SYSTEM ANALYSIS FOR DECISION-MAKING IN SUSTAINABLE E-COMMERCE PACKAGING LOGISTICS: A CASE STUDY IN CHINA

A Thesis

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ABSTRACT

E-commerce is considered as a catalyst for the transition of trade and a transformative toolkit for the fulfillment of SDGs (5b, 8.3, 9.3, 17.11, etc.). China, now as the world's largest and fastest growing B2C E-commerce market, upholds e-commerce development to actualize inclusive wealth. The e-commerce logistics underpins the mobility of e-commerce supply chain and the packaging sector is significant for logistics performances. Despite sustainable attributes of the e-commerce model, the current packaging system of e-commerce logistics still features high eco-burden and lack of sustainability. A systematic approach would help explore the optimum amongst effective protection, minimum socio-environmental impacts and value creation.

This study adopts the concept of 'sustainable packaging logistics' (García-Arca et al., 2016) and applies it to the case study in China. Its general research objective was to capture the systematic features of e-commerce packaging logistics in China and provide decision-making support to improve its sustainability and competitiveness. A 'System Analysis Framework' has been devised as the methodological basis. Three domains (value domain, operation domain and impact domain) were dissected by three respective system analysis methods, which were stakeholder analysis, packaging logistics analysis and lifecycle impact analysis. In-between the methods, linkages were built and construed. This innovative analytical framework could leave legacies to future studies in similar fields.

As for the case study, three specific objectives aligned with the three domains were investigated: 1) to identify stakeholders, stakeholder needs/ value flows, and their perceptions on sustainable e-commerce packaging logistics; 2) to describe the interactions of packaging and logistics activities, identify occurring challenges and propose alternative scenarios; 3) to evaluate the compare impacts of e-commerce packaging logistics under different scenarios. For each objective, the study garnered both expected and unanticipated results.

For objective one, 12 stakeholder groups were identified, with 6 groups as definitive stakeholders and 6 groups as expectant stakeholders. Value flows between al1 12 stakeholders were mapped and modeled in a stakeholder value network, which further demonstrated the value loops between stakeholders. Both monetisable value loop and non-monetisable value loop were detected, specifically the market value loop and the policy value loop. It shed light on the value delivery mechanism between stakeholders and provided a communicative tool for decision-making. Stakeholder perceptions on sustainable e-commerce packaging logistics shared commonality yet presented prioritisation differences.

For objective two, detailed mapping of e-commerce packaging logistics in 'supplier + 3PL' and 'supplier + self-run logistics' mode were conducted and compared, with which redundancies of logistics activities and packaging challenges were explored. In comparison, 'supplier + self-run logistics' generally surpassed 'supplier + 3PL' due to higher controllability of the supply chain. Four alternative scenarios were developed upon stakeholder perceptions and packaging logistics analysis, which were: 1) automation upgrade scenario; 2) material substitute scenario; 3) packaging rationalisation scenarios; 4) stakeholder integration scenario. This is a preparation for the objective three, which quantitively evaluated the environmental impacts of the scenarios. For objective three, the LCA modelling results indicated that 'self-run logistics' performed better than '3PL' in terms of impacts and damages to ecosystems, human health and resources. Comparison between a baseline scenario and four alternative scenarios elucidated that the packaging rationalisation scenario and the stakeholder integration scenario demonstrated relatively higher performance. Discussions were made to certain packaging solutions and lifecycle activities and responded to the disputes observed earlier in the study.

Nevertheless, there are limitations of this research. It is constrained by the state-of-the-art e-commerce packaging logistics and choices of packaging solutions in the future could differ substantially. Furthermore, sensitivity analysis is missing in the impact analysis, and future studies are encouraged to attest its validity.

ACKNOWLEDGEMENT

Everything has a crack. That is where the light comes in. -- Leonard Cohen

At this moment, I am blessed, as I know the light has come in. Two years passed in the blink of an eye. No matter how imperfect this master thesis is, it is now a token of my struggles and efforts throughout the master years. For those who have enlightened and helped me, I here would like to express my deepest gratitude.

First, I would like to thank my advisor Dr. Mino Takashi. Without his patient guidance and unwavering encouragement, I would not be able to complete this thesis. Then, I would like to thank my co-supervisor Dr. Hiekata Kazuo. He is the one who brings me into the field of system analysis and instructs me in learning methods. I also would like to thank Dr. Heng Shue Teah from Waseda University for his special support. He helps me conduct the LCA part and always steers me to the right direction. Moreover, I sincerely appreciate the MEXT scholarship, which sponsors my study here in Kashiwa-noha. This tranquil town enables me to stay calm and delighted.

In the next place, I would like to thank all the key informants and stakeholders I have interviewed. Their contribution to this study is incomparable, and their trust stimulates me to try hard. Meanwhile, I am very thankful to my supportive schoolmates with whom I can always share thoughts and discuss the study.

Finally yet importantly, I am eternally grateful for my beloved parents. Their unfailing love is the source of my courage. I am also indebted to Louisa Yan and Roy Wang for their company. They relieve my pains and sufferings along the way. This accomplishment would not have been possible without them.

Back to this moment, I clearly know that it is not an end. In the long journey of exploring the life essence, I would both keep a critical mind and a grateful heart.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF TABLES (continued)

LIST OF ABBREVIATION

ICT	Internet and communication technologies
UNECE	The United Nations Economic Commission for Europe
WTO	World Trade Organisation
SDG	Sustainable Development Goal
GDP	Gross domestic product
B2C	Business to consumer
C2C	Consumer to consumer
NDRC	National Development and Reform Commission
MoC	Ministry of Commerce
MoT	Ministry of Transport
MEP	Ministry of Ecology and Environment
SPB	State Post Bureau
SAC	Standardisation Administration of China
CEPF	China Environmental Protection Foundation
CPF	China Packaging Foundation
CCFA	China Chain Store & Franchise Association
CEA	China Express Association
CECA	China Electronic Commerce Association
ISTA	International Safe Transit Association
WWF	World Wildlife Foundation
GCSG	Alliance of Green Consumption and Green Supply Chain
ENGO	Environmental Non-governmental Organisation
SKU	Stock Keeping Unit
RFID	Radio Frequency Identification

CHAPTER 1 INTRODUCTION

1.1 Research Background

1.1.1 E-commerce and Sustainability Development

E-commerce, a business model enabled by the proliferation of ICTs, has been entitled with 'the catalyst for the transition of trade' by UNECE (2016). Its dis-intermediation role sharply exploits potentials out of the traditional trade, creating new value access to all. It is now developing into a transformative toolkit for sustainable development. OECD/WTO (2017) suggested e-commerce's high relevance to several SDGs, including gender empowerment, job creation, entrepreneurship, industrial innovation, and exports of developing countries (specifically associated with SDG 5.7, 8.3, 9.3, 17.11, etc.). By reducing transaction costs (Laudon and Laudon, 2007) and spawning channels for good and services, it could help mobilise the market, accelerate its liquidity and scale up global productivity in the long run. For organisations and individuals, they can benefit from e-commerce through both running online business and being customers with widened and convenient choices.

In spite of its indisputable contribution to economic sustainability, whether e-commerce contributes to the environmental sustainability is questionable. The virtual business model has been primarily deemed as more energy-efficient and low-carbon compared to its brick-and-mortar counterpart. However, alarmed by its skyrocketing growth, recent studies started to cast doubt upon the actual environmental performance of e-commerce and grew interests in investigating and quantifying its environmental tolls. Studies have been mixed and still at the nascent stage, leaving much space for further exploration.

1.1.2 E-commerce Development and its challenges in China

China is a key player in the global e-commerce, and as a developing country, its lessons learnt can offer rich implications for international e-commerce stewardship.

2015 is a remarkable year for China's e-commerce development. The total share of e-commerce in China's GDP was 7.05% in 2015, the highest percentage around the globe (E-commerce Foundation, 2016). Considering that its internet penetration was only 51%, China could foresee a continuous e-commerce growth (E-commerce Europe, 2016). Starting from 2015, China also surpassed the United States to become the largest B2C e-commerce market, reaching over 33.7% of global B2C sales (China National Bureau of Statistics, 2015). Meanwhile, it is also worth noting that before 2015, in the area of consumer-oriented e-commerce, C2C was a predominate mode represented by taobao.com. As the market gradually matured, B2C mode began to carve up the market. In 2015, its market share (51.9%) exceeded C2C (48.1%) for the first time (PwC, 2017). Statistics demonstrate that since 2015, China has entered a new era of e-commerce development.

Accompanying with the expanding e-commerce market, e-commerce logistics emerges to sustain the mobility and performance of the e-commerce supply chain. As defined by Jiao (2016), it is a type of logistics driven, transformed and upgraded by e-commerce, with characteristics of professionalism and segmentation. In Chinese context, Fang (2014) and Han (2014) pinpoint that among the three pivotal flows for e-commerce (information flow, capital flow and logistics flow), the logistics flow has become a critical bottleneck due to its unclear positioning and salient negative externalities. In 2015 alone, China's e-commerce logistics consumed nearly 9.92 billion carton boxes, 8.27 billion plastics bags, 16.60 billion metres of tape and 3.1 billion women bags for delivery (State Post Bureau, 2016). Such appalling data has made e-commerce packaging, e-commerce logistics and correspondingly the e-commerce business model to bear with harsh criticism. Moreover, phenomena including over-packaging, toxic packaging and robust handling of packaging have been receiving public attention and query.

This study reckons the high eco-burden and socio-economic setbacks brought by packaging and logistics to e-commerce as issues to be addressed in the discourse of sustainability. Interactions between packaging, logistics, the business model and the general public are essential for comprehending the problem mechanism and proposing countermeasures.

1.1.3 Rationale Breakdown

Section 1.1.1 suggests that the global e-commerce development has incomparable potentials to help fulfil the SDGs. The global e-commerce is an inclusive system incorporating functional subsystems. E-commerce development in China can be counted as a subsystem with regional features. E-commerce logistics in China serves as an underpinning for China's e-commerce operation, and the packaging is a critical enabler of e-commerce logistics. Layers of system interact and contribute to the general goal in dynamics. A devised system analysis of the packaging in e-commerce logistics is the study boundary, and details will be expatiated in the following chapters.

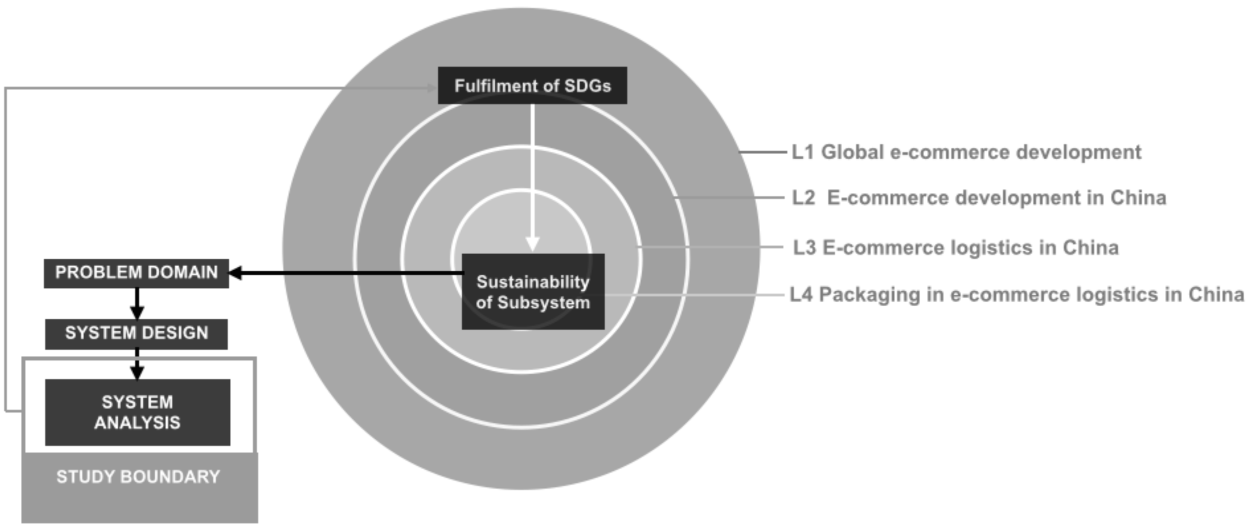


Figure 1 Rationale breakdown diagram

1.2 E-commerce logistics and packaging logistics

This section is a literature review on the previous conceptual framing of and case studies on e-commerce logistics, packaging logistics and sustainable packaging logistics.

The terminology of ‘e-commerce logistics’ was first brought forward by Bayles and Bhatia in 2000. Bask et al. (2012) conducted a systematic review on the existing literature relevant to e-commerce logistics and categorised them into seven approaches, among which retailing strategies, logistics support and consumer preferences were the ones mostly studied. They concluded that few studies casted attention on the specific solutions for e-commerce logistics and there was a research gap. Yu et al. (2016) reviewed the state-of-the-art e-commerce logistics with worldwide practices from a supply chain management perspective to shed light on possible solution pathways.

In terms of packaging in e-commerce logistics, Matthew et al. (2001) and Webster (2008) respectively compared the life cycle impact between traditional retailing and e-commerce logistics for book and electronic product delivery, and discovered that although e-commerce logistics was eco-efficient in inventory management, it could underperform in packaging.

Early in 1999, Johnsson conceived the idea that an integrated management over packaging and logistics could be a value-added approach. Jahre and Hatteland (2004) underlined the importance of taking packaging as part of a lager integrated system involving actors throughout the whole supply chain. At the same year, Saghir (2004) precisely termed such integrated management as ‘packaging logistics’. The definition is presented as the following:

> *“The process of planning, implementing and controlling the coordinated packaging system of preparing goods for safe, secure, efficient and effective handling, transport, distribution, storage, retailing, consumption and recovery, reuse or disposal and related information combined with maximising consumer value, sales and hence profit.”*

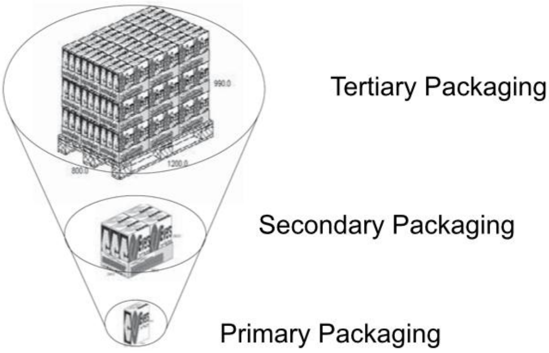


Figure 2 Packaging levels in a packaging system (Sighr, 2004)

The 'coordinated packaging system' mentioned in the definition of 'packaging logistics' comprises several levels of packaging, and the classification of packaging has been diverse due to the supply chain variances. A commonly accepted classification is illustrated in Figure 2. Primary packaging are directly in contact with the individual product. Secondary packaging groups a bunch of products into a unit. Tertiary packaging can also be considered as transit packaging that assembles secondary packaging on pallets (Jonson, 2000). Here in this research, given the segmented feature of e-commerce logistics, the delivery packaging particularly for containing the product is considered as an individual level in the packaging system. Figure 3 suggests the structure of the packaging system for this study.

Figure 3 Packaging levels in a packaging system for this study

Nevertheless, the concept of ‘sustainable packaging logistics’ was coined rather recently. Garcia-Arca et al. (2014) revisited the definition of ‘packaging logistics’ with a short complement “from a sustainable perspective, and on a continuous adaptation basis”. Koeijer et al.(2017) then carried out a study on stakeholder decision-making in sustainable packaging logistics. Till now, there have been very limited research on sustainable packaging logistics and no literature of the subject has been done in the e-commerce context. Therefore, this study will serve as a pilot study in exploring the momentum of packaging logistics within the e-commerce model.

1.3 Research Objective

The general objective of this research is to help frame a sustainable e-commerce packaging logistics system by supporting its decision-making process through identifying decision-making agents, system operation dynamics and corresponding impacts.

In order to fulfil the research objective, research questions are raised and divided into three domains with regard to the decision-making process.

- **Value domain**: Who are stakeholders to be included the decision-making? What are their roles, needs and value delivery in the decision-making? (Chapter 3)
- **Operation domain:** What is the operation dynamics in e-commerce packaging logistics? What challenges and solutions can be spotted for decision-making changes? (Chapter 4)
- **Impact domain:** How will the changes in the decision-making influence the impact results brought by e-commerce packaging logistics? What implications can be drawn from the impact results? (Chapter 5)

With the research objective and the research questions, the next chapter will introduce the methodological framework and consolidate the thesis structure in detail.

Chapter 2 SYSTEM ANALYSIS FRAMEWORK

2.1 Overview of the Framework

To begin with, the framework basis is illustrated with a logic diagram (Figure 4). It demonstrates how the system analysis framework corresponds to the decision-making loop and provides support to it through three integral stages.

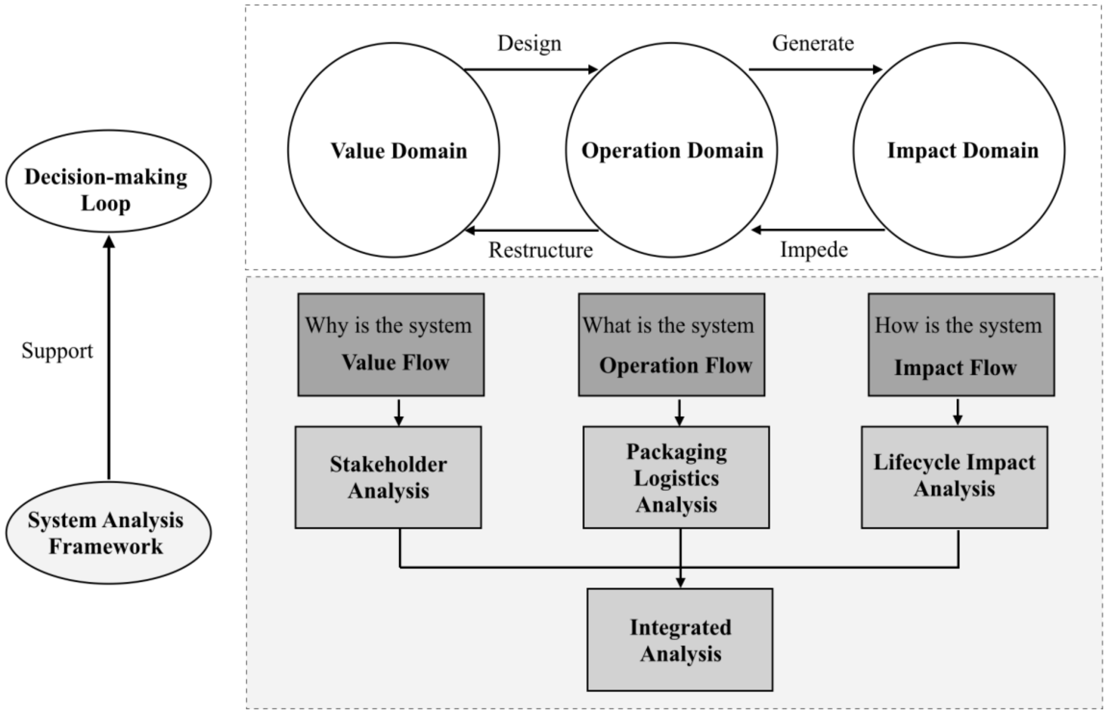


Figure 4 Basis of 'system analysis framework'

In short, this study intends to dissect the architecture of the e-commerce packaging logistics system by answering why, what and how the system is. In specific, each question probes into a certain domain and breaks down crucial flows with a pertinent analytical tool. The selected tools are often applied to system mapping and evaluation.

2.1.1 From Value Domain to Stakeholder Analysis

The value domain is where the decisions are conceived and devised. A sustainable e-commerce packaging logistics system is complex in structure, and the challenge lies in the diverse needs and value propositions of multiple stakeholders across the domain.

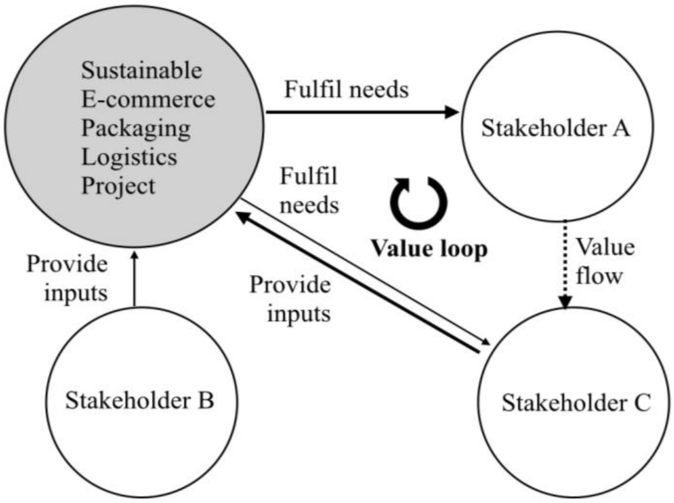


Figure 5 Basis of 'stakeholder analysis'

The basis diagram above depicts the interrelations of a sustainable e-commerce packaging logistics system (here considered as project) and its stakeholders. Stakeholders are broadly defined as "any group or individual who can affect or is affected by the achievement of an organisation's purpose" (Freeman, 1984). A stakeholder value network model will be developed to clarify stakeholder groups, stakeholder needs and value loops connecting stakeholders. How the analysis is conducted of the packaging logistics system will be expounded in Chapter 3, and here are the main steps:

- Identify, characterise and group stakeholders
- Specify stakeholder needs (inputs) and value creation (outputs)
- Establish stakeholder value network model

Besides, perceptions on sustainable e-commerce packaging logistics are garnered from stakeholder interviews. Parameters of sustainable e-commerce packaging logistics and challenges of promoting it are then summarised based on stakeholder perceptions. This extra section invites the insights of how sustainable e-commerce packaging logistics would be like in the future into discussion.

2.1.2 From Operation Domain to Packaging Logistics Analysis

The operation domain is where decisions are tested and implemented. It is apparent that for an e-commerce logistics system, the packaging system involved in logistics process is a dominant component for operation and constantly influenced by changing decisions. Compared to stakeholder analysis that answers 'why the system is', the packaging logistics analysis puts emphasis on presenting the system structure and actual interactions between packaging and logistics activities, which responds to 'what the system is'.

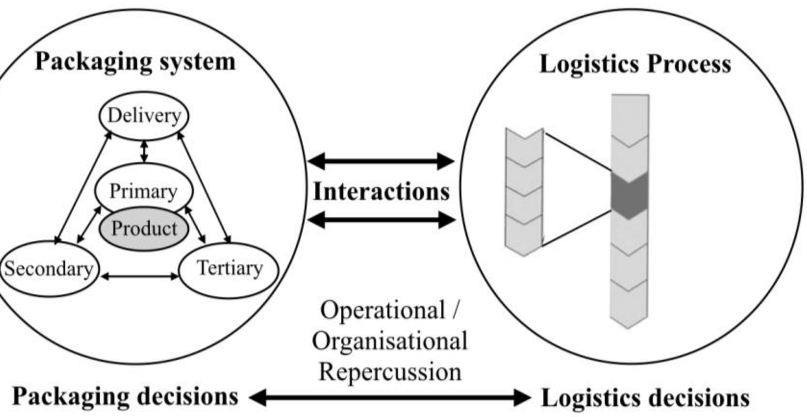


Figure 6 Basis of 'packaging logistics analysis'

The basis diagram is developed upon previous works (Hellström and Saghir , 2007; García and Prado, 2008) to depict the interactions. The packaging system here is defined as a dynamic aggregation of primary, secondary, tertiary and end-delivery packaging. In common retail logistics, end-delivery packaging is missing since products are sold on shelf.

Notwithstanding, end-delivery packaging in this study shall be treated as an individual category to accentuate the e-commerce characteristics. The logistics process goes through the supply chain from the product supplier to the end-consumer. It faces with operational and organisational repercussions brought by packaging and logistics decisions.

To carry out the analysis, a system boundary of the supply chain shall be outlined first. In this study, the analysis comprises two parts. The first part describes the currently practiced interactions of packaging and logistics at each logistics site using the method of packaging logistics mapping. To both delineate the operation flows and distinguish influential factors, a set of activity symbols proposed by Hellström and Saghir (2007) is introduced. The second part, echoing the stakeholder perceptions and existing literature, will bring forward alternative scenarios that take sustainability into consideration. Alternative scenarios will be defined, mapped and discussed detailedly in Chapter 4.

2.1.3 From Impact Domain to Lifecycle Impact Analysis

The impact domain is where the operation of decisions exerts impacts. It is beyond the scope of the packaging logistics system yet exists in every operational stage. Altering decisions in minor points will result in different impacts, therefore the lifecycle thinking is necessary to capture possible changes. The basis diagram below elucidates how decisions influence actual impacts.

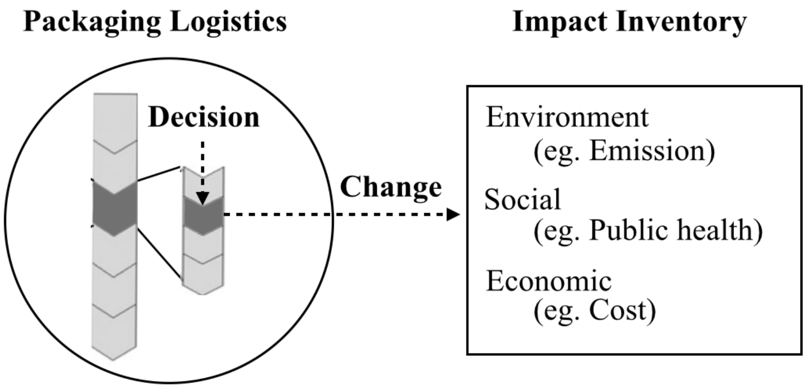


Figure 7. Basis of ‘lifecycle impact analysis’

A sustainable packaging logistics system entails in-depth investigation of its latent impacts across social, environmental and economic spheres. This lifecycle impact analysis puts more weight on the environmental impacts. Despite the public consensus that the current e-commerce packaging features high eco-burden, the environmental impacts brought by the entire e-commerce packaging logistics have not been quantified. Impacts on public health, labour and cost will also be covered.

Consistent to the packaging logistics analysis that both describes the current packaging logistics system and proposes alternative scenarios, the impact analysis will also focus on whether decisions in alternative scenarios would eventually mitigate impacts and how effective they could be. Valid results are supposed to support most efficient decision-making. Life cycle assessment ('LCA' hereafter) method used for the impact analysis will later be introduced in Chapter 5.

2.2 Data Collection

A system analysis framework should be grounded in reliable data sources. This section gives an account of the details in data collection.

2.2.1 Primary data collection

This study obtains primary data mainly from semi-structured interviews and site visits, and the data are qualitative. Semi-structured interviews are conducted to identify stakeholders and their needs, and survey perceptions of sustainable e-commerce packaging logistics. Four expert interviews and 18 stakeholder interviews have been completed. Site visits aim to grasp real-life packaging logistics activities and packaging properties, which later facilitate the packaging logistics mapping as well as impact modelling. In total, seven site visits have been carried out. Six site visits are in logistics sites including warehouses, distribution centres, delivery points, etc. One visit to an international industrial expo enables this study to learn cutting-edge practices in e-commerce packaging logistics.

2.2.2 Second-hand data collection

The study acquires second-hand data from literature and open databases to fill the data gap between obtained primary data and the expected dataset.

For the data-intensive LCA, two types of quantitative data are requisite. The foreground inventory data are process data required to model the specific packaging logistics system. This study extracts relevant second-hand data from a wide range of sources including supplier websites, industrial reports, governmental publications and journal papers. The background inventory data are generic information for material, energy, waste and transport which are not specific to one system and difficult to get access to. Therefore, the open life cycle inventory database Ecoinvent 3.4 is applied to meet the data demand. It offers data at the unit process level and provides calculation information, so the data transparency is ensured.

CHAPTER 3 STAKEHOLDER ANALYSIS

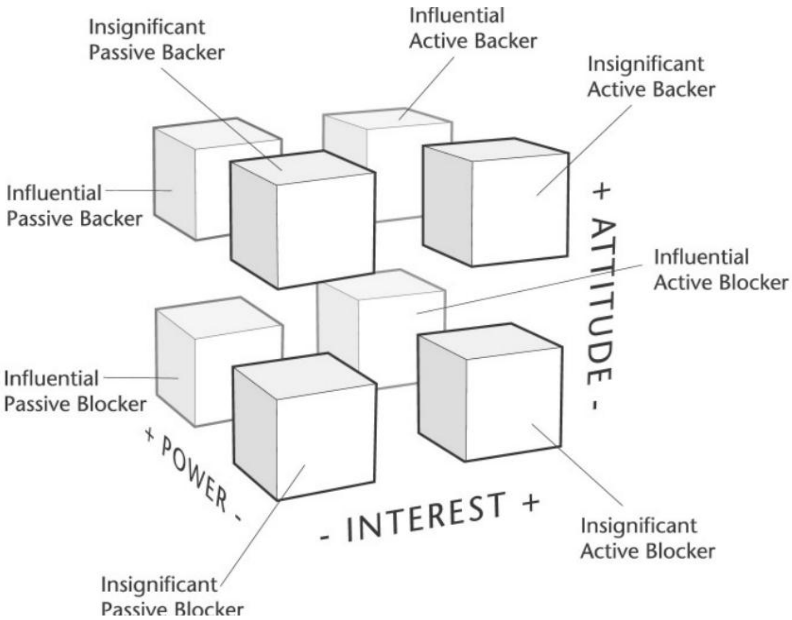
This chapter aims to answer the research questions in the value domain by identifying stockholders, understanding their needs and modeling the value exchange.

