IPC, 2020). Effective strategies set clear goals and objectives for IPC participants. Every participant submits data on the topics of electricity, carbon emissions, destination of waste, and vehicle types using the Sustainability Performance Indicator tool. The data is also evaluated through a plausibility check (IPC, 2020). The IPC has a calculation mechanism and a mechanism of execution and checks; it accumulates data and analyses the results and offers self-tailed guidance to members. An extra sustainability pays survey was conducted by the IPC and tells the customer how much they paid and what the delivery company will do for more sustainable packaging in the future. The IPC also calculates the CO_2 emission of other scope 1 and scope 2 factors. While there is no indication of what the other scope 1 and scope 2 factors are, it gives SPB a hint that we can go further into this area.

(8) The IPC method, which includes 19 member countries, uses the GHG Gas Protocol guidance, and Chinese express delivery method adopts the ISO 14064 guidance, therefore, there is a huge gap between these methods. In the long term, we will utilise our method and incorporate the beneficial elements of the IPC method for our use. Sustainability is a long-term strategy.

6.4 Recommendations for Different Stakeholders

Carbon dioxide emission reduction requires the joint efforts of the entire sector. All stakeholders in the sector, such as the regulator, express delivery companies, consumers, packaging material suppliers, and e-commerce platforms generate carbon dioxide emissions and can contribute to emission reduction.

6.4.1 Recommendations for Regulators

(1) Regulators must formulate mid-term and long-term development plans. In the mid- and long-term planning, rational layout of railways, highways, aviation, and waterways can be implemented to achieve multimodal transport connections, which can facilitate enterprises to adopt emission reduction methods for transportation. Efficient railway networks can provide a emission reduction mode of transportation. At the same time, phase out energy-intensive trains gradually. Regulators can set clear CO_2 emission reduction targets, which provide express delivery companies with “emission sources”, “different outsource emission factors” and CO_2 emission indicators for “employee commuting and business travel”. Some emission factors, such as commuting, water, waste, gasoline, and diesel related to aviation are not listed in the SPB Measurement Methods. While outsourcing is listed in SPB method, there are different kinds of outsourcing and various emission sources. In practice, it has not been documented until now. Quantification and monitoring can follow up with the practice of emission data collection. Strategy and policy, measurement and evaluation can be analysed by the regulator for express delivery companies to link the daily CO_2 emissions with the Chinese national level and sector-level CO_2 emissions peak and neutralisation commitments, and set the rewards and penalties for outlets, transit centres and staff.

(2) According to the analysis of CO_2 emission of transit centres, outlets and transportation, more efforts should be made on key processes to reduce emissions. The results show that the key operational processes which emit the most CO_2 are transportation and packaging in outlets. The sector 's key emission reduction measures focus on the packaging process. Therefore, more focus on transportation is urgently needed. There are many problems regarding alternative-fuel vehicles to be tackled.

(3) Regulators can also take the lead in issuing guidance and training managers to strengthen environmental awareness and improve environmental protection capabilities. Awareness of CO_2 emissions is not popular with express delivery companies. Regulators and express delivery companies should cooperate with news media, environmental protection organisations, and other social organisations, and regularly organise activities related to CO_2 emissions to enhance the sustainability awareness of the express delivery sector.

6.4.2 Recommendations for Express Delivery Companies

(1) SF Express' measurement unit is based on daily practices, and it is inconvenient to calculate some carbon emissions using SPB method, such as paper, waybills, and gasoline. When collecting the above activity data, it is better to convert it to the SPB's measurement unit.

(2) Recommendations for SF Express. With the rapid expansion of the company, it is better to buy alternative-fuel vehicles, especially electric vehicles, due to the local government subsidies at the provincial level. Compared with its counterparts in China,

SF has gone further in CO_2 reduction; however, there is still room for improvement compared with its international counterparts.

