CHALMERS

Electric Vehicle Design for Chinese Express Delivery Market

——based on PUNCH project

Master of Science Thesis in the Master Degree Program, Industrial Design Engineering

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CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenborg, Sweden 2014

Department of Product- and Production Development
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Abstract

A small electric vehicle project ‘PUNCH’ has been carrying in the Applied Mechanics of Chalmers for years, but the distribution and potential user of it still remains ambiguous. Meanwhile, the express delivery industry in China is experiencing a tremendous growth in the new century; however, the chaotic market condition and low service quality could hardly either face the direct competition from foreign companies or meet the developing trends of future. This research aims to apply the fruitful results of project PUNCH to the Chinese express delivery context and design a specialized delivery vehicle for the local enterprises to raise their competitiveness. In this paper, a mixed approach of user-centered design and activity-centered design was applied, and a series of systematic methods were implemented to obtain user requirements and their undesired behaviors. The final deliverable is presented via CAD model and evaluated in accordance with user needs, ergonomics, the effect of behavior alteration and technical feasibility.

Key words: *express delivery, electric vehicle, China, PUNCH project, user-centered design, activity-centered design*

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In charge such a long-term and complex master project alone is not an easy thing for me, which even includes a long return flight to the field research place, Shanghai. But luckily, in the last four months, I have received so many help from different peoples, who support me to gradually make the project possible.

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Chengang Cao

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1. Introduction

This chapter presents the background and scope in terms of purpose, aim and delimitations of the master thesis project. The project's relation to connected projects, the project process and the structure of the report is also presented.

1.1 Background

The initiator of this project is Ralf Rosenberg, a professor in master programme Industrial Design Engineering, who has once traveled to the one of the biggest city in China, Shanghai, and found the undesired but interesting illegal vehicle overload situations.

Shanghai is an extremely large city with 23 million populations. The traffic load is huge, and the demand for distribution and transport is also tremendous. A majority of these transports, to a very large extend, are considered quite short and mostly carried out with mopeds, scooters or electric trikes, which are not designed for the purpose. It is not very likely that these vehicles can meet the demands for working and traffic standard in the future.

Meanwhile, a project about a small electric vehicle called 'PUNCH' has been going on at the department Applied Mechanics Chalmers. After the negotiation with Sven Andersson, the initiator of PUNCH project, the intention of implanting PUNCH to the Chinese market has been generated.

Figure 1.1 The illegal vehicle overload situations in Shanghai (Taken by Ralf Rosenberg)

1.1.1 PUNCH project

Years before, Professor Sven Andersson initiated the PUNCH project in the scope of the Automotive Engineering Master's Program at Chalmers University. The fundamental idea behind PUNCH was to design, and eventually manufacture, a safe one-seat hybrid low speed vehicle (Riazi et al., 2010). It should be small, safe, eco-friendly and certified and be able to run on Swedish roads as a "moped car" which consists of four wheels and enough space for a piece of luggage (Auzenau et al., 2010).

Groups of students have been working on different parts of it and most of the technical solutions have been generated. But due to project's technology-centered nature, the purpose of use and the demands of the user remained blurry. No specific usage description could be found and very few user studies had been executed. In addition, vehicle ergonomics and anthropometry research was also quite insufficient.

1.1.2 Chinese express delivery market

A majority of the illegal overload vehicles Ralf saw in Shanghai are run by express deliverymen. Due to the combined effect of political, economic, cultural and technical factors, the express delivery industry in China is experiencing an extremely rapid growth in the new century. Local companies are springing up like mushrooms after the rain, and foreign investments are itching to enter the recently opened domestic service field.

Most of the intra-city and inter-city business is currently dominated by state-owned and private-owned companies for their low price, good reachability and flexible service modes. However, their service qualities are not that satisfying, frequent cargo damage or loss and poor service attitudes lead to consumers' increasing dissatisfaction. The inherent defects of the local companies such as poor management, old-fashioned business mode, poor service quality, unqualified employees, low technologies etc. are gradually being exposed. With the coming competition from international industry giants in near future, these problems would become more obvious and threaten their survival in the industry.

1.1.3 Express delivery vehicle

The improper transport tools used in express delivery is also one of the primary inducements of the undesired service quality. Most of delivery vehicles used currently is either illegal-modified or illegal operated. Especially in intra-urban distribution, overloaded electric scooters/mopes, unlawful –used electric tricks and illegal-refitted MPVs/minibuses undertake almost all the business. These unqualified vehicles could not provide enough protection to the cargos; and the overload and aggressive driving behaviors of the deliverymen endangers their safety and affects the local traffic condition.

Though some foreign automotive enterprises have already started their research and development on tail-made delivery vehicles, their solutions concentrate in high and medium price region and could hardly meet the actually requirements and legislations in China. With government's increasing intention of issuing standard delivery vehicles to unify the chaotic market situation, it is a great opportunity to introduce the existing safety-guaranteed PUNCH vehicle into China's express delivery context.

1.2 Project aim

The aim of this master thesis project is to design a small express delivery electric vehicle which is base on the fruitful results of project PUNCH, and compatible with users' requirements, ergonomics, market conditions and mechanical feasibility within an extensive urban context in China. The final product should be able to facilitate deliverymen to perform their work in a legal, safe, efficient and comfortable manner; and raise the competitiveness of the local express delivery enterprises.

1.3 Project goals

The brief structure of this thesis follows the process of user-centered design, while the activity- centered thinking keeps implanting in the research and design phases. To facilitate the accompaniment of the project aim, a series of goals are raised throughout all the phases of the project. The goals addressing in each segment are listed as below.

Phase 1 - Design Research

1. Understand the development of Chinese local express delivery industry.
2. Understand the existing products and their pros and cons.
3. Understand the existing technical solution of PUNCH project and briefly judge its fitness to the target industry.
4. Identify the user of the new product and specify their requirements and ergonomics.
5. Identify the undesired behavior of user and analyze their antecedents.
6. Understand the context of use.

Phase 2 – Solution design

1. Identify and integrate the traits of users' aesthetic feeling.
2. Realize the functions retrieved from user requirements, ergonomics, market conditions, mechanical aspects and context.
3. Integrate design interventions to prevent or alter user's undesired behaviors

Phase 3 - Design evaluation

1. Evaluate the legality, safety, efficiency and comfort of the design.
2. Evaluate the user aesthetic feeling of the design.
3. Evaluate the mechanical feasibility of the design.

The final deliverable of this thesis project is a proposal of a concept vehicle, more specificly, it includes a CAD-model of the finalized product, high quality renderings of the vehicle and important vehicle details, a documentary development process of the generation of of the final product and its features and recommendations about the potential market distrubution and futher product development.

For the author, important learning goals are also carried out throughout the project. The first is about how to effectively manage a long-term and complex project to make it clear, logical and methodical. The second is how

to closely cooperate with the mechnical engineers to make the end product more convincing, realistic and technically 'in reach' rather than a good looking 'art piece'.

1.4 Delimitations

The following delimitations have been made to ensure the end concept enjoying a high pertinence to the main focus area of the project.

The project aim is to design a delivery vehicle for express delivery usage within Chinese urban context, which means other delivery activities such as logistics, post, flower, food, water, etc. are temporarily not included in the research field; and the inter-city or cross-border express delivery activities are also excluded from the project scope as well.

The main subject of the final product limited to the delivery employees from local private-owned or state-owned companies. Deliverymen from foreign companies are not included in the research scope.

All the mechanical solutions about the PUNCH project are retrieved from three student reports 'PUNCH 2011' (Atchison et al., 2011), 'Punch Power Train Report' (Auzenau et al., 2010) and 'PUNCH Final Frame Report' (Riazi et al., 2010). Several differences can be observed within the same parameters among the reports, and modifications seem to be done when manufacturing the real physical aluminum frame. In this paper, when a contradictory record is identified, the author would use the one in the relatively new published paper. And all the modifications on the frame are built based on the real model instead of the CATIA one.

Mechanical solutions of the end product are just raised, but not detailed specified. No detailed mechanical drawings are presented in the paper and the product has not reached a production ready state. All the technical decisions made in this report are all needed to be further verified.

The methods of vehicle manufacturing and production are recommended in the paper, but not meant to be the most optimal solutions. And the price estimation is just built on similar product in the market, no detailed costs of different parts and manufacturing processes is included.

Though a marketing strategy is raised after the introduction of the final concept, it is constructed on ideal assumption. No guarantee is made about the success of the proposal.

No final physical model or mockups is created in this project.

1.5 Project process

This section explains an overview of this project's structure. The project contains six phases, the first one and the last three were carried out in Gothenburg, Sweden, and the rest two were executed in Shanghai, China.

The project started from a planning and initial research phase. Two methods were applied to set the main project flow and time schedule, and the other two were used to collect various required knowledge for later field research.

The second and third steps were accomplished during three weeks in Shanghai. It was the most essential parts of the project where the actual end users were contacted, and their insights, requirements, reflections, feedbacks and behaviors were detailed recorded. A quick ideation phase was done and users' comments on product form were also acquired.

The fourth, fifth and sixth phases were carried out after back from the user research. More detailed design development was done in the concept refinement phase. According to the actual user requirements, modifications to the technical solutions of PUNCH were raised, and consulted with the experts in Applied Mechanics Chalmers. After getting approved, the final concept was visualize by a series of methods and presented as a CAD model and high quality renderings. A brief concept evaluation was done afterwards to see the validation of required functionalities and other issues.

Figure 1.2 shown in the next page is the flow chart used to presents the overview of this project's process. The structure of this paper would also follow this sequence.

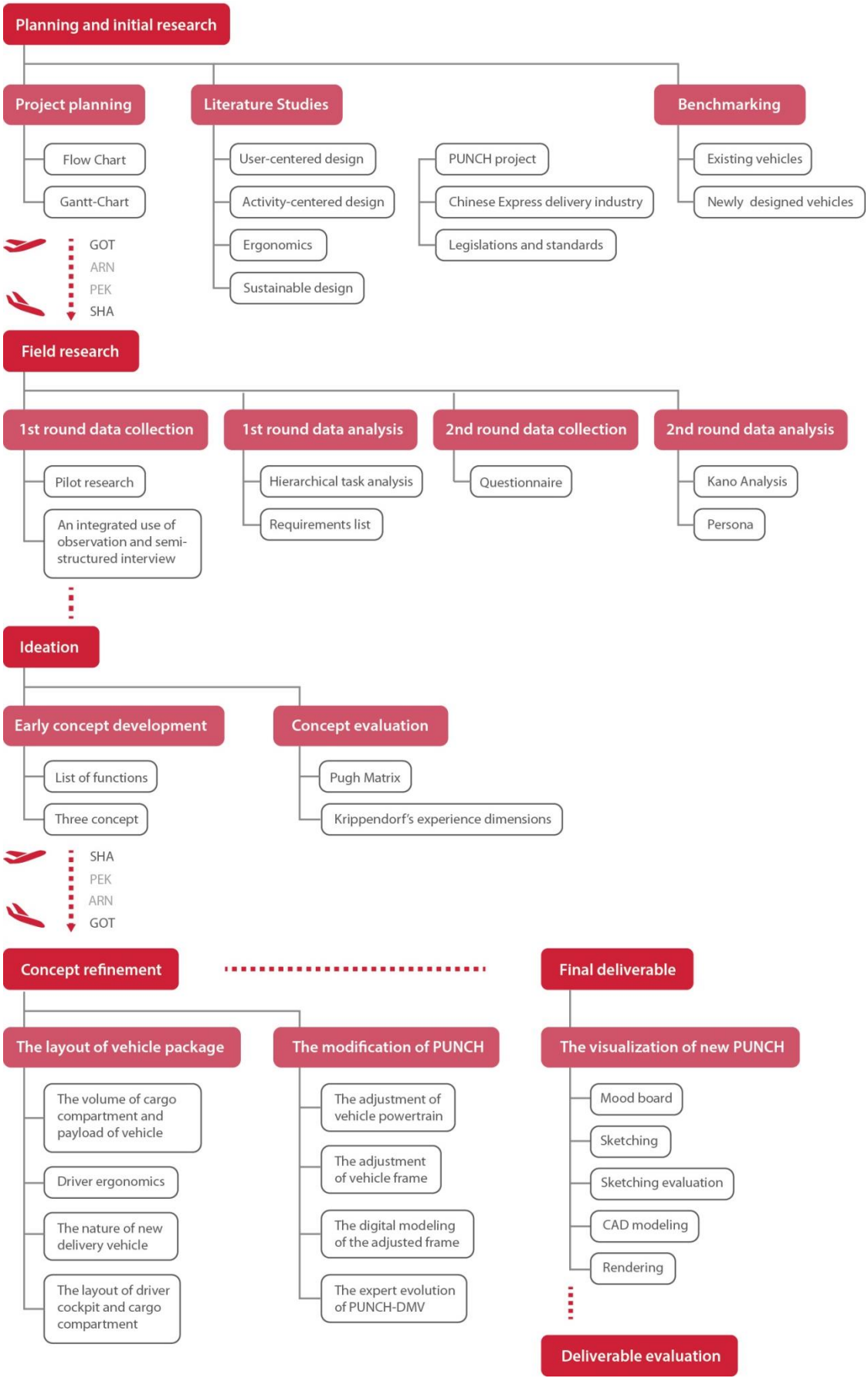

Figure 1.2 The process of the project

1.6 Report outline

This report explains the implementations and the results of all the phases in project. Since the product is quite complex and many multidisciplinary content is included, for readers' convenience, the outline of the chapters are concluded here. For those who are familiar with certain fields, more focuses could be put on the specific sections of interest.

Chapter one presents the background and scope in terms of purpose, aim and delimitations of the master thesis project. The project's relation to connected projects, the project process and the structure of the report is also presented.

Chapter two presents ergonomics theories which have been used as a framework throughout the design phases. Parts of the decisions made during the project are based on information found in this chapter.

Chapter three describes the main design research methodology which has been used as a framework throughout the entire project. It also explains why different methods have been selected and how they have been implemented. The methods are presented according to different study phases.

Chapter four contains a knowledge foundation of facts and principles that are closely related to the project. This knowledge base provides a basic understanding of the project as well as the product, which helps the author and readers to comprehend the information obtained in the later studies. The information gathered here includes three main aspects, previous achievement of PUNCH project, facts of express delivery industry and the knowledge of product background.

Chapter five describes contents of the field research carried out in Shanghai, China. Theories and methods mentioned in the previous chapters are implanted in practice, and the results of two rounds of user investigations and corresponding analysis are respectively displayed. These requirements and problems identified in this phase would be used in combination with the knowledgebase to serve for the later design phase.

Chapter six describes the process of the creative ideation phase. In the early concept development stage, three concepts are generated according to the list of functions. Then the three concepts were respectively evaluated by Pugh Matrix and Krippendorf's experience dimensions. After the evaluation, one concept is selected for further development.