3.1 Introduction of Stakeholder Analysis

The advent of stakeholder analysis can be traced back to 1984 when Freeman advocated the application of stakeholder theory to corporate strategic management. He was also the one who initiated the stakeholder mapping to visualise the concept. Since its inception, the stakeholder analysis have then been applied broadly to answer “who and what really counts” (Freeman, 1994) in project management or system design.

One type of analysis emphasised ‘stakeholder categorisation’. Bonke and Winch (2000) developed a structured stakeholder analysis process and proposed a power/interest matrix to group stakeholders. Murry-Webster and Simon (2006) modified the matrix by adding an axis of ‘attitude’ and formed a stakeholder cube (Figure 8). Likewise, Bourne and Walker (2008) devised a five-stage ‘stakeholder circle’ method to reflect power, proximity and urgency for deciding stakeholder salience.

Another type of analysis laid stress on the ‘network’— namely, stakeholder relationships. The early form of network mapping gestated by Freeman (1984) was a ‘hub-and-spork’ model demonstrating direct and dyadic interactions between stakeholders. Rowley (1997) pinpointed the limitation of dyadic relationships and introduced Social Network Analysis into the model development. A group of MIT scholars then advanced a stakeholder value network model (‘SVN’ hereafter) based on Social Exchange Theory to grasp multi-relational value exchanges (Cameron et al., 2008; Sutherland, 2009; Feng, 2013) (Figure 8). The SVN method not only explored latent stakeholder relationships, but also provided a communication platform for stakeholders to reduce decision-making complexity. It could help seize research opportunities in issue-focused management, engineering systems and social science studies. In light of the above, the SVN method is selected for this chapter.



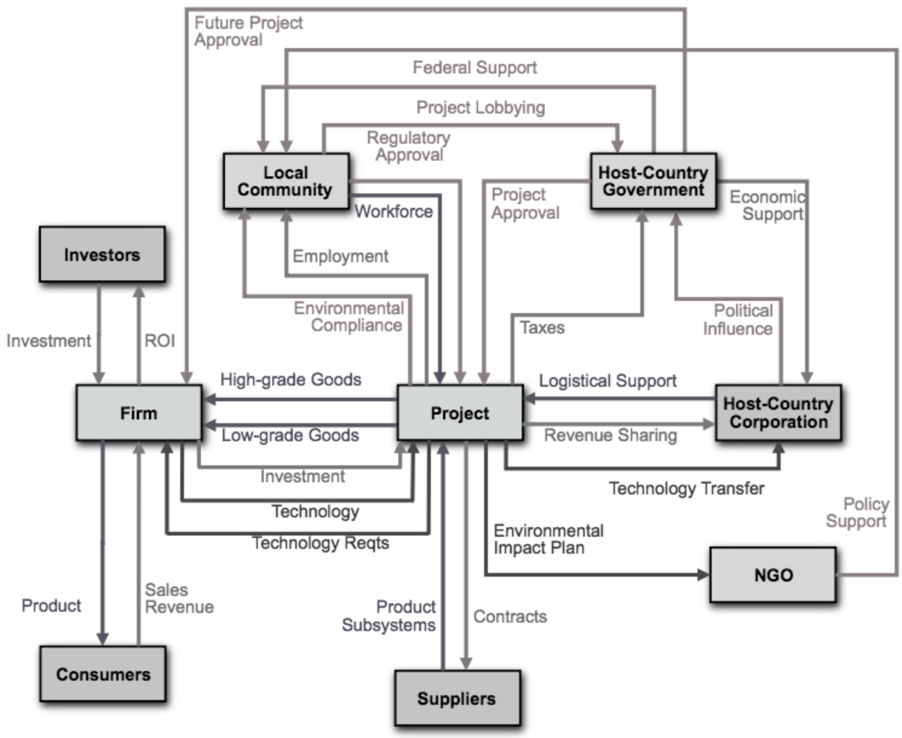


Figure 8 Comparison of ‘Stakeholder Cube’ (Murry-webster and Simon, 2016) and ‘Stakeholder Value Network’ (Feng, 2013)

3.2 Application of SVN

The SVN method comprises two stages: 1) the qualitative description of a stakeholder value network; 2) the quantification of value flows, value loops and solution space of value paths. Considering that this study adopts stakeholder analysis mainly for understanding varied value propositions and stakeholders needs in developing a sustainable e-commerce packaging logistics system, only the qualitative model will be included. Chapter 2 has succinctly introduced major steps in qualitative SVN analysis, and here is a flowchart giving detailed account of each step, with applied techniques and outputs (Figure 9). It borrows the flowchart structure from Feng (2013) and serves as an illustrated summary of qualitative SVN process set by Cameron et al. (2008), with a few revisions suggested by Sutherland (2009).

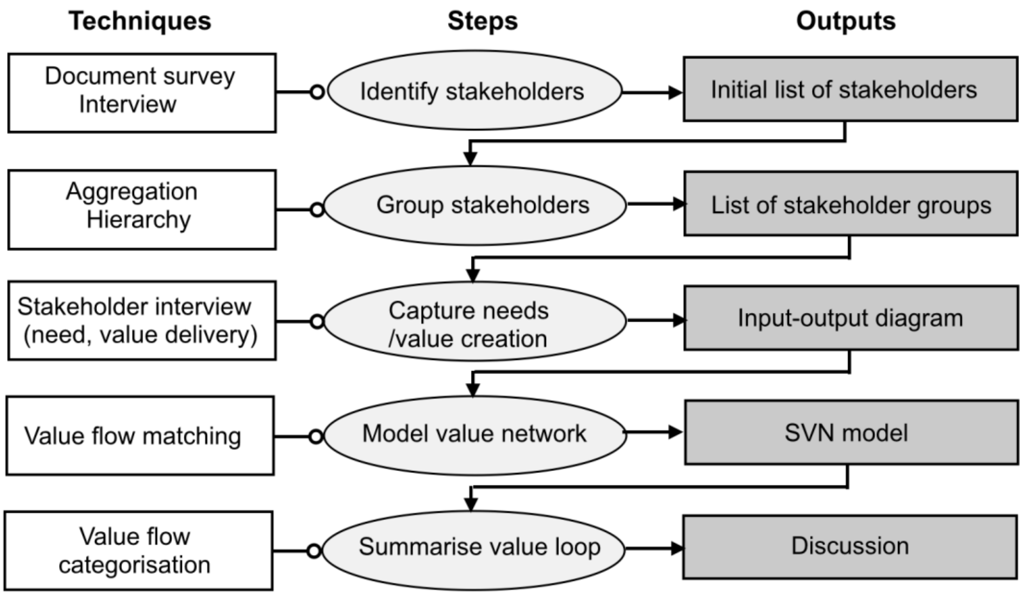


Figure 9 Process of qualitative SVN analysis

In the following parts, section 3.3 will present the identification and grouping of stakeholders. Section 3.4 will focus on input-output diagrams with stakeholder characterisation, and the modeling of SVN. Section 3.5 is a complementary part to account for stakeholder perceptions on ‘what a sustainable e-commerce packaging logistics system is’ and to propose parameters for Chapter 4 and 5.

3.3 Identification and Grouping of Stakeholders

A e-commerce packaging logistics system is complicated, therefore two representative projects are chosen as the prototypes for structuring a sustainable e-commerce packaging logistics system. They are: 1) ‘Green Momentum Project’ led by Cainiao Green Coalition in 2016, a strategic partnership between Alibaba Group and 32 logistics companies; 2) ‘Green Logistics Project’ launched by JD.com, Inc. and nine upstream suppliers in 2017. Although the two projects are not particularly designed for packaging logistics, the packaging logistics is considered as a decisive enabler for achieving overall sustainability. Stakeholder related to these two projects will be first identified and then summarised into general groups.

3.3.1 Initial Stakeholder List

Since the concept of ‘stakeholder’ is broad, making stakeholder analysis shall narrow criteria to select stakeholders. Taking the view of project management, three primary questions are raised for identifying stakeholders of the two projects with respect to power, interest and benefit (adapted from Sutherland, 2009). Questions are as the following:

- **Power:** Who can exert a direct or indirect influence on the system?
- **Interest:** Who will have a significant and legitimate interest in the system?
- **Benefit:** Who can benefit directly or indirectly from the system?

Answers are sourced from documents and interviews, and listed in Table 1 and 2 below. To shorten the initial stakeholder list, many are shown only as abbreviations. The lists roughly categorise the stakeholders into four arenas according to their functions: governance-related, market-related, innovation-related and public/advocacy-related.

Table 1 Initial list of stakeholder identified in 'Green Momentum Project'

Governance-related	Market-related	Innovation-related	Public / Advocacy -related
- NDRC	- Taobao.com/ Tmall.com	- Cainiao Green Logistics Research Plan	- Cainiao Green Coalition Fund
- MoC	- Cainiao Network		- Alibaba Fund
- MoT	- Express companies	- Ali Research Centre	- CEPF
- MEP	- Alliance express operators		
- SPB		- Transport Institute	- CPF
- SAC	- Logistics workers	- Telecommunication Institute	- CAWS
- MEP	- E-retailers		- CCFA
		- Automation Institute;	- CEA
- Local govts. (infrastructure; municipal waste treatment)	- Packaging material suppliers	- Standardisation Institute	- CECA
	- Packaging manufacturers		- End-consumers
	- Packaging solution providers		- Media

Table 2 Initial list of stakeholder identified in 'Green Logistics Project'

Governance-related	Market-related	Innovation-related	Public / Advocacy -related
- NDRC	- JD.com	- JD Green Packaging Lab	- JD Green Logistics Fund
- MoC	- JD Logistics		- WWF
- MoT	- JD employers	- Packaging Institute	- GCSG
- MEP	- Brand suppliers	- Material Institute;	
- SPB		- ISTA	- CPF
- SAC	- Packaging material suppliers		- CCFA
- MEP			- CEA
	- Packaging manufacturers		
- Local govts. (infrastructure; municipal waste treatment)			- End-consumers
	- Packaging solution providers		- Media

However, the categorisation is not rigid, since a stakeholder could engage in several arenas for value exchanges. For instance, a start-up named He2t providing recyclable packaging solutions is originally affiliated to Packaging Institute and entered into the market to commercialise its patents. Another example could be GCSG ('Alliance of Green

Consumption and Green Supply Chain') and CEPF ('China Environmental Protection Foundation'). Though officially as independent ENGOs for public promotion and fundraising, they are primarily initiated by MEP ('Ministry of Ecology and Environment').

In both projects, it is noteworthy that stakeholders have been actively forging multi-faceted partnership and attracting high publicity. Media and industrial associations emerge as galvanisers to deliver value propositions and bridge information gaps. In terms of media, M.Success Media Group has been undertaking E-commerce Packaging and Logistics Expo for years to facilitate direct procurement and communication between e-commerce platforms, logistics companies and packaging providers. Industrial associations, wielding their negotiating power, have been fostering collaboration between national government, industries and academies. These associations can range from packaging, express, warehousing to chain-store (CPA, CEA, CAWS, CCFA, etc.). Apart from domestic organisations, international partners such as WWF ('World Wide Fund for Nature') and ISTA ('International Safe Transit Association') also partake in the projects. These findings have already touched upon unexpected interactions and will be recapitulated in the following sections.

3.3.2. Stakeholder Grouping

Given the initial stakeholder lists of two prototype projects, this section tends to group stakeholders in an abridged list. The method of aggregation, similar to market segmentation which identifies groups based on their homogeneity, distinction and reaction, is adopted here.

NRDC, MoC, MoT, MEP, SPB, SAC and MEP are grouped into 'national regulators' by virtue of their governance and policy-making role. Although discrepancies may exist between e-commerce expansion goals and environmental constraints, a common ground could still be found in the long run. Municipalities are the local government with the role of policy facilitation and regional supervision of e-commerce logistics. For some municipalities, e-commerce logistics can either be a key industry for local economy or bring trouble to the municipal management. Municipalities' concern over e-commerce logistics might differ from the 'national regulators', which is why they are still kept as an independent category. Industrial associations including CPA, CEA, CAWS, CCFA, CEA, etc. are sorted as 'industrial advisories' considering their industrial expertise and guiding roles.

In 'Green Momentum Project', the e-commerce packaging logistics is handled jointly by the logistics platform (Cainiao Network), 3PL companies (Yunda, Yuantong, Zhongtong etc.) and alliance logistics operators (for feeder-line delivery). In 'Green Logistics Project', JD Logistics takes charge of the entire delivery as a vertical logistics service provider. These entities are all aggregated as 'logistics entities' despite their in-group differences. Nevertheless, the group of 'logistics workers' is breakaway from 'logistics entities' owing to its socio-economic distinctiveness. Table 3 exhibits logistics worker types for reference. From the interviews, it is said that the high turnover rate and the unclear liabilities between logistics workers, especially in 3PL delivery, have posed great threats to both delivery quality and cost control. Meanwhile, logistics workers play a crucial participative role in packaging handling, transport and delivery. The group's interests in promoting sustainable packaging logistics could be both obstructive and positive; therefore it is necessary to examine its value exchanges with other stakeholder groups.

Table 3 Logistics Worker Types (Adapted from Ali Research, 2016)

Front-line Worker	**Supporting Personnel**
- End-delivery couriers - Pick-up site workers - Delivery outlet workers	- Order Pickers - Parcel Packers - Customer Service Representatives; - Lorry drivers

Besides, all packaging-related companies are generalised as 'packaging industries', regardless of materials, manufacturing services, technologies or integrated packaging design solutions. The interactions within the group are simplified to avoid complicating the SVN modelling. Likewise, all labs, projects and research institutes are seen as 'research bodies' that sustain and evaluate packaging logistics innovations. 'ENGOs' are identified in both projects, some are specifically founded by multiple stakeholder groups to underlie sustainable packaging logistics while some are reputed ENGO funds for environmental protection. They could be agents of both cash pooling and public promotion.

The other groups, which are media, end-consumers and upstream suppliers are not aggregated since they have met the criteria of homogeneity and distinction at the first place. It is estimated that until 2017, there has been 5,330 million online shoppers who are also the end-consumers of e-commerce logistics (CNNIC, 2018), so the end-consumer group can also be perceived as the general public owing to its large population. After selected aggregation, the revised list is composed of 12 stakeholder groups (Table 4).

Table 4 12 Stakeholder groups for 'Sustainable E-commerce Packaging Logistics Project'

Governance-related	Market-related	Public / Advocacy-related
- National regulators - Municipalities	- E-commerce platforms - Logistics entities - Logistics workers - Upstream suppliers - Packaging industries	- ENGO - Industrial advisories - Research bodies - End-consumers - Media

Among these 12 stakeholder groups, some directly act on the operation domain of e-commerce packaging logistics while some have lack of immediate proximity to it. According to Mitchell et al. (1997), power, legitimacy and urgency are key attributes to characterize stakeholders. Feng (2013) noted that it shall be more appropriate to view the attributes as the properties of stakeholder relationships than of the stakeholder themselves. In this study, relationship attributes of power, interest and benefit are adopted. Definitive Stakeholders possess all the three attributes. Stakeholders having two attributes are Expectant Stakeholders, and those only having one attribute are called Latent Stakeholders (Feng, 2013). Here, Definitive Stakeholders are those at the supply chain interfaces of e-commerce packaging logistics, whereas the Expectant and Latent Stakeholder groups are away from participating in the market and the operation domain. Table 5 exhibits the three types of stakeholders.

Table 5 Definitive, expectant and latent stakeholder groups

Difinitive Stakeholders	Expectant Stakeholders	Latent Stakeholders
- E-commerce platforms - Logistics entities - Logistics workers - Upstream Suppliers - Packaging Industries - End-consumers	- National regulators - Research Bodies	- Municipalities - ENGOs - Media - Industrial Advisories

Within the Definitive Stakeholders groups, e-commerce platforms and logistics entities are the major influencers to engage other Definitive Stakeholders in the intermediated market activities, since the e-commerce platforms prosper the e-commerce market and logistics entities take charge of logistics operation. Their efforts devoting to sustainable e-commerce packaging logistics will directly propel other Definitive Stakeholders to take actions. For instance, upstream brand suppliers will be driven to reconsider their choice of packaging types for the particular requirements of e-commerce logistics. Packaging industries, both challenged and profited by the e-commerce model, would reconstruct their portfolio to meet the market demand. Logistics workers would have to respond to the changing decisions of packaging logistics, and their performance in promoting the sustainable solutions is highly correlated to the internal policies of the e-commerce platforms or logistics entities. When it comes to end-consumers, they are exposed to the information dissemination of the e-commerce platforms and at the service window of logistics entities. Their engagement in sustainable e-commerce packaging logistics will be undoubtedly relevant to the strategies carried out by the two key stakeholder groups.

The groups of ‘national regulators’, though lacking of operation proximity, have both power and legitimate interest in the sustainable e-commerce packaging logistics. In this sense, the group can be viewed as Expectant Stakeholders. Research bodies can exert influence via technology advancement and can be benefited from the industrial practices, therefore they are also Expectant Stakeholders. Municipalities, industrial advisories, media and ENGOs have only legitimate interest to guard the e-commerce packaging logistics, and whether they can benefit from the sustainable practices remains unclear. From this aspect it is sensible to take them as Latent Stakeholders.

Stakeholder decision-making in an e-commerce packaging logistics system can be either instant or structured, and it depends on which denotation of ‘e-commerce packaging logistics system’ is referred to. In day-to-day e-commerce packaging logistics activities, Definitive Stakeholders are expected to make instant decisions on packaging materials, handling procedures and waste disposal. A logistics entity would procure certain packaging types periodically from packaging suppliers with lowest cost. An end-consumer, in face of a delivered parcel, shall think over the choice of discarding or reusing it. Nevertheless, an e-commerce packaging logistics system is a highly complicated socio-technical system relevant to multiple industries and non-market players.

To achieve sustainability in the e-commerce packaging logistics system entails fore-sighted and planned decision-making to overcome the setbacks of instant decision-making. The ‘distant’ engagement of Expectant and Latent stakeholders, as construed, is significant for the across-the-board and long-term decision-making. The issue arises with this approach is that Expectant and Latent stakeholders are normally ill-defined, which results in the negligence of their needs, perceptions and contribution to the overall image. The identification and grouping of stakeholders is thus an indispensable step for this stakeholder analysis.

To this point, the abridged list of stakeholder groups and the process of aggregation has paved the way for characterising stakeholder groups, capturing needs and discussing value delivery in later sections.

3.4 Stakeholder Characterisation, Needs, Value Flows and SVN

This section constructs a rigorous stakeholder value network. Stakeholder characterisation is the first step to sketch the role, objective and need of every stakeholder group, followed by an input-output analysis to comprehend the value delivery mechanism. Then a SVN could be established after the value matching.

Based on Sutherland (2009)'s stakeholder characterisation template and input-output flow diagram, this study combines the two into a 'characterised input-output value flow diagram' for each stakeholder group (see Figure 10). The role and objective will be mapped in the upper box, with needs at the lower part. Values created by other stakeholder groups partially or fully meeting the needs of the targeted stakeholder group will be the input flows, whereas the output flows are values the stakeholder group brings forward to other stakeholder groups. With this diagram, both the characterization process and the flow matching process can be implemented.

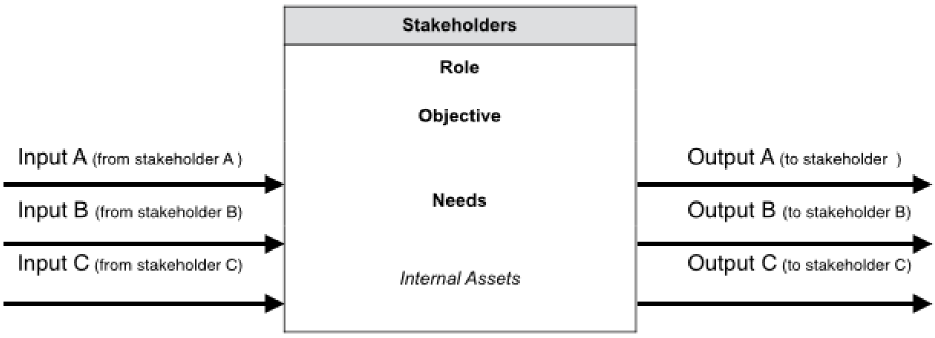


Figure 10 Characterised input-output value flow diagram (Adapted from Sutherland, 2009)

The clarification on diagram components is made here. These components are crucial for justifying the stand of stakeholder analysis.

- **Role:** the main functional role of the stakeholder group in respect to the sustainable e-commerce logistics system;
- **Objective:** the general goal statements of the stakeholder group specifically for or relevant to the sustainable e-commerce logistics system;
- **Need:** the specific requirements, wants or desires derived from the general objectives; needs can be common, synergistic; conflicting or orthogonal;
- **Internal asset:** measure of satisfaction of an stated objective (Cameron et al., 2008)
- **Value flow:** the output of one stakeholder and meanwhile the input of the other (Feng, 2013)
- **Value loop:** the value path beginning from and ending with the same stakeholder, namely, the focal organization (Feng, 2013)

The process of determining the stakeholder role, the key objective and specified needs requires progressive revisions. With regard to the changing environment for e-commerce logistics, what recorded in this study can only be tentative. Notwithstanding, the significance of stakeholder characterisation and input-output analysis rests in the abstraction of the intricate reality as well as the extraction of embedded values. To facilitate the mapping of SVN, the sustainable e-commerce packaging logistics system is simplified as a 'focal project' ('packaging logistics project' hereafter) to be characterised and drawn with input/output flows. In this way, it is similar to a 'stakeholder group'. Figure 11 is attached here to illustrate how the project is treated equally with other stakeholder groups.

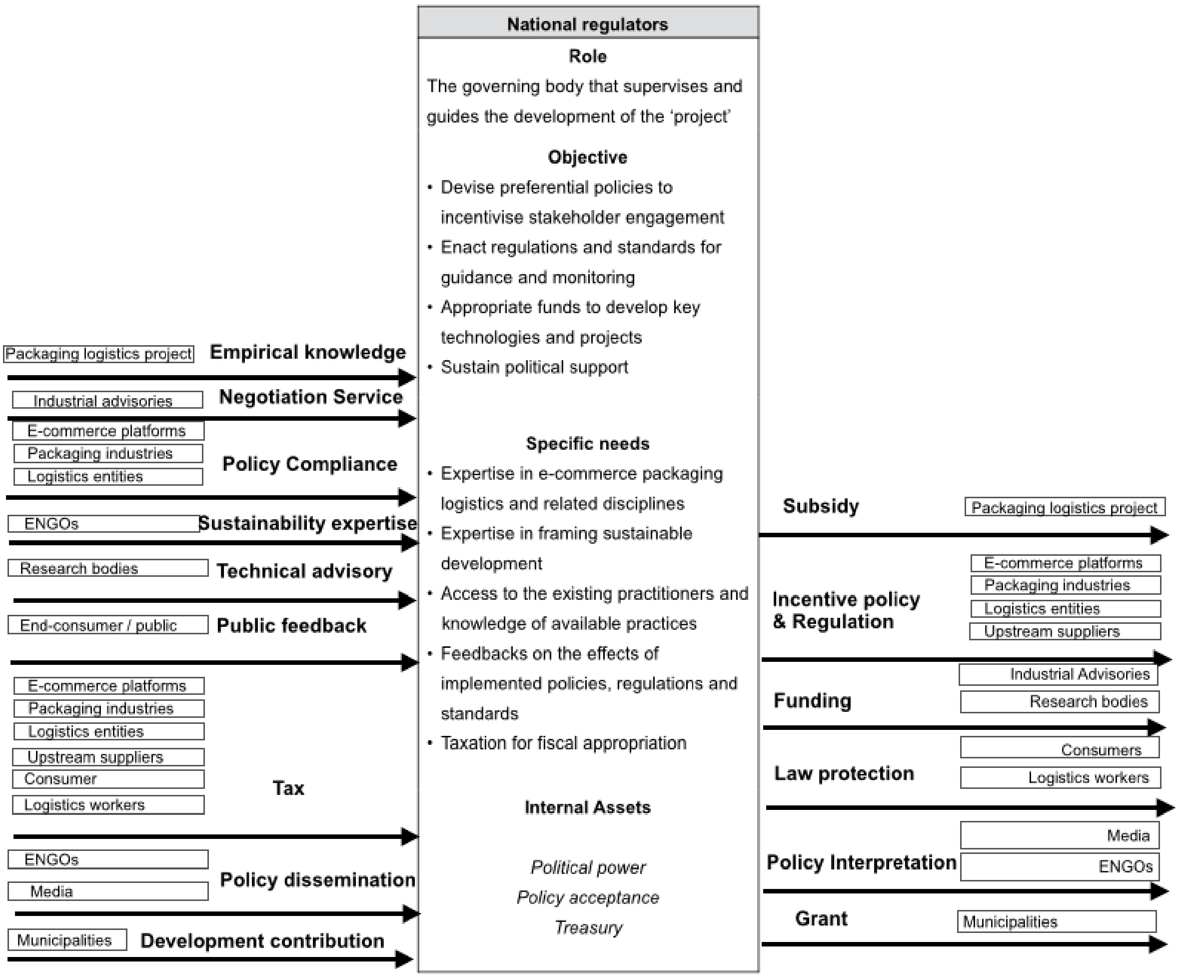


Figure 11 Characterised input-output value flow diagram of 'national regulators'

For the national regulators, the needs and respective inputs are mostly knowledge-based and comprehensive, as the enactment of laws, regulations, policies and standards will be influential in a long span. As the implementation of packaging logistics project can provide empirical knowledge to support policy-making, the national regulators in turn leverage the project with a subsidy toolkit. Similar ‘knowledge-to-capital’ value exchange can also be seen between the ‘regulators’ and ‘research bodies’ or ‘industrial advisories’. The two stakeholder groups each play an irreplaceable role to the policy-making process, one offers technical advisories while the other bridges the gap between the government and the market.

A consensus reached by interviewed stakeholders is that the top-level policy is the most potent external driver for promoting sustainable e-commerce packaging logistics. In the past five years, ministries or bureaus in charge of different fields (e.g. environmental protection, commerce, transport, post, customs, telecommunication, construction) have issued eight joint announcements to together monitor the e-commerce logistics and its packaging externality. This study browses the relevant policies and detects the high occurrence frequency of ‘green e-commerce packaging’ and ‘green logistics’ in the documents. This suggests that the ‘national regulator’ group has not yet adopted the concept of ‘sustainable packaging’ or ‘sustainable logistics’ and failed to give equal weight to the socio-economic performance of the packaging logistics solutions. The ‘ENGOs’ group, as the value provider to better frame the sustainability concept, can further launch dialogues with the ‘national regulator’ group.

The value exchange between ‘national regulators’ and ‘municipalities’ shall also be examined. The GDP-oriented performance assessment of municipalities has been gradually abolished, and key performance indicators including ecological conservation, livelihood and public facilities have been winning municipals’ attention. With the allocated grants from the national government, the ‘municipalities’ group can devote to constructing infrastructure for road transportation and waste treatment. Meanwhile, the group can either bolster the implementation of national regulations with the local supervision systems. This accounts for why the group should not be neglected in the decision-making scheme.

Figure 12 is about 'logistics entities'. It explicates how the needs of this key Definitive Stakeholder Group are fulfilled by other stakeholder groups, meanwhile lists out the output flows created by the group.