(3) Recommendations for other express delivery companies in China. Express delivery companies can collect activity data and follow up with CO_2 emission calculations based on the list of carbon dioxide emission sources and calculation methods. The emissions of each company, transit centre, and outlet are different. With data accumulation and analysis over several years, the outlets, transit centres and companies will know more about CO_2 emissions. SPB provides a calculation mechanism, however, the companies can have execution and checking mechanisms. The companies can analyse the results and offer self-tailored guidance to its outlets, transit centres and outsources. Express delivery companies can strike a balance between economic interests and sustainable interests.

(4) SF is a directly owned company without franchisees. The eight major express delivery companies have a total of 28,103 franchisees. The CO_2 emissions of outsources must be taken seriously.

6.4.3 Recommendations for Customers

Customer's environmental awareness should be cultivated. The internet, mass media and Apps should be used to enrich consumers' knowledge of CO_2 emissions and environmental protection. Recommendations to encourage emission reduction, promote customer awareness, and form a better social atmosphere of sustainability include:

(1) Clearly label the amount of carbon dioxide emitted on express delivery packaging, such as an envelope, express package box, or the envelope of the item. It is easy for the customer to know how much CO_2 each delivery generates and how much every customer generates through express delivery every year. By stating the carbon dioxide emissions of each shipment and the impact of carbon emissions, the company can encourage customers to donate a few cents to the tree planting activities and increase their awareness of sustainability. With more and more consumers saying "no" to more CO_2-generated and harmful packaging, the use of CO_2 neutral, degradable, and biodegradable packaging will be emphasized.

(2) In order to solve the problem of CO_2 emissions and excessive consumption of resources in the sector, express companies can provide sustainable packaging for consumers to choose. Even spend a few Yuan more on express packaging, many consumers will choose low-carbon and environmentally friendly packaging.

(3) In general, the CO_2 emissions of each package delivered by road, aviation, railway, and waterway can be calculated. As a survey shows, 72% of consumers would use a "greener, slower, cheaper" delivery and use more than 50% of them would accept at least 2 more delivery days (United States Postal Service, 2020). When the express speed is not a requirement, the customers can choose the mode of transportation and delivery time to reduce CO_2 emissions. The CO_2 emission results can be shown on customers' APPs, which allow users to clearly understand the CO_2 emissions and reductions during every delivery.

The article also advocates for multiple collaborations in the sector to further sort out emission sources, add necessary emission sources and indicators into the systems, delete unnecessary indicators, and reach consensus. After the concept of low-carbon awareness becomes a social consensus, it can encourage the express sector to embark on a path of sustainable development.

7. Conclusion

7.1 Summary

China's carbon emissions accounted for approximately 29% of the world's carbon emissions in 2019 (IEA, 2020). According to a study, “the world’s largest carbon dioxide emitters will have their carbon dioxide emissions reduced in 2020 because of Covid-19. Studies have found that the epidemic lockdown in various countries has promoted the reduction of carbon emissions. However, due to the trend of increasing emissions in recent years and the shorter lockdown period, China’s emissions fell by 1.7%” (Cable Network, 2020). The situation of CO_2 emissions is still extremely grim in China. On the other hand, China's express delivery volume broke the records several times and the State Post Bureau predicts that the express delivery volume in 2021 will reach a new high, exceeding 95 billion pieces (BJNEWS, 2021). To achieve the national goals of “carbon peak” and “carbon neutrality”, the basic and primary task for the express delivery sector is carbon accounting.

This article focuses on CO_2 emissions. All CO_2 emissions were calculated according to the formula: AE=AD×EF (SPB, 2014). While the formula was published seven years ago, the CO_2 emissions of the express delivery industry were not been documented until January, 2021. Since the emissions sources, emission factors and emissions of every operational process in express delivery sector have not been listed, the document is not sufficient to serve as a guidance of CO_2 emissions reduction for all the staff of every operational process. With the CO_2 emissions results of different operational process, we can determine which process generated the most CO_2, and what specific measures can be taken by different staff in different operational positions. To fill this gap, this article identified CO_2 emission sources and calculated the emissions of different operational processes in this sector.