Chapter seven describes the development process of the selected concept, including package design, PUNCH modification, modification evaluation and form exploration. Many essential decisions of the finial product are made in this chapter

Chapter eight presents the final concept design and end result of the master thesis project. The form, function, ergonomics, technical aspects and product strategy of PUNCH-DMV are respectively explained.

Chapter nine presents the evaluation of the final concept and a description of the strong and weak aspects of the design according to the evaluation result. The evaluation is conducted base on the requirement list obtained in Chapter 6.

Chapter ten is the project discussion, includes author's thoughts on the entire project. The discussion also includes some recommendations on further development for the final concept.

Chapter eleven contains the conclusion of the project.

2. Ergonomics

This chapter presents ergonomics theories which have been used as a framework throughout the design phases. Parts of the decisions made during the project are based on information found in this chapter.

2.1 Introduction to ergonomics

Ergonomics is science of designing human with machines, products, systems, etc. under their environments. According to the International Ergonomics Association, the definition of ergonomics is "*the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance*" (IEA, 2014). It takes user's needs, capabilities and limitations into consideration and ensures the fitness among user attributes, tasks, functions, information and the environment

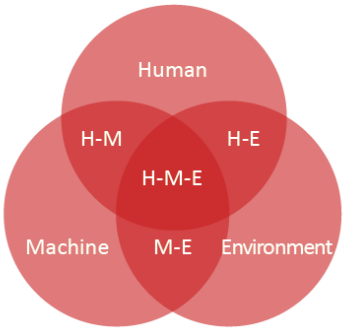

Figure 2.1 Ergonomics model of Human-Machine-Environment (MMESE, 2014)

The aim of ergonomics is to improve the human-machine interaction and make the environment around a product more favorable. Employing ergonomics in product development process could not only fulfill the fundamental demands of safety and comfort of the occupational individuals, but also provide desired efficiency and productivity for the company or organization, and even enhance market competitiveness and economic situation in the society level (Bohgard, et al., 2008).

The following sections present two essential ergonomic domains which are vital to this project.

2.2 Physical ergonomics

Physical ergonomics concerns subjects that study physical activity of human being, including human anatomical, anthropometric, physiological, etc. (IEA, 2014). The relevant topics of it are relatively broad and often connect to mechanical interaction between the user and a product.

2.2.1 Anthropometry

Anthropometry refers to the measurement of the human individual. It is usually connected to ergonomics and used as an important tool to identify human physical variation on specific populations to meet the physical requirement from users. Anthropometric data are usually presented in percentage and categorized according to gender (Bergqvist and Wiklander, 2010).

The increased needs of 'design for all' as well as adjustability and customization products constantly push the designer to take users with extreme body dominations into consideration. 5-percentile female to 95-percentile male data are commonly applied in nowadays design projects (Bohgard, et al., 2008). And with the rapid variation in human life styles, changes in the distribution of body dimensions become more and more obvious. Regular updating of anthropometric data is often required.

During 1986 to 1988, for the first time, China launched a national wide measurement of human body dimensions and an anthropometry database was established on the result. The database is called GB10000-88; it respectively contains 47 different items of human body statistics of both male and female, and classifies each item by three age groups. Three years later, a national standard of human dimensions in workspaces named GB/T 13547-92 was released, in which data of five postures were included. But 20 years have passed, no update has been provided. The old statistics could hardly correspond to the current situations. According to estimation, the stature of adult male is two centimeters higher and the waistline is five centimeters longer (Hu, 2013). And a small range research involves 12622 samples in Beijing in 2010 also demonstrate that the stature of young man between 20-24 years old is almost 4.5 centimeters higher than shown in the database.

Since no updated anthropometric data could be used, the old database has to be applied in this paper. But the changes in body dimensions would be taken into consideration and simple anthropometric data like stature and weight would be collected during the field research phase to compare with the literature studies.

2.2.2 Seat ergonomics

The spatial relationships between driver seat and important operating devices highly determine the driver environment. A good design of driver seat is important for the occupant to reach comfort and safety.

According to Bergqvist and Wiklander (2010), the seat should lean backwards about 10-15 degrees and an angle of 105-110 degrees should be formed in between the backrest and seat. The seat height should be less to the popliteal height; the seat depth should not be greater than the buttock-popliteal length; and the minimum seat width is required not be less than 25 millimeters shorter on either side of the maximum breadth of the hips (Pheasant, 2003). All these body dimensions mentioned above should all take the extreme user, i.e. 5-percentile female or 95-percentile male into consideration when compromises are needed to be done.

The backrest of the seat is divided into three areas according to the height. The low-level backrest is about 400 millimeters, which could provide enough support on driver's lumbar and lower thoracic region and allow free movements of the shoulders and arms. The medium-level backrest is 100-150 millimeters higher, which provides an extra support on mid-thoracic level. The high-level backrest with 900 millimeters gives support for not only the entire back, but also occupant's neck and head. The higher the backrest is, the more effective in supporting the weight of the trunk is, but whilst it limits the mobility of the parts upper shoulder (Pheasant, 2003).

The shape of backrest and seat should adapt to the S-shaped contour of the spine to provide enough support to driver's lumbar. A maximum 40 millimeters protrusion could create preferable seating position for driver (Pheasant, 2003).

2.2.3 Body postures

Bohgard et al. (2008) have listed several general recommendations for human body postures in working environment. As they claim, the possibility of varying body posture is highly recommended. Postures with front tilted head and body, with twist and asymmetry demands or where joints need to be positioned in stretched out position for longer periods of time are required to be avoided. When there is a need of lifting heavy stuff, body parts which endure loads should be positioned in the way that maximum power is acquired. The lifting height is suggested to be at least 150mm below elbow height, and working with hands above head is only allowed for very short periods.

Society of Automotive Engineers (hereinafter SAE) presents a method recorded in their recommend practice J4004 to calculate the positional relation among seat and vehicle hand and foot controls. Via using driver seat position models, the length and location of adjustable seat tracks as well as the position of pedals and steering wheel can be determined to ensure the comfort of driver posture (SAE, 2005). This method uses five different variables, H30, L6, SgRP, PPA and t, to calculate the optimum setup. Only using the H30 measurement, all of the rest variables can be calculated and output, with a 95% percentile accommodation principle. Since this method is not the crucial part of this paper, detailed calculation formulas are not presented here.

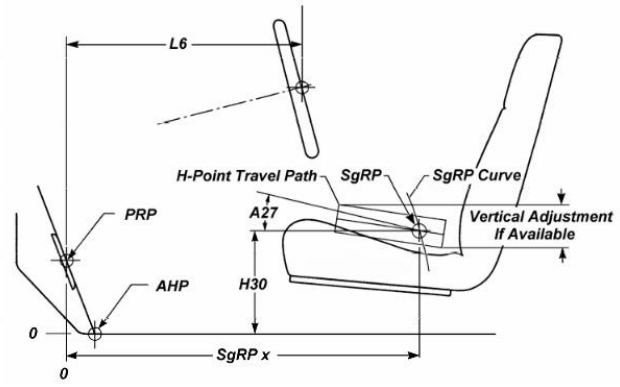

Figure 2.2 Seating package description showing package factors used to calculate driver seat positions

2.2.4 Overall driving ergonomics principles

Gyi, Sang, Haslam and Williams from Loughborough University has published seven guidelines of optimizing driving ergonomics within a car. The points list below could be seen as a summary and complement for the above contents (Bergqvist and Wiklander, 2010).

1. The seat height should ensure the comfort of driver and provide the maximum vision of the road. Adequate clearance from the roof is also a hard requirement for the seat position.

2. Clutch pedal and accelerator pedal should be easily reached and able to fully control by the occupant.

3. Driver thighs should be supported along the length of seat cushion to avoid pressure behind the knees.

4. Backrest should provide continuous support along the length of driver back. Excessive forward bending of the head and neck should be avoided by the design of seat.

5. Adjustable lumbar support should be provided to give even pressure along the length of the back rest.

6. The steering wheel should be between 400-450 millimeters in diameter and is able to be adjusted rearwards and downwards for each reach. Enough clearance should be provided for the driver to use pedals or to observe panel display.

7. Head restraints are required to reduce the risk of injury in the car accident.

2.3 Cognitive Ergonomics

In accordance with the definition given by IEA (2014), cognitive ergonomics is the subject that concerns with human mental processes, including perception, memory, reasoning, and motor response. It is usually relevant to topics such as mental workload, decision-making, skilled performance, human-computer interaction, etc. Wicken purposes a model to illustrate human's cognitive process dealing with information (Bergqvist and Wiklander, 2010). It involves sensory inputs, attention, perceptions, short-term memory, long-term memory, decision, response and a feedback loop.

Ensuring perfect and no interferential sensory perception is the most essential part of driving behavior. Since it is the first phase of human cognitive process, wrong or inadequate sensory inputs would not only vastly influence the later decision making or behavior responding, but also endanger the life safety of driver and the public.

2.3.1 Sensory perception

Sensory perception is the organization, identification, and interpretation of sensory inputs to represent and understand the environment (Schacter, 2011). People have recognized five senses 2300 years ago including vision, hearing, touching, olfaction and gustation. In fact, touching involves much more than just haptic feelings; force, pressure, temperature, electricity and pain are included as well (Kroemer, 2005). Among all the senses, vision and hearing perform the most significant roles in driving behavior.

1. Visual perception
Visual perception is the capability to interpret the surrounding environment by processing information collected by eyes. It is one of the most sophisticated sensory perceptions of human beings and significantly influences people's driving behavior. Common vision deficiencies include shortsightedness, night blindness, astigmatism, chromatic, aberration, color weakness, floaters and cataracts. Some of deficiency symptoms can be alleviated by medical or surgical interventions. Yet, many people suffer from subpar visual abilities, and some of them are still allowed to drive according to relevant regulations. Providing bright illumination, raising the color contrast of traffic signs and using shape-coding of objects could be possible solutions for them. (Kroemer, 2005)

For the normal people with good visual abilities, having a correct location of drivers' eyes inside a vehicle is also particularly vital. In the recommended practice J941 launched by SAE, a term called 'eyellipse' is defined as a statistical representation of driver eye locations in three-dimensional space (SAE, 2002). It is used to facilitate design and evaluation of vision in vehicles.

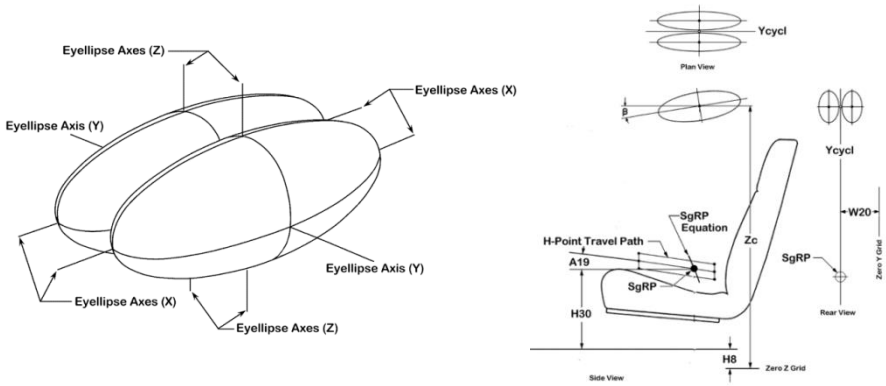

Figure 2.3 Three-dimensions of eyellipses and its location in vehicle

The location of eyellipses varies from different populations and vehicles. The position of eyellipses' mid-eye point is related to the sitting eye height of driver and the length of H30 which reflects vertical distance between floor of vehicle and the lower hip point of driver. And the eyellipses is not aligned with the vehicle axes in the side view; it is tilted down at the front and forms a side view angle β, where β = 18.6 – (A19). A19 is the angle between driver thighs and horizontal line (SAE, 2002).

The size of eyellipses depends on the stature values of target population. Statistics from two countries are given in the J941 and shown as below. Data for Japan and Netherlands are respectively supplied by Toyota and TNO.

Country	Percentile	X Axis Lengths	Y Axis Lengths	Z Axis Lengths
Japan	95	195.1	60.3	93.4
	99	271.5	85.3	132.1
Netherlands	95	202.0	60.3	93.4
	99	283.1	85.3	132.1

Table 2.2 Left and right eyellipse axis lengths (mm) (SAE, 2002)

According to the data recorded in GB10000-88, the mean statures of Chinese male and female are just over 1 centimeter higher than the average data of Japanese population shown in J941, and no Chinese eyellipse data record could be found. Thus, in this paper, Japanese data would be used with the data of human visual field, which is about 50 degree over eye level and 70 degree below eye level in the vertical plane, to help to arrange a correct location of driver in cabin.

2. Auditory perception

Hearing plays an important role in driving behavior as well. It collects the sound feedbacks from vehicle as well as the environment. With the development of modern society, more and more people suffer from auditory loss due to diseases, excessive noise, medications, physical injury, chemicals, etc. In accordance to the data in 2000, over 250 million people had moderate to profound hearing disability (Mathers et al., 2000) and this number kept climbing and reached 360 million in 2013 (WHO, 2013). And a part of them are still holding their driving licenses.

The main impact of hearing loss is on the individual's ability to communicate with people and context by sound, which may lead to the incomplete or inaccurate understanding of the surroundings (WHO, 2013). Despite the functional aspects, people with impaired hearing are more likely to suffer from loneliness, depression, frustration, anxiety and insecurity. Currently, there is not effective treatment except using hearing aids or implanting artificial cochlear.

However, the lack the sense of hearing motivates other senses like vision, tactus, vibration, smell and taste to compensate the hearing loss. For vehicle designer, using this feature of impaired hearing people could be a reasonable solution. Via combining other senses inputs like seat/steering wheel vibration, color change of illumination, etc. together with sound stimulation could effectively remind the driver of emergency situations

2.3.2 Overall cognitive design principles

The rest phases of human cognitive process would not be further discussed here because they are not so relevant to the main purpose. Instead, several cognitive design principles raised by Bohgard et al. is used as

guidance in this project. It involves four main categories and is listed as following.

1. Awareness: Information should be found with minimum time and efforts. Related information should be place close to each other.
2. Perceptions: Less information levels with good readability could help to make a decision. Similar objects or information should be avoided.
3. Memory functions: Using world knowledge to minimize displayed information could help to reduce unwanted burden on the memory. Coherent presentation of products could match a new design quickly with previous user experiences.
4. Mental models: Animated object should match people's mental image

2.4 Chapter conclusion

Ergonomics is an essential subject for the product design. It takes user's needs, capabilities and limitations into consideration and ensures the fitness among user attributes, tasks, functions, information and the environment. Especially for this vehicle design project, adapting user's physical ergonomics is one of the primary tasks that need to fulfill. Selecting proper anthropometric data, designing good seat ergonomics and providing suitable driving posture would help to let the occupant to reach comfort and safety. Other body posture is also worth to pay attention to, for example, lifting is quite essential during the delivery activities. Cognitive ergonomics is also very important for the vehicle driver. Though it is not a key point of this project, yet ensuring user's adequate visual and auditory inputs are the fundamental requirements for driving decision making or behavior responding. In addition, user's traits of awareness, other perceptions, memory functions and mental models are also recommended to take into account during the design phase.