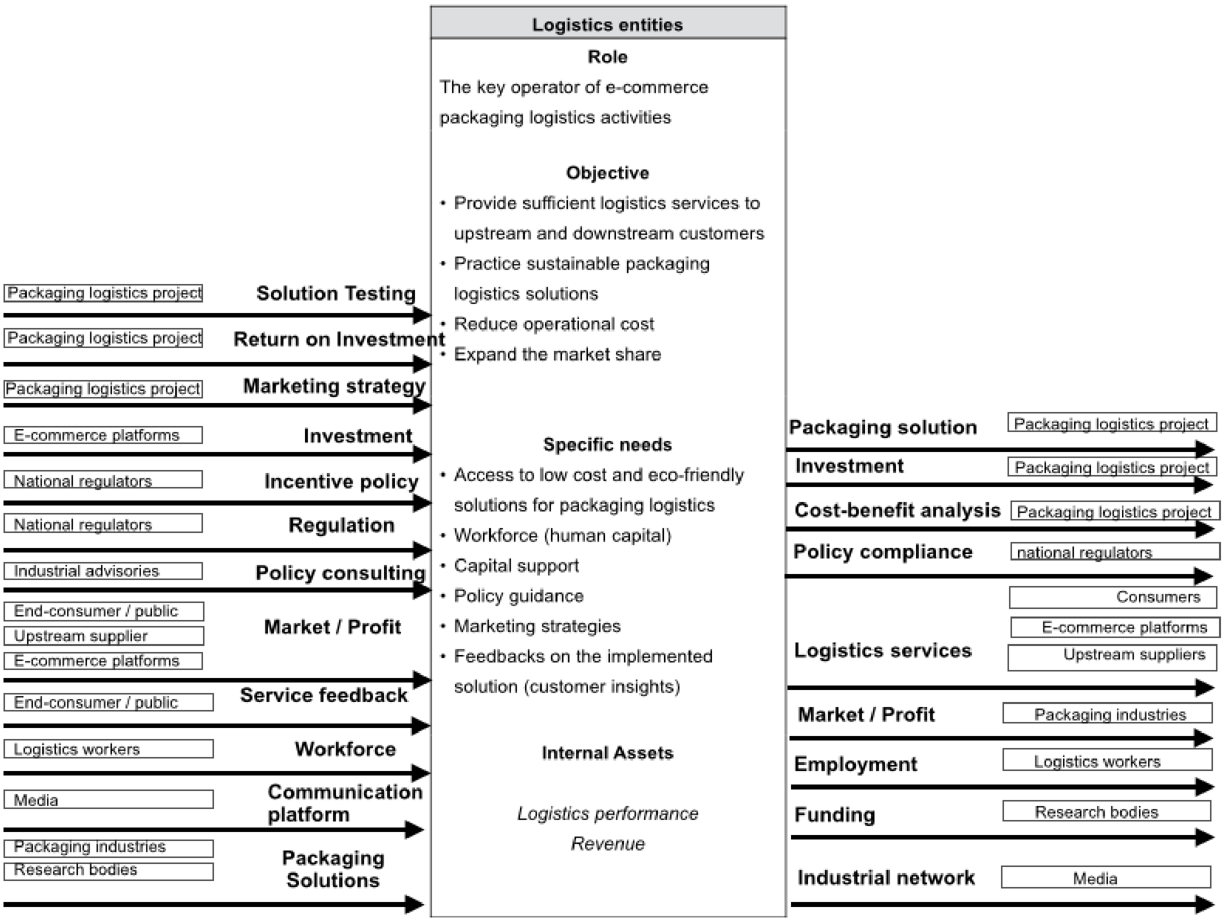


Figure 12 Characterised input-output value flow diagram of 'logistics entities'

Compared to the 'national regulators' group which in principle commits to the goal of sustainable development, the 'logistics entities' group concerns itself with more trade-offs. The interviews to three logistics operators indicate that the group's primary objective, even with the presence of 'packaging logistics project', is to gain revenues. It can be ascribed to the fact that the practice of Corporate Social Responsibility (CSR) and Extended Producer Responsibility (EPR) is still at the budding stage in China, and most companies that promote CSR or EPR regard them as marketing instruments. Because of this, in Figure 12, one input from the ‘packaging logistics project’ is stated as a ‘marketing strategy’ for the purpose of expanding the market share. The two prototype projects, ‘Green Momentum Project’ and ‘Green Logistics Project’, are in fierce competition with each other. Even though each project forges partnership with other stakeholder groups to promote sustainable packaging logistics, the in-group synergy is rarely effectuated. Such competition pattern can be double-sided. For one thing, it expedites the displacement of wasteful and unsustainable practices in e-commerce packaging logistics; for the other, it doubles the trial-and-error cost by overlapping investment. Chances are that a certain packaging logistics technology is not fully proven to be sustainable but popularised by all logistics entities in a short time for the sake of winning the competition. The introduction of PLA biodegradable bags is an example here. Soon after ‘Green Momentum Project’ declared that it would substitute all PE bags with PLA ones, all other projects sought the same application even though the technical support is insufficient. Chapter 5 will expound on the evaluation of this issue from a LCA perspective.

More implications can be drawn from this input-output diagram. The value exchange between the ‘logistics workers’ and ‘logistics entities’ is problematic in the light of social sustainability. As illustrated above, there are different types of logistics workers and their employment status can vary substantially. For self-run logistics, an employment contract is guaranteed and the ‘logistics entities’ group will pay insurances correspondingly. In contrast, it is estimated that over 90% of frontline logistics workers in 3PL companies work without employment contracts (Ding, 2016). Moreover, 80% of them are from rural areas and undereducated (AliResearch, 2016). The rapid expansion of 3PL companies is enabled by the franchising business mode, and as the competition rages on, the workers would have to deliver parcels as many as possible to gain enough commission. Taking this into account, to engage the logistics workers of 3PL companies in a parcel recycling project would be difficult, as they have little motivation to bother themselves with the reverse logistics.

This section will not keep elaborating on the characterised input-output diagrams but directly arrives at the stage of SVN modeling. The crucial step in SVN modeling is to match value flows and put them in categories.

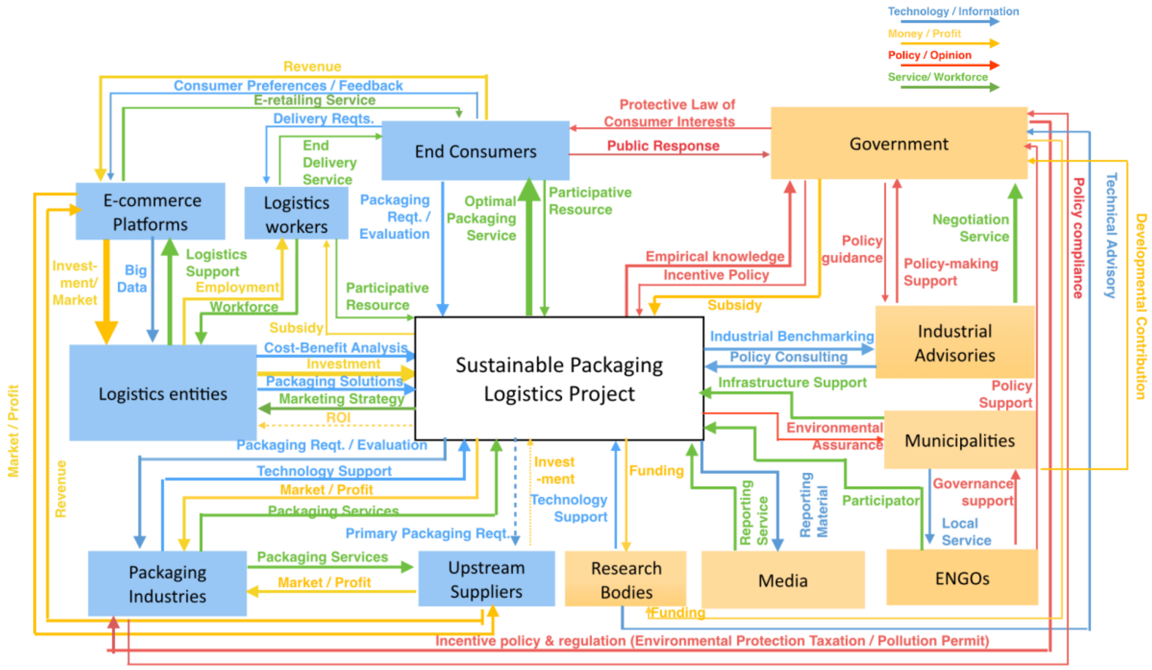


Figure 13 Stakeholder Value Network of 12 stakeholder groups

Figure 13 is the final version of the SVN model developed by this study, constituted by political/opinion flows (red), technology/information flows (blue), financial/market flows (yellow) and service/workforce (green) flows. In total the model involves 60 flows, with some simplified and redefined. The Sustainable Packaging Logistics Project is the focal organization/project in the centre. The Definitive Stakeholders are listed at the left side, with the Expectant and Latent Stakeholders listed at the right side. It is obvious that policy/opinion flows are predominant among the Expectant and Latent Stakeholders whereas the financial flows, service flows and technology flows are more exchanged between the Definitive Stakeholders. The SVN model is a qualitative indication of how different values are delivered and it provides an overview of decision-making dynamics in terms of stakeholders' value transactions. Key value loops could help illustrate the interconnectedness of stakeholder groups. For instance, upstream suppliers (SME e-retailers or brands' online branch) and end consumers are identified as indispensable for forming the financial value loop. The form of financial flows could be direct investment/return on investment, scaled market/revenues, subsidies/funding, etc. The service/workforce value loops will be incomplete without logistics workers and e-commerce platforms to be the service windows. The demand and supply sides in the market are equally crucial for the success of Sustainable E-commerce Packaging Logistics Project, e.g. the upstream suppliers, logistics entities and packaging industries. For the value flows of information/ knowledge, service requirement and technology advancement drive the project upgrading, one specified by the demand side and the other fulfilled by the supply side. Service requirements could cover the range of packaging, logistics and the overall performance evaluation. Technology advancement entails joint efforts by the logistics entities, packaging industries, research institutes, etc. Most definitive and expectant stakeholders are involved and connected by such value exchanges. Latent stakeholders are mostly in the public sector for delivering the non-monetisable values considering their advising, guiding and supervising roles. As Sutherland (2009) pointed out, the non-monetisable flows are typically neglected by methodologies such as cost-benefit analysis. The political/opinion flows revealed by the SVN model suggest the significance of including the consideration of wielding political and public influences to leverage and scale up the project.

In short, the application of SVN model provides a comprehensive understanding of the value delivery between stakeholders, contributing to identifying the essential stakeholders and reflecting the decision-making dynamics in consideration of stakeholder interactions and value transactions.

Nevertheless, the failure to conduct a follow-up quantitative analysis of the SVN model is a limitation of this research to make consolidated recommendations to the stakeholder prioritisation and value-producing interactions for the Sustainable E-commerce Packaging Logistics. The future study can make improvement in this aspect.

3.5 Stakeholder Perception on sustainable e-commerce packaging logistics

Despite that exploring stakeholder perception is not in the scheme of the SVN modeling, it is a necessary step for the requirement breakdown of stakeholders from the view point of system design. The '-ilities' of sustainable e-commerce packaging logistics can be multi-dimensional to fulfil the ideals of social, environmental and economic sustainability. To conduct this part, this study carried out semi-structured interviews to 18 stakeholder representatives. During the stakeholder interviews, stakeholders were asked to describe the challenges of current e-commerce packaging logistics they concerned themselves with and then propose parameters that could address the challenges. These problem-solving parameters are considered as 'sustainability parameters'. Table 6 is a summary of all perceived sustainability parameters. This table will help frame the alternative scenarios to be finally assessed in Chapter 5.

Table 6 Stakeholder perception of sustainability parameters

Identified Challenges	Perceived Sustainability Parameters
Disposable/non-degradable/ toxicant packaging system (find low-cost raw materials)	- Recyclability - Reusability - Biodegradability - Cost-efficient - Toxicity-free
Violent distribution/delivery process frequently exists (no traceability)	- Supply chain collaboration - Traceability - automation
E-commerce logistics packaging only regarded for transport use	- Added value (Consumer education; branding)
Lack of top-level standard design for e-commerce logistics packaging; Lack of compulsory regulatory mechanism	Standardisation Supply chain responsibility

In general, most parameters are at the packaging level and a few are elevated to the logistics and supply chain level. Since the stakeholders are not familiar with the concept of packaging logistics, therefore their perceptions are not precisely the '-ilities' of the e-commerce packaging logistics. This study views such incompetency of defining the '-ilities' of the newly emerging system as an embedded shortcoming. Nevertheless, in combination with the packaging logistics analysis, the parameters can be placed into scenarios and tested throughout the operation.

In specific, packaging-related parameters in the form of packaging properties could be recyclability, reusability, biodegradability and toxicity-free to both the human health and the ecosystem. Recyclability is the parameter most frequently mentioned amongst the property parameters. Meanwhile, cost-efficiency and added value are crucial socio-economic parameters. As for the packaging level, rationalised design is considered as a means to achieve cost-efficiency by balancing material use and logistics performance. Added value is significant to increase the WTP ('willingness to pay') of possible service premium brought by the packaging upgrades. Detailed presentation of added values can differ from scenario to scenario, and more importantly, determined by the decision focus of stakeholders.

When it comes to the logistics and supply chain level, '-ilities' are more conceptual and based on stakeholder vision. Supply chain responsibility refers to the EPR (Extended Producer Responsibility) that is reckoned as important by stakeholders. Together with supply chain collaboration, it incorporates the concept of realising circular economy. Automation capacity rely on the state-of-art packaging logistics technologies, and are enabled by stakeholder consentience to internalise the technology transfer cost. There exist trade-offs of human resource allocation and automation application. Traceability and standardisation of supply chain practices in packaging choices and handling procedures are regulatory parameters that are dependent on supply chain collaboration. Therefore, the degree of stakeholder collaboration is fundamental to fulfil supply chain '-ilities'.

To put it shortly, the stakeholder perceptions on sustainable parameters of e-commerce packaging logistics involve several levels and provide an overview of possible '-ilities' of the e-commerce packaging logistics system. Further investigation shall be launched to build the connection between '-ilities' and sustainable outcomes.

CHAPTER 4 PACKAGING LOGISTICS ANALYSIS

E-commerce packaging logistics interworks with all e-fulfilment and transport processes within the operation domain. It is a key factor of influence to logistics performance and overall e-commerce success. To better correlate decisions with their consequences in the impact domain, a thorough inquiry into the interfaces and interactions of the e-commerce packaging logistics system is entailed. This chapter exercises a packaging logistics analysis to gauge operational dynamics of the system, and to set alternative scenarios consistent with stakeholder perceptions on sustainable e-commerce packaging logistics.

4.1 Introduction to Packaging Logistics Analysis

Chapter 1 has conducted a concise literature review on how the concept of packaging logistics was coined and developed. At present, analytical tools for packaging logistics has remained rather limited, albeit a few European scholars have been advocating the adoption of packaging logistics analysis in supply chain studies at their full tilt for almost two decades (Johnsson, 1998; Sjöström, 2000**;** Olsson & Jönson, 2001; Chan et al., 2006; Hellström & Saghir, 2007; Azzi et al., 2012; García-Arca et al, 2016).

Jönson and Saghir (2001) pointed out that to evaluate packaging through 'multifunctional and systematic methods' will empower supply chain practitioners in devising proper packaging solutions and communicating decisions. To close the methodological gap, they first formulated a packaging logistics analysis model incorporating four steps: 1) identify relations between different packaging levels; 2) evaluate how different packaging levels meet packaging requirements; 3) probe into relations between packaging levels and packaging logistics processes; 4) construe relations between packaging levels and their performance. Matrixes templates were proposed to help compare and pinpoint insufficiencies across packaging levels, packaging systems, packaging logistics and the supply chain. The two scholars admitted that the model was very tentative and shall invite further construction. Hellström & Saghir (2007), based on the model, explicated the packaging logistics interfaces with methods of 'detailed mapping' to support decision-making.

Chan et al. (2006) punctuated that taking a system approach in packaging logistics would increase cost-efficiency and generate values for the supply chain. Their analysis started with investigating interfaces along the logistics flows, followed with a cost evaluation to determine the optimum cost-reliability point. Lastly it brought in an information flow model as well as a value chain model to reduce uncertainties and diagnose add-on values. Although the study worked on an offline retail supply chain, it suggested that the emergence of e-commerce would require a completely new approach to the existing packaging logistics and the proposed model could be further tested in an e-commerce context. García-Arca et al. (2017) forwarded a 'benchmarking' analysis to 17 detergent products for implementing 'sustainable packaging logistics' with regard to three parameters: differentiation improvement, cost reduction and environmental sensitivity. They acknowledged that the limitations were ascribed to restricted 'empiric basis' and future studies might validate the method when broadening the basis.

In short, the packaging logistics analysis is still under development and methods can vary from case to case. Accordingly, a study on e-commerce packaging logistics will contribute to knowledge building and methodology verification with its insights into a distinctive supply chain model. Section 4.2 will offer an overview of the packaging logistics analysis tailored for the e-commerce supply chain.

4.2 Application of Detailed Mapping and Scenario Proposal

The most arresting feature of e-commerce supply chain is its last mile delivery to consumers, which is highly dispersed and efficiency-oriented. It is where the volume of packages being delivered becomes much smaller yet the total amount drastically increases. However, simply looking into the last mile delivery would not only neglect other inefficient or problematic packaging issues along the supply chain, but also fail to discover add-on values.

To address this, this e-commerce packaging logistics analysis borrows the detailed mapping method devised by Hellström & Saghir (2007) to canvass all related packaging logistics activities in current e-commerce supply chains and their underlying interactions or unspotted problems. Based on detailed activities and interactions, perceptions on sustainable packaging logistics could then be crystallised into practicable scenarios that not only enable quantitative analysis but also visualise the abstruse vision of 'sustainability'. These mixed approaches are combined into a phased framework, which is to: 1) first nail down the system boundary; 2) then map detailed interfaces; 3) later summarise and characterise interactions; 4) lastly propose scenarios that either resolve problems or create values. Figure 15 displays the overall layout of this analytical framework.

In terms of structuring the chapter, section 4.3 will first specify the system boundary, section 4.4 will present the detailed mapping results and section 4.5 will provide a descriptive summary table of packaging logistics interactions. Section 4.6 will elaborate on alternative scenarios for the preparation of impact analysis.

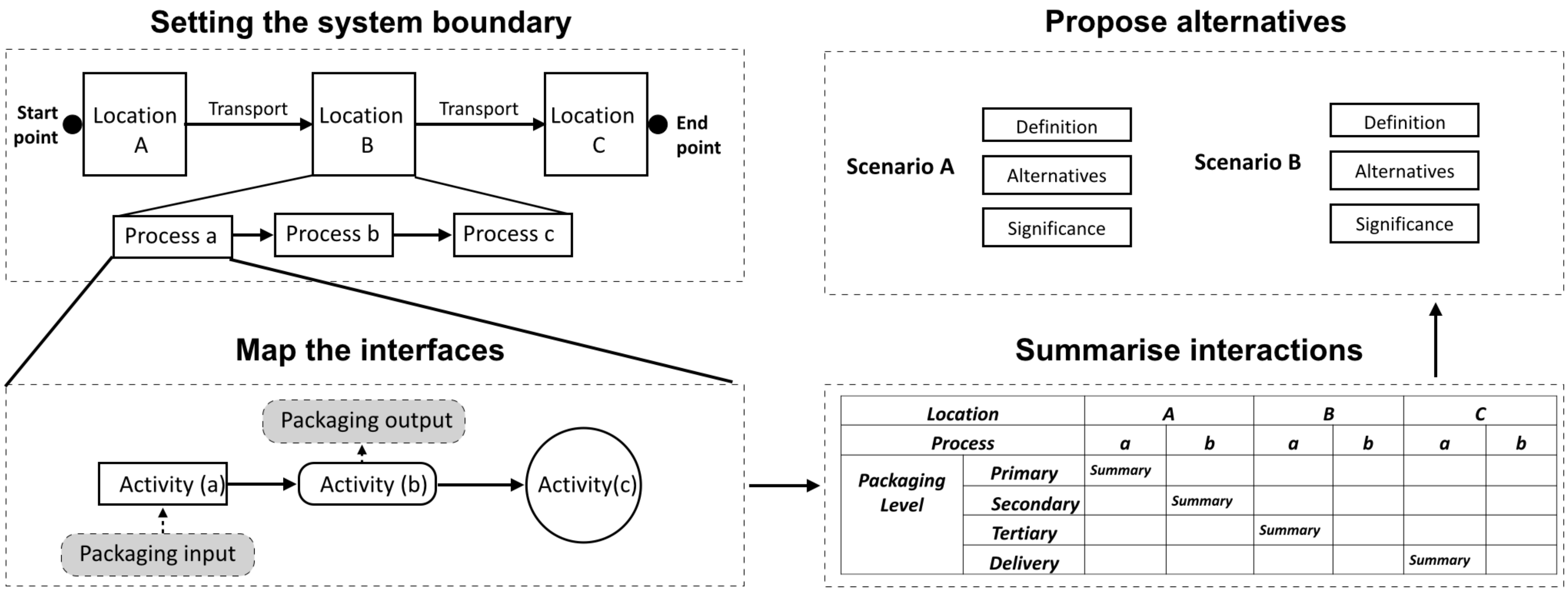


Figure 14 Analysis framework of e-commerce packaging logistics

4.3 Setting of System Boundary

Here the analysis borrows the case of liquid detergents from García-Arca et al. (2016). From the stakeholder analysis, it is known that decisions on the primary packaging level will exert influences upon the following parts of the supply chain, so the start point is set at the manufacturer's filling process — filling liquid detergent into bottles. Since consumers are those served by the supply chain and the lifecycle of packaging shall be covered, the disposal process at end-consumers is selected as the end point.

When taking account of all 'operators' engaged in the e-commerce logistics, this study makes an assumption that the manufacturer is the direct e-retailer (or tier-one supplier). This assumption entirely removes the role of distributors and echoes the ultimate disintermediation function of the e-commerce model. Figure 16 lays out the differences between traditional retailing logistics and e-commerce logistics.

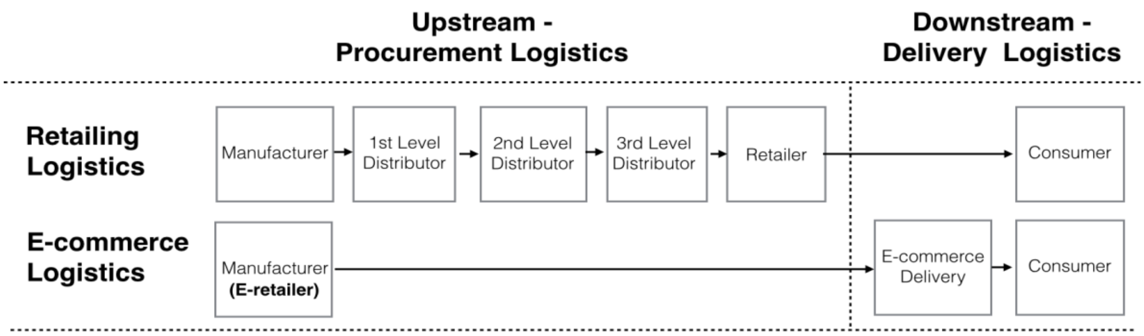


Figure 15 Comparison of traditional retailing logistics and e-commerce logistics (Adapted from Cui and Wang, 2015)

Meanwhile, differences exist between 3PL delivery and self-run logistics delivery. Consideration shall also be given to the differences between inter-province logistics and intra-city logistics, as the former involves line-haul transport and the latter is of short-distance transport. Here Figure 16 illustrates different e-commerce logistics modes of delivery products from A province ('A' hereafter) to B province ('B' hereafter).

Two temporary findings here are: 1) e-commerce logistics frequently omit some handling or transport procedures in real-life delivery; 2) the supply chain of 'supplier +3PL' mode could be more extended compared to that of 'supplier + self-run logistics'. The first phenomenon is a result of both the short time window allowed for e-commerce delivery and the limited availability of logistics infrastructure. The second accords with previous studies that e-commerce self-run logistics could even shorten the supply chain with multifunctional e-warehousing. This study here would choose inter-province logistics for both 'supplier + 3PL' delivery and 'supplier + self-run logistics' delivery to comprehensively unfold the detailed packaging logistics activities.

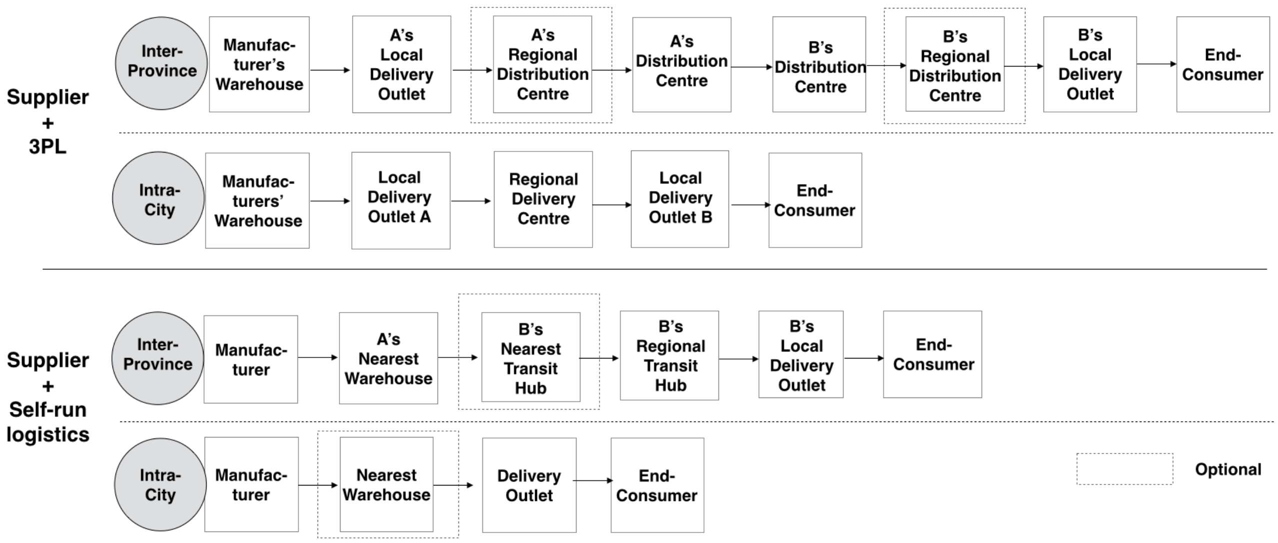


Figure 16 Comparison of Flow Differences Between E-commerce Delivery Logistics (Adapted from Cai and Wang, 2015)

Fixed start point and end point, together with determined locations along the supply chain, have roughly outlined the boundary, and the next step is to understand and confirm major logistics processes taking place at every location. Grounded on the available literature, two system boundary diagrams for inter-province delivery are accomplished as the below (Figure 17 and 18). It should be noticed that in 'supplier + 3PL' delivery, there are several times of handling between levels of distribution centres, logistics processes of which are almost identical. Regional distribution centres (RDCs) are not displayed in the diagram. The two diagrams are frameworks for detailed mapping.

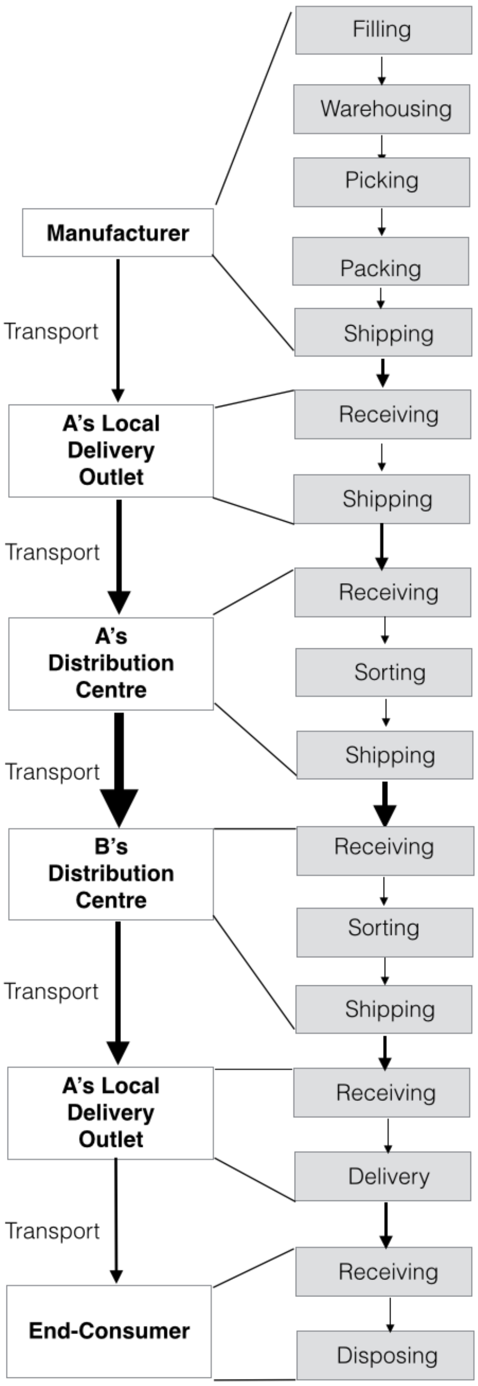


Figure 17 System Boundary of 'Supplier + 3PL'

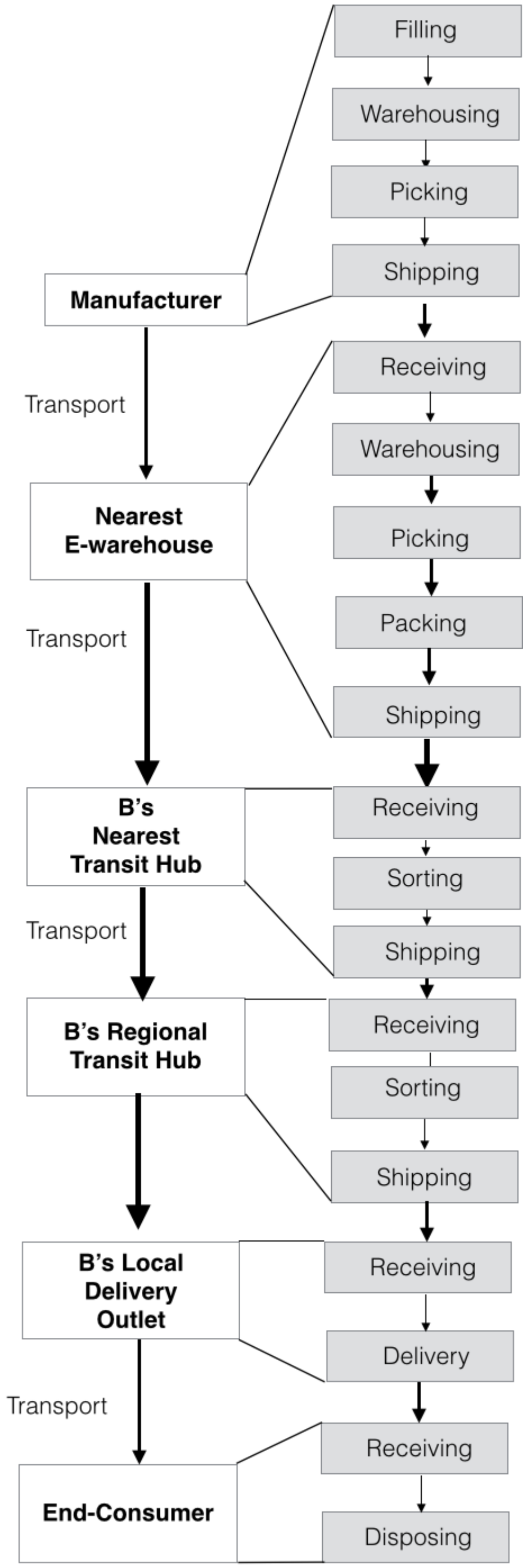


Figure 18 System Boundary of 'Supplier + Self-run logistics' Delivery

4.4 Detailed Mapping of Packaging Logistics Activities

From the supply chain level down to the activity level of packaging logistics, this section will present detailed maps of packaging-logistics activities in each logistics process. The framework above has provided an overview of all logistics processes, some of which are iterative. Hence, in this section, only distinguishable processes will be mapped.