First, this article analyses the chart flow of operational processes of China's express delivery sector. From intracity routes to interprovincial routes, the delivery route runs from outlets and transit centres and is connected by transportation. Second, the emission factors are collected according to the SPB guidance, which is suitable for China's national conditions. Third, this research uses SF Express as a case study. The activity data is collected from the 2020 SF Sustainability Report. SF Express, one of the top express delivery companies in China, was used as a case study because it is the only express delivery company in China which collected and released CO_2 related data in their annual report. This article hopes to use SF Express' example to develop a further understanding of China's express delivery sector.

The results show that the total CO_2 emissions of SF Express in are 5,292,109.59 tCO_2, among which, transportation accounts for 78%, outlets 17%, transit centres 5% of total CO_2 emissions. In transportation, road accounts for 62.8% and aviation 37.2%. In road transportation, diesel vehicles account for 94.10% of CO_2 emissions, followed by gasoline and electricity. In outlets, packaging is the major emission source, accounting for 73% of total emissions. In transit centres, due to data unavailability, emissions from water and paper use, and waste etc. are not calculated, and electricity is the only emission source accounted for.

By clarifying the key emission sources of the express delivery sector in different processes, we can take specific measures to control CO_2 emissions. The author has made several recommendations which include more focus on the hybrid mode of transportation and alternative fuel vehicles. SF's measurement unit of activity data is unsuitable for carbon emission calculations and some improvements are needed. Whether or not to include indicators used in international peers' practice, such as outsourcing and employee commuting, in national standards should be discussed. The article gives recommendations from four different perspectives:

- Recommendations from the perspective of main operational process which emits the most CO_2, including recommendations for transportation, packaging in outlets, electricity, and building-related emissions.
- Recommendations from the perspective of the calculation method, including suggestions of CO_2 mitigation measures related to emission sources, emission factors, and activity data.
- Recommendations for the express delivery sector, by comparing the CO_2 emission structure of SF Express with the International Post Corporation's practice.
- Recommendations for different stakeholders, including regulators, express delivery companies, customers and multiple collaborators in the sector and society.

7.2 Contribution of the Research

The research identifies CO_2 emission sources in the operational processes of China's express delivery sector and calculates the emissions in the operational processes of SF Express. It can serve as a guidebook to calculate what we have achieved in relation to CO_2 emissions and what to do in the near future. It also helps to identify all stakeholders to reduce the emissions, including outsourcing, express delivery companies, employees, packaging producers and regulators.

It provides SF Express and China's express delivery sector with a list of emission sources of the main operational processes and calculation methods for outlets, transit centres and transportation, to provide references for SF staff to reduce CO_2 in different operational processes, and to facilitate SF decision-makers to adopt more effective measures to reduce CO_2 emissions in their organisation in a practical way. With further understanding of SF Express, the sector will also have a further understanding of CO_2 emissions and reduction.

It facilitates the regulators to participate in the sustainable development of the express delivery sector by setting clearer figures. It also provides decision-makers in the express delivery sector with a reference to calculate the current emissions, offset carbon emissions by different means, and predict future trends.

7.3 Limitations and Suggestions for Future Studies

The limitation of this research is data deficiencies from related authorities and SF Express. The research applied emission factors and data activities, without considering topographical characteristics of China and fuel efficiency in different circumstances. Considering China is a large country with various topographical characteristics, and considering different fuel qualities, vehicle ages and vehicle decelerations, therefore fuel efficiency and fuel emission factors differs. Furthermore, the statistical calibre of the activity data of every process in the express delivery enterprise is not accurate, which leads to the data not being accurate enough and relative randomness. For example, some use Liter and others use Mileage as the calibre of gasoline or diesel. In the future, SF and other express delivery companies in China can measure the amount of CO_2 emissions based on the activity data provided by the purchasing department's energy supply list, purchase invoices, payment, and the financial department's annual and monthly financial reports.

For future research, accurate statistics can be calculated on the carbon dioxide emissions of a certain operational process of a particular express delivery company. The carbon emissions of the express delivery sector of a specific city can also be calculated. To achieve the CO_2 emission peak and CO_2 neutrality, CO_2 emission accounting is an essential research topic for the sector. While there have been great improvements in China’s express delivery sector, there is still room for further improvement.

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