3. Methodology

Chapter three describes the main design research methodology which has been used as a framework throughout the entire project. It also explains why different methods have been selected and how they have been implemented. The methods are presented according to different study phases.

3.1 User-centered design

User-centered design (hereinafter UCD) is one of the major approaches of this project. It is defined as a broad term to give a description of design processes in which end-users influence how a design takes shape (Abras et al., 2004). It could be regarded as a broad design philosophy as well as variety of research methods. The term UCD was first proposed by Donald Norman in the 1980s and began to be widely used after the publication of the book *User-Centered System Design: New Perspectives on Human-Computer Interaction* (Norman and Draper, 1986). Now it becomes one of the crucial approaches to the product development, which creates more effective, efficient and safer products and contributes to the product acceptance and success (Preece et al., 2002).

3.1.1 User-centered design and technology-centered design

Before user-centered design is extensively applied, technology-centered design (hereinafter TCD) is the main approach to the product or system development, and it is still applied in some of the technology-oriented companies. It would be helpful to understand the differences as well as the pros and cons of both design approaches before further discussing about the UCD.

Technology-centered design

Traditional product design approaches are fundamentally technology driven. Although engineers may collect consumer requirements at the beginning of the project, little or no user input are gathered during the design and development process (Vredeburg et al., 2001). This type of design approaches could be described as a typical inside-out structure, i.e. the internal technical architecture of product is constructed first, and then an interaction stage is created to let the users have access to manipulate to perform the product function. Social consequences together with the human factors can be studied and influence on future product development (Winograd and Woods, 1997).

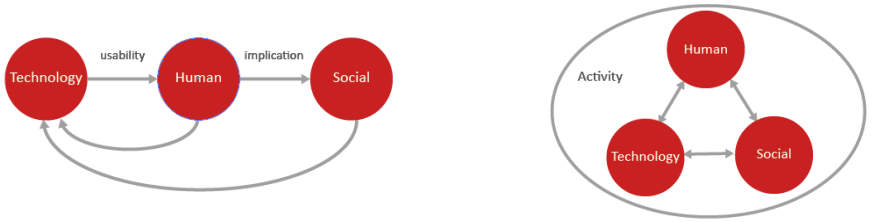

Figure 3.1 & Figure 3.2 The model of TCD and UCD (Vredeburg et al., 2001)

User-centered design

In contrast to the technology driven design, UCD challenges designers to mold the product based on the capabilities and needs of the end users (Abras et al., 2004). Customers are involved in most of the stages of development and design. The operator experience is decided prior to the construction of technical architecture. Rather than let the user adapt the product, a user-centered design integrates product features to fit the goals, tasks, and needs of the users, in other words, it is a representative structure of outside-in (Vredeburg et al., 2001). Three basic attributes could be characterized to interpret user-centered research and design: problem-driven, task-centered and context-bound (Winograd and Woods, 1997).

3.1.2 Comparison between UCD and TCD

Vredeburg (2001) lists ten primary differences between UCD approach and the traditional TCD approach in his book *User-centered Design*, and they are briefly listed as below.

1. Technology/user driven: The most distinct difference between these two design approaches lies in the involvement of users. As stated previously, TCD seldom integrates the user data in development, while UCD involves the end user during the entire design process, and even prolong their participation to packaging, advertising, ordering and support. The total customer experience is guided by continuous user inputs.

2. Component/Solutions focus: TCD focus more on product components executing certain functions, while UCD regards an entire application as a tool that works as an auxiliary to help an operator accomplish tasks.

3. Multidisciplinary cooperation: Traditional TCD approach involves limited cross disciplinary cooperation during the design process, which often makes the final product seem like a patchwork made by different factions. On the other hand, UCD approach requires a strong multidisciplinary collaboration throughout the process. The whole team shares the same goal and the resulting product appears much unified.

4. Internal/external design: As mentioned above, TCD is an inside-out strategy whilst UCD is just opposite. TCD focus more on the technology implantation, and UCD holds the user perspective.

5. Specialization: In TCD teams, there are some influential technical members who enjoy more power than others. But in UCD crews from user experience disciplines are equivalently essential.

6. Competitive focus: Most of the TCD approaches involve some competitive focus on technical aspect. UCD have a broader focus on the task accomplishment level, which means the competitors not only limited to the products from other company with large market share, but also the analogue methods which may achieve the same goal. The primary ways to analysis in UCD are forming the comparison and benchmark.

7. Validation: TCD approaches often exclude user validation as a part of process. Therefore, more iteration is required to make the design right, which leads to short product lifecycle, waste of time and money and the losses of consumers' patience and satisfactions. On the contrary, validation occurs iteratively throughout entire UCD process. Problems could be identified in time and extremely inexpensive and quick to modify.

8. View of quality: No technical defect almost equals good quality in traditional TCD approaches. IInstead, UCD stands at a customer point of view. In spite of perfectly working product, if users are not able to use it to finish the aimed task, the design should be reconsidered and modified to fit consumer's expectation.

9. User measurement: In traditional approaches, customer measurement and evaluation are thought as subjective information and not so useful. In UCD, user customer measurement and evaluation are carried in different stages throughout the process and act as the criterion of the success of the product.

10. Customers: Some TCD approaches collect user feedbacks from their existing customers, whilst UCD concerns consumers in the entire market segment, including the users of competitors' product. Therefore, the products generated by UCD strategy are designed for the whole market.

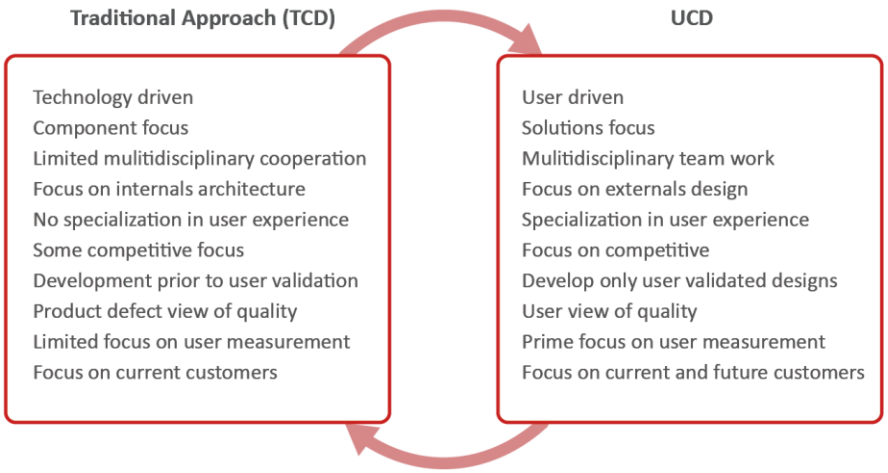

Figure 3.3 Contrasting TCD approach to UCD approach (Vredeburg et al., 2001)

As the powers of technology explode around us, it is easy to imagine that the pursuit of technological advances could produce many useful products to the users and bring generous benefits to the developers. However, empirical studies demonstrate that new technology-driven products often have surprising consequences or even fail (Winograd and Woods, 1997; Norman, 1988). A large set of product problems have been identified, including information overload, error, clumsiness, high learning cost, etc. Some of these failures could be directly regarded as "ways to design things wrong" from a human-centered point of view (Norman, 1988).

Therefore, in today's fast consumption context, compared to traditional TCD approach, UCD is considered as a more suitable approach to execute product development process. Via placing the user desires and requirements in the center, developers could not only obtain transforming user requirements, keep pace with the changing markets, reduce risks and raise sales performance, but also vastly reduce the development time and cost of the project. Meanwhile, from users' perspective, more friendly products apparently provide sufficient usability, fewer errors during usage, and faster learning times (Norman, 2005), and therefore improve their quality of lives.

3.1.3 Notes of applying UCD approach

Although the advantages of applying UCD approach to the actual product development process are tremendous, the drawbacks and misconceptions of UCD also commonly exist. It is worthwhile to be aware of the disadvantages of this approach and try to avoid or make them up in this project.

1. UCD is that improvements for one group of users can be detrimental to others (Norman, 2005; Webster, 2012). In UCD, the amount of available resources is usually restricted; the requirements of limited participants cannot stand for all the others. "*The more something is tailored for the particular likes, dislikes, skills, and needs of the particular target population, the less likely it will be appropriate for others*." (Norman, 2005)

2. Users are moving targets (Norman, 2005; Webster, 2012). With the rapid developing situation nowadays, design for the user requirements today might be wrong tomorrow.

3. UCD does not equal asking users what they want and giving it to them (Abras et al., 2004). Most of the users don't always know what they want (Webster, 2012). They often have only brief ideas about what might be better. And limited to their knowledge or situation, they might not precisely express or even notice their needs, let alone bringing radical changes to the product.

4. Too much listening to users (Norman, 2005). One of the basic philosophies of UCD is to listen to users, but too much listening to consumers and adding their critiques to design can lead to overly complex solutions.

5. UCD research is expensive, unreliable and time consuming (Webster, 2012).

6. People do adapt to technologies (Norman, 2005). UCD follows a basic tenet that technology should adapt to user. However, numerous examples of successful examples demonstrate that people do well adjust to the technology. If the device people use fit gracefully into the requirements of the underlying activity and the device itself could be in a manner understood by users, people are probably accept and adjust themselves to the product.

3.1.4 UCD Processes

UCD process generally consists of three core phases, including design research plan and execution, solution design, and design evaluation (Williams, 2009). These three activities are carried out in an iterative fashion with the product development process. The process may keep repeating until the particular usability objectives have been attained (Maguire, 2011).

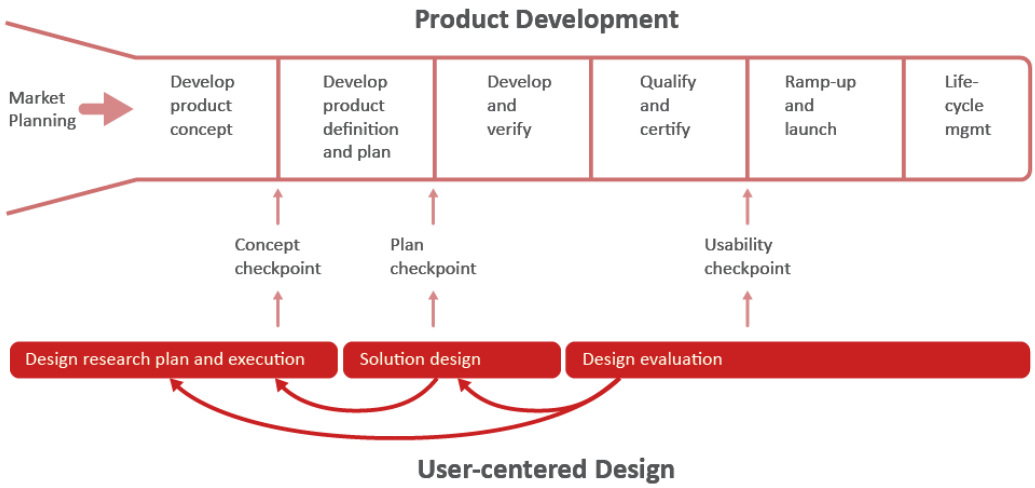

Figure 3.4 Integrating UCD into the product development process (Vredeburg, 2001)

The accomplishment of every phase is supported by a set of methods or activities. These methods can be applied solely, but the logical combination of methods could get a better user insight, remedy the defects of each other and further confirm the facticity of research result. The UCD methods used in this project are listed in section 3.3 in which the theories and their implantations are presented respectively.

Phase 1 - Design Research

During design research, the designer's purpose is to assess who the users are, what the contexts of use are and what user needs are (Williams, 2009; Maguire, 2011).

1. Identify the user

Kujala and Kauppinen (2004) state that identifying users for user-centered design of mass-market products is challenging. In order to reach representative users, they purpose a brief process of approaching core user group of the product. It starts with brainstorming a preliminary list of users. Then a description of the main user characteristics follows. After that, designer begins to describe and prioritize the Main User Groups and selecting representative users for the later research.

Though the amount of sample is the more the better, the number of users in UCD approach is usually limited. The precise number of necessary users should depend on the real case, but Kujala and Mäntylä's (2000) research has demonstrated that "as few as six users may provide extremely useful information for product development."

2. Understand the context of use

The use of a product always happens within a certain context. It may be affected by factors including the characteristics of user population, user's goal or wish of performing tasks, the technical, physical and social or organizational conditions, etc. The quality of use of a product depends on the level of understanding of the product context.

3. Specify the user requirements

In UCD, the primary principle is involving user in the design of products and not just in their use (Case, 2013). In other words users should not be passive recipients of products. Therefore, the collection, elicitation and analysis of user requirements become the most crucial part of product development. How well this activity is carried out can largely determine the success of the final product (Maguire, 2001).

Identifying user requirements contains a series of contents including the identification of the range of relevant users and other personnel in the design, an indication of appropriate priorities for the different requirements, the evidence of acceptance of the requirements, the acknowledgement of legislation, etc. UCD's rich practical foundations are able to provide a variety of research methods to help the designer obtain all the required information.

Phase 2 – Solution design

Based on findings from design research, designers start to use their innovative creativity to visualize design solutions (Williams, 2009; Maguire, 2011). This iterative phase involves brainstorming, conceptualizing, sketching as well as prototyping the drafts of the design. The deliverables of these stages could be quickly evaluated by users and experts, which help to avoid the costly correcting design faults in the later stages.

Phase 3 - Design evaluation

Once a solution is drafted, the UCD practitioner turns to evaluate the result of design. It is a really essential phase which indicates how far user's objectives have been met, and provides further information for revising the design (Maguire, 2011). Two main kinds of evaluation methods could be found in this phase, user-based methods and expert-based methods. User-based methods are more likely to reveal real problems, while expert-based methods can uncover unnoticeable shortcomings by a limited number of users.

3.1.5 UCD Deliverables

Many deliverables are produced in each of the three UCD phases. These results are intended be integrated and served as resources or references for design and modification. Meanwhile, these documents may submit formally to a client, customer, or key stakeholder as well (Williams, 2009). These kinds of documents include interview notes, questionnaire sheets, competitor analysis results, etc. during research phase; sketches drafted during the early stages of the design phase, and usability test scripts and observation forms during the design evaluation phase.