A set of activity symbols is employed in the mapping to group activities with their key functions or features. The original set is designed by Hellström & Saghir (2007) for traditional retailing cases, and a few symbols are added by this study to better portray the state-of-the-art e-commerce logistics (Figure 19).

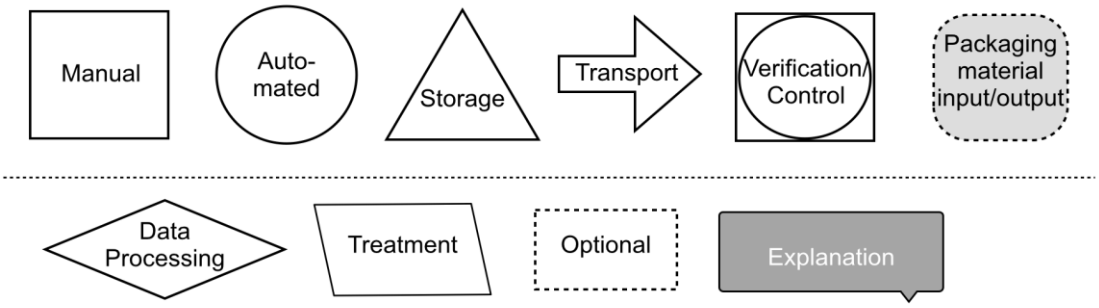


Figure 19 Activities Symbols for Detailed Mapping

The mapping of the manufacturer end is mostly supported by existing literature, whereas the e-delivery logistics are mapped in accordance to on-site investigation and stakeholder interviews. For the consumer end, consulting reports on last-mile delivery and e-commerce consumer behaviors are informative sources.

4.4.1 Packaging Logistics Activities in 'Supplier + 3PL' Delivery

The representative processes to be mapped in 'supplier+3PL' logistics are selected as: 1) filling, warehousing, packaging and shipping at the manufacturer end; 2) receiving and shipping at the A's delivery outlet; 3) receiving, sorting, shipping at the A's distribution centre; 4) receiving and delivery at B's delivery outlet; 4) receiving and disposing at the consumer end. This section will exhibit the maps in line with the process sequence. Some processes are mapped together to ensure consistency.

Manufacturer

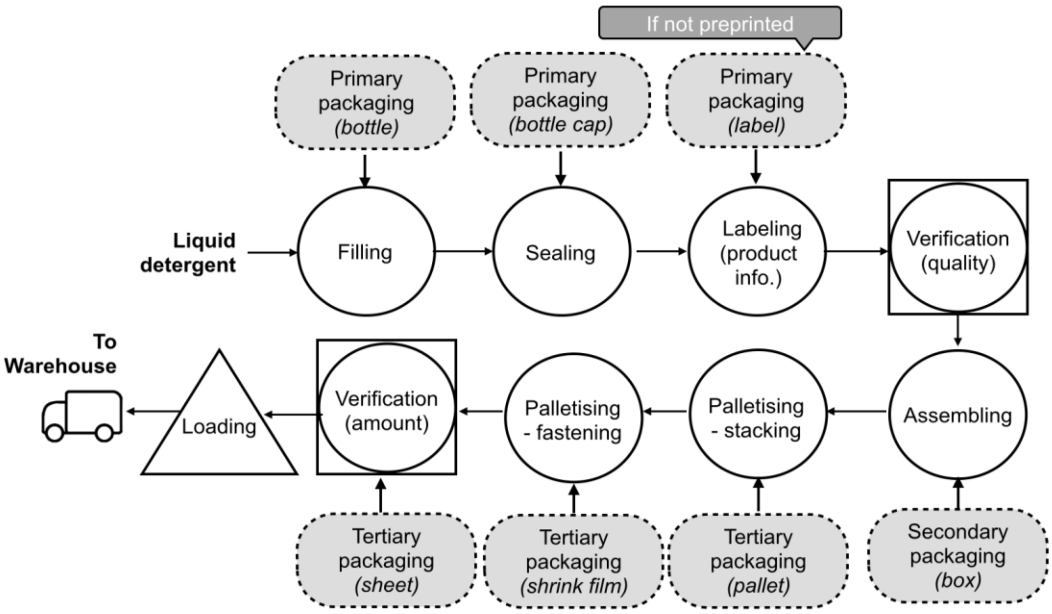


Figure 20 Packaging logistics activities in filling process (manufacturer)

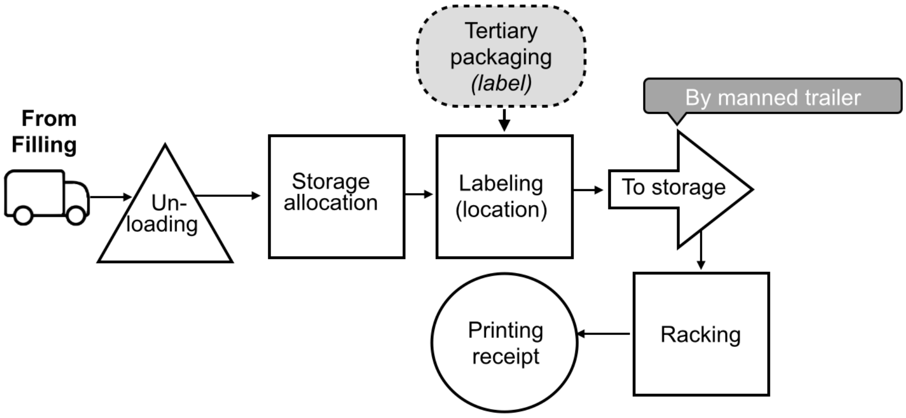


Figure 21 Packaging logistics activities in warehousing process (manufacturer)

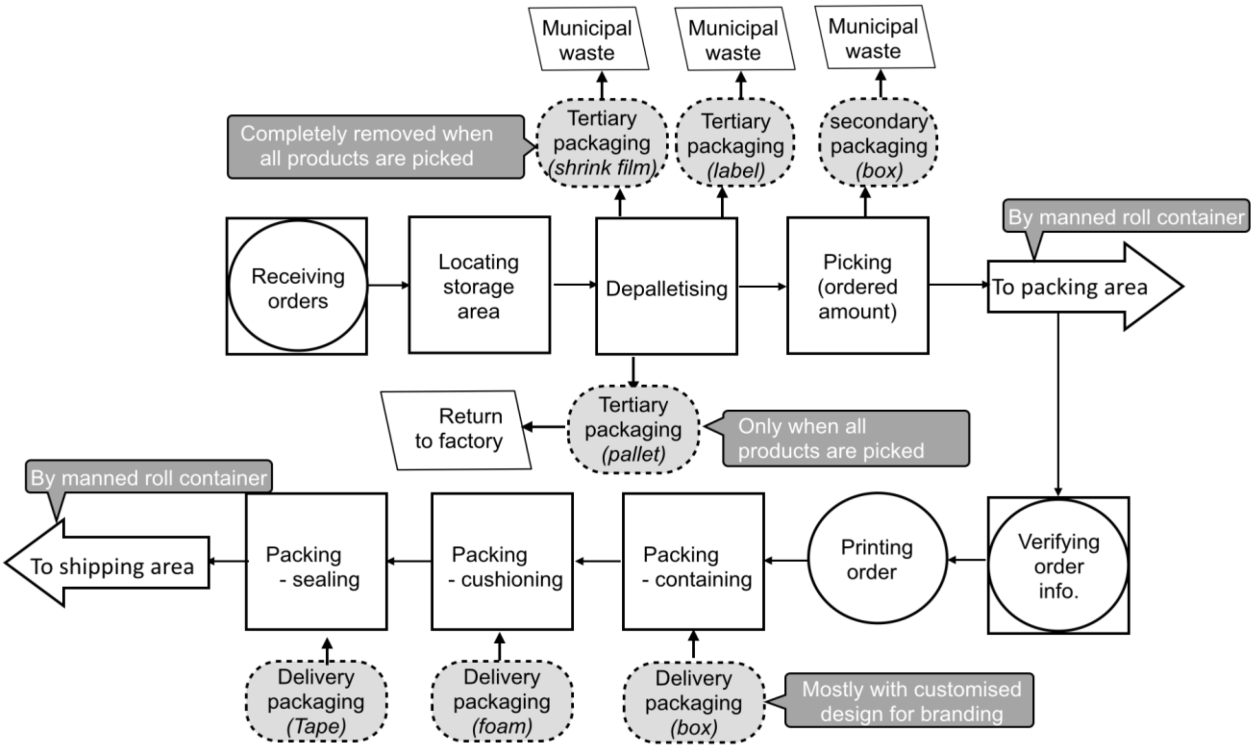


Figure 22 Packaging logistics activities in picking & packing process (manufacturer)

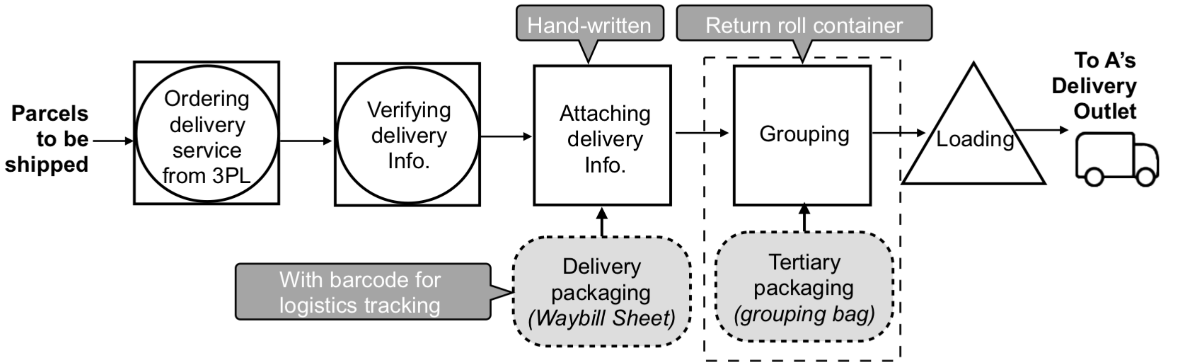


Figure 23 Packaging logistics activities in shipping process (manufacturer)

The manufacturer end is ultimately influential for the entire packaging logistics, as it is where major decisions on primary packaging and delivery packaging are implemented. A pump bottle is normally chosen to contain liquid detergent in retailing, with a conspicuous label for the marketing purpose. However, as shown, the detergents will be picked and packed into delivery packaging at an early stage of the supply chain. Rather than highlight advertising features, such supply chain restructuring would first underline the primary packaging's compatibility to both the delivery packaging and the multi-handling logistics. Compared to bottles, soft primary packaging could be advantageous with respect to ductilibility, portability and shatterproof capacity. Newly invented INNATE™ soft pack, for instance, caters for leakage prevention and weight reduction in e-commerce logistics (Dow, 2017).

Distributed online orders would affect manufacturers' decisions of both labour and packaging issues in the picking, packing and shipping process. For the filling process, automated pipelines are fully realised; for factory warehousing, though it requires manual work, the workload is even and predictable. Nevertheless, online orders attach much importance to quick-responsiveness, customisation and product protection in e-commerce logistics operation. To meet the expectation, the manufacturer has to bear the cost of recruiting more pickers, packers and customer service personnel, as well as purchasing certain delivery packaging materials. In fear of product damage that hampers the business reputation, over-packaging emerges as a prevailing phenomena in practice, and plastics materials made of industrial wastes are preferred to offset the costly over-packaging. As a result, it evokes the concerns about both solid waste generation and toxicity risks. The customised delivery packaging and the distributive e-commerce delivery together complicate the waste collection and recycling process, whereupon the situation can be exacerbated.

In the meantime, tertiary packaging underpins all logistics activities at the manufacturer end, from palletising, depalletising to grouping. As the e-commerce sales grow, some palletising-related activities can become redundant, that is to say, products filled into primary packaging may be directly transferred to the picking process without being stacked and stored in the warehouse for a period. Effectuated by the collaboration between manufacturer factory and warehouse, this practice would both curtail the time window for e-commerce delivery and lessen the material input of tertiary packaging or even secondary packaging, further relieving the cost burden brought by delivery packaging decisions. An optimum cost-efficient point can be explored here considering these packaging logistics interactions.

On the whole, at the manufacturer end, albeit packaging logistics interactions are perplexing and at some points problematic, there leaves much room for optimising logistics processes and introducing cost-reliable packaging solutions.

A's local delivery outlet

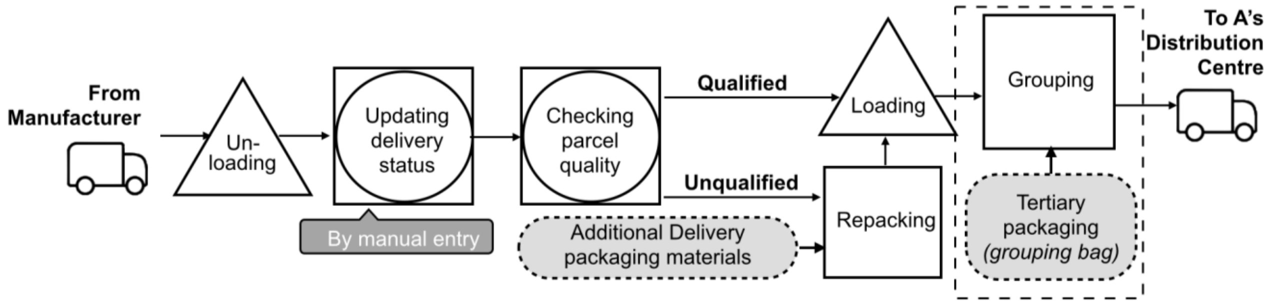


Figure 24 Packaging logistics activities in receiving and shipping process
(A Province's local delivery outlet)

The A's delivery outlet is where the 3PL company starts to take charge of the e-commerce logistics. After the unloading activity, outlet workers (sometimes couriers) will enter the delivery information and status of every parcel to the logistics management system. This repetitive and laborious activity interacts with the five-layer handwritten waybill, a part of the delivery packaging. Handwriting recognition brings uncertainties to entry correctness and eventually delivery accuracy. In addition, such manual activity can severely impedes delivery efficiency by occupying most workforce in the outlet. Its alternative, three-layer electronic waybill (e-waybill hereafter), has been popularised to address such inefficiencies. Cainiao Network invites manufacturers to access to its e-waybill portal and print standardised thermal-sensitive e-waybills for corresponding delivery outlets. In delivery outlets, workers can conveniently upload the delivery status with scanners. E-waybills, open data platforms and scanning devices together set the manufacturer end and frontier outlet workers free from writing and checking delivery information. Since it consumes less paper, the e-waybill is also deemed as a cost-efficient and eco-efficient solution.

The repacking of delivery packaging is also worth considering. Over-packaging is an ambiguous concept. Reaching a consensus on what is a proper delivery packaging is difficult with the absence of authoritative standards and the reality that different products demands different degrees of protection. The repacking activity, now taken as an indispensable step for quality control, could be surplus in advanced scenarios where packaging standardisation is enacted and the protection sufficiency could be quantitively assessed for each delivery. Likewise, since the local delivery outlet is an independent franchisee to the 3PL, workers will procure packaging materials at the lowest price to guarantee profits, and the same concerns over packaging risks will persist.

A's distribution centre

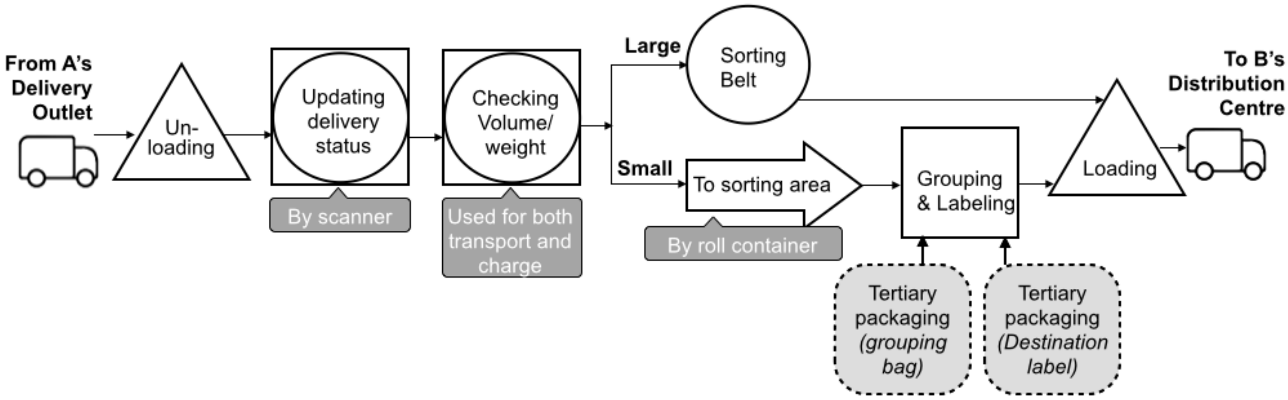


Figure 25 Packaging logistics activities in receiving, sorting and shipping process (A Province's distribution centre)

The A's distribution centre is constructed to sort both inbound and outbound parcels. In the centre, the delivery packaging, in the form of parcels, is unloaded, scanned, checked and sorted. The tertiary packaging is to group the sorted small parcels, prevent them from flopping in transit and carry the logistics information. One distinction here is that large parcels will be directly sorted and loaded onto the lorry, whereas small parcels are roughly sorted first and then moved to the sorting and grouping area. Rough handling usually happens during the sorting process, as a small parcel would be thrown into the roll containers, tossed down on the ground and slung to grouping bag within only a few seconds. An interviewee acknowledged this prevalent practice, and stated that too many parcels for sorting compelled the sorters to shorten the handling time at their best. Another correlative factor is the existing practice of over packaging. There forms a vicious cycle of 'the more the packaging is used, the rougher the sorting could be'. To exterminate the cycle, automation is perceived as a salient alternative and its performance will be expatiated in the section of 'supplier + self-run logistics'.

Another interface between packaging and logistics is in the shipping process. As an interprovincial truck-line connects A's distribution centre to B's distribution centre and a heave lorry is usually applied to the delivery, the loading efficiency is held in great account here. Packaging volume and weight are two determinant factors for vehicle dispatching and actual load rate, thereupon cube optimisation and light weight are regarded as key strategies to minimise the environmental impacts engendered by both packaging materials and transport. For this purpose, the compatibility between packaging levels and their individual optimality are equally important.

B's delivery outlet

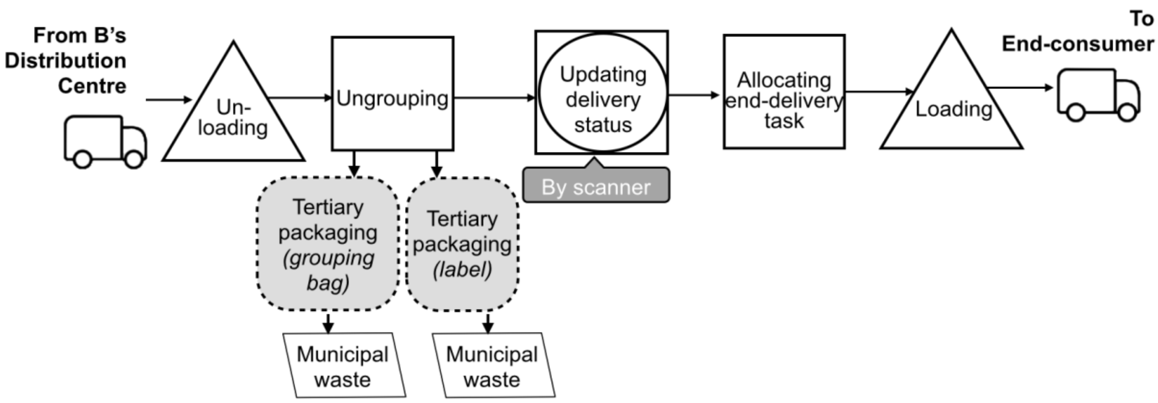


Figure 26 Packaging logistics activities in receiving and delivery (B's delivery outlet)

A delivery outlet takes responsibilities of both parcel collection and last mile delivery, and B's delivery outlet fulfils the later part. Though the ungrouping activity is only mapped here, it can be practiced at every logistics site depending on the situation. Grouping bags are disposable due to their low quality and the tough handling environment. If reckoned with the handling times per delivery, these tertiary packaging would be a non-negligent contributing factor to the total waste generation. Nonetheless, concerning the irreplaceable grouping function in the current commerce logistics, durable bags or bags made of biodegradable materials are taken as effective alternatives instead of erasing the packaging group entirely.

Allocating end-delivery tasks is another crucial activity at B's delivery outlet. In the interviews, couriers expected technology innovations to maximise the utility of each end-delivery. Apart from the planning of delivery routes, how to make best use of the space inside end-delivery vehicles with to-be-delivered parcels can be challenging. Packaging decisions made at the prior stages could still influence the allocation results.

End-consumer

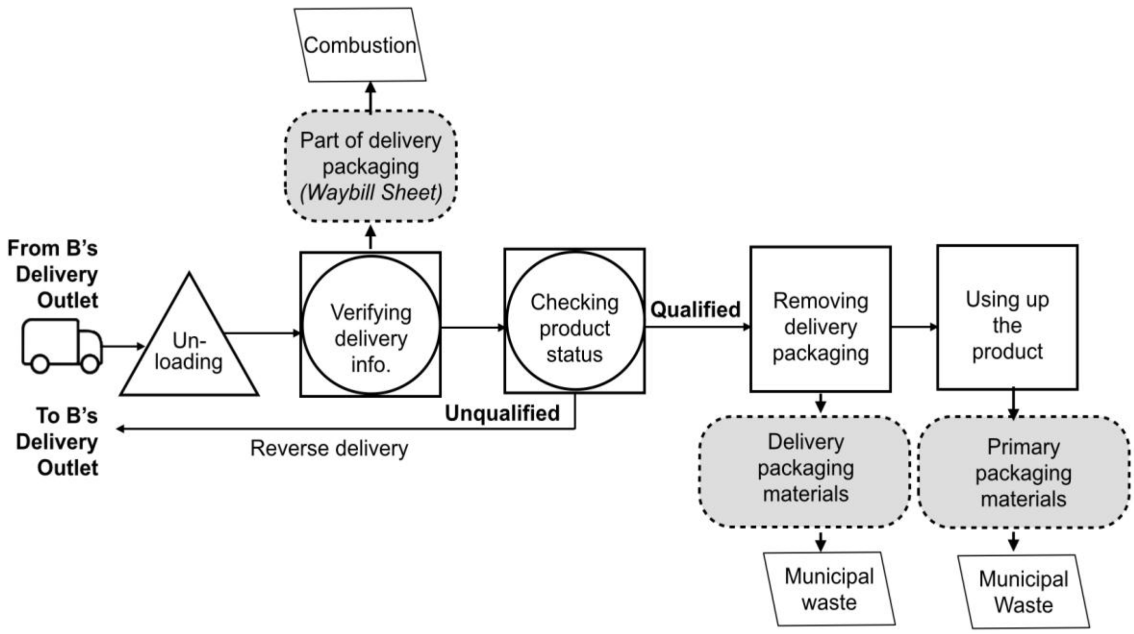


Figure 27 Packaging logistics activities in receiving and disposal (consumer-end)

As the end point of e-commerce packaging logistics, the end-consumer evaluates the performance of packaging logistics and handles the rest packaging wastes.

On confirming the packaging information, the consumer will receive the entire packaging except for the waybill copy. The 3PL company will retain the copy for a year and then dispose the concentrated copy mass in compliance with GB/T 27917-2011 ('Express Service Series Standards'). Incineration is at present the most common practice. When checking the packaging quality, the breakage of delivery packaging may impact on the end-consumer’s trust to both the supplier and the 3PL company, and the damaged primary packaging will rightly lead to the reverse logistics. It is a result of inadequate packaging logistics. In opposition to insufficient packaging, over-packaging remains as an issue and receives divergent viewpoints. According to the interview, for some consumers, over-packaging could demonstrate the supplier’ close attention to product protection and shall be encouraged. Some others regarded such practice as utterly detrimental to the environment and shall be abandoned. More or less, they expressed their dissatisfaction with the troublesome disposing. Once the product is used up, the end-consumer shall also deal with the primary packaging. Due to the lack of a effective waste sorting mechanism in China, primary and delivery packaging will all be mixed into the municipal waste flows and further processed. Scavengers can engage in collecting the e-commerce packaging waste, but there is no available official data to indicate their actual contribution.

In evaluation of e-commerce logistics performance, the consumer accents both delivery efficiency and packaging integrity, which are closely related to decisions on logistics processes, packaging materials, packing strategies, sorting methods, etc. Delivery packaging, serving as the final interface between the e-commerce logistics service and the end-consumer, has potentials for value creation. The supplier, as shown previously, chooses customised delivery packaging for market differentiation; the 3PL company, if able to both keep the packaging integrity and recycle the packaging materials on the spot, can gain consumer trust and social reputation. At the disposing stage, the delivery packaging itself could become a tool for consumer education. Unilever redesigns its delivery box so that end-consumers are guided to scan the QR code after flattening the delivery box, which is the first step for recycling. The QR code will continuously promote Unilever’s sustainability projects and cultivate pro-environmental behaviours. To improve consumers’ willingness for recycling, Yiside invents a tape-free box that largely reduces the inconvenience in packaging dismantling.

Even though the packaging system interacts with limited activities at the consumer end, each interaction touches upon fundamental trade-offs throughout the e-commerce packaging logistics (e.g., product protection vs. packaging minimisation, logistics efficiency vs. packaging integrity, customisation vs. standardisation, direct disposal vs. recycling). Compared to other processes, the innovations for the last-mile delivery will drastically change the interfaces at the end point, and chances for value creation can be further explored.

4.4.2 Packaging Logistics Activities in 'Supplier + Self-run logistics' Delivery

Since several processes in 'supplier + self-run logistics' delivery are the same to 'supplier + 3PL' delivery, they will not be repeated in this section. The left representational processes are: 1) packing and shipping at the manufacturer end; 2) receiving, sorting and shipping in the nearest e-warehouse; 3) receiving, sorting and shipping at the A's transit hub; 4) receiving and disposing at the consumer end.

Manufacturer

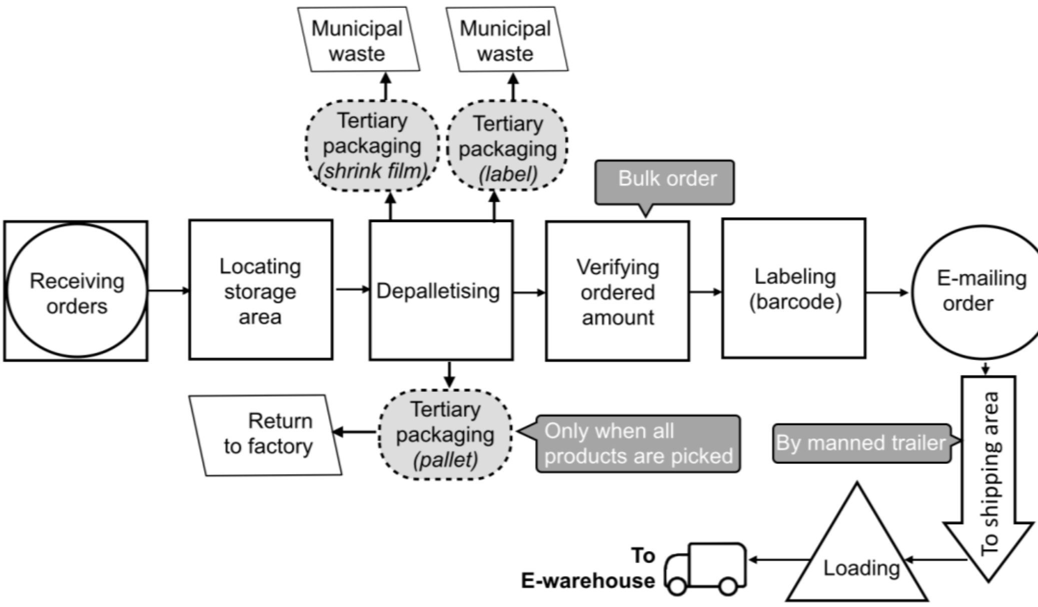


Figure 28 Packaging logistics activities in packing and shipping process (manufacturer)

There could be two collaboration modes between the upstream supplier and the e-commerce platform in this logistics scenario. One is a ‘fully self-run' mode, that is, the e-commerce platform directly procures products from the manufacturer and delivers products to the consumer. The other is a 'collaborative warehousing' mode, with which the manufacturer in advance stores a certain number of products in a e-commerce warehouse nearest to the end-consumer. Instead of sorting and packing products individually, the manufacturer here only labels the secondary packaging with a barcode rightly after the depalletising activity. Transferring the product from the manufacturer’s warehouse to the e-commerce warehouse is a typical B2B logistics to ensure transport stability. By this means, the manufacturer can avoid expenses of delivery packaging and employ less workforce at the expense of packaging customisation. Once the manufacturer gets access to the e-commerce warehouse system, the paper consumption can be largely reduced since all processes are recorded electronically.

E-commerce Warehouse

The integrated e-commerce warehouse is a vital integrant of the self-run logistics. Compared to the manufacturer warehouse that manages limited SKUs, the e-commerce warehouse can store, schedule and manoeuvre abundant SKUs with high flexibility, efficiency and accuracy. The e-commerce warehouse investigated by this study is a representative with high-level automation, large-scale storage and sophisticated management system.

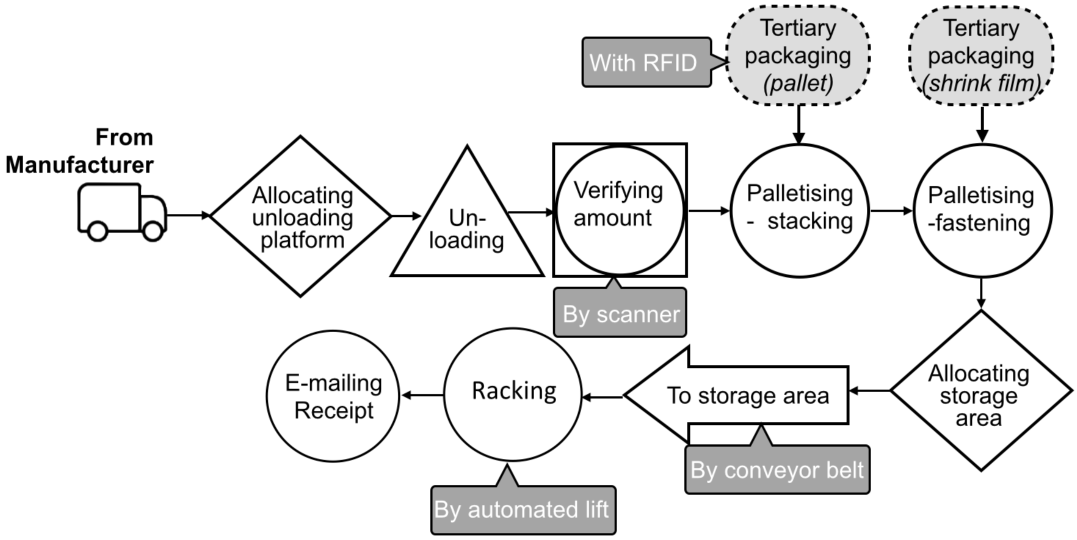


Figure 29 Packaging logistics activities for receiving and warehousing process (nearest e-warehouse)

Before the manufacturer's lorry (or a lorry owned by e-commerce warehouse) arrives at the e-commerce warehouse, the TMS (Transport Management System) will allocate the unloading platform to shorten the waiting time. Throughout the ‘supplier +3PL’ logistics, the packaging is unloaded manually by casting and throwing. In comparison, the assorted facilities of automated unloading belts, stackers and forklifts can realise the smooth handover of the secondary packaging onto the pallets. Albeit efficient and safe, the repeating palletising activities can be further optimised to reduce the wastes of tertiary packaging. JD.com and P&G has piloted a pallet pooling project and proved it to be cost-efficient and even more timesaving. From a regulatory perspective, the premise of pallet pooling is the standardisation of pallet forms. Recently, the national government has been vigorously promoting the 1200mm*1000mm pallet standard (Ministry of Commerce et al., 2016; General Office of State Council et al., 2018) to encourage industrial collaboration. The inception of IoTs (Internet of Things), especially the radio frequency technology, enables the real-time tracking of pooled pallets to prevent loss.

In the warehousing process, the already barcoded secondary packaging (here as a corrugated board box) can facility the inventory check and updates, and the pallet circulating inside the e-warehouse is equipped with RFID (radio frequency identification) tags to share its instant location as well as the SKU information. Here different levels of packaging function as carriers of digital information and interfaces for data exchange, underpinning the automated warehouse management. This can be taken as an irreplaceable value of packaging in logistics activities: only with the digitalised packaging, can full automated warehousing be actualised. The WMS will assign the storage area stochastically by an intelligent algorithm, and the AS/RS (Automatic Storage& Retrieval System) can then transport the palletised unit up to the assigned area with automated belt, AGV (automated guided vehicle) and automated lifts.

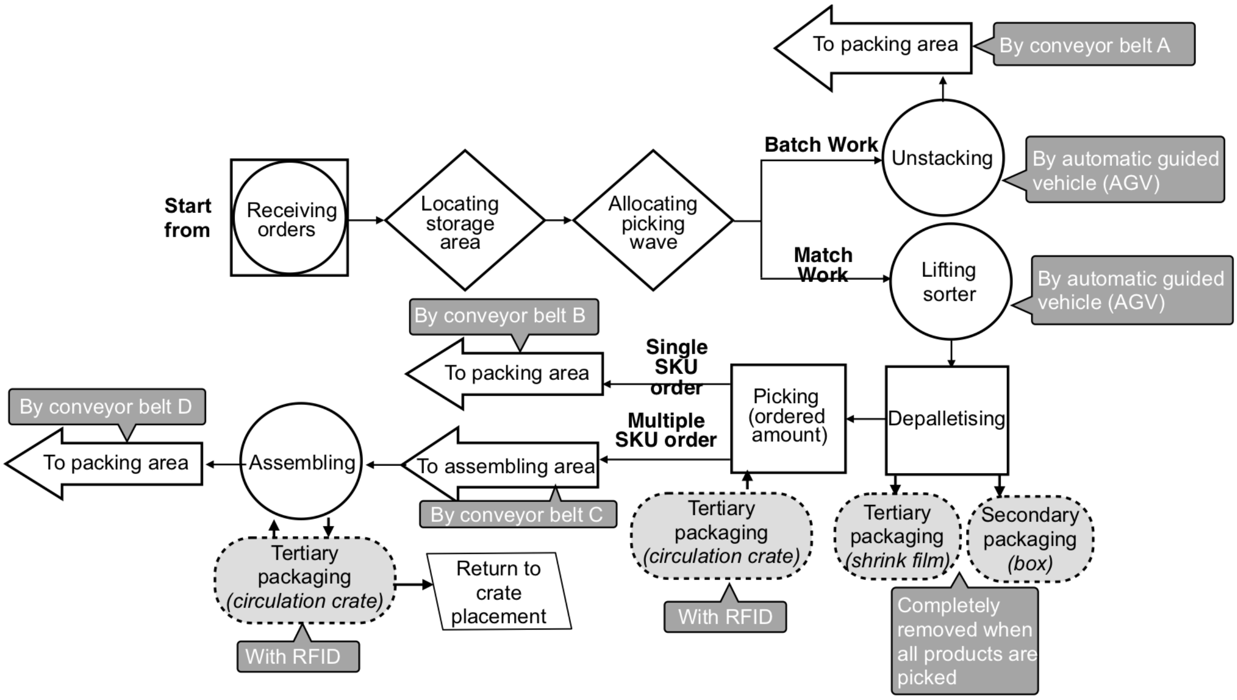


Figure 30 Packaging logistics activities for picking process (nearest e-warehouse)

When it comes to the picking process, the e-commerce warehouse copes with a great deal of diverse orders constantly, so its picking strategy can differ from that of the manufacturer's warehouse. In this study, a mixed practice of wave picking and order picking is observed (Figure 30). Once the order is confirmed, the WMS will first locate the storage area and then allocate the wave picking tasks. The batch order can be fully handled by an AGV and a conveyor belt, whereas the match order is handled by pickers with crates (here considered as secondary packaging). A series of packaging interactions take place here. The picker removes the shrink film, opens the corrugated board box, picks out the product and places it in a circulation crate. If the picker can handle the box properly and keep it undamaged, there are possibilities for it to be reused. JD Group and P&G have again collaboratively tapped the potential of secondary packaging by reusing it as the delivery packaging. Amazon China endeavours to totally erase the use of secondary packaging and even tertiary packaging by adopting a 'random shelf' system. After the wave picking activity, the circulation crates will be sent to the assembling area for order picking. The pickers will take the exact product out of the wave crate and put it into an order crate in preparation for packing.

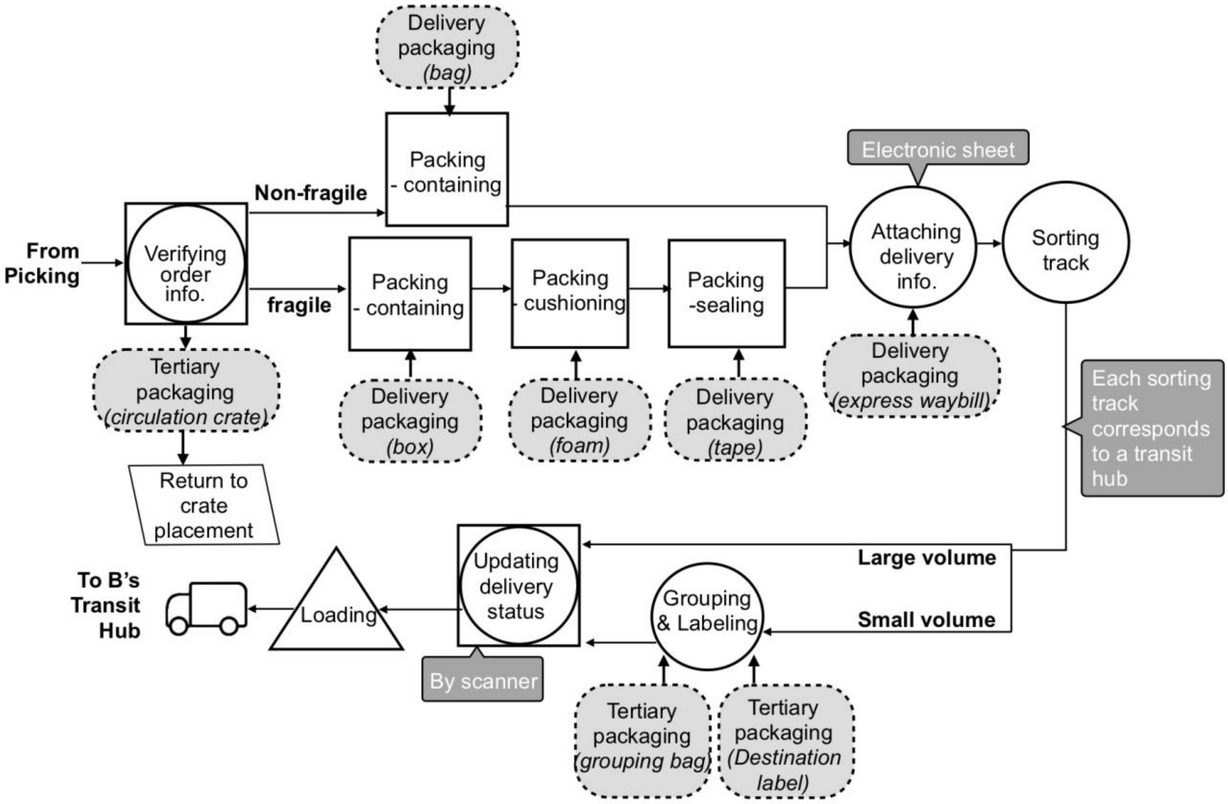


Figure 31 Packaging logistics activities for packing and shipping process (nearest e-warehouse)

The current packing process, even in e-commerce warehouse, is labour-intensive considering the high cost of a automated packing line. The packer will make following decisions on the delivery packaging: 1) for products that have shock-proof primary packaging (e.g. 3C products), no delivery packaging is needed; 2) for non-fragile products, a sealed plastic bag is applied as the delivery packaging; 3) for fragile products, a corrugated box and cushioning materials will be used. The flexible packaging decision-making here is grounded on the self-run logistics' full control of all logistics activities. In this sense, in order to lower the uncertainty of logistics activities in 3PL delivery, a low-priced sensor that can detect shocks will be an apt measure.

Prior to the e-waybill solution, the e-commerce warehouse prints delivery information on CCP waybill and can be bothered by the printing speed during peak seasons. The e-waybill can both guarantee the printing efficiency and refrain the loss of waybill codes since it removes the carbon copy. In self-run logistics, it is even updated to ‘privacy waybill’ which encodes delivery information to prevent the privacy leakage. The packed product then is conveyed to the sorting belt and directly drops into the grouping bag. During the conveyance, the scanner aside can immediately read and update the e-waybill information. Thanks to the well-established data platform, all operational commands and problems can be communicated on handheld devices and the computer terminal, by which the paperless warehousing management is achieved. Empirical evidence supports that the paperless approach can bring both environmental and economic benefits. According to the operational data of Yhd.com, its paperless warehousing in 2015 alone reduced 9 ton of carbon emission and saved 9 million (China Warehousing Association, 2016).

The in-depth analysis of packaging logistics activities in the e-commerce warehouse indicates that the self-run logistics has partially optimised the receiving, warehousing, picking, packaging and loading processes compared to the 3PL logistics, and its collaboration with upstream suppliers can further reduce the redundancies. Besides, the standardisation and digitalisation at the packaging end can lay the basis for IoT, automation machinery and intelligent warehousing system.

B's Transit Hub

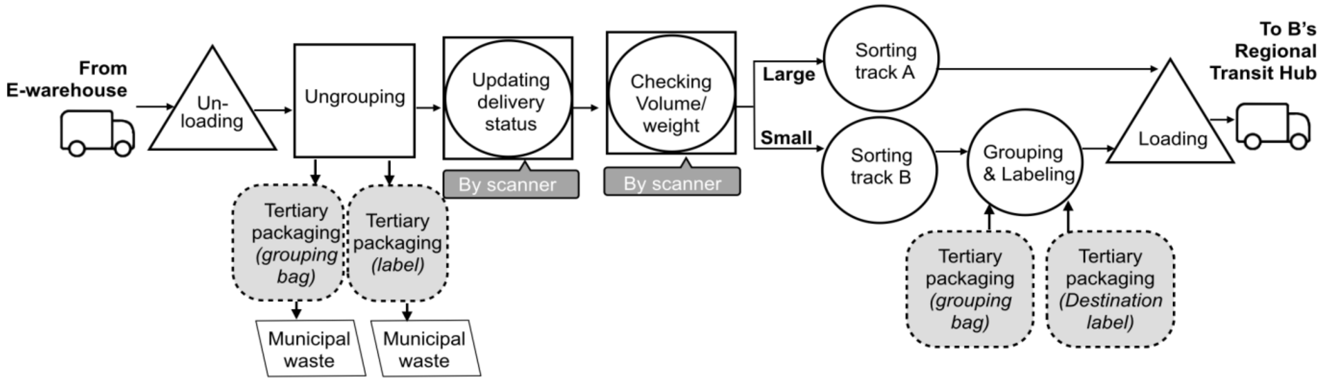


Figure 32 Packaging logistics activities for receiving, sorting and shipping process (B's transit hub)

Each e-commerce warehouse is a district centre managing levels of transit hubs and delivery outlets in a spiderweb layout. For each transit hub, the direct interactions between packaging and logistics are ungrouping, sorting and grouping. Unlike the distribution centre in 3PL delivery which sorts both inbound and outbound parcels, a transit hub only targets at the sorting of inbound parcels. Since the task is simplified, a few automated sorting belts can be installed to avert rough handling. In terms of packaging materials, this study discovers that the transit hub uses white grouping bags made of raw PP granulates, whereas the 3PL distribution centre chooses grey ones made of recycled PP granulate. In self-run logistics, all the material costs are burdened by the district management centre and the packaging decision is highly centralised. This reveals the relative advantage of self-run logistics to implement and generalise new solutions.

B's Delivery Outlet

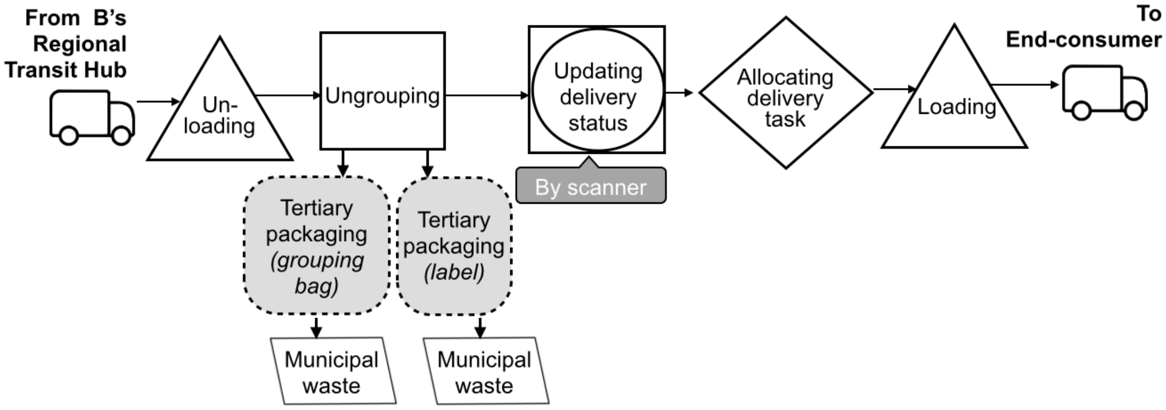


Figure 33 Packaging logistics activities for receiving and delivery process (B's delivery outlet)

At the delivery outlet, the front-line worker ungroups the parcels and updates delivery information with a handheld scanner. One distinctive feature here is that its backstage management system can employ intelligent algorithm to optimise the task allocation of loading and last-mile delivery. Technical operation can thus significantly cut down the workload of front-line workers. It is reported that AGVs will gradually replace the manual delivery, improving the performance of both end-delivery and reverse logistics (China Academy of Transportation Sciences, 2017). At present, the cost structure of box recycling projects launched JD Group, Suning Group and Yhd.com comprises reverse transport expenses and subsidies to both couriers and end-consumers, whereupon the introduction of energy-saving AGVs in such projects can both reduce the subsidy demand and the extra expenses in reverse logistics.

End consumer

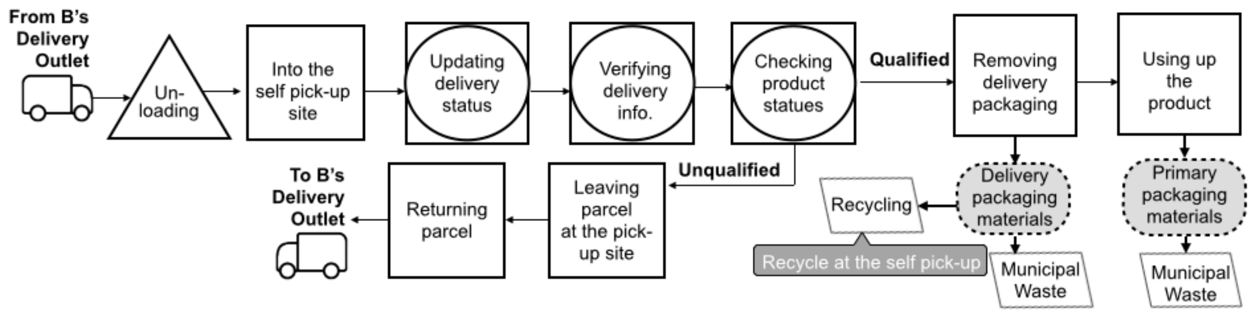


Figure 34 Packaging logistics activities for receiving and disposing process

In a door-to-door situation, there are many factors to fail the delivery. To address this, the smart parcel delivery locker and the self pick-up site have grabbed the market attention. The smart parcel delivery locker, for instance, allows the courier to store the parcel in a locker and informs the end-consumer of the parcel arrival automatically. It also enables the end-consumer to return the parcel and inform the courier of the parcel status. Theoretically speaking, both the delivery locker and the self pick-up site can serve as recycling spots. In practice, it can be challenging. An interviewed worker at a pick-up site noted that even though half of delivery boxes were returned, only 10% of them were finally reused. The low detachability of delivery packaging is the main concern. The analysis of 3PL logistics have proposed that packaging with detachable design can motivate end-consumers to practice recycling, and here such packaging property can be the guarantee for recycling success.

Given the fact that the recycling of paperboard box is costly and the raw material price increases evidently, some self-run logistics operators resort to the reusable PP corrugated box in lieu of the disposable paperboard box. Nevertheless, some ENGOs strongly oppose the choice as more plastics materials will be consumed and finally discarded to pollute the environment. Chapter 5 will resolve this dispute by providing quantitive results of their environmental performance.

4.5 Summary of Packaging Logistics Interactions

The detailed mapping section has thoroughly analysed the e-commerce packaging logistics activities to answer how packaging decisions interact with logistics and eventually influence the supply chain performance. This section tends to summarise the packaging logistics interactions for further discussion. Table X. and X set forth the overview of interactions between logistics processes and different packaging levels in the two modes of e-commerce delivery.

Table 7 Interaction of logistics processes and packaging system in 'Suppler + 3PL'

Logistics Site		Manufacturer					A's Local Delivery Outlet		A's Distribution Centre			B's Distribution Centre			B's Local Delivery Outlet		End-consumer	
Logistics Process		Filling	Warehousing	Picking	Packing	Shipping	Receiving	Shipping	Receiving	Sorting	Shipping	Receiving	Sorting	Shipping	Receiving	Shipping	Receiving	Disposing
Packaging System	Primary	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o
	Secondary	o		o														
	Tertiary	o	o	o		o		o	o		o	o		o	o		o	
	Delivery				o	o	o	x	x	o	x	x	o	x	x	o	o	o

Table 8 Interaction of logistics processes and packaging system in 'supplier+self-run logistcis'

Logistics Site		Manufacturer					A's Local Delivery Outlet		A's Distribution Centre			B's Distribution Centre			B's Local Delivery Outlet		End-consumer	
Logistics Process		Filling	Warehousing	Picking	Packing	Shipping	Receiving	Shipping	Receiving	Sorting	Shipping	Receiving	Sorting	Shipping	Receiving	Shipping	Receiving	Disposing
Packaging System	Primary	o	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	o
	Secondary	o		o														
	Tertiary	o	o	o		o		o	o		o	o		o	o		o	
	Delivery				o	o	o	x	x	o	x	x	o	x	x	o	o	o

In the tables above, the symbol '**o**' denotes expectant interactions while '**x**' indicates latent interactions as its complement. Expectant interactions could be packaging inputs, outputs and direct handling interfaces as shown in the detailed mapping, whereas latent interactions are brought by the close interdependency within the packaging system. Overall conclusions can be drawn as : 1) the concern over delivery packaging in self-run logistics is much less then in 3PL logistics due to its supply chain controllability; 2) primary packaging shall be highlighted concerning its latent interactions to the logistics activities; 3) redundancies in the repeating input/output of tertiary packaging shall be removed by streamlined logistics activities in both logistics modes.

4.6 Design of Alternative Scenarios

Detailed mapping and interaction tables have both laid bare the problems and explored the potential breakthroughs in e-commerce packaging logistics. With the previous discussion, this section will devise a few alternative scenarios to 'Supplier + Self-run logistics', each hammering at a specific solution field and will be assessed in Chapter 5.

4.6.1 Automation Update Scenario

To Improve the overall logistics efficiency

By automating the packing process of delivery packaging

Using automated machinery (e.g. packing pipeline) and AI technology (e.g. machine vision)

The automation update scenario is developed based on the observation that the packing process of delivery packaging still relies on manual work. The inaccurate decision-making in this particular process can result in severe consequences including the inefficient load rate in transport and unnecessary resource depletion, eventually more emissions and solid waste.

This scenario assumes that the automation update in the packing process can realise cube optimisation when introducing automated packing pipelines together with machine vision. The compatibility of delivery packing to primary packaging can also be increased. Moreover, Suning Group has piloted such practice, so the scenario can refer to a benchmark case.

4.6.2 Material Substitution Scenario

The material substitute scenario tackles with the material solutions concerning stakeholder

> **To** enhance the eco-efficiency of the packaging system
>
> **By** replacing the packaging materials perceived as relatively unsustainable
>
> **Using** their 'sustainable' alternatives（e.g. biodegradability; reusability; byproduct material ）

perceptions and market prototypes identified throughout the packaging logistics analysis. The packaging materials perceived as unsustainable shall be linked to their actual applications in packaging logistics. For instance, HDPE is considered as 'unsustainable' due to its lack of biodegradability, so its 'sustainable' alternative PLA is adopted. The corrugated board, though biodegradable, is deemed as 'unsustainable' since it is largely disposable as the delivery packaging. Reusability is prioritised for choosing its alternatives. The wooden pallet, reusable and biodegradable, can still be taken as relatively unsustainable in comparison to the straw pallet which is made of agriculture wastes. Basically, this material substitute scenario is a collection of temporarily 'sustainable' solutions to be assessed.

4.6.3 Packaging Rationalisation Scenario

> **To** balance the packaging function and the environmental toll
>
> **By** rationalising the packaging forms
>
> **Using** light-weighted and reusable designs

The packaging rationalisation scenario focuses on the optimal packaging design, especially light-weighted and reusable design which are reckoned most effective by stakeholders. By only altering the forms of existing packaging in 3PL and self-run logistics, this scenario can demonstrate how the design phase contributes to the overall performance of packaging logistics. Specific practices distinguished by this study are: 1) soft pack to replace hard bottle; 2) thickened woven bag to replace disposable woven bag; 3) one-layer tape-free corrugated box to replace two-layer corrugated box; 4) half-sized e-waybill to replace full-sized e-waybill, etc.

4.6.4 Stakeholder Integration Scenario

To build an efficient and closed-looped packaging logistics system

By integrating the supply chain

Using stakeholder consensus and concerted efforts

The stakeholder integration scenario is established upon the ideal vision of supply chain development and the pareto improvement of logistics activities. It presumes that all identified redundant logistics activities and corresponding packaging are eliminated, and all packaging are made of HDPE and fully recycled in the end-life phase. Although the scenario is too ideal to be practiced in real-life, it can inquire into the effectiveness of stakeholder collaboration in promoting sustainable packaging logistics.

CHAPTER 5 IMPACT ANALYSIS

In this chapter, Life Cycle Assessment was adopted to estimate the impacts of packaging logistics scenarios with regard to market reality and socio-technical advancement. A specific e-commerce delivery case consisting major supply chain stages would be proposed. Assessment results were later employed to compare respective pros and cons of each scenario, which could finally buttress the supply chain decision-making.

5.1 Introduction of LCA Application

LCA, according to ISO14040 (2006), systematically complicates and evaluates the inputs, outputs and potential environmental impacts of a product, process or service system from cradle to grave. First coined in 1960s, LCA is rooted in internal studies of packaging alternatives for companies with little public disclosure (Bjørn et al., 2017). The period 1970s-1990s witnesses its conception forming and expansion to the scientific community, followed by 1990s-2000s for methodological consolidation and 2000s-2010s for scope elaboration in policy-making (Guinee et al., 2010). To this day, Life Cycle Sustainability Analysis integrating varied models has manifested itself as an interdisciplinary instrument to address sustainability challenges (Onat et al., 2017).

Despite LCA's intensive application in identifying sustainable packaging alternatives dating back to its formation, its application in sustainable packaging logistics has been rather scarce. In general, eco-design and waste management of packagings are two approaches mostly considered (Yang et al., 2010; Laurent et al., 2013). The eco-design approach targets at balancing trade-offs between resource depletion and packaging functions, and the waste management approach explores optimal waste packaging treatment to minimise pollutant emissions and energy consumption. Going beyond these two approaches which normally position logistics as a connective part in the packaging life cycle, the packaging logistics approach would reckon logistics activities (handling, transport, distribution, storage, retailing) and multiple packaging groups (primary, secondary, tertiary) as an integrated yet specific service system to be assessed. For the e-commerce industry, performance of which heavily relies on logistical performance, a thorough understanding of environmental impacts along packaging logistics activities could add to its competitiveness.