3.2 Activity-centered design

Activity-centered design is another essential approach applied in this project. It is used to make up the inherent defect of UCD. As an extensive project of PUNCH, some of the technical solutions have been made and highly recommended to obey if they do not violate fundamental user requirements. In addition, the poor service quality of Chinese delivery market indicates that some of users are not acting in a desired way. Blindly following their saying may not bring the expected result for this project. Therefore, integrating some activity-centered design thinking may provide a more heuristic way to deal with the users.

3.2.1 Definition of activity-centered design

Activity-centered design (hereinafter ACD) has roots in a variety of theories and disciplines. It can be traced to early Russian and Scandinavian research (Williams, 2009). ACD is very much like UCD. Many of the excellent attributes of UCD carry over. A deep understanding of people is still a part of ACD, but the difference lies in that ACD moves from "understanding your users as people" to "understanding them as participants in activities" (Constantine, 2006). ACD focus on what tasks or activities must be enabled by the product rather than what tasks or activities the user must perform with the product. Human activities stand in the center of this approach. They reflect the possible range of tasks, actions and operations of conditions. They also present dynamic interactions of functions and constraints among user, technology and context.

Compared with UCD, ACD is believed to have some advantages (Webster, 2012). First of all, people and technology are at the same importance in this approach. In order to achieve a certain activity, bidirectional adaption and coordination has to take place in environment, which immediately solve the dilemma happened in the UCD approach. In addition, learning about user behavior rather than user could screen out invalid and incorrect research data and fasten the design process; predicting activity purpose is easier than conjecturing user goals; focusing on problems holds a broader mind than concentrating on user mistakes; etc.

3.2.2 ACD related theories

Norman's activity model

Norman (2005) approved the superiority of ACD theory in his article *Human-centered design considered harmful* and further developed it toward to the product design orientation. He regards an activity as a coordinated, integrated set of tasks. Activity stays in the highest level, which is composed of tasks, which themselves consist of a series of actions, and actions are made up of operation behaviors. The hierarchical structure of 'activity', 'task', 'action' and 'behavior' makes up his activity theory.

Figure 3.5 Norman's activity theory (Norman, 2005)

As shown in the model, user behaviors are the fundamental elements which make up the entire hierarchical structure. User's behavior within certain context directly influences the execution of a task and further affects the result of an activity. Altering user behavior towards a desired orientation via products can be an important part of ACD design.

The Theory of Interpersonal Behavior

Understanding the influencing factors of people's behavior is the premise of changing people's behavior. Triandis (1977) develops a theory to explain human behavior. According to his explanation, one's behavior is determined by three dimensions: intention, facilitating conditions and habits.

Intention encompasses three antecedents, attitude, affect and social factors, which respectively presents one' beliefs and evaluation of the behavior outcome; one's emotional state evoked via the behavior; and the impacts from social rules, surrounding/important people as well as self-identification towards the behavior. The second

factor 'facilitating conditions' consists of either objective factors that make the realization of a given behavior easy to do or barriers that impede or constrain the realization of the behavior. The third dimension, habit, refers to the level of the behavior repetition, i.e. the frequency of its occurrence.

Overall speaking, a behavior in any situation can viewed as the coordinating result of what one intends, what one's habitual responses, what one operates under situational constraints and conditions.

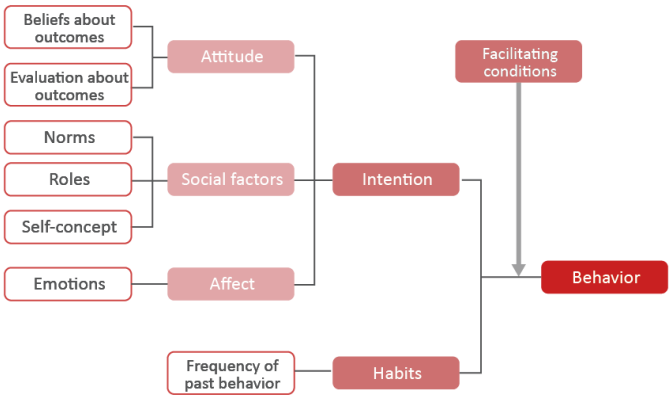

Figure 3.6 The Theory of interpersonal behavior (Triandis, 1977)

Among the three behavior antecedents, intention can be classified as an internal factor which is directly determined by people; facilitating conditions are considered as external factors that provide situational liberties or constraints; habit can be seen as certain repetitive behavior with long-time or high-frequency and restrained by both internal and external factors. Both of the intention factors and habit factors are moderated by the facilitating conditions and can be viewed as the strongest one among the three dimensions (Triandis, 1977; Stern 2000), but changing the other two could also have the possibility of alter people's behavior towards the desired orientation.

Design interventions of behavior

A lot of research has suggested that product design can be used as one of the approaches to alter human behaviors to desired ways (e.g. Lockton et al., 2008; Lilley 2009). Using the given power of user as scale, Zachrisson and Boks (2010) categorize product design interventions into three levels, informing, persuading and determining.

In the end where user is in control, interventions focus on altering internal factors of the user. In the other end where product is in control, products, or broadly speaking, external factors either force people to perform in a certain way or act automatically to reduce the control of user. Between these two ends are interventions with a varying degree of control.

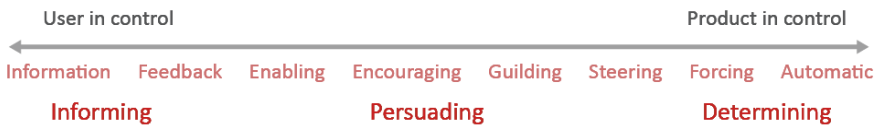

Figure 3.7 Zachrisson and Boks' model for categorization of design strategies (Zachrisson & Boks, 2010)

3.2.4 Defects of ACD approach

Although ACD has been proved to have many advantages which UCD does not possess and rich ACD foundations have already set up, this approach remains largely theoretical in nature (Otwell, 2005). Very little ACD design process and deliverables could be found among the industry-oriented publication. Apparently, the rich and complex theories have not been translated readily to the day-to-day practices of design (Williams, 2009).

3.3 An integrated approach

Since very less reference of the practical application of ACD could be found, in this design-oriented project, UCD is still considered as a more suitable approach to direct the design process for its ample practical foundations. But meanwhile, ACD thinking would be constantly implanted in different design phases to overcome the defects of UCD. It is not necessary to pit the two approaches against each other and choose the theoretically better one. The mixed approach allows the author to look at facts from different levels and perspectives, and therefore, produce more convincible and appropriate solutions.

3.3.1 Applying UCD to this project

Although the project PUNCH has been going at the department Applied Mechanics for years, the project aim keeps being of a technical nature, i.e. the entire project uses a typical TCD approach. No user has ever been involved in the research, and very less research on ergonomics has been executed. In order to transfer the technical results to actual market, it is crucial to immediately apply UCD approach in the PUNCH project to define its user group and address their core requirements.

The UCD process in this project would basically follow the three core phases mentioned in section 3.1.4. A bunch of methods would be utilized in the planning, research and analysis stages. After collecting and assessing the universality and significance of deliveryman's requirements, an ideation phase would be started followed by several rounds of evaluation tests. The final solution tries to meet the demands and desires from user whilst fulfill the requirements from environment, technology, laws and regulations, industrial stands, sustainability and other related factors.

During the UCD process, several notes should be kept in mind. First, due to the nature of PUNCH project, funds, time and effects have been put into producing technical solutions, and a general technical picture of the final product has already been displayed by these results. It is impossible and unworthy to overturn all these achievements and starts again just to adapt the requirements from user. Second, as mentioned, the chaotic Chinese delivery market indicates that some of users may not act in a desired way. Blindly following their saying may not bring the expected result for this project. Third, ample facts have proved that unlike UCD believes, the relationship between user and technology is not a simply unidirectional adaption.

3.3.2 The embedment of ACD related theories in this project

Therefore, ACD approach is applied to remedy the defects of UCD. The three theories described raised in section 3.2.2 could be respectively embedded in three different phases in the project.

1. Norman's activity model

   Driving is not the only human-vehicle interactions that deliverymen meet in their daily routine. More activities like parcel sorting, loading, unloading, communicating and even eating take place on the vehicle. Applying Norman's activity theory in the field research phase could effectively record and classify information in accordance with different activities and hierarchical levels. This method could quickly eliminate unvalued information, and then generated well-organized data.

2. The Theory of Interpersonal Behavior

   After getting the data organized by Norman's model, a series of behavior could be gained. Some undesired behaviors can be discovered and analyzed via The Theory of Interpersonal Behavior. Influencing factor behind these unexpected behaviors would be traced. Reasons would be sorted in line with the three dimensions and the results of the undesired behaviors would also be recognized and evaluated.

3. Design interventions of behavior

   Product intervention design would be utilized in ideation phase. According to the consequence of the undesired behaviors, interventions with diverse the level of user/product control would be generated to restrain or facilitate user behaviors. In this phase, product and technology is no longer required to adapt to the user, on the contrary, it would guide people to perform expectedly to achieve better efficiency, safety, comfort, or avoid potential risks or bad consequences.

3.3.3 The integration of UCD and ACD in this project

A special designed integrated methodology is developed and implanted in this project. As shown in Figure 3.8, the main process of this approach still follows the outline of UCD approach. But after reaching the field research phase, the approach splits into two orientations. The first one follows the regular procedures of UCD approach, in which user requirements are gathered, analyzed and organized for the solution design. Another one follows the three theories of ACD approach. Users' daily activities, tasks and behaviors would be recorded; unexpected situations are going to be identified and the antecedents of these undesired behaviors are analyzed to seek proper interventions. All the obtained information together with the demands from ergonomics and sustainable design mentioned in next section would converge in the design phase. These requirements and interventions would be integrated and interpreted into functions, and implanted to the final concept.

The whole process would try to keep as much existing technical solutions of PUNCH as possible, but still, with the coming inputs of user requirements, some technical modifications are inevitable to reduce the unnecessary product iteration and avoid future risks.

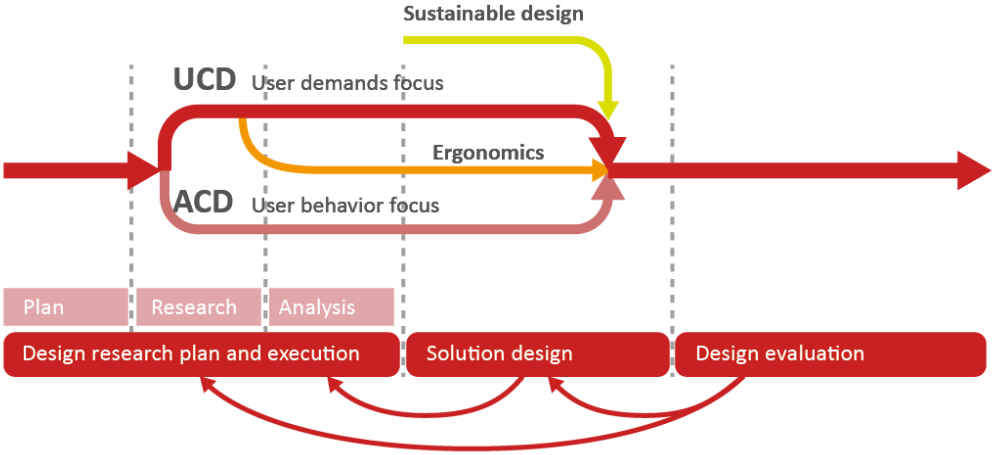

Figure 3.8 The integration of UCD and ACD in this project

3.4 Methods

This section describes why different methods have been selected and how they have been implemented throughout the project. The methods are presented according to different study phases. The generated results and further analysis are explained respectively in the later chapters.

3.4.1 Initial Research

The initial research of the project was carried out in Gothenburg, Sweden. In this phase, a project planning was done ahead of the execution of other methods. Then, literature studies and a benchmarking were made to obtain deep understandings of previous PUNCH project, China's express delivery industry and existing delivery-used vehicles.

- ***Planning***

Planning tools are used to improve the arrangement of project in order to raise the possibilities of being success. Since in this project, most part of the user research would be carried out in China, it is necessary to understand the overall workload and have a reasonable schedule arrangement before departure. Flow-cart and Gantt-Chart are the two primary methods used in this project.

1. Flow Chart

A flowchart is a type of broadly used diagram that using annotated symbols and links to represent a process in various fields. Geometric figures and arrows mark out different elements of the process and their orders, and imply their relationship and sequencing of operation (Mind Tools, 2014). Usually, these symbols are standardized, which enables the communication and understanding more clear and universal. The flow chart of this project is attached in Appendix I. Using geographic locations as project segmentations, the main working flow and their subtasks throughout the design process are displayed. Iterations are also taken into consideration in every stage, which allowed later modification if required.

2. Gantt-Chart

A Gantt-chart is a type of bar chart developed by Henry Gantt in 1910 (Wilson, 2003). It remains a popular management tool due to its effective means for illustrating the relationships between different activities and time. It consists of a horizontal time line, where tasks performed in the project are visualized via bars with specific lengths ranging from starting date to its finishing date (Ulrich & Eppinger, 1995). In addition, a Gantt chart can also display the dependency relationships among listed activitie. The Gantt-chart of this project is shown in Appendix II. Missions identified in the flow chart are listed as the task items, whilst the mission durations are indicated and visualized aside. By means of the combination of Gantt-chart and flow chart, the entire process were quickly illustrated and reasonably arranged. What to be conducted, when to be complete as well as how to be reached were simply clarified.

- ***Data Collection***

Initial data collection is really essential in this project. It helps to establish a comprehensive and systematic topic-related knowledge base before starting field research. Knowledge, experience, methods and statistics released by previous researchers can be viewed as significant references for the ongoing project. Less rehandling shall be done and more energy can be devoted to explore unclear problems. Literature studies and benchmarking are the two primary methods applied in this project.

1. Literature Studies

Literature studies are used to collect background information about a subject. Information within the topic could be gathered via various mediums, for instance, searching documentations, books, scientific publications, reports, or visiting internet database, etc. The purpose of utilizing this method is to understand the current knowledge development in the specific field and abstract the domain knowledge for the later use (Bohgard et al., 2008). Literature study acted as one of the primary methods in this project. Information, theories and statistics were collected, read and reorganized regarding topics including user-centered design, activity-centered design, ergonomics, electric vehicle design fundamentals, PUNCH related technical solutions, China's express delivery industry and delivery vehicle. These materials are treated as a cornerstone of the entire research, which are either worked as frameworks for the later research and design process or viewed as crucial factors that influences decision making. Meanwhile, limitations and restrictions in technologies, user aspects and relevant legislations are also meant to be identified via this method.

2. Benchmarking

Before embarking a new product, an analysis of existing competitors on the market can be beneficial (Ulrich &

Eppinger, 2008). Benchmarking is a method which product developer could use to compare preferably their own practice to other products with similar function or solving the same problem. Measured dimensions commonly are quality, cost, time, etc. The purpose is to find out competitors' superiorities and weaknesses whilst utilizing as an inspiration input or an evaluation tool for the product design process. The benchmarking analysis in this paper was built on the data obtained from internet research. A graph with six dimensions respectively measured total nine products to find out the superiorities and weaknesses of them, and another graph measured price-payload relationship was used to discover market blankets for the later concept development.

3.4.2 Field research

The field research of the project was conducted in Shanghai, China from 11th to 24th March 2014. The main purpose of having this oversea field research instead of online investigation is to know the real situation of China express industry, to get in contact with the product end-users, and to obtain actual user requirements through systematic methods.

- ***Theoretical framework of field research***

As stated by Abraham Maslow (1943), human's needs could be portrayed in the shape of a pyramid, where the physiological needs act as fundamental with the need or self-actualization at the top; in between, there are hierarchies named safety needs, love and belonging and esteem. Basic level of needs should be met before the individual strongly desire the secondary or higher level needs. Sanders (1992) interprets this theory and further develops it for design usage. She categorizes human need as observable needs, explicit needs, tacit needs and latent needs, and points out the corresponding behaviors that convey the information of these needs.

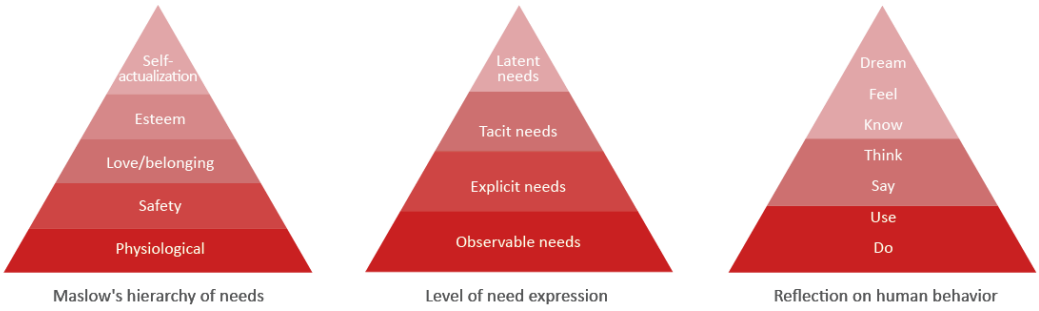

Figure 3.9 Maslow's hierarchy of needs and Sanders' level of need expression (Maslow, 1943)

Accordingly, the superiority of executing a close-to-user field research is self-explanatory. Via the application of a convergence of systematic methods, different levels of user needs can be induced. The researcher is able to capture a higher level understanding of user and thus provide more effective solutions. Meanwhile, the multiple approaches help to identify overlapping information and receive unbiased results in the process. In this report, a series of methods were applied to capture and classify the needs of deliverymen, including observation, semi-structured interview, questionnaire, HTA, requirement list, etc. The results of them are presented in Chapter 5 and Chapter 6.

- ***The first round field data collection***

The first round field data collection started on 11th March and lasted for a week. The investigation subjects were employees mainly from three private-owned express delivery companies, ZTO Express, YTO Express and S.F. Express. Over ten deliverymen were more or less involved and three of them were selected as main subjects. The outlets they worked for and their service areas were all close to Tongji University, Yangpu District.

There are two main purpose of this round research, including the collection of user, vehicle, cargo, task and environment information, as well as the verification of the existing situation in private-owned express delivery companies with previous literature studies. Detailed contents which were expected to obtain are listed in Table 3.1. Systematic methods were used to support the realization of purpose, including observation and semi-structured interview. In addition, a pilot research was done in advance to test the feasibility and effectiveness of the plan.

1. Pilot research

A pilot study is a preliminary analysis to exam research logistics and gathers information before committing to full-blown research (Altman et al, 2006). The aim of a pilot study is to evaluate the feasibility of a plan, i.e. reveal deficiencies in the design of a proposed procedure before time and resources are expended on large scale research. It contributes more on testing planned strategies rather than collecting statistics of the data. For

inexperienced researchers, it is a brilliant tool to test defects and improve research quality.

User	Product	Task	Context
Demographics Name, gender, age, native place, anthropometrics	**Vehicle information** Type, brand, size, price, energy, ownership, maintenance, pros and cons, expectation	**Freight** Sorting, arranging, loading & unloading behaviors	**Workstation** Vehicle primary and secondary controls, display, sightlines
Sociological traits Education	**Cargo information** Type (package/letter), amount, weight, size, shape, packaging material, categorized or not	**Operation** Driving, parking & charging behaviors	**Work place** Type of road, surface of road, road capacity, traffic density
Health conditions Fatigue, disease, physical / mental / cognitive impairment, occupational illness	**Safety** Vehicle: top speed, road speed, accident frequency, Cargo: protection or not (waterproof?), damage and missing	**Service** Delivering & picking behaviors	**Work setting** Weather, air quality, terrain, day/night, infrastructure, deadline of journey
Career / job information Company, income, working hours per day, workday per week, working place, service area, basic workflow, career time (company & industry)	**Efficiency** Amount/weight of cargo, service covering area, mileage per charge, charging duration, cargo arrangement, dedicated component/refit	**Others** Communicating behavior	**External issues** Climate, economics, legal and regulatory framework, industrial standards, technology, sustainability
Personal attitude Satisfactory or not (why), emotion, demission intention,	**Comfort** Driving gesture, seat shape & material		

Table 3.1 A list of required information

A pilot study was conducted on 11th March to exam the effectiveness of the original research proposal. It was about giving a restrict-structured questionnaire table to deliverymen from different private-owned companies; and then followed by entire working hours' observation on some of them. The questionnaire was almost another version of Table 3.1. The items intended to check in the pilot research included:

- whether the sequence of questionnaire is reasonable in the research process;
- whether questions numbers and arrangement are appropriate;
- whether the form and contents of the guideline are comprehensible to interviewee;
- the effectiveness and efficiency of interview process
- the reliability and validity of results

2. An integrated use of observation and semi-structured interview

After the pilot study, the original plan was substituted for its inherent disadvantages. An integrated use of

observation and semi-structured interview was applied instead to collect the required information in Table 3.1.

Observation
Observation is a method to learn how people behave in real situations. It provides observable information about how a product is used, how a task is performed, etc. Observation can also help to unveil user's tacit and latent needs, which can be hardly acquired through interview or some other methods. Both qualitative and quantitative data are able to be gathered via this method (Bohgard, et al., 2008).

Semi-structured interview
Interview is one of the most basic research methods to collect information from participants. It can be loosely differentiated as unstructured, semi-structured and structured (DiCicco-Bloom & Crabtree, 2006). A semi-structured interview contains both predetermined open-ended questions and improvisational questions emerging from the interviewing process. This method could also collect both qualitative and quantitative data, but it is suggested to be applied in combination with observations to exam the facticity of the result (Bohgard, et al., 2008).

Therefore, both observation and semi-structure interview were used in this round research to collect users' different levels of needs. Instead of the regular way of using the methods one after another, an integrated approach was executed. The strategy of this approach can be seen as an eclectic method between 'participation observation' and 'unobtrusive observation'; during deliveryman's key operation process, the practitioner would try to minimize his involvement to reduce potential behavioral influence; whilst in the rest periods or other suitable hours, the practitioner would either raise improvisational or predetermined open-ended questions as interview or start conversations about their lives, hobbies or other topics they interested.

There are two main aims of applying this complicated integrated method:

1. Collect as much precise objective observable and explicit information as possible.
2. Try to create a close and intimate familiarity with them over a short period of time to obtain inner feelings, emotions and needs.

This integrated method was applied on three express deliverymen respectively from ZTO Express, YTO Express and S.F. Express respectively on 14th , 17th and 24th March 2014. The studies were carried out throughout their working hours, approximately 11-12 hours each. Photos, videos and audios were utilized to make a detailed documentary for later analysis. A bicycle was used to follow their delivery routes. Some rewards were given before, during or after the research to increase familiarity.

● *The first round data analysis*
After received the information from the first round research, analysis methods were implanted to process the data. Hierarchical Task Analysis together with Norman's activity theory and The Theory of Interpersonal Behavior were used to find out unexpected behaviors during the express delivery activities and provide enlightenments. A requirements list was also used to summarize the potential demands of the user.

The main purpose of this round analysis is to extract the needs and the factors behind the undesired behavior. The results of this step would be used to get further confirmed, and evaluated their importance by the user.

3. Hierarchical task analysis
A Hierarchical task analysis, also called HTA, is a broad, objective method to describe the task in terms of a hierarchy of operations and plans based on structure chart notation. It provides an understanding of the tasks users need to perform to achieve certain goals. Three levels of task analysis are included in the method, goals, tasks and actions or operations, which gives a clear overview over the difficulty and required effort of a task. (Jordan, 1998)

In this project, HTA is the primary method to execute the concept of activity-centered design approach. After getting the results from the integrated method, numerous of tasks found in the express delivery process were broken down and analyzed piece by piece. ACD theories raised in the theoretical framework are integrated; Norman's activity theory is used to classify the information in accordance with different activities and hierarchical levels, and The Theory of Interpersonal Behavior is utilized to discover the undesired behaviors and trace their inducements.

4. Requirements list
Requirements list is a tool that can support researcher's requirements practices. It can encompass and delay the needs demanded to meet for a new or altered product, taking account of the possibly requirements of the

various stakeholders, analyzing, documenting, validating and environment or system requirements.

The requirements list used in this stage is to conclude the information got in the first round field research phase. Similar needs would be merged and less relevant information can be eliminated. After finishing the list, the validity of it would be tested in the second round field research.

● *The second round data collection*

The second round field data collection started on 18th March. The main method used in this phase was questionnaire. Compared with the previous round's qualitative-oriented research, this round data collection focused more on the quantitative aspect. More participants were involved and mathematical analysis was applied to process the data.

The main purpose of this round research was to exam the validity of the requirement list, evaluate the importance and universality of the listed requirements and collect some simple anthropometric data such as stature and mass to support the later design.

5. Questionnaire

A questionnaire can be seen as a form of structured interview but without the interviewer and interviewee having to meet. It can help to collect a large amount of data from a large number of participants within a relatively short period of time. A questionnaire consists of either open or closed questions, or a combination of both. An open question allows the respondent to reply freely with their own thinking, but it is somehow time-consuming and requires lots of efforts. While a closed question only provide predefined multiple choices, it is more efficient but less well-designed questions make the answers too shallow and general (Bohgard et al., 2009).

According to the feedback received from the pilot research, only two types of questions were used in this round's questionnaire. The first was blanks filling, which was used to collect participants' information about age, gender, stature, mass and the ownership of motor vehicle driving license. And the rest were all single-choice questions with requirements listed and the same five options: totally agree, agree, slightly agree, do not care and disagree. Totally 32 pieces of questionnaires were sent to an YTO outlet and 21 were retrieved. Obviously, the identical source of all the research samples may somehow influence the universality of the results, but since homogeneity of the franchise delivery companies and various sources inputs during the first round data collection phases, this limitation was not supposed to be very influential. The full questionnaire table can be found in Appendix IV and the research results are presented in section 5.5.

● *The second round data analysis*

The second round data analysis intends to comprehensively process and conclude all the information gathered from the first and second round field research. Two methods were used in this stage. Kano analysis was firstly applied to process the result gathered in the questionnaire; requirements were categorized into five different types, and their priorities of embedding in the later design are decided accordingly. A persona was attached at last to summarize the features of user.

6. Kano Analysis

The Kano Analysis is based on the Kano Model developed in the 1980s by Professor Noriaki Kano. It is a very useful technique for deciding which features should be included in a product or service. The Kano Model classifies customer preferences into five categories.

1. Must-be Quality

   The attributes belong to this category are obliged to be fulfilled by a product/service, or it would directly leads to customers' dissatisfaction when the product/service failed to, but no satisfaction would be increase after satisfied. It can be regarded as the most basic functions a product or service should possess.

2. One-dimensional Quality

   These attributes result in satisfaction when the users get fulfilled, and dissatisfaction when not. The attributes are not product hard requirements, but they are usually the ones which companies use to show their competitiveness.

3. Attractive Quality

   These attributes provide satisfaction when they are fully achieved, but do not lead to dissatisfaction when failing to fulfilled. Commonly they are some unspoken ideas and out of user's expectations.

4. Indifferent Quality

Indifferent attributes refer to aspects that are neither good nor bad, and they do not lead to either customer satisfaction or dissatisfaction.

5. Reverse Quality

These attributes refer to some conflict aspects resulting to different consumer reflections. (Knockoutsurveys, 2014)

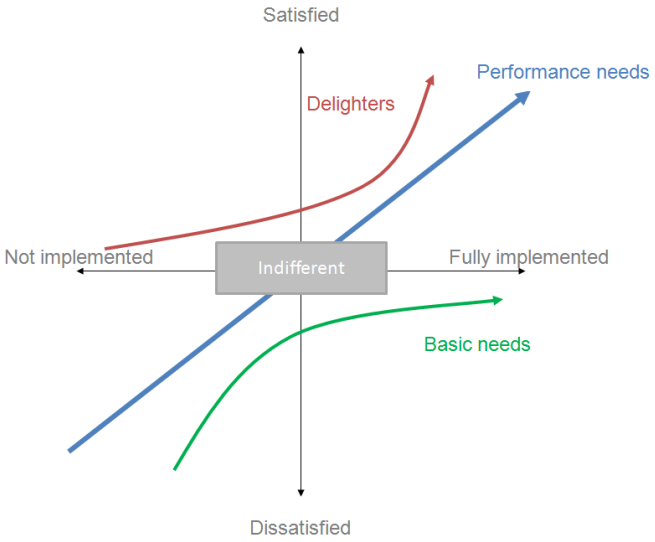

Figure 3.10 Kano model (Knockoutsurveys, 2014)

In this project, the data gathered in the questionnaire analysis would be applied to the Kano Model. User requirements were accordingly classified into the five categories. The requirements belong to must-be, one-dimensional and attractive qualities would be reflects in the design, while the indifferent and reverse attributes would be judged with the overall situation and decided their embedment or not. More specific analysis could be found in section 5.6.

7. Persona

Personas offer a way of visualizing the needs of different users found in the data collection. Via creating a made fictional character with the features of a specific customer group, designer can focus on creating a product fitted for only one person rather than creating a general but unfit solution. Information such as specific names, ages, genders, families, occupations, hobbies and so on should be created, and their behaviors, need and goals are required to be described precisely (Bergqvist & Wiklander, 2010). In this project, a fictional deliveryman was created according to the information gathered in the field research. The facts, behaviors and requirements were listed, and the ideation phase would be constructed on him.