Studies touching upon packaging logistics and LCA of logistical packagings has laid the groundwork for LCA of packaging logistics in this thesis. The previous chapter 'Flow Analysis' has expounded the real-life e-commerce packaging logistics activities and proposed a set of scenario setting incorporating future possibilities. Prior to this study, extensive researches has been conducted for packaging LCA, with most as comparative cases of a certain package type. For typical logistical packagings, Koskela et al. (2014) discovered that HDPE crates outperform recyclable corrugated boxes in a bread delivery system. Silva et al. (2013) applied a case study of replacing disposable packaging model with a returnable packaging model in Brazil and attested the substitute's efficacy to both environmental and business sustainability. Bengtsson and Logies (2015) compared environmental impacts of pallet alternatives in pooled and one-way systems in both Chinese and Australian context, which explained how diverse logistics modes and packaging materials jointly influence environmental impacts. Two recent studies, in particular, studied the Chinese e-commerce context. Fan et al. (2017) calculated the environmental burden exerted by packaging materials production and distribution at the delivery industry level. Yi et al. (2016) examined environmental impacts and energy consumption of express packages, namely, corrugated boxes, plastic bags, tapes and air bubble films from production to end disposal at the unit package level. Based on previous literature, this research would like to bring actual logistics activities and systematic packaging interactions into discussion, and shed light on LCA application in e-commerce supply chain management.

5.2 Outline of LCA Method

As formulated in ISO 14040 and 14044 (2006), four main phases shall be completed in a LCA study. The four phases are outlined in Table x.

The rest parts of this chapter would elaborate on each phase. Assisted with the open source software Eco-invent 3.0, the calculation could provide weighted LCIA results of mainstream environmental impact categories, which greatly simplifies result presentation and corresponding interpretation. It should be noticed that this LCA would not strictly fulfil all the components in Table x. considering the data availability and research purposes. Nevertheless, the overall structure would be borrowed with details to flesh out this chapter.

Table 9 An overview of LCA phases (Adapted from Bauman and Tillman, 2004)

Phase	Function	Form
Goal and Scope	To provide a clear and specified problem formulation	***Goal*** 1) The intended application; 2) The reason to carry out; 3) The intended audience ***Scope*** 1) System boundary (in relation to natural systems, geography, time, technical systems, etc.) (Tillman et al., 1994) 2) Functional unit 3) Choice of impact categories 4) Types of LCA methods
Inventory Analysis (LCI)	To build a system model required by the goal and scope	1) Construction of the flow model (a flowchart documenting activities and in-between flows) 2) Input-output data collection 3) Calculation (refer to functional unit)
Impact Assessment (LCIA)	To denote the quantified environmental impacts	1) Classification 2) Characterisation 3) Weighting
Interpretation	To combine findings in LCI and LCIA to reach conclusion and recommendation (ISO 14040, 1997)	1) Identification of significant issues; 2) Evaluation of results 3) Conclusions and Recommendation

5.3 Goal and Scope

5.3.1 Goal

The key purpose of this LCA section is to quantify, evaluate and compare the impacts brought by different e-commerce plastics logistics scenarios. On the basis of logistics analysis, a typical 'supplier + 3PL' e-commerce scenario ('S_3PL' hereafter) and a typical 'supplier + self-run logistics' ('S_Self-run' hereafter) e-commerce scenario respectively represented by Taobao and JD mode are first paired for comparison. It is to test that to what extend the packaging logistics of a vertical self-run logistics could surpass that of a decentralised 3PL in terms of environmental performance. The typical 'S_Self-run' scenario would then be posed as a baseline scenario and compared with its four alternative scenarios. The result could demonstrate the environmental efficiency of different alternatives and their distinctive contributions.

The study's ultimate goal is to support the decision-making in framing sustainable e-commerce packaging logistics with scientific data and a replicable model. The intended audience, in line with stakeholders analysis, includes stakeholders groups aggregated in Chapter 3. The processed LCA results are expected to guide major decision-makers to rethink, optimise and popularise sustainable options, meanwhile, invite more supply chain stakeholders to ponder over the environmental impacts of e-commerce packaging logistics and actively take roles in the management. Although the case exemplifies the Chinese context, it also aims to sort clues for the shared conundrum of global e-commerce, that is, how to devise sustainability packaging solutions in a consumptive and dynamic supply chain.

5.3.2 Scope

5.3.2.1 System Boundary

The e-commerce packaging logistics system studied here comprises complicated logistics activities for an e-commerce delivery, with major packaging material flows linking logistics systems and natural systems. The system boundary is mapped in the flow chart below.

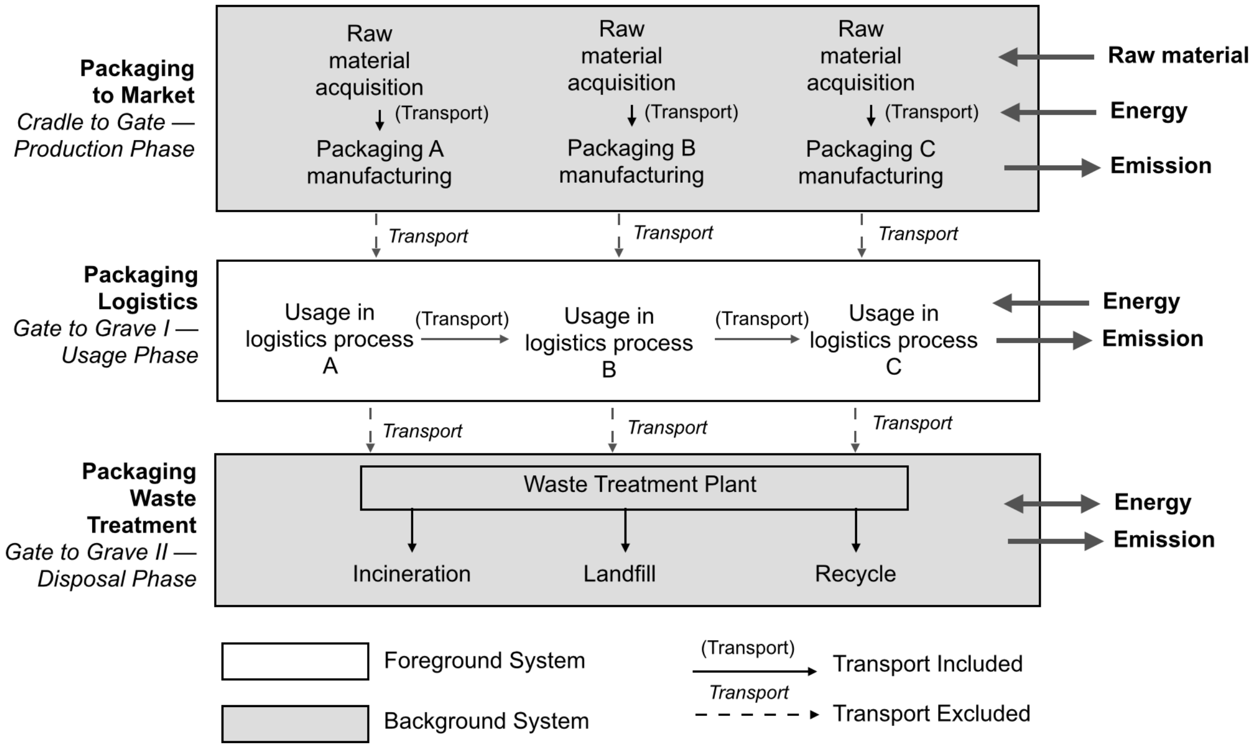


Figure 35 System boundary of the LCA study

Two specific cases are designed to fit two comparison purposes mentioned above, and the geographical boundary is initially set within Southeast China, the birthplace of Chinese e-commerce modes. Each case has its own functional unit.

- *Functional Unit of Case One:* For the first case, the functional unit would be a service of delivering two 500ml detergents from two manufacturers located in Shanghai to an end-consumer who lives in Changxing, Zhejiang. Along the decentralised 'S_3PL' supply chain, the two manufacturers would pack the detergents individually in two parcels and collaborated with a 3PL company to distribute the parcels. In contrast, the 'S_Self-run' scenario sees that the e-commerce platform directly procures detergents from the two manufacturers, and delivers the two detergents to an end-consumer in one parcel. The logistics section could be different when taking multiple operators into account.

- *Functional Unit of Case Two:* For the second case in which all scenarios follow the basic logistics setting of 'S_Self-run' scenario, the functional unit is a service of delivering a 500ml detergent from one manufacturer in Shanghai to an end-consumer in Changxing. Direct procurement and identical vertical delivery are placed.

5.3.2.2 Assumptions

Assumptions are made to facilitate the life cycle inventory and impact assessment due to the limited data availability.

- The manufacturing processes of packaging are streamlined in the modelling. For instance, the processes of transforming plastic granulates into packages (melting, molding, etc.) are excluded, which indicates that plastic granulates equal to final applicable package forms in this study.
- Plastics material variants are considered the same as plastics material originals (e.g. extended polythene accounted as polythene).
- All packaging materials are assumed to be procured from local manufacturers. At the meantime, all packages wastes will be treated at where they are disposed. So in the system boundary diagram, these transport processes are neglected.
- Energy consumption and its changes brought by technological advancement at logistics sites (warehouse, allocation centre, pick-up site, etc.) would not be taken into consideration.
- Non-plastics packages lacking the record of waste treatment flows will be treated as municipal solid waste. In terms of recycling, all plastics lacking recycling data are taken as HDPE for viewing material recovery output, whereupon certain deviation is unavoidable.

5.4 Inventory Analysis

This LCA study obtains foreground data from supplier websites, interviews, regulations, industrial reports and journal papers whilst getting background data from Eco-invent 3.4. Detailed data sources regarding materials, packaging forms, transport and waste treatment along the supply chain will be given in each part. It should be noticed that all foreground data the inventory tables (material use, transport and waste) are calculated based on the activities per delivery.

5.4.1 Packaging Materials

5.4.1.1 Basic Setting

Basic packaging material flows are presented in the form of packaging groups.

- The primary packaging is firstly set as a HDPE bottle.
- The secondary packaging is initially assumed to be a double corrugated cardboard box with adhesive tapes on two sides. Plastic crates are sometimes used for picking processes.
- The tertiary packaging at the stacking stage is a four-way pool wooden pallet in combination with heavily wrapped shrink film. At the distribution stage, grouping bags are introduced.
- The delivery packaging typically consists of a corrugated box for containment, a certain length of tape for sealing, some foam for cushioning and a handwritten express waybill.

Table 10 detailedly displays the form, material, dimension, weight and reference data of each type.

Table 10 Basic packaging setting[1]

Group	Package	Material	Dimension	Mass (g)	Reference
Primary	Product Bottle	HDPE	80mm x 220mm x 60mm	70	Footnote [1](1)
Scondary	Box	Double corrugated cardboard	400mm x 600mm x 250mm	823.2	Footnote [1](2), [1](3)
	Tape	BOPP	8mm x 5.5mm x 0.01mm	2.9	Footnote [1](4)
	Crate	HDPE	400mm x 600mm x 250mm	2800	Footnote [1](5) [1](3)
Tertiary	Pallet	Wood	1000mm x 1200mm x 125mm	22000	Footnote [1](6)
	Shrink film	LDPE	Wrapping height: 1250mm Wrapping thickness: 35mm	400	Footnote [1](7)
	Grouping bag	PP	1000mmx1200mm density: 42g/m2	252	Footnote [1](8)
Delivery	Box	Double corrugated cardboard	260mm x 180mm x150mm	193.2	Footnote [1](9)
	Foam	EPE	Fulfil the empty space between the delivery and the bottle	30	Footnote [1](10)
	Tape	BOPP	8.2mm x 5.5 mm x0.01mm	3	Footnote [1](11)
	Waybill	CCP	210 mm x 15mm Thickness: 4mm	6	Footnote [1](12)

1

(1) 70g is a median weight of 500ml HDPE bottle displayed by 16 packaging suppliers on China's largest B2B platform alibaba.cn, and 15g is drawn from one supplier's product description.
(2) GB/T 6543-2008 has classified the two types of corrugated box for transport, and 70% of cardboard box are double corrugated in Chinese market (Yi, 2016). The density of double-layered corrugated board box is 840g/m^2
(3) ISO 19709-1:2016 defines 400mm x 600mm as a standard modular area for logistics to enhance logistics efficiency.
(4) BOPP Tape in consideration of side length (800mm), thickness (0.1mm), width (55mm) and PP density (946 g/m^2).
(5) The density of HDPE is considered as 946 kg/m^3 (Proverbs et al., 2016)
(6) Currently, 78% of pallets circulated in China are wooden (Ministry of Commerce, 2016). The national standard 'GB/T 16470-2008' has set 1000mm x 1200mm as the standard pallet size with total loads no taller than 1500mm. As the weight of a wooden pallet could vary significantly depending on wood material, structure and moisture content, this study follows Eco-invent's record that the wet mass of a wooden EU-pallet (same with Chinese standard) is 22kg.
(7) The weight of shrink film consumed per pallet is determined by wrapping height and thickness. Considering that the product stacking could be up to 1250mm (5 layer) and is mostly heavily wrapped, the shrink film made of LDPE could weigh 400g (VAL-I-PAC, 2016).
(8) The grouping bags are primarily disposable PP woven bags for gathering delivery parcels in between delivery and allocation centres. A bag here is sized as 1000mm x 1200 mm with a density of 42g/m^2 in accordance with the site investigation, therefore its weight could be 100.8g.
(9) 260mm x 180mm x 15mm is the No.6 standard size applied by China Post referring to GB/T6543-2008. In e-commerce end-delivery, over packaging could result in nearly 70% of the box space filled with cushioning.
(10) EPE foam is accepted here for its better shock-proof capacity compared to EPS foam. Its weight is around 30g (alibaba.com)
(11) Bopp tape of end-delivery in consideration of the consumed amount of tape (17 billion meter) and delivered parcels (9.9 billion) throughout 2015 (National Post Bureau, 2016).
(12) A handwritten express waybill, usually of 3 or 5-layer, is handled for the delivery tracking and kept by multiple stakeholders. A 5-layer waybill could be of 6g.

5.4.1.2 Packaging material inventory of scenarios

This section would elaborate on the packaging material inventories incorporating packaging logistics activities. For each scenario will present a inventory of material use per delivery.

S_3PL (Case One)

In S_3PL, most packages are disposable owing to violent handling and low cost. Pallet is the only type being reused within manufacturers' warehouses.

Table 11 Inventory of material use in S_3PL"

	Material	Primary	Secondary	Tertiary	Delivery	Remark
Plastic	BOPP		0.232		12	S: 4 pieces of tape D: 4 pieces of tape
	EPE				60	D: 2 pieces of foam
	HDPE	140				P: 2 bottles
	LDPE			0.66		T: 2 pieces of film
	PP			20.16		T: 2 woven bags
Non-plastic	2-layer corrugated cardboard		32.92		386.4	S: 2 boxes D: 2 boxes
	Printed paper				12	D: 2 waybills
	Wood			0.12		T: 2 pallets

S_Self-run (Case One)

The logistics analysis has shown that the B2C scenario delivers one end-delivery parcel and reduces the material use in this packaging group, and meanwhile, it avails of more secondary and tertiary packaging throughout distribution.

Table 12 Inventory of material use of S_Self-run

	Material	Primary	Secondary	Tertiary	Delivery	Remark
Plastic	BOPP		0.232		6	S: 2 pieces of tape D: 1 piece of tape
	EPE				30	D: 1 piece of foam
	HDPE	140				P: 2 bottles
	LDPE			1.32		T: 3 pieces of film
	PP		0.224	10.08		S: 2 crates T: 2 woven bags
Non-plastic	2-layer corrugated cardboard		32.92		193.2	S: 2 boxes S: 1 box
	Printed paper				6	D: 1 waybill
	Wood			0.24		T: 3 pallets

S_Baseline (Case Two)

This baseline scenario (S_Baseline) only deals with one detergent in a 'supplier + self-run' delivery.

Table 13 Inventory of material use of S_Baseline

	Material	Primary	Secondary	Tertiary	Delivery	Remark
Plastic	BOPP		0.116		6	S: 1 piece of tape D: 1 piece of tape
	EPE				30	D: 1 piece of foam
	HDPE	70				P: 1 bottles
	LDPE			0.66		T: 2 pieces of film
	PP		0.112	10.08		S: 2 crates T: 2 woven bags
Non-plastic	2-layer corrugated cardboard		16.46		193.2	S: 1 box S: 1 box
	Printed paper				6	D: 1 waybill
	Wood			0.12		T: 2 pallet

Automation Update Scenario (S_AU)

The automation update scenario employs automation machinery and pipelines of stacking, sorting, picking and packing of products in warehouses. Cushioning is left out due to the intelligent box volume algorithm and the e-waybill replace the handwritten waybill.

Table 14 Inventory of material use of S_AU

	Material	Primary	Secondary	Tertiary	Delivery	Remark
Plastic	BOPP		0.116		6	S: 1 piece of tape D: 1 piece of tape
	HDPE	70				P: 1 bottles
	LDPE			0.66		T: 2 pieces of film
	PP		0.112	10.08		S: 2 crates T: 2 woven bags
Non-plastic	2-layer corrugated cardboard		16.46		86.52	S: 1 box S: 1 box
	Thermal paper				1.68	D: 1 electric waybill
	Wood			0.12		T: 2 pallets

Material Substitute Scenario (S_MS)

The material substitute scenario mainly selects available packaging alternatives emerging in the market. Attributes of biodegradability, reusability and byproduct materials are emphasised in view of stakeholder perceptions. In particular, PLA, waste paper, straw, woven cotton are chosen for this scenario. As for the substitute of disposable corrugated paper cardboard, reusable corrugated PP board (delivery packaging) and PP crate (secondary packaging) are mostly practiced by logistics operators and thus included.

Table 15 Inventory of material use of S_MS

	Material	Primary	Secondary	Tertiary	Delivery	Remark
Plastic	PLA	90.2		0.886		P: 1 Bottle T: 2 pieces of shrink film
	PP		0.112		9.87	S: 3 crates D: 1 corrugated box
Non-plastic	Woven cotton			2.18		T: 2 canvas bags
	Recycled paper				30	D: Paper Cushioning
	Printed paper				1.68	D: electric waybill
	waste straw			0.025		T: straw pallet

Packaging Rationalisation Scenario (S_PR)

The packaging rationalisation scenario amalgamates innovative package designs to improve actual environmental performance. Here light weight and waste reduction are two predominant parameter, combined with foldability, recyclability and other factors. Each packaging has its prototype in the market.

Table 16 Inventory of material use of S_PR

	Material	Primary	Secondary	Tertiary	Delivery	Remark
Plastic	HDPE	15		0.075		P: a soft pack T: 2 pallets (HDPE part)
	LDPE			0.32	0.2832	T: 2 piece of shrink Film (light wrapping) D: Air bag
	PP		0.112	0.48*2		S:2 crates; T: 2 woven bags
Non-plastic	1-layer corrugated box		8.82		101.52	S: corrugated box; D: corrugated box
	2-layer corrugated box			0.005858		T: 2 Pallets (Cardboard part)
	Printed paper				0.42	D: 1-layer half-length electronic waybill

Stakeholder Integration Scenario (S_SI)

Stakeholder Integration Scenario is an ideal scenario in which the logistics processes are restructured by stakeholder collaboration to reduce the handling times and the recycling scheme is fully implemented.

Table 17 Inventory of material use of S_SI

	Material	Primary	Secondary	Tertiary	Delivery	Remark
Plastic	HDPE	70	0.056	0.0097		**P:** bottle; **S:** Circulation box; **T:** pallet;
	LDPE			0.33		**T:** Film;
	PP			0.48	9.87	**T:** Grouping bag **D:** Delivery box

5.4.2 Transport

When it comes to transport, data for transport processes, distances, as well as vehicle types are sorted.

- Shanghai Jinshan Logistics Park, Hangzhou GLP Logistics Park and Changxing Comprehensive Logistics Park are taken as the major logistics sites. Their relative locations are shown in Figure X. Reasonable distances between other logistics sites are proposed based on the courier interviews[2].
- Vehicles for road transportation and the actual transport process are specified in Figure . grounded on literature review (Cai and Wang 2015; Fan et al. 2017; Cherry et al. 2009)[3].

Figure 36 Map of logistics sites (Source: Google Maps)

[2] A to B represents cross-province delivery. Shanghai is provincial-level municipality (A), whereas Hangzhou and Changxing are affiliated to Zhejiang Province.

[3] Cai and Wang (2015) identified the diverse needs of lorries throughout e-commerce logistics, Fan et al. (2017) hypothesised that electric bikes are utilised for end-delivery. As for emission level, China 3 (equal to Euro 3) was implemented in 2008. The scooter-type electric bike, calculated by Cherry et al. (2009), consumes 2.1 kWh per 100km.

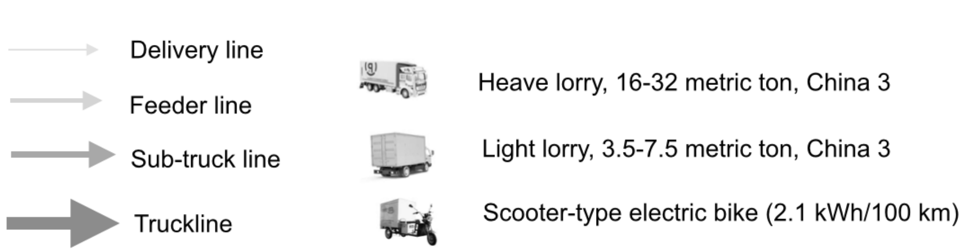


Figure 37 Graphic symbols for transport flows

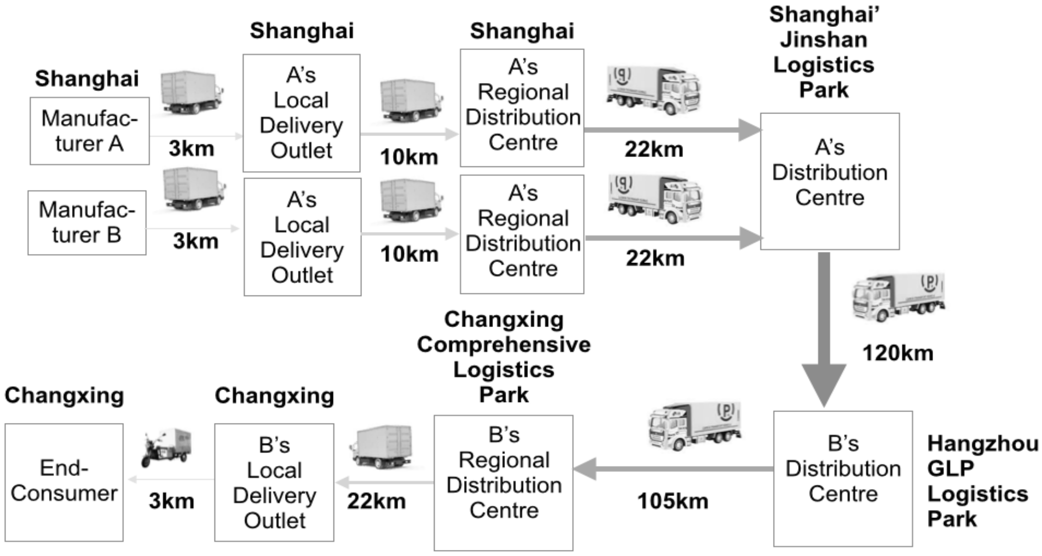


Figure 38 Transport flow of S_3PL

Table 18 Transport inventory of S_3PL

	Delivery Outlet (from manufacturer)	A's Regional Distribution Centre	A's Distribution Centre	B's Distribution Centre	B's Regional Distribution Centre	B's Delivery Outlet	End-consumer
Location	Shanghai	Shanghai	Shanghai	Hangzhou	Changxing	Changxing	Changxing
Transport Mode	Light lorry	Light lorry	Heavy lorry	Heavy lorry	Heavy lorry	Light lorry	Electric Bike
Distance (km)	6	20	44	120	105	22	3
Weight (g)	805.2	805.2	805.2	1620.48	1620.48	1610.4	1610.4

Figure 39 Transport flow of S_Self-run

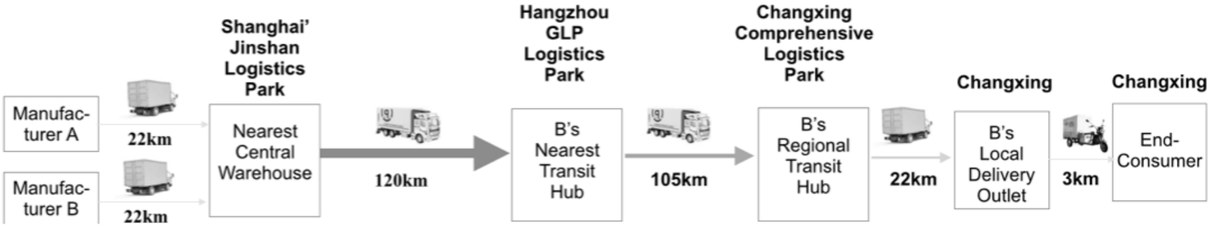


Table 19 Transport inventory of S_Self-run

	Nearest Central Warehouse (from manufacturer)	B' Transit Hub	B's Regional Transit Hub	B's Local Delivery Outlet	End-consumer
Location	Shanghai	Hangzhou	Changxing	Changxing	Changxing
Transport Mode	Heavy Lorry	Heavy lorry	Heavy lorry	Light lorry	Electric Bike
Distance (km)	44	120	105	22	3
Weight (g)	586.756	1408.12	1408.12	1375.2	1375.2

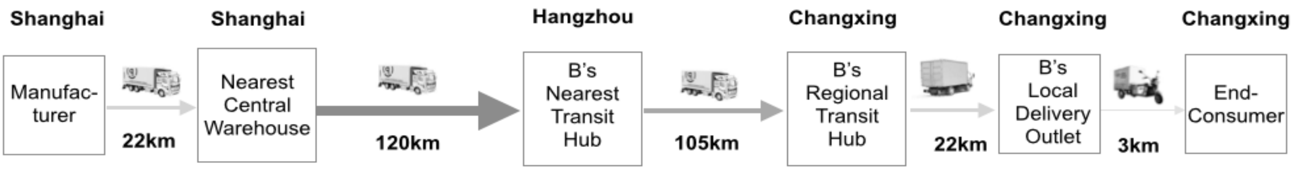


Figure 40 Transport flow of S_Baseline, S_AU, S_MS, S_PR and S_SI

Table 20 Transport inventory of S_Baseline, S_AU, S_MS, S_PR and S_SI

		Nearest Central Warehouse (from manufacturer)	B' Transit Hub	B's Regional Transit Hub	B's Local Delivery Outlet	End-consumer
Location		Shanghai	Hangzhou	Changxing	Changxing	Changxing
Transport Mode		Heavy Lorry	Heavy lorry	Heavy lorry	Light lorry	Electric Bike
Distance (km)		22	120	105	22	3
	S_Baseline	586.756	820.24	820.24	815.2	815.2
	S_AU	586.46	664.24	664.24	659.2	659.2
Weight (g)	*S_MS*	645.8	1138.2	1138.2	1087.3	1087.3
	S_PR	523.82	716.42	716.42	692.4232	692.4232
	S_SI	584.77	791.4	791.4	767.4	767.4

5.4.3 Waste

Three main waste treatment methods are considered: sanitary landfill, municipal combustion and recycling. Percentage data are extracted from governmental reports and available literature[4].