3.4.3 Ideation

The ideation phase consists of three stages, including early concept development, concept evaluation and concept refinement. The first stage was carried out during the field research phase; product function was decided and a brief product image was constructed in mind. The concept evaluation was also executed in Shanghai, but since the time is really limited, some existing product images were tested instead of concept sketching. After received users' evaluation, concept refinement stage started at the beginning of April.

- ***Early concept development***

Once the requirements were settled, the function of the product could be decided, and then the product form could start to be discussed. Therefore, in this stage, all the requirements from user, constrains for behavior as well as the enlightenments got in the theories and knowledge base would be interpreted to product function and implanted to the initial design.

1. List of functions

A list of functions aims to describe the functions that a product has to be able to perform. Each function is stated with as a phrase including a verb, a noun and appropriate limits. The functions should not focus too much on specific solution but state relatively abstract. In addition, a weight scales from 1 to 5, would be given to every function in accordance to their importance to user (Wikström, 2004). In this report, the list of function was used

to organize all the contents mentioned in the previous text and extract the essential vehicle functions. The weights of the functions which generate from user requirement were given according to the Kano Model, while the other functions' weights were judged in line with author's estimation of function outcome.

- ***Concept evaluation***

After finish the initial concept development, two methods were applied to evaluate the generated concepts. A Pugh Matrix was used to exam the three concepts' realization of required functions, and the application of Krippendorf's experience dimensions were to identify the relationship between users' visual perception and vehicle form design.

2. Pugh Matrix

Pugh matrix is a quantitative technique used to evaluate and select a concept for further development. A set of criteria is established in a basic decision matrix and each design concept can then be decomposed, scored and summed to gain a total score. A concept is selected as the reference and compared with the others. The concept or concepts that get the best result would be selected for further development (Ulrich & Eppinger, 2003).

In this report, the existing situation is selected as the reference. All the vehicle design concepts would be compared with this baseline, and respectively marked as '0', '+1' or '-1' to symbolize their maintenance, improvement or deterioration of the current situation. The concept with the highest score can be viewed as the most promising solution for it embeds more required functions.

3. Krippendorf's experience dimensions

Krippendorf's experience dimensions are a kind of scale table with many pairs of antonymous adjectives on the ends and numbers in between such as -3 to 3, or -5 to 5. It is used to test users' certain experience upon a product. They would choose the most suitable positions in scale according to their actual feelings. The common antonyms appear in the dimensions include robust/fragile, stable/unstable, expensive/cheap, etc.

Applying Krippendorf's experience dimensions in this paper aims to identify the relationship between users' visual perception and vehicle form design. The evaluation test started on 26th March and lasted about two days. Totally 17 deliverymen were involved in the test and they came from 9 different companies. All the deliverymen had not participated in the previous questionnaire research, which might make the test result more correct. In addition, the single anthropometric data collection was still carrying out in the test.

The test contained 13 pairs of antonyms, which were divided into six categories. The first is objective aspect including unstable/stable, fragile/robust and bulky/flexible. The second is aesthetics aspect which contains low/high quality. The third category is about social status such as cheap/expensive and common/exclusive. The fourth is about feeling which contains boring/ exciting. The fifth is related to product specifics, including load less/load more, inconvenient/convenient ingress, invalid cargo protection/valid cargo protection, uncomfortable/comfortable and dangerous/safe. The last one is an overall judgment scale of the product.

At the beginning of the test, the participants were told to mark the first dimension table according to their experience of their own electric delivery scooters. It was a warm-up test and also set a potential reference for their later concept evaluation. After that, the pictures of three concepts were displayed in turns, and meanwhile, participants were informed that all the design concepts had the identical load capabilities and the same road performance. And then, all the participants were told to respectively mark their judgments according to their imagination of the three concepts. The result of the concept evaluations were used to compare with each other. The one getting most appreciations would be picked out, and synthesizes with the result of the Pugh Matrix to decide the direction of further development.

3.4.4 Concept refinement

After the ideation, a series of methods was used to develop the selected concept. There were two categories of methods used in this phase. The evaluation method was applied to access the result of modifications applied on the PUNCH, while the visualizing methods were used to illustrate and drive concept to the final product.

1. Expert evaluation

Expert evaluation methods utilize the knowledge of experienced professionals in evaluating relevant field. Compared with user studies or experiments, expert evaluation is often much easier to conduct. Experts can also evaluate rare and difficult materials to facilitate the generation of solutions. In addition, basic problems can be avoided by conducting an expert evaluation before other more expensive or time-consuming study methods (All

About UX, 2014).

The expert evaluation in this project was used to access the modifications on the PUNCH solutions instead of more time-consuming FEM or digital simulation. The experts in Mechanical Department, Chalmers were involved in the assessment and their suggestion would be taken to ensure the vehicle safety as well as the technical realizability and accessibility of the new design.

2. Mood board

A mood board is a collection of images put together in a composition to represent an intended visual aspect or emotional response of a design. It can be either very detailed specification of elements or loose and broad information for inspiration and creativity. The method allows designers achieve some indescribable expression. Various content can be included in a mood board, such as details, surface materials, textures, colors, shapes, graphics, etc. (Österlin, 2010).

The mood board in this project was used to extend the select concept got in the ideation. The desired functions, form features and other elements of the new product were collected and demonstrated in the form of pictures. The user traits got in the persona were also somehow integrated in this part. The design sketches would extract the elements in the board to construct the vehicle exterior and interior.

3. Sketching

Sketching is a method for exploring, visualizing and communicating ideas during product development. It can be thumbnail size doodles to detailed rendering in large formats depending of the level of refinement. Via sketching, ideas can be efficiently illustrated and described visually. The rapidness of sketching enables quickly ideas sharing among the people involved in the idea generation, and facilitates the production of solutions (Österlin, 2010).

Sketching was a quick but essential phase in this project. It was an important bridge which transfers required functions and user appreciations to the visible forms and shapes. The visual inputs acquired in the Krippendorf's experience dimensions, the elements presented in the mood board and the user traits gathered in the observation would all be integrate to the sketch and reflects on the final result.

4. CAD

CAD (Computer-Aided Design) is a useful tool to visualize a product by computer software ahead of making a physical model. Virtual objects are built in a three-dimensional environment and constructed with surfaces or solids. It is a fast and effective way of testing processes and operations (Johannesson, 2004).

In this thesis project, two kinds of modeling software were involved in the digital model construction. A plug-in of Rhino called T-splines was used in the initial modeling stage to explore the profile of the vehicle. Then, Autodesk Alias was applied to model all the details of both interior and exterior. A render, Keyshot, combined with Photoshop was used to form the final renderings.

3.5 Chapter conclusion

User-centered design is one of the major approaches of this project. It is a crucial approach to the product development, which creates more effective, efficient and safer products and contributes to the product acceptance and success. But the tenet of this approach that technology should adapt to user seems not fit the situation of this approach. As an extensive project of PUNCH, some of the technical solutions have been made and highly recommended to obey if they do not violate fundamental user requirements. In addition, the poor service quality of Chinese delivery market indicates that some of users are not acting in a desired way. Blindly following their saying may not bring the expected result for this project. Therefore, activity-centered design is applied in this project to remedy the defects of UCD.

Since very less reference of the practical application of ACD could be found, in this design-oriented project, an integrated approach is used throughout the project. UCD acts as a framework to direct the design process for its ample practical foundations, while ACD thinking would be constantly implanted in different design phases to bring heuristic ideas.

A serious of UCD and ACD methods are picked out to support each project phase and their results would be presented in later chapters and act as really essential inputs for the design phases.

4. Knowledge base

This chapter contains a knowledge foundation of facts and principles that are closely related to the project. Most of the information in this chapter was collected and analyzed by the methods listed in Chapter 3.

This knowledge base provides a basic understanding of the project as well as the product, which helps the author and readers to comprehend the information obtained in the later studies. The information gathered here includes three main aspects, previous achievement of PUNCH project, facts of express delivery industry and the knowledge of product background.

4.1 PUNCH project

With the development of automotive technology, people are increasingly confident to the prospect of electric vehicle. Car manufacturers all devote to provide the solution for a sustainable industry. In the meantime, a hybrid electric vehicle project called PUNCH has been kept running for years in Chalmers University of Technology in Gothenburg.

4.1.1 Electric and hybrid electric vehicle

Environmental and economic issues keep pushing the automotive industry to develop clean, efficient and sustainable vehicles. Urban transportation motors constitute an integral part of people's daily life, and the exhaust emissions of the conventional internal combustion engine vehicles (ICEVs) are the primary source of urban pollution, which causes the tropical island effect and further leads to global greenhouse effect (Husain, 2011). And the reduction of oil source makes the ICEVs no longer a reliable and wise choice. Electric solutions made their way into public as early as in the middle of 19th century; and with over 50 years' development, related technologies are relatively mature and the limited range problem of battery is close to being solved. With the recent success of Tesla Motor, all the signs indicate that the era of electric vehicles has come.

There are two main types of electric alternative solutions, electric vehicle (EV) and hybrid electric vehicle (HEV). According to Husain (2011), an electric vehicle has two primary features: the energy source is portable and electrochemical or electromechanical in nature, and traction effort is supplied only by one or several electric motor(s). The special feature of EVs is their zero emission within the vehicle is concern, but during their energy production, i.e. the electricity generation, the use of fossil fuel may still produce massive carbon emissions. Therefore, encouraging sustainable electricity generation, such as utilizing solar, wind or tide energy could ultimately realize true zero emission.

Another type of electric alternative solution is hybrid electric vehicle. It generally refers to "vehicles that use an internal combustion (IC) engine in conjunction with one or more electric machines for propulsion" (Husain, 2011). Two or more kinds or types of energy stores and sources are installed on the vehicle, which could be chosen according to specified operational missions. This allows the vehicle to have lower emissions compared to similar sized conventional ICEVs, but two different energy systems significantly increases the complexity and cost of vehicle. It is widely admitted that HEV serves as a compromise product for increasing environment/energy problems and the limited range capability of today's EV technology. It is a short term solution and can be completely substituted after solving the battery and infrastructure problem of EV.

4.1.2 PUNCH background

Years before, Professor Sven Andersson initiated the PUNCH project in the scope of the Automotive Engineering Master's Program at Chalmers University. The main starting point of this project was the lack of small, safe and low-emission vehicles on the Swedish market. Other incentives include the increased demand of personal urban transportation and the trend of eco-friendly products (Li et al., 2012). The fundamental idea behind PUNCH was to design, and eventually manufacture, a safe one-seat hybrid low speed vehicle (Riazi et al., 2010). It should be certified and be able to run on Swedish roads as a "moped car" which consists of four wheels and enough space for a piece of luggage (Auzenau et al., 2010).

Students was divided into two teams taking care of two main aspects of the project; the first team was intended to in charge of the frame design, materials, architecture and crashworthiness, and to some extent suspension, steering and braking; whereas the second team was responsible for the hybrid powertrain design (Riazi et al., 2010). But due to project's technology-centered nature, the purpose of use and the demands of the user remained blurry. No specific usage description could be found and very few user studies had been executed. In addition, vehicle ergonomics and anthropometry research was also quite insufficient.

So far, most of the technical solutions have been created including vehicle frame architecture, chassis crash test, battery storage arrangement, powertrain components and brakes design and suspension design. But in the design process of this paper, some of the existing technology results have to be altered or temporarily put aside due to the user-centered and activity-centered project approach. The changes would be negotiated with mechanical experts to ensure the technology realizability and accessibility.

'PUNCH 2011' (Atchison et al., 2011), 'Punch Power Train Report' (Auzenau et al., 2010) and 'PUNCH Final Frame Report' (Riazi et al., 2010) are the key technical reference for this this project. All the unchanged parts of the future design would follow the technological suggestions raised in these papers.

4.1.3 Powertrain design

Powertrain refers to the path of power and energy flow in vehicle. It starts from the source of energy and ends at the wheels with the delivery of propulsion power (Husain, 2011). The energy source could be either diesel or gasoline for IC engines or batteries for electric motors. A set of electronic controllers are place to control the power flow and a vehicle supervisory controller is designed to master controllers for coordination the system level functions of the vehicle.

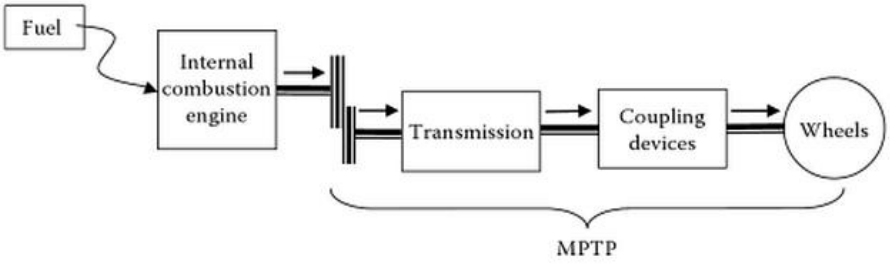

Figure 4.1 Power transmission path in a conventional IC engine vehicle (Husain, 2011)

The powertrain in electric vehicle is mostly electrical except for the coupling device between the electric propulsion motor and the wheels. The coupling device can be a gear to match electric machine speeds to vehicle speeds or even be directly eliminated in wheel-mounted motors, i.e. hub motors. Unlike IC engine vehicle, the power and energy in electric motor is bidirectional. When the vehicle brakes or stop, kinetic energy can be processed back to energy storage (Husain, 2011).

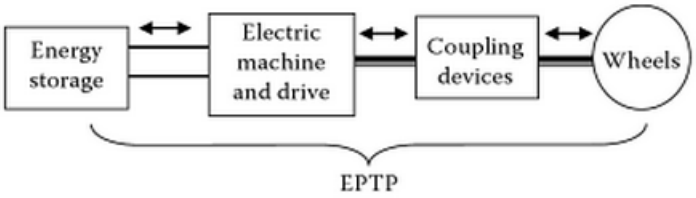

Figure 4.2 Power transmission path in an electric vehicle (Husain, 2011)

In the powertrain of a hybrid vehicle, both electrical and mechanical transmission paths could be found. The architecture and components of the powertrain varies according to vehicle's specified type. But the generic configuration for charge-sustaining hybrid is quite close and shown in Figure 4.3. The propulsion power comes from one or more electric motors and the IC engine, and is transmitted to vehicles wheels via either electrical or mechanical transmission paths, or the combination of two (Husain, 2011).