Table 21 Waste inventory for S_3PL and S_Self-run

		Material	**Waste Treatment (g)**		
			Landfill	*Incineration*	*Recycled*
S_3PL	Plastic	HDPE	63.00	42.00	35.00
		LDPE	28.51	18.20	13.95
		PP	15.22	9.72	7.45
	Non-plastic	Paperboard	155.14	75.48	188.69
		Waste paper	1.60	10.40	0.00
		Waste wood	0.03	0.01	0.08
S_Self-run	Plastic	HDPE	63.00	42.00	35.00
		LDPE	14.72	9.40	7.20
		PP	7.77	4.96	3.80
	Non-plastic	Paperboard	45.22	22.61	158.28
		Waste paper	0.80	5.20	0.00
		Waste wood	0.05	0.02	0.17

[4] Waste Treatment Percentage (Landfill : Incineration : Recycled)

- HDPE: 45:30:25
- Other plastic: 47:30:23 (overall plastic incineration rate as 30% [Roland et al, 2017], and the overall recycling rate as 23% [NRDC, 2014])
- Paperboard: 37:18:45
- Waste Paper: Waybill at E-commerce side are required to be combusted; Waybill at consumer-side follows 2:1 (Landfill : Incineration); weight disposed at e-commerce side : weight disposed at consumer side = 4:1
- Waste Wood: 20:10:70 (overall waste wood recycling rate as 70% [NRDC,2014])
- Other non-plastic: 2:1:0

Table 22 Waste inventory of S_Baseline, S_AU, S_MS, S_PR and S_SI

		Material	Waste Treatment (g)		
			Landfill	*Incineration*	*Recycled*
S_ Baseline	Plastic	HDPE	31.5	21.0	17.5
		LDPE	19.11	12.20	9.35
		PP	8.00	5.11	3.92
	Non-plastic	Paperboard	77.57	37.74	94.35
		Waste paper	0.80	5.20	0.00
		Waste wood	0.03	0.01	0.08
S_AU	Plastic	HDPE	31.5	21.0	17.5
		LDPE	0.31	0.20	0.15
		PP	8.00	5.11	3.92
	Non-plastic	Paperboard	36.25	17.64	44.09
		Waste paper	0.75	0.93	0.00
S_MS	Plastic	PLA	42.81	27.33	20.95
		PP	4.72	3.48	2.67
	Non-plastic	Waste cotton	1.46	0.72	0.00
		Waste paper (recycled)	20.00	10.00	0.00
		Waste paper	0.75	0.93	0.00
S_PR	Plastic	HDPE	6.78	4.52	3.77
		LDPE	0.28	0.18	0.14
		PP	0.50	0.32	0.29
	Non-plastic	Paperboard	40.83	19.86	49.66
		Waste paper	0.28	0.14	0.00
S_SI	Plastic	HDPE	0.00	0.00	70.07
		LDPE	0.00	0.00	0.33
		PP	0.00	0.00	10.35

5.4.4 Inventory summary

In the material inventory, material use of primary, secondary, tertiary and delivery packaging are separately presented, and the inventory results of producing the exact amount of materials will be directly processed in Ecoinvent 3.4. Transport inventory data will be processed by the software, concerning emission level/energy consumption and packaging loads at a certain traveled distance. The waste inventory is applied in consideration of country-specific waste treatment.

5.5 Lifecycle Impact Assessment (LCIA)

LCIA is a crucial step of translating inventory data and calculated results into communicable impact categories for decision-making. There already exist a great amount of LCIA methods in fulfilment of varied research scopes, and selecting a method out of them necessitates close attention to the suitability between the method and the research purpose.

In terms of comprehensiveness, synthetical methods include CML, Eco-indicator 99, ReCiPe, TRACI, etc. while category-specific ones are IPCC (climate change), CED (energy demand), USEtox (chemical toxicity), etc. It is needful to evaluate where impact categories of methods arrive at — midpoint or endpoint in the cause-effect chain. The midpoint approach is problem-oriented, helping to identify the relevant contribution of emissions to a certain category with a complete environmental profile. The end-point (damage-oriented) approach generalises the impacts as damages to human health, ecosystem and resources. Midpoint-level categories capture more details but complicate the interpretation; on the contrary, endpoint-level categories facilitate the interpretation yet increase uncertainties. Bare et al. suggested that a consistent framework for decision-making shall invite both approaches (2000). This study is first conducted as an academic research and an actual decision-making support for stakeholders beyond the academia. To better meet its dual functionality, this study will expand on midpoint impact categories and briefly touch upon aggregated endpoint impact categories for delivering straightforward messages.

CML 2001, a widely accepted midpoint method, is primarily selected for the study. It provides both baseline and non-baseline categories (Guinèe et al., 2001), and here only baseline categories are considered for concentrated discussion. The method is recommended as a solution to reflect long-term emissions (Hischier, 2010). ReCiPe Endpoint method is then chosen to assess the endpoint damages, as acknowledged by ILCD (2011) in its handbook. Table 23 And 24 respectively sketch the midpoint and endpoint impact categories with their definition, selected indicator and unit.

Table 23 List of eight mid-point impact categories (Adapted from Acero et al., 2014)

Impact Category	Definition	Indicator	Unit
Acidification	Decrease of the pH in aquatic and soil systems induced by acidifying emissions	Acidification potential - average Europe	kg SO2-Eq
Climate change	Disturbances of global temperature engendered by greenhouse gases (GHGs) emissions	Climate change - GWP 100	kg CO2-Eq
Eutrophication	Accumulation of nitrogen and phosphorus in aquatic systems	Eutrophication - generic	kg PO4-Eq
Depletion of abiotic resources	Lessening of non-biological resources due to excessive exploitation	Scarcity	kg antimony-Eq
Ozone layer depletion	Attenuation of the stratospheric ozone layer caused by emissions of ozone depleting substances	Ozone layer depletion - ODP steady state	kg CFC-11-Eq
Photochemical oxidation	Summer smog resulted by the reactions of NMVOC and NOx with sunlight and heat as catalysers	Photochemical oxidation - High Nox POCP	kg ethylene-Eq
Human toxicity	Toxic effects of chemicals and ionising radiation on human health, giving rise to cancer and non-cancer diseases	Human toxicity- HTP infinite	kg 1,4-DCB-Eq
Eco-toxicity	Toxic effects of chemicals on an ecosystem, resulting in biodiversity degradation	Freshwater aquatic eco-toxicity - FAETP infinite	kg 1,4-DCB-Eq
		Marine aquatic eco-toxicity - MAETP infinite	kg 1,4-DCB-Eq
		Terrestrial eco-toxicity - TETP	kg 1,4-DCB-Eq

Table 24 List of three aggregated end-point impact categories[5]

Impact Category	Definition	Indicator (H)	Unit
Damage to ecosystems	Species loss as a result of climate change, land occupation, eco-toxicity, acidification,etc.	Ecosystem - total	species.yr
Damage to human health	Life year loss as a result of climate change, human toxicity, ozone depletion, photochemical oxidation, etc.	Human health - total	DALY (Disability Adjusted Life Years)
Damage to resource availability	Surplus cost as a result of depleting resources including water, fossil fuels and metal	Resource - total	$ (Surplus cost)

5.6 Interpretation

Interpretation is the last step of LCA to assess and transform raw results into presentable diagrams and concise explanation.

5.6.1 Scenario Comparison

In consistent with the goal to evaluate impacts of proposed scenarios, this section first overviews the relative impacts of scenarios for each case by normalising the LCIA results, and then presents the overall quantified damage results for decision-making support.

5.6.2.1 Scenario Comparison of Case One

As shown in Table X., S_Self-run exerts less impacts than S_3PL concerning all midpoint impact categories. By and large, for most categories, the impact ratio of S_Self-run to S_3PL is approximately 2:3. In consideration of 'freshwater eco-toxicity', the impact can even be trimmed down to 34%. The previous packaging logistics analysis has discovered that S_Self-run removes several logistics redundancies by combining the orders , and this comparison attests the argument that a vertical 'supplier + self-run logistics' supply chain is superior to the decentralised 'supplier +

[5] ReCiPe method gives consideration to three cultural perspectives: 1) 'individualist' which is of short-term and optimistic to technological solutions; 2) 'hierarchist' which is in between short-/long-term and an inclusion of scientific consensus; 3) 'egalitarian' which is of long-term to consider all possible effects. Here in this study, 'hierarchist' (H) is set as the default perspective.

3PL' supply chain in consideration of the impact domain. If the redundant processes spotted in 'S_Self-run' logistics could be further phased out, the advantages of 'S_Self-run' in promoting sustainable packaging logistics will be fortified.

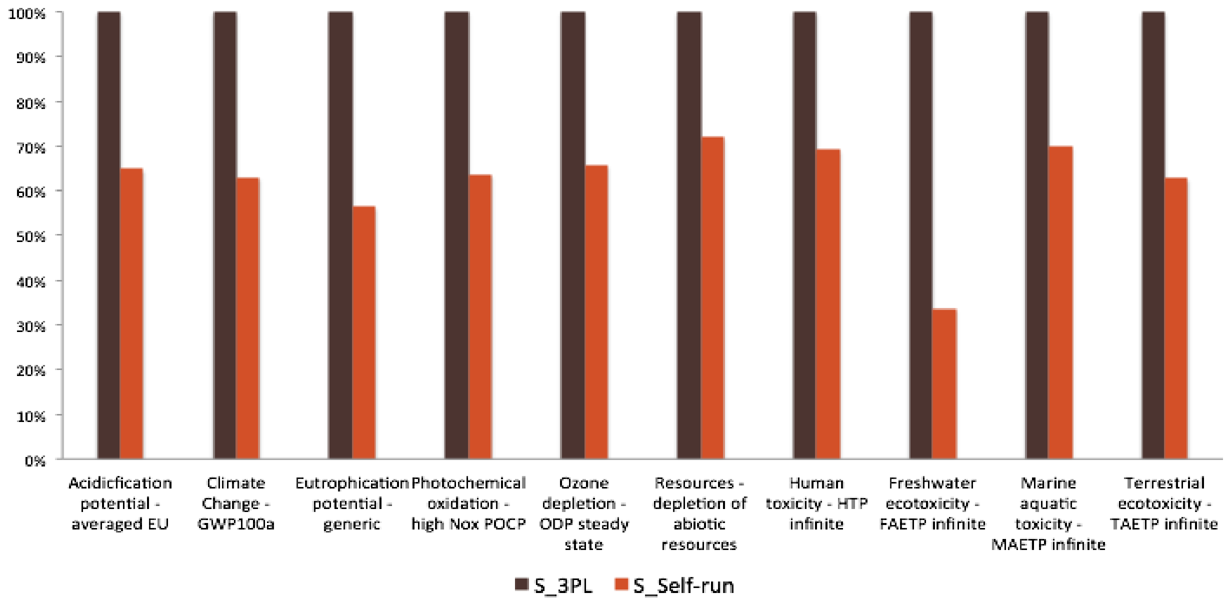


Figure 41 Normalised characterisation results of S_3PL and S_Self-run

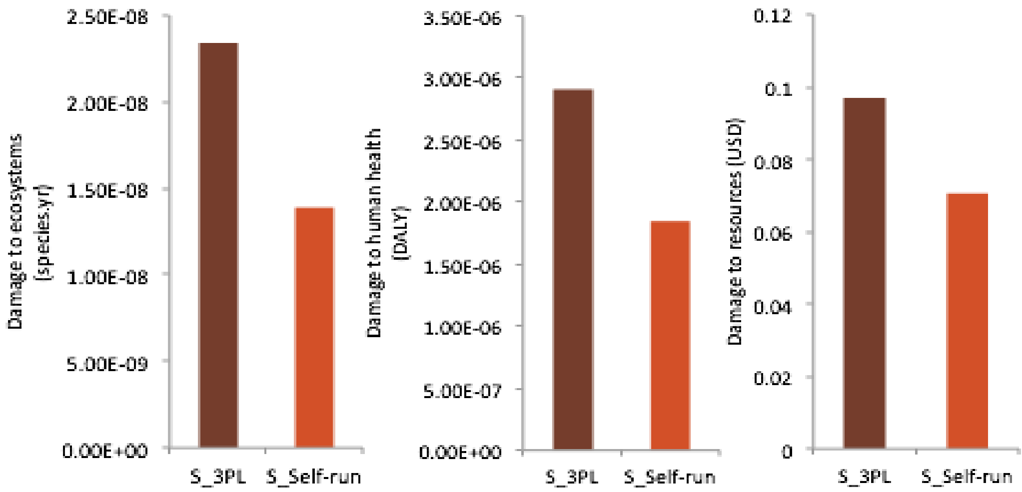


Figure 42 Damage results of S_3PL and S_Self-run

Figure 42 quantifies and compares the two scenarios' damages to ecosystem quality, human health and resource availability. The end-point damage ratio of S_Self-run to S_3PL is roughly the same as the mid-point impact ratio. Even though the damage quantities of the three categories seem rather non-considerable, they shall be stressed in connection with the totality of Chinese e-commerce logistics market. It should be noticed that in 2017 alone, 40 billion parcels are delivered via e-commerce logistics (National Post Bureau, 2018) and the overall damages brought e-commerce packaging logistics are consequentially substantial. Taking the damage to resource availability as an example, 40 billion parcels handled by S_3PL could lead to economic burden of nearly 3.8 billion USD on future extraction of resources, and S_Self-run could somehow relieve the burden by a reduction of 1 billion USD. From this perspective, to invest in technological advancement and integrated packaging logistics solutions will in the long-run benefit the economy.

5.6.2.2 Scenario Comparison of Case Two

Case two is devised to compare a baseline scenario and its alternatives. In Figure 44., both expected and unanticipated results can be detected. Hypothesised as sustainable alternatives for S_Baseline, S_AU, S_PR and S_SI indeed lower the impacts of all categories, each demonstrating a certain level of effectiveness. Among the three scenarios, S_SI reduces impacts in all categories most drastically except for the category of 'depletion of abiotic resources'. S_PR, in promotion of lightweight packaging, emulates S_SI in this category. S_AU generally has lower performance than S_SI and S_PR. The findings first testify the significance of stakeholder engagement in optimising logistics processes and designing recycling mechanism, then support trade-offs in prioritising solutions for structuring sustainable e-commerce packaging logistics.

The characterisation results of S_MS, somehow, require a dialectical interpretation. Compared to S_Baseline, S_MS quadruples the impacts on 'ozone depletion', multiplies impacts of 'terrestrial eco-toxicity' more than threefold and increases the 'eutrophication potential' by 150%. In other categories, S_MS only presents minor improvement. Nevertheless, considering the availability of alternative materials, S_MS can still enhance its environmental performance once the predominant contributory factors to the specific impact categories are identified and replaced.

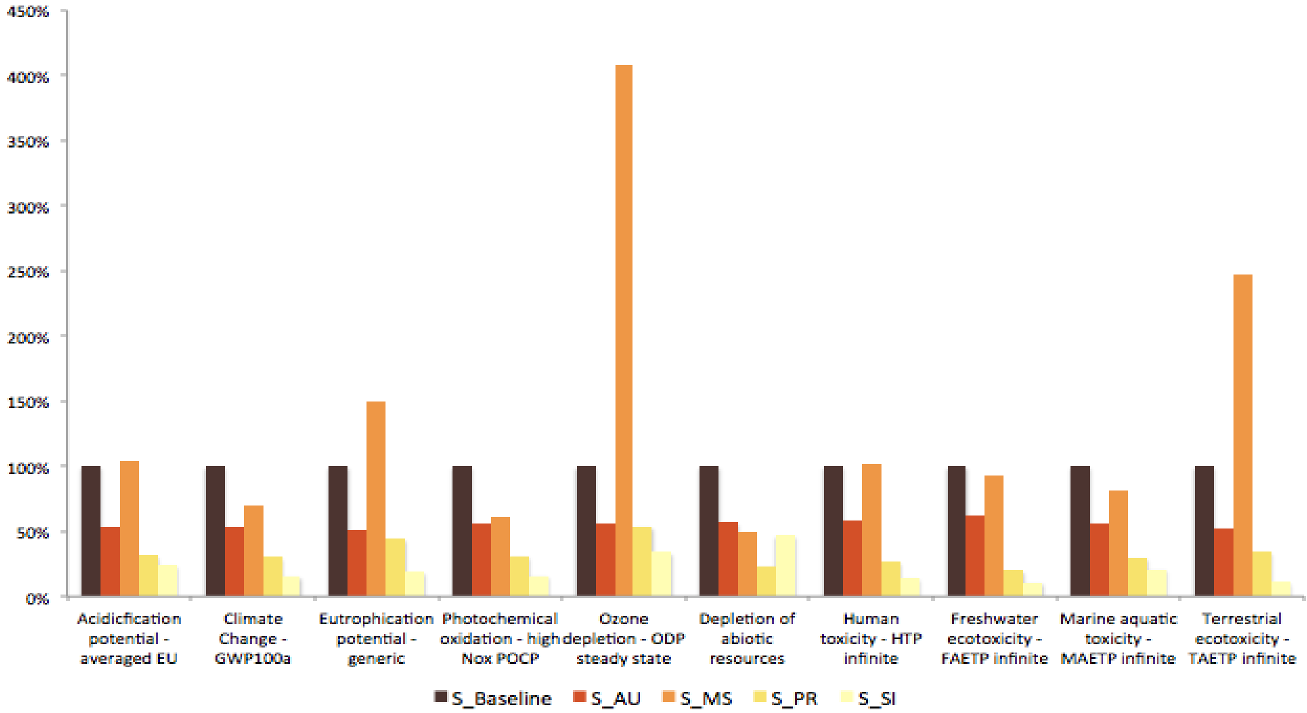


Figure 43 Normalised characterisation results of S_Baseline, S_AU, S_MS, S_PR and S_SI

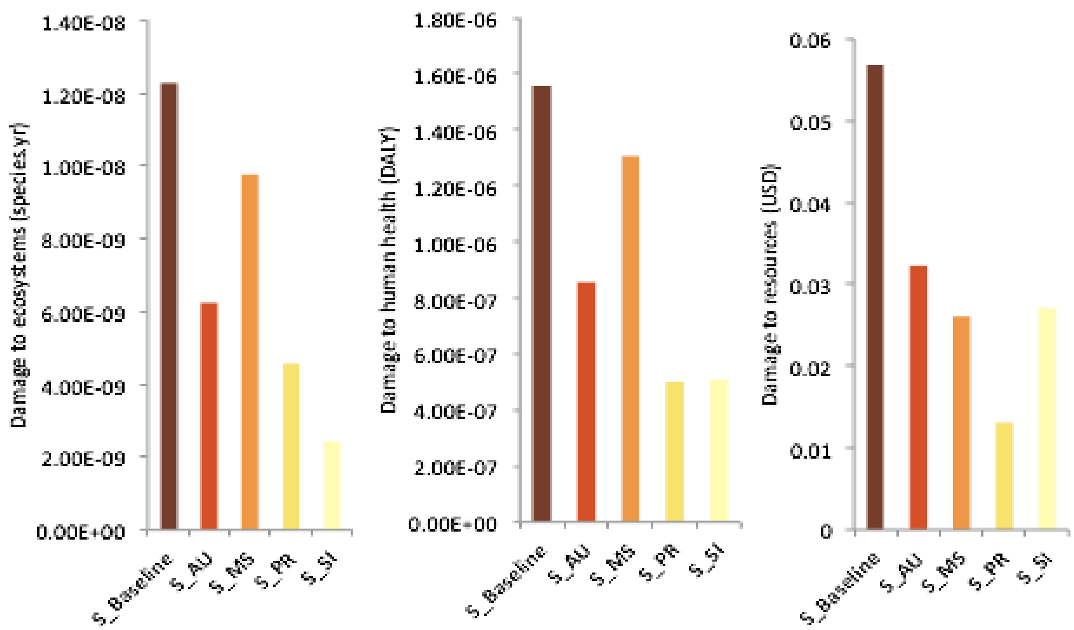


Figure 44 Damage results of S_Baseline, S_AU, S_MS, S_PR and S_SI

The end-point damage results, upon aggregation, eliminate the sharp comparison shown in mid-point characterisation. In specific, ‘ozone depletion’ impacts are incorporated with six other categories in the calculation of damages to human health, and ‘terrestrial eco-toxicity’ is treated together with other ten impact categories to output the damages to ecosystems. Given the damage results, S_MS can also be justified as a relatively effective alternative with respect to its fewer damages to resources. S_SI and S_PR each hold superiority in different protection areas, one for ecosystem preservation and the other for loss prevention.

5.6.2 Dominance Analysis

Since the study centres on e-commerce packaging logistics, to identify key contributors in the light of packaging logistics is pivotal. The previous section depicts a broad image of lifecycle impacts at the scenario level, and this section will dissect the scenarios and determine the dominant contributors for each impact category. Contributors can be broken down to the group level and the activity level. The group level consists of six groups. Four packaging material groups (delivery, primary, secondary and tertiary packaging) are composed of activities at the production phase yet characterised by their specific applications in the use phase. The transport group includes transport activities only in the use phase and the waste group comprises all waste treatment and recovery activities at the closing phase. Foreground inventory data of each group can be found in '5.4 Inventory Analysis'.

5.6.2.1 Dominance Analysis of Case One

Figure 45 and 46 present group-level contribution to impact categories in S_3PL and S_Self-run logistics. In S_3PL, delivery packaging group is the greatest contributor to two thirds of the impact categories. For 'eutrophication potential', 'ozone depletion' and 'terrestrial eco-toxicity', it brings about over a half of total impacts. If looking into the group, then the 'cradle to gate' activity of corrugated board box is dominant over other activities. This accounts for why corrugated board boxes are mostly concerned and addressed in current e-commerce packaging logistics. In S_Self-run, since the delivery package is reduced by the order combination, the primary packaging replaces the delivery packaging to be the central contributor to 'photochemical oxidation' and 'depletion of abiotic resources'. The primary packaging group only contains the 'cradle to gate' activity of

HDPE, which indicates that cutting down the amount of HDPE material produced for primary packaging is a potential measure.

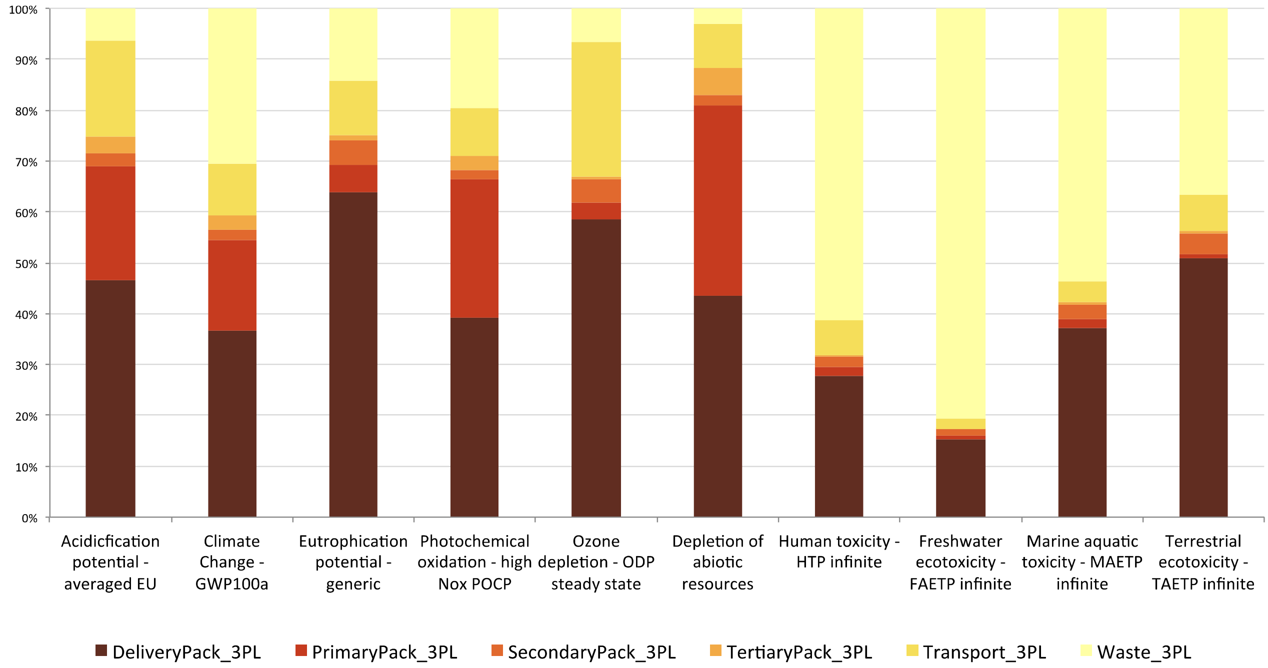


Figure 45 Group-level contribution to characterised impacts in S_3PL

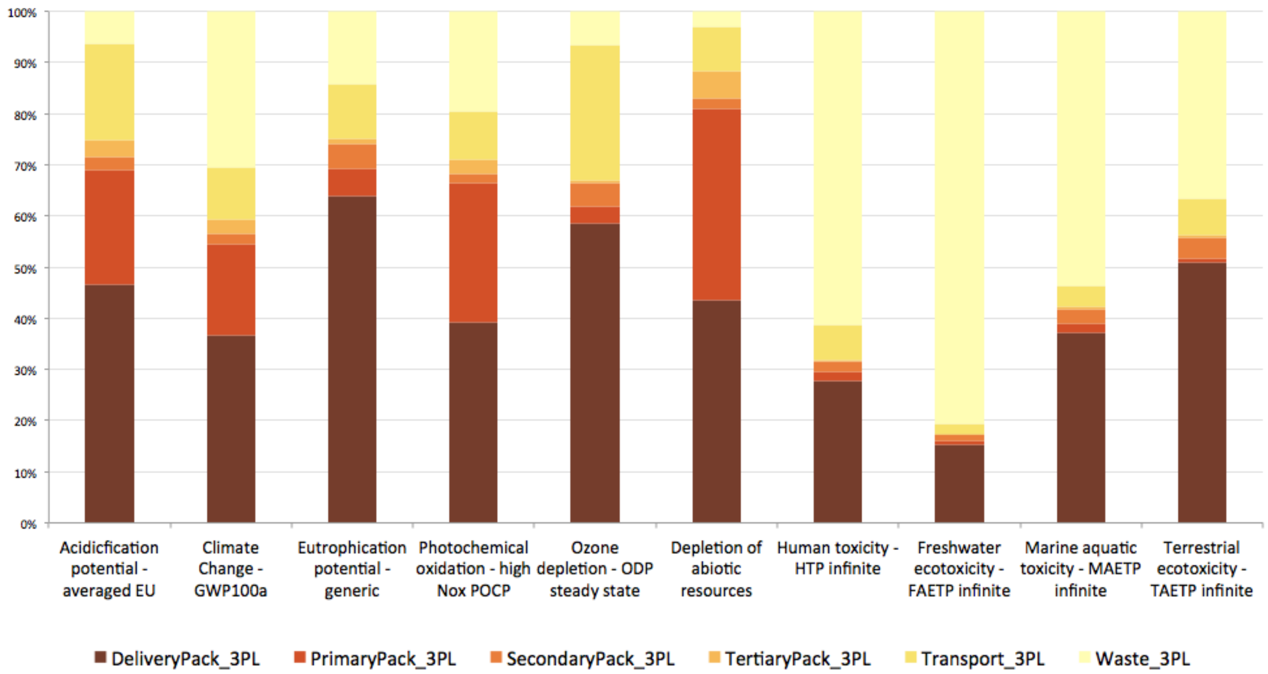


Figure 46 Group-level contribution to characterised impacts in S_Self-run

Besides, in both S_3PL and S_Self-run, attention shall be paid to the waste group, for it engenders significant impacts in all toxicity-related categories. In 'freshwater eco-toxicity', markedly, it can yield over 80% of the toxic effects. Cascading down to the key contributors within the waste group, sanitary landfill and municipal incineration activities of HDPE and LDPE are discovered as equally predominant to generate impacts. The same activities also contribute most to 'human toxicity' and 'marine eco-toxicity'. Compared to landfill and combustion, recycling HDPE and LDPE shall be encouraged and implemented. Moreover, the waste group is also a weighty contributor to 'climate change' owing to the sanitary landfill activity of corrugated board box and again the incineration activity of PE wastes.

5.6.2.2 Dominance Analysis of Case Two

The distribution of leading group contributors to impact categories in S_Baseline is similar to that in S_3PL. Even though much tertiary packaging is consumed in 'supplier + self-run logistics' supply chain and the issue of disposable woven PP bag has been underlined in the previous packaging logistics analysis, the impacts brought by the entire tertiary packaging group are still limited in comparison with other groups.

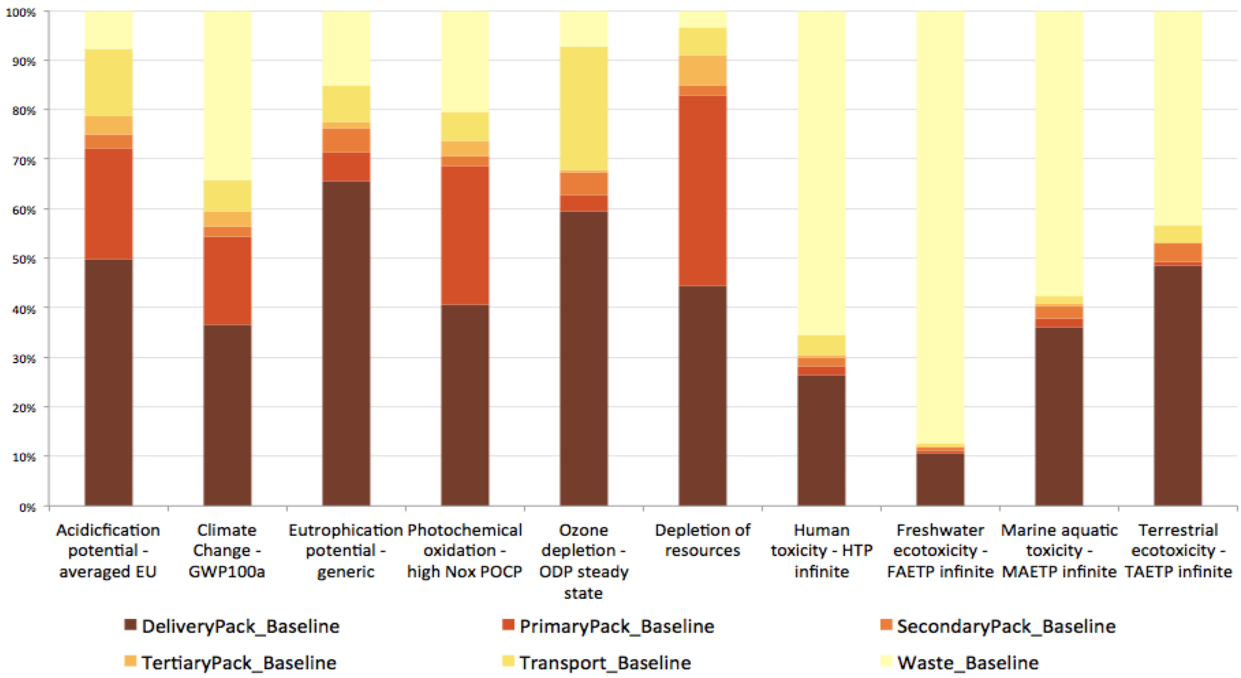


Figure 47 Group level contribution to characterised impacts in S_Baseline

Alternative scenarios reconstruct the composition of each group by changing packaging logistics decisions, insomuch that the distribution of key group contributors can become diverse (Figure 48 to 51). The variation in distribution can explain where the decision change influences impact outputs, and the identification of vital contributors could help refine on each alternative scenario to better devise the scheme of sustainable e-commerce packaging logistics.