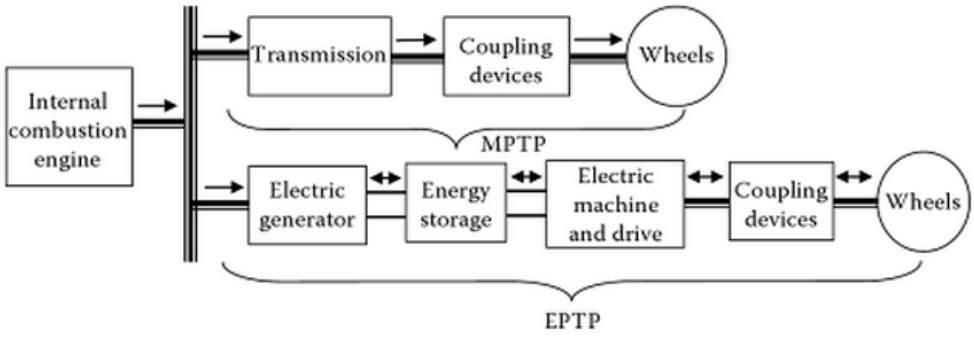

Figure 4.3 Power transmission path in a charge-sustaining hybrid electric vehicle (Husain, 2011)

In PUNCH project, students in powertrain team defined PUNCH as a plug-in hybrid "EU-moppe" in their project specifications. The engine is directly connected to the generator over a dog clutch. The controller of the electric generator and the motor is connected to the power distribution unit. And a battery charging unit is placed to realize the plug-in function of the vehicle. More detailed and accurate parameters were also provided including a top speed of 45 km/h, an acceleration of 2.1543 m/s^2, a total range of 100 km per day and an electrical range of 40 km per day (Auzenau et al., 2010).

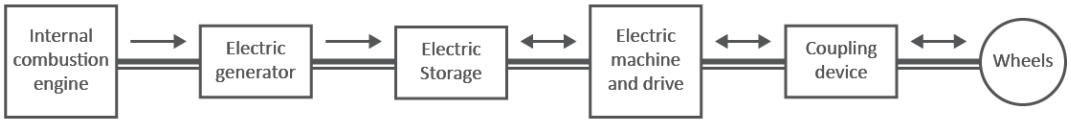

Figure 4.4 Power transmission path in PUNCH project

Internal combustion engine

IC engines are energy conversion devices which use combustion process to transfer stored energy in fuel to mechanical power. IC engines in conventional vehicles are designed to operate in all conditions, while IC engine in hybrid electric vehicles only require operation within a narrow band of torque-speed characteristics (Husain, 2011).

The IC engine used in PUNCH is a Honda GXH50. Since a serial hybrid powertrain is used, this Honda engine would not apply propulsion of the car but generate electricity together with the generator and then load the battery or run the electric motor. The size of the engine is 225mm long, 274mm wide and 353mm high. Detailed technical parameters are not listed here, but can be traced in Auzenau et al.'s paper.

Electric generator

Electric generator is a device which converts mechanical power to electrical energy in HEV. It couples with IC engine and generates electricity for the battery or electric motor.

A brushed electric motor LEM 130 95S designed and manufactured by The Lynch Motor Company is chosen for PUNCH for its light weight, high efficiency and project conformity. Meanwhile, a direct coupling can be obtained between the engine and generator. It enables the later to run with only about 1% less than its maximum efficiency point, which massively reduces unnecessary energy loss due to the friction appeared in indirect coupling. In addition, a direct coupling can also decrease the weight of the driveline and therefore improve the car performance (Auzenau et al., 2010).

Electric storage

A portable supply of electrical energy is a basic requirement for an EV or a HEV. It converts electricity to chemical energy and stores in devices such as batteries and fuel cells. The portable electric energy storage is currently the biggest obstacle in the wide scale application of EVs or HEVs for its unsatisfying energy density. Batteries are the most popular choice of energy storage device till now. Batteries provide high specific power and energy, high charge acceptance rate for recharging and regenerative braking, long cycle life, established recycling facilities and reasonable cost. Major types of rechargeable batteries used in EVs and HEVs include Nickel-metal-hydride, Lithium-ion, Lithium-polymer and Sodium-sulfur. Currently, the Li-ion battery technology is accepted as the most promising among the four categories (Husain, 2011). But also, this kind of batteries has relatively high dangerousness in the case of unqualified production, overcharge, long-term sunlight exposure and external forces (Battery.com, 2013). Therefore, the protection of Li-ion batteries in EVs and HEVs is an essential segment in vehicle architecture design.

In PUNCH project, Lithium iron phosphate ($LiFePO_4$) batteries are selected. Though this kind of batteries has a lower energy density than the Li-ion ones, they are relatively safer and have a very high cycle life. But proper protections are still required to prevent battery from possible damage. Eight $LiFePO_4$ batteries produced by M2 Power are plugged together to create PUNCH battery pack. They can provide an overall energy amount of 3840 Wh, which is fairly sufficient to meet the output requirement (Auzenau et al., 2010). Detailed battery specifications are listed in the following table.

Single battery specifications							
Voltage	12.8 V	**Rated capacity**	40 Ah	**Discharge rate**	80 A	**Peak discharge rate(30 sec)**	100 A
Length	198 mm	**Width**	166 mm	**Height**	171 mm	**Weight**	5 kg
Battery pack (8 batteries stacked together) specifications							
Length	664 mm	**Width**	396 mm	**Height**	171 mm	**Weight**	40 kg

Table 4.1 Battery specifications (Atchison et al.; Auzenau et al., 2010)

Electric machines

An electric machine is an electromechanical device which delivers processed power or torque to the transaxle to

move the vehicle. It converts the energy from electrical to mechanical and also regenerate electricity from mechanical energy of the wheels during braking. The term “motor” is used to describe the electric machine when the energy conversion goes from electrical to mechanical; and the term “generator” is used when power flows in the reverse direction. In EVs, electric motor is the only propulsion component, while in HEVs, electric motor and IC engine together in a series or parallel combination supply the propulsion power. There are two main types of electric motors, DC and AC type. The DC motors was popular for their developed status and ease of control, but size problem and maintenance requirements are restricting their application. AC and brushless motors are more widely employed in EVs and HEVs recently. Significant research and development activities make the technology quite mature. Although the control of AC motors is more complex than DC ones, the availability of digital aids easily diminishes the problem (Husain, 2011).

A brushless electric motor HPM5000B made by Golden Motors is chose to propel PUNCH. The motor is the sole propulsion component which transmits power to the two rear wheels due to the serial hybrid mode. It is about 126mm long with a 206mm diameter and weighs about 11 kg. The rated power is 3kW to 10kW and could reach a maximum speed of 5600rpm. In addition, the compact design and self-cooling fan can effectively save the space in the vehicle (Auzenau et al., 2010).

Other electrical elements

In addition to the four primary elements listed above, there are some other important electric components in PUNCH to make it work (Auzenau et al., 2010).

1. A motor controller is required to regulate the speed of the engine. HPC300A designed for the Golden electric motor is a perfect choice, because it could not only solve the unsteady voltage and current problem, but also handle the energy that get from regenerative braking.

2. To control the generator, a generator controller, Sigma PMT425S, can be used. It is designed for permanent magnet motors and effect in both directions (driving and braking).

3. A battery management system is also required to master the eight batteries. BMS-MCU-EV2 is installed to interface with vehicle and charging electronics to protect the battery pack.

4. Since the PUNCH car is a plug-in hybrid vehicle, a battery charger is needed to load the batteries. Zivan NG1 is an ideal product, because it guarantees a high level of security during the charge, which internally protected against overload, short circuit, incorrect connection and voltage transients. In addition, it can be programmed freely to any kind of battery chemistry.

5. Two DC to DC converters from Electric Motorsport Company are plugged in parallel to converts a source of direct current from one voltage level to another. In this case, a 12V battery is linked on a side to load it with the current from the 48V on-board circuit.

6. Approximately 20 meters of 25-mm^2-section cable is used to connect all the electrical parts

7. For safety concerns, contactors which work as big ON switches are connected to the batteries to prevent short-circuit or too high current. NanfengZJW200A contactor can get activated with a 12V control voltage and can handle a maximum current of 500A, which is a wise choice for PUNCH.

8. In order to further improve security, a manually activated, emergency stop button is designed to break the power supply of the contactors and then disconnect the batteries. It can effectively contribute to avoid fire hazard in the vehicle. Moreover, an inertia switch is equipped to prevent accidental crashes. This switch can automatically open the vehicle contactor, shut down the traction circuit and isolate the battery pack in the event of an accident.

9. A 12V AGM (Absorbed Glass Mat) lead acid battery is needed to supply electricity to the 12V circuit without decreasing the electrical range.

Weight and costs

The table below summarizes the total weights and prices of the main components mentioned above. The weight is quite acceptable while the total price is relatively high for a small one-seat vehicle. This is partly because the powertrain group locates the range of suppliers solely in Sweden. Lower offers are supposed to be found in China.

Component	Weight (kg)	Price (€)
Auxiliary (12V battery + DC/DC converter)	3.45	95
Battery Pack	40	2800
Battery Charger	2.2	430
Engine	5.7	300
Generator	3	520
Generator controller	1.2	375
Motor	11	260
Motor Controller	3.3	300
Cable	5	100
Contactors	2.4	120
Total:	77.25 kg	5000 €

Table 4.2 Weight and price of the powertrain parts (Auzenau et al., 2010)

4.1.4 Frame design

A frame is the main structure of the chassis of a motor vehicle. It provides enough strength to support the vehicular components in proper relation to each other, and deals with static and dynamic payloads. Specifically, a vehicle frame should handle the weight of car body, passengers, and cargo loads; vertical and torsional twisting generated by uneven grounds; transverse lateral forces induced by road conditions, side wind and steering; torque from the engine, elector motor and transmission; longitudinal tensile forces from starting or accelerating, and compression from braking; sudden impacts from collisions; etc. (Rajput, 2007)

There are two main kinds of frame and body construction, separate type and integrated type. The separate frame and body type is the most common one used in a majority of full-size and cargo vehicles production. In this type of construction, the frame and the vehicle body are designed and manufactured as different complete units. The body generally is bolted to the frame by several points which allow for the flexure of the frame and distribute the loads to the intended load-carrying members (CMC, 1999).

There are several tremendous advantages of the separate frame and body construction, including:

1. Ease of mounting and dismounting the car body
2. Versatility of adapting different body types on a chassis
3. Ease of achieving strong and robust designs
4. Isolation of noise produced by the powertrain components from the passenger compartment via the use of rubber mounts between frame and body
5. Low cost and easy manufacturing process

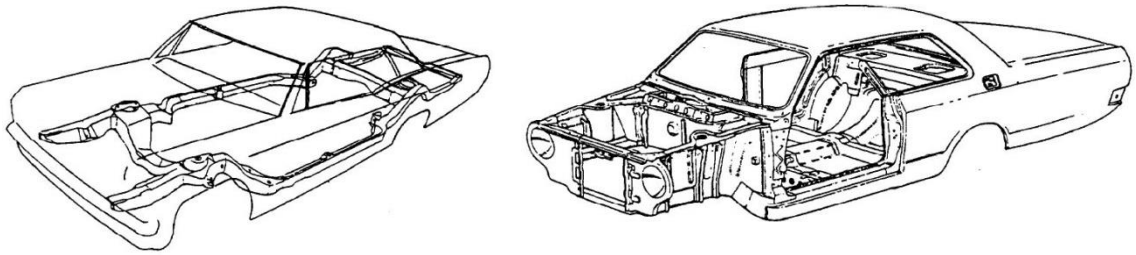

Figure 4.5 Separate construction (left) and integrated construction (right) (CMC, 1999)

Another kind of frame and body construction, integrated type, is called Monocoque. It refers to a unitized construction which combines frame and body into a single structure. Components are welded together to form or cast the entire piece. Rather than simply weld body and frame, the whole frame-body unit is treated as a load-carrying member that reacts to all loads experienced by the vehicle-road loads and cargo loads (CMC, 1999).

Though the integrated construction increases the noise impact in the passenger compartment, this disadvantage cannot belittle the following advantages:

1. Considerable weight reduction
2. Lower vehicle height and cargo floor
3. Protection from mud and water for powertrain components
4. Reduction of vehicle structure vibration

PUNCH frame architecture

Since the aim of PUNCH project is design a safe and low cost alternative moped car, and it has to be manufactured with the available resources in Chalmers University, a separate frame and body construction is therefore used for its superior cost-efficiency, robustness and accessibility. The general dimensions of the frame are presented as following.

General	Unit	Specification
Vehicle Weight (not laden)	kg	300
Weight distribution, front/rear	%	40.0/60.0
Length	mm	2860
Frame Structure Width	mm	966
Estimated Vehicle Width	mm	1500-1600
Height	mm	1341(+100 of ground clearance)
Centre of gravity	N/A	Height * 0.3
Wheelbase	mm	1900
Track width, front/rear	mm	1500/1500
Tire radius	mm	240
Outer brake disc radius	m	110
Inner brake disc radius	m	70
Brake pads – brake disc friction coefficient	N/A	0.3
Maximum surface pressure on the disc	MPa	6
Road friction coefficient	N/A	0.8
Laden weight (driver, batteries, fuel, etc.)	kg	445
Frame structure weight	kg	45
Top speed	Km/h	50

Table 4.3 Vehicle parameters of PUNCH (Riazi et al., 2010)

The frame is made of 6063-T6 aluminum alloy. It is one of the most common alloy types and shows good welding characteristics. In the same loading conditions, the weight of the aluminum beam is only 60% of the steel one providing equal performance. And the price of this material is fairly reasonable. Figure 4.6 shows the initial CAD version of PUNCH frame and Figure 4.7 shows the full scale test model built in Chalmers Automotive Lab.

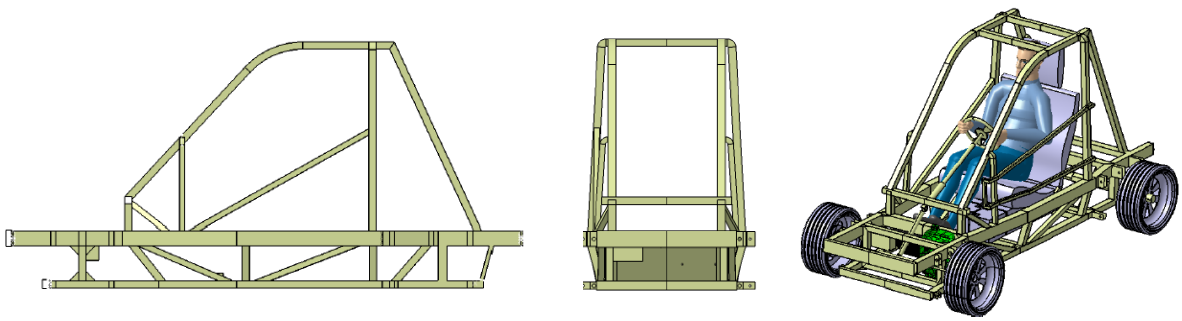

Figure 4.6 PUNCH frame side view, front view and perspective view by CAD (Riazi et al., 2010)

Figure 4.7 Full scale test aluminum PUNCH frame

Three main portions can be observed in the structure. The front structure provides enough space for front suspensions and powertrain components such as DC/DC converter, IC engine, auxiliary battery, etc. Meanwhile is also provides a sufficiently long crash zone to reduce the front impact during accident. The passenger compartment structure in the middle could effectively protect the driver from intrusion during a crash scenario. The rear structure allows the mounting of rear suspensions, differential and electric motor, and also absorbs energy during rear-end collisions.