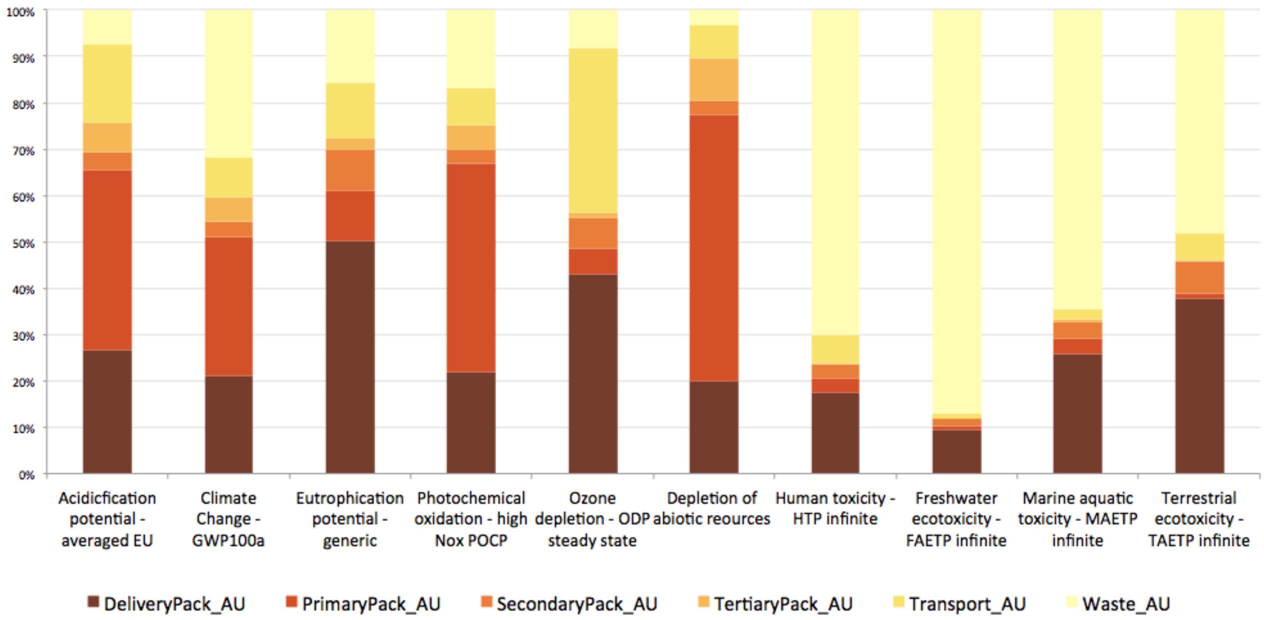


Figure 48 Group level contribution to characterised impacts in S_AU

For S_AU, thanks to the application of intelligent packing facilities, the use of delivery packaging, particularly corrugated board box, EPE foam and printed paper, decreases to a large extent. As shown here, the impacts brought by the delivery packaging group are relatively ameliorated compared to S_Baseline. Similar distribution comparison can be found between S_3PL and S_Self-run. The transport group, though not conspicuous, shall not be neglected for 'ozone depletion'. Trunkline transport by heavy lorry is an activity that overarches the group's contribution. To lower the package weight during delivery and to improve the lorry's emission efficiency can be both deemed as countermeasures.

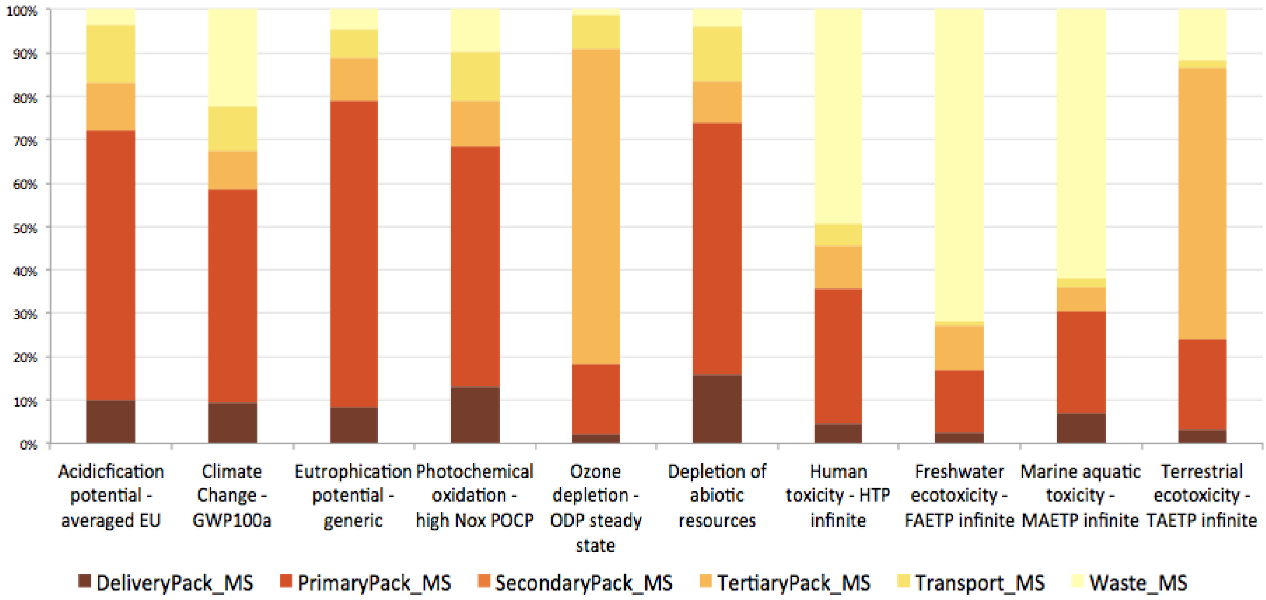


Figure 49 Group level contribution to characterised impacts in S_MS

S_MS displays a dissimilar distribution layout. In S_MS, impacts brought by the delivery packaging group diminish acutely in all categories whilst the tertiary packaging group becomes the foremost contributor in ‘ozone depletion’ and ‘terrestrial eco-toxicity’. Within the delivery packaging group, a PP corrugated box in replacement of a corrugated board box attains to higher environmental performance at the ‘cradle-to-gate’ production phase. Notwithstanding, the water footprints of cleaning the returned box, as well as emissions of reverse logistics, are not included. Hence, the result can only serve as a theoretical support to the argument that a PP corrugated box outperforms a corrugated paperboard box in e-commerce packaging logistics from a sustainability perspective. Waste paper is also proved eco-efficient to substitute EPE foam. In contrast, within the tertiary packaging group, the production activity of a woven cotton grouping bag turns out to be the greatest impact maker, giving rise to 72% of total impacts in ‘ozone depletion’ and 62% in ‘terrestrial eco-toxicity’. This finding echoes the scenario comparison in which S_MS demonstrates much higher impacts in the two specific categories. Even though the woven cotton bag is reusable and bio-based, it shall not be considered as an appropriate alternative.

Furthermore, the primary packaging group in S_MS is the primal contributor to five impact categories, and its only activity is the 'cradle-to-gate' production of PLA. Despite that PLA is introduced as a biodegradable plastic, it is not necessarily a competent alternative to HDPE in this case. With regard to 'eutrophication', a PLA bottle of 500ml emits 8.E-04 kg PO4-Eq, whereas an equivalent HDPE bottle causes 4.31E-05 kg PO4-Eq. For other categories, the impact level of PLA is generically higher than HDPE. Tabone et al. (2010) paralleled the two polymer rankings by Green Principle Assessment and LCA, and pinpointed that although biopolymers (PLA and PHA) ranked high to meet green design principles, polyolefin polymers (HDPE, LDPE and PP) manifested the best performance in LCA as their production required fewer chemical processing stages. PLA has its apparent strengths in biodegradability, yet given the status quo of waste treatment in China, its large-scale industrial compost is difficult to be realised. Cainiao Network and JD Group have invested much in popularising PLA/PBAT packaging in e-commerce logistics, to which this study holds a conservative attitude.

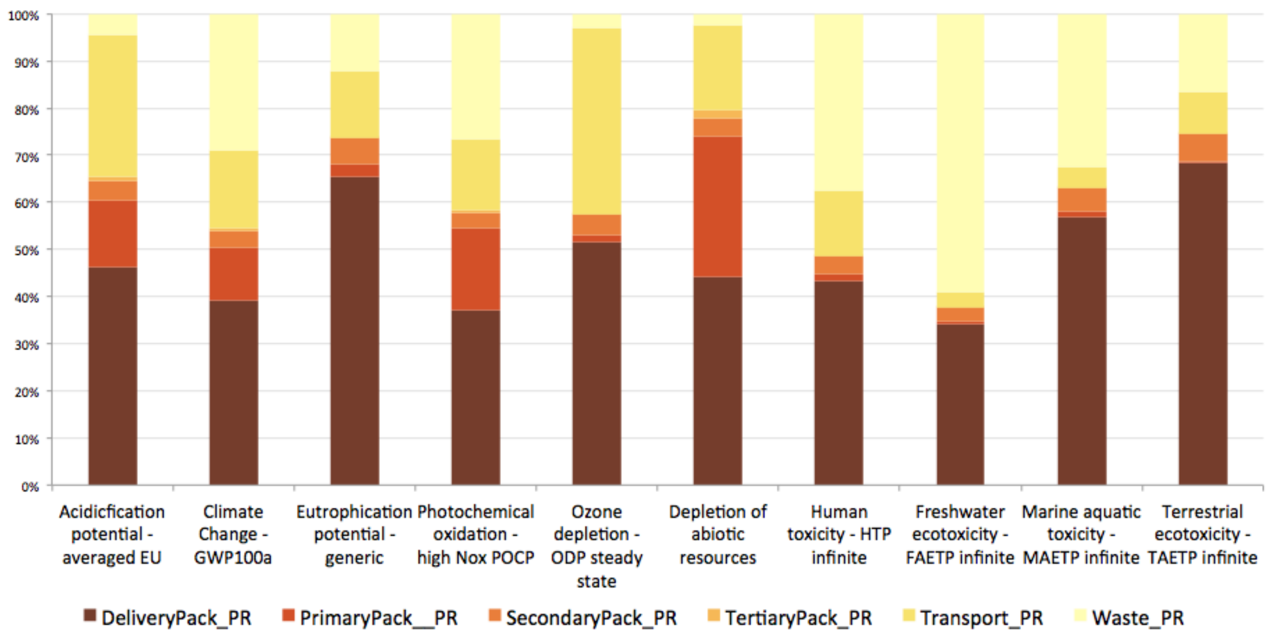


Figure 50 Group level contribution to characterised impacts in S_PR

Rather than put much emphasis on biodegradable materials, this study upholds the viewpoint that packaging rationalisation catering to e-commerce logistics conditions can be more critical. The overall impact efficiency of S_PR has been discussed in the scenario comparison. Here the prioritised contributor for analysis is still the delivery packaging group, with the production of a one-layer corrugated board box as the contributory activity (Figure 51). This study proposes that concerted efforts by automation updates and packaging rationalisation can optimise the packaging volume and structure spontaneously. To introduce PP corrugated box into the group can also help ameliorate the impacts. A thickened PP grouping bag, for the reuse purpose, exerts much lower environmental impacts than a woven cotton bag. A light-weighted HDPE soft pack, compared to a PLA bottle, can be preferential in decision-making. At this point, the combination of applicable alternatives has come into its form, which requires further detailed analysis on economic returns and societal significance.

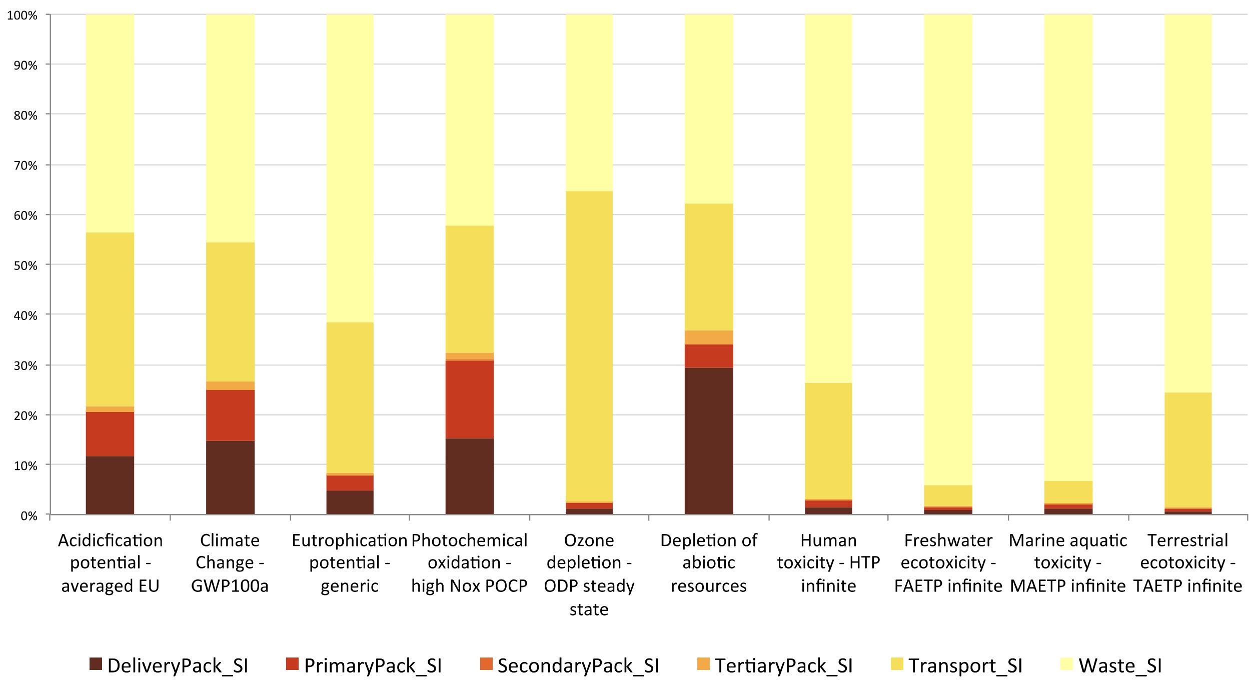


Figure 51 Group level contribution to characterised impacts in S_SI

Unlike other alternative scenarios grounded on market prototypes, S_SI assumes that the full collaboration between stakeholders can be reached for eco-design at the production phase, optimised processes in packaging logistics and recycling at the disposal stage. By simplifying the market reality, this ideal scenario undoubtedly enjoys superiority over other alternatives, but there is still a necessity to unravel its inefficient parts. From Figure 51, it is clear that apart from 'ozone depletion', the waste group is predominant in all categories. The only activity in the waste group is the production of recycled HDPE granulates (a mean of material recovery). When considering the impact quantities, its impact level can be higher than the waste group in S_Baseline in categories of 'acidification' and 'depletion of abiotic resources'. This result implies that even if the closed-loop supply chain is actualised, risks persist out of the loop. More scientific data are needed to ascertain the underlying environmental mechanism.

5.6.2.3 Complementary findings and Summary

The previous two sections of dominance analysis first set their stand at the group-level and then probes into the corresponding activities. Concerning that there are some overlapping activities across the groups (i.e. production of corrugated board box) and the dominancy is indistinctive, another approach of dominance analysis is to unearth the direct contributory activities and their flows to the characterised impacts. By this approach, more insights into the LCA results can be made. An example will be given to shed light on the approach, and an overview of all primary contributors at both group- and activity-level will also be charted.

The example here is to elucidate the lifecycle activities that render impacts on the categories of 'climate change' in S_Baseline. Figure 52. presents the distribution of all causative activities. Although the 'cradle-to-gate' production of corrugated board box is the primary contributor, a few other activities can also be counted as significant. For the production of corrugated board box, specifically, emissions of carbon dioxide (fossil), methane (fossil and non-fossil) and dinitrogen monoxide are detected. The manufacturing activity of HDPE sees emissions of carbon dioxide (fossil) and methane (fossil). The emission of the municipal incineration of waste PE is carbon dioxide (fossil) whereas the sanitary landfill of waste paperboard contributes to emissions of methane (non-fossil). More details can be drawn from each activity and its related emission flows.

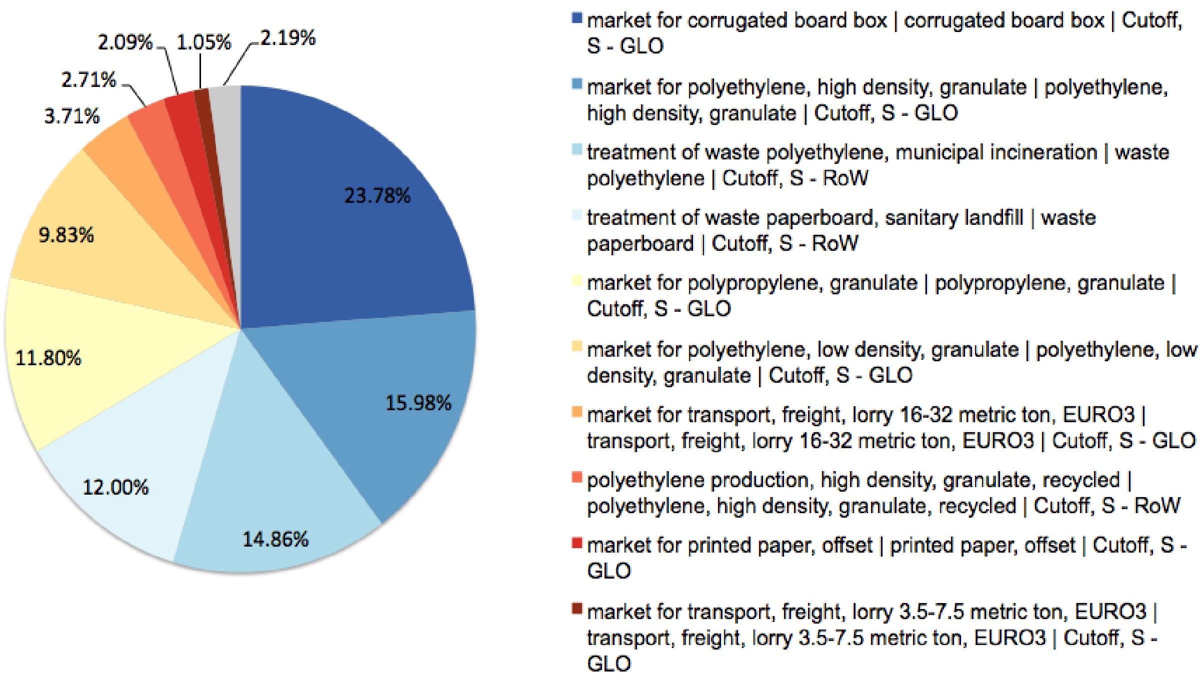


Figure 52 Activity level contribution to 'human toxicity' in S_Baseline

Table 25 and 26 above lay out the main contributory groups and activities to the characterised mid-point impact categories. The summary immediately conveys the message that for most impact categories, to address certain groups or activities can bring forth foreseeable and controllable improvement. In S_3PL and S_Self-run, the production activity of corrugated board box is undoubtedly centrical. For the scenarios in case two, the targeted groups and activities vary but still concentrative.

Table 25 and 26 below lay out the main contributory groups and activities to the characterised mid-point impact categories. The summary immediately conveys the message that for most impact categories, to address certain groups or activities can bring forth foreseeable and controllable improvement. In S_3PL and S_Self-run, the production activity of corrugated board box is undoubtedly centrical. For the scenarios in case two, the targeted groups and activities vary but still concentrative.

Table 25 Dominant contributors to characterised impacts in S_3PL and S_Self-run

Impact Category	S_3PL		S_Self-run	
	Group	*Activity*	*Group*	*Activity*
Acidification	Delivery packaging	Production of corrugated board box	Delivery packaging	Production of corrugated board box
Climate change	Delivery packaging	Production of corrugated board box	Delivery packaging	Production of corrugated board box
Eutrophication	Delivery packaging	Production of corrugated board box	Delivery packaging	Production of corrugated board box
Photochemical oxidation	Delivery packaging	Production of corrugated board box	Primary packaging	Production of corrugated board box
Ozone layer depletion	Delivery packaging	Production of corrugated board box	Delivery packaging	Production of corrugated board box
Depletion of abiotic resources	Delivery packaging	Production of corrugated board box	Primary packaging	Production of corrugated board box
Human toxicity	Waste	Production of corrugated board box	Waste	Production of corrugated board box
Freshwater eco-toxicity	Waste	Production of corrugated board box	Waste	Production of corrugated board box
Marine aquatic toxicity	Waste	Production of corrugated board box	Waste	Production of corrugated board box
Terrestrial eco-toxicity	Delivery packaging	Production of corrugated board box	Waste	Production of corrugated board box

Table 26 Dominant contributors to characterised impacts in S_Baseline, S_AU, S_MS, S_PR, S_SI

Impact Category	S_Baseline		S_AU		S_MS		S_PR		S_SI	
	Group	*Activity*	*Group*	*Activity*	*Group*	*Activity*	*Group*	*Activity*	*Group*	*Activity*
Acidification	Delivery Packaging	Production of corrugated board box	Primary Packaging	Production of HDPE granulate	Primary Packaging	Production of PLA granulate	Delivery Packaging	Production of corrugated board box	Waste	Production of HDPE granulate
Climate change	Delivery Packaging	Production of corrugated board box	Waste	Production of HDPE granulate	Primary Packaging	Production of PLA granulate	Delivery Packaging	Production of corrugated board box	Waste	Production of HDPE granulate
Eutrophication	Delivery Packaging	Production of corrugated board box	Delivery Packaging	Production of corrugated board box	Primary Packaging	Production of PLA granulate	Delivery Packaging	Production of corrugated board box	Waste	Material Recovery - production of recycled HDPE granulate
Photochemical oxidation	Delivery Packaging	Production of HDPE	Primary Packaging	Production of corrugated board box	Primary Packaging	Production of PLA granulate	Delivery Packaging	Production of corrugated board box	Waste	Production of HDPE granulate
Ozone layer depletion	Delivery Packaging	Production of corrugated board box	Delivery Packaging	Production of corrugated board box	Tertiary Packaging	Production of textile, woven cotton	Delivery Packaging	Production of corrugated board box	Transport	Production of HDPE granulate
Depletion of abiotic resources	Delivery Packaging	Production of corrugated board box	Primary Packaging	Production of corrugated board box	Primary Packaging	Production of PLA granulate	Delivery Packaging	Production of corrugated board box	Waste	Material Recovery - production of recycled HDPE granulate
Human toxicity	Waste	Municipal incineration of waste PE	Waste	Municipal incineration of waste PE	Waste	Production of PLA granulate	Delivery Packaging	Production of corrugated board box	Waste	Material Recovery - production of recycled HDPE granulate
Freshwater eco-toxicity	Waste	Municipal incineration of waste PE	Waste	Municipal incineration of waste PE	Waste	Municipal incineration of waste PE	Waste	Production of corrugated board box	Waste	Material Recovery - production of recycled HDPE granulate
Marine aquatic toxicity	Waste	Municipal incineration of waste PE	Waste	Production of corrugated board box	Waste	Production of PLA granulate	Delivery Packaging	Production of corrugated board box	Waste	Material Recovery - production of recycled HDPE granulate
Terrestrial eco-toxicity	Delivery Packaging	Municipal incineration of waste PE	Waste	Production of corrugated board box	Tertiary Packaging	Production of textile, woven cotton	Delivery Packaging	Production of corrugated board box	Waste	Material Recovery - production of recycled HDPE granulate

The comprehensive view of where to focalise can facilitate the decision-making, and the in-depth dissection of scenarios, groups, activities and flows help guarantee the level of details for tailored solutions. In addition to the dominance analysis, other interpretation approaches such as breakeven analysis can also be applied for this study.

CHAPTER 6 CONCLUSION

This chapter is a concise summary of both the major contribution to system analysis in the form of methodological assets and the key recommendations drawn from the case study on e-commerce packaging logistics in China. Limitation would also be mentioned in the later part.

6.1 Contribution to system analysis

This study brings forward a system analysis framework for decision-making in e-commerce packaging logistics, and it is replicable to studies in supply chain management, logistics or packaging-related subjects. The major contribution of this framework stems from its logical stand of combining value domain, operational domain and impact domain in a decision-making loop to grasp the interrelations. The methods selected for the three system-level questions to each domain are all 'interaction-based'. The qualitative SVN model centres on the latent stakeholder groups and their value delivery flows. The network approach can outperform other stakeholder analysis in extracting more embedded interactions. In the packaging logistics analysis a specific mapping tool is applied to reveal the interactions of packaging systems and logistics activities, and by then identify the improvement space. The lifecycle impact analysis touches upon the interactions between the packaging logistics system and the wider system with impact flows. The dynamics in decision-making could then be better grasped and apprehended.

6.2 Key recommendations from the case study

The focal case, here in this study, is the e-commerce packaging logistics within Chinese context, thus the findings are country-specific. The thorough discussions on levels of interactions are conducted in the previous analysis, and here this part serves as a recommendation summary to the decision-making.

6.2.1 Recommendations from stakeholder analysis

The main recommendations of this stakeholder analysis are the identification of unexpected stakeholders to be incorporated in the scheme, and the latent value delivery between the stakeholders. Here recommendations will be presented in a bullet list.

- Upstream suppliers shall be included for the entire packaging logistics performance; they and end consumers are crucial for forming the financial value loop;
- Trade-offs of technology advancement and cost reduction are mostly concerned in definitive stakeholder’s decision-making while political regulation is the most influential external driver;
- Media shall be included as the main facilitator for value delivery to the general public;
- Municipalities shall be differentiated from the national government, as the group has its own role to the e-commerce logistics with infrastructure support and local supervision;
- Though all as NGOs, industrial associations shall be differentiated from ENGOs. The ‘industrial associations’ group acts as a significant advisory body and negotiator between the national government and the industries, whereas ENGOs are more at the side of public promotion and stay distant from the collaborated discussions; ENGO funds, particularly, have the cash pooling input to the sustainable e-commerce packaging logistics;
- Logistics workers shall be differentiated from logistics entities, as their appeals to the e-commerce packaging logistics can be both indifferent or obstructive;

6.2.2 Recommendations from packaging logistics analysis

The main findings of this stakeholder analysis are the identification of redundant logistics activities and the emerging problems at the interface of packaging system and logistics. Here are the recommendations made to the decision-making.

- The concern over delivery packaging in self-run logistics can be less then in 3PL logistics due to its supply chain controllability;
- Primary packaging shall be highlighted concerning its latent interactions to the logistics activities;
- Redundancies in the repeating input/output of tertiary packaging shall be removed by streamlined logistics activities in both 'supplier + 3PL';
- Approaches for packaging logistics solutions can be summarised into automation upgrade, material substitute, packaging rationalisation scenarios and stakeholder integration.

6.2.3 Recommendations from lifecycle impact analysis

The lifecycle impact analysis is to reflect how the changes in decisions can influence the impact mechanism. Here are the key messages derived from interpretation of lifecycle assessment.

- 'Self-run logistics' performed better than '3PL' in terms of impacts and damages to ecosystems, human health and resources, and the average reduction is around one third; Further removal of redundant process can help highlight its advantages;
- Technological advancement and integrated packaging logistics solutions will in the long-run benefit the economy considering the future loss; funding for sustainable packaging logistics can have diverse sources to relieve the burden on definitive stakeholders;
- Packaging rationalisation and stakeholder integration have most remarkable contribution to the reduction of impacts. The scenario combination of packaging rationalisation, automation updates and certain packaging solutions in material substitution will be more effective to impact reduction;
- Material substitution can be controversial due to some predominant contributing activities either at the production or the disposal stage. To revisit the activity contributors can help identify where the improvement can be carried out.

6.3 Limitations

The limitation of this research can be three-folds.

- Due to the state-of-the-art solutions in e-commerce packaging logistics, the research has limited choices in the case study;
- Data availability is insufficient, especially for LCA study. Therefore there are many assumptions and simplification of the sources, which increase the uncertainty in the study results;
- Sensitive analysis is missing in the study.

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