Two kinds of load-carrying members can be found in PUNCH frame. The side members are used to accommodate body and support vehicle weight. They are shaped narrow toward the front of the vehicle to permit a shorter turning radius and widen under the main part of the body to support passengers and cargo weights. Another type is called cross member. They fix to the side members to prevent weaving and twisting of the frame. The type of vehicle decides the number, size and arrangement of the cross members. Generally, a front cross member supports the front of the engine; several rear cross members provide safety for passengers in rear trunk; and additional cross members are placed to support the powertrain components (CMC, 1999).

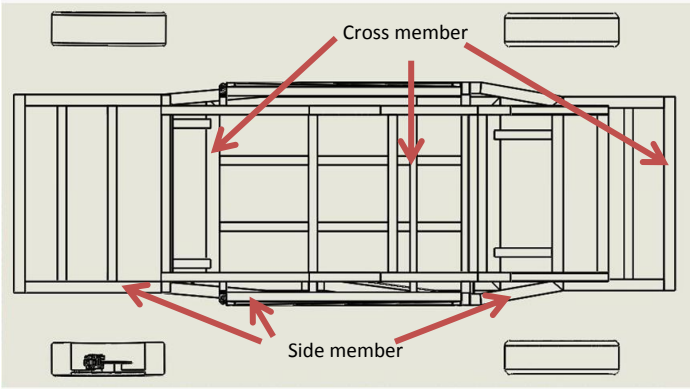

Figure 4.8 Components of PUNCH frame design

Frame crashworthiness

'Crashworthiness' is a term used to describe the ability of a structure and any of its components to protect the occupants in survivable crashes. Specifically, in the frame design, the approaches that could realize good crashworthiness include the design of sufficient progressive crush zones to absorb crash kinetic energy, the maintenance of the integrity of the passenger compartment, the control of crash deceleration pulse, etc.

Currently, vehicle crashworthiness is evaluated in four distinct modes: front, side, rear and rollover crashes. According to the data from French National Inter Ministry Agency for Traffic Safety (2008), in 2006, among the moped car accidents on French roads, 67.9% of all impacts occur in the front; 15.7% of accidents happen in the rear and 11.7% of them occur on the side. The unmentioned 4.7% of the accidents are speculated as marginal accident cases such as rollovers (Riazi et al., 2010). These figures indicate the general trend of accidents and imply the priorities in the crash optimization process.

In the papers 'PUNCH Final Frame Report' (Riazi et al., 2010) and 'PUNCH 2011' (Atchison et al., 2011), the authors respectively evaluated the crashworthiness of PUNCH in the front, rear, side and during rollovers. The digital model was built in CATIA and the dynamic analysis was done in LS-DYNA. Passenger seat, battery pack and IC engine were included as rigid bodies with added mass. Although passenger manikin was not placed in the tests, 120kg weight was added in the driver's place during the simulations.

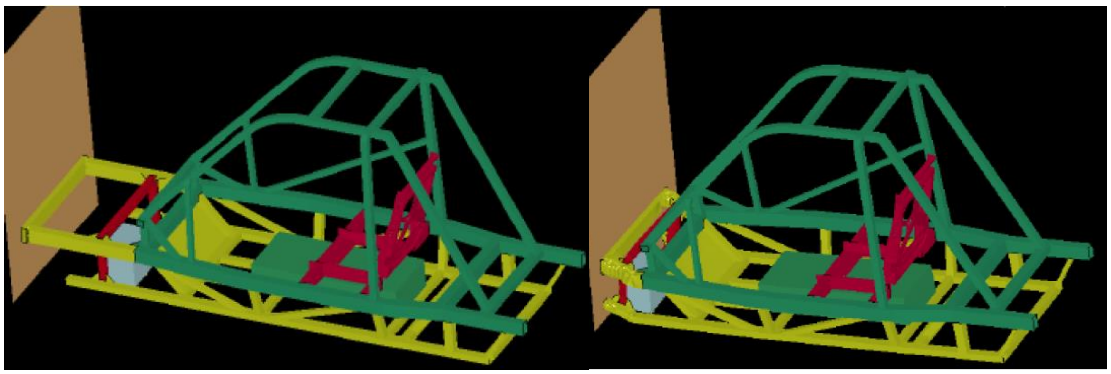

Figure 4.9 Front crash simulation, before start (left) and 54ms (right) (Riazi et al., 2010)

1. The front crashworthiness simulation

A speed of 50 km/h for the test setup was chosen and done in LS-DYNA. The simulation lasted 54 milliseconds. Result showed that the front structure is well buckled, and the passenger compartment was almost intact with

only just 8mm intrusion. The impact energy was successfully transferred during crash occurrence. A peak acceleration of 38g was observed, which was almost equal to the performance of a Toyota Yaris. Overall speaking, the result was more than acceptable (Riazi et al., 2010).

2. The rear crashworthiness simulation

Due to the uncertainties of rear end collisions, two simulations were made for the rear-end crash. The varying parameters included speed and type of collision (wall or barrier collision).

The first scenario was the rear frame hit a rigid wall at the velocity of 24.8 km/h. The result showed that the main beams were nicely deformed up to the beams coming from the roof the lower part of the rear structure, where the higher stiffness made the deformation stagnated. The energy curves also demonstrated the result. The kinetic energy assigned by the initial velocity of the body was absorbed by the beam deformation and therefore protect the passenger compartment.

Another scenario was a 35 km/h barrier crash test. The barrier mass was 1100 kg and the PUNCH was 450kg in total. The simulation result was fairly close to the wall crash. The main beams deformed nicely until reaching other parts of the structure. Energy is totally absorbed and the driver compartment stayed without intrusion.

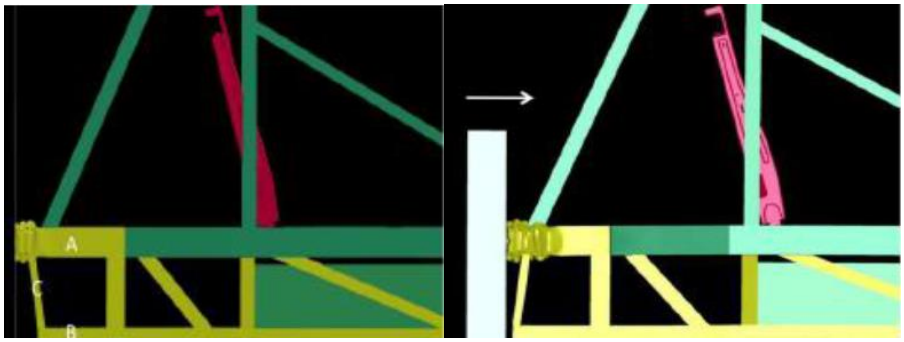

Figure 4.10 Rear crash simulation, test1 (left) and test2 (right) (Riazi et al., 2010)

3. Side crashworthiness simulation

Two different side impact tests were performed, one with a movable deformable barrier and another with a rigid pole

In the first test, the model was hit by a rigid wall in the velocity of 50 km/h from both sides to simulate the worst situation. During the right side crash simulation, though parts of powertrain components dropped from their mounting points, driver compartment had not been intruded. When it crashed from the left side, an extensive deformation appeared in the B-pillar, which was cause by belt force. The deformation area was quite close to the position of occupant's head and could be a big threat to the safety of the passenger. A cross-diagonal bar was later added by the students to reinforce the structure strength (Atchison et al., 2011).

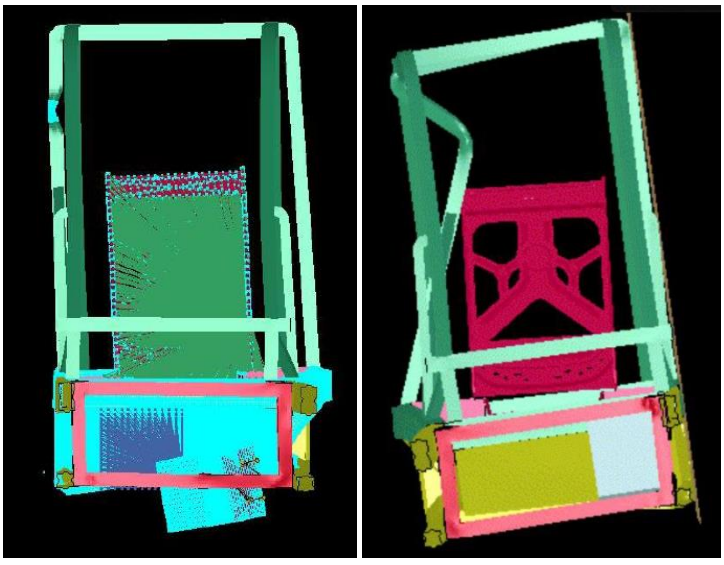

Figure 4.11 Side crash simulation, test1 right side impact (left) and left side impact (right) (Atchison et al., 2011)

In the second test, the crash is performed by impacting a 254 mm diameter rigid pole at a speed of 29 km/h. The frame well withstood the impact force with only about 50 mm deformation. A sufficient clearance was kept between the seat and the intruded side structure, and no significant influence would happen on the occupancy (Atchison et al., 2011)

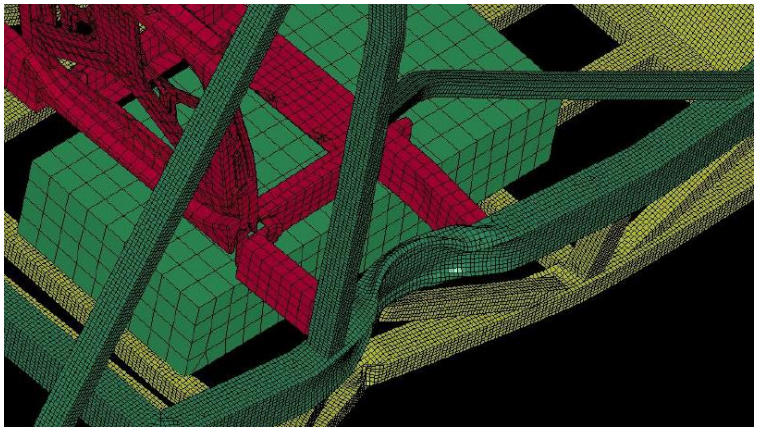

Figure 4.12 Side crash simulation, test2 (Atchison et al., 2011)

A series of modification was made after the side crash test. Besides the addition of a cross-diagonal bar, the chassis was widened from 855mm to 1000mm to obtain a good crashworthiness in side impacts as well as increasing the comfort for the driver. The roof and torsional stiffness simulation was tested on the modified frame.

4. Roof crashworthiness simulation

Twice the weight of the PUNCH vehicle was applied on the roof to test its strength during the rollover accidents. A force of 10.2 kN was evenly distributed on four roof beams while the other structure kept static. The maximum deformation reaches 3.3 mm, which was a very satisfying result. Enough clearance had left on the occupants head. The stress test also proved the strength of roof material, no material failure could be discovered (Atchison et al., 2011).

5. Torsional stiffness simulation

Stiffness is defined as the amount of force required per degree of twisting. Torsional stiffness was measured by adding a constraint to the beam where rear suspension was mounted. And an opposite force was added on the beam where mounted the front suspension. This generates a bending moment around the longitudinal axis, making the chassis twist.

A maximum deformation of 11 mm was observed in the result. It could be estimated that after the addition of windows, floor and outer bodywork, the torsional stiffness could be much higher than the obtained result.

Thickness distribution of the frame

The thickness distribution of the frame is shown in Figure 4.12. The green area has a constant thickness of 3mm to protect the driver compartment from intrusion, and the yellow area has a constant thickness of 2mm to absorb the front and rear impact energy.

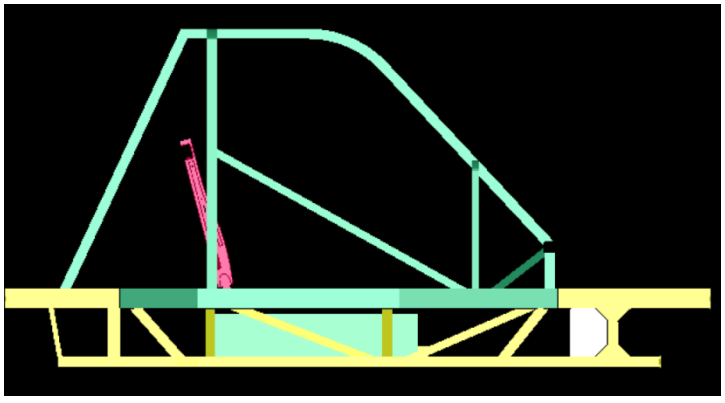

Figure 4.13 Thickness distribution of the frame (Riazi et al., 2010)

4.1.5 Steering, brake and suspension design

The frame team students in 2010 and 2011 also did some research on PUNCH's steering system, brake system and suspension construction. They either designed dedicated components for PUNCH or specified reasonable choice for the vehicle.

Steering System

Steering mechanism provides operator with a means of maneuvering the direction of travel. It is an integral portion of the chassis. A steering wheel is joined to the steering system, and then successively connects with a track rod, tie rods and steering arms. Via moving the track rod left-to-right across the car, the diver could manipulate the direction of vehicle (Heisler, 1989).

There are two important parameters regarding steering system design, steering ratio and turning circles. According to Heisler (1989), steering ratio is "the rotation angle of a steering wheel divided by the steer angle of the front wheels". The steering ratio of a street car is normally around 10:1. Turning circles is another important parameter. It refers to the diameter of the circle generate by the outside wheels of a car when turning on full lock. The turning circle can be roughly calculated by Automotive Bicycle Model, which almost equals the quotient of the length of wheelbase and the value of steering angle.

Due to the low cost consideration, a simple steering system was chose for PUNCH. It generated a weight of around 5 kg, and provided a steering circle of 4.1m. No power assist steering was equipped but a collapsible steering column was designed to ensure the diver safety during a crash (Riazi et al., 2010). In addition, the steering column had both tilt and telescopic adjustment to ensure an optimum steering wheel position for the 99th percentile driver (Atchison et al., 2011).

Brake System

Vehicle braking system converts the kinetic energy to heat to provide the driver with a mechanism to reduce the speed or stop the vehicle (Husain, 2011). It is one of the most critical components of a car because it is highly concerned with safety, performance, reliability, quality and cost. Qualified brake system should be effective, extremely reliable and durable; it is also required to have smooth graduated response and resist to contamination, corrosion and wear.

The brakes in automotive are actually mechanical clutches which rub to slow down a rotational disc. The driver uses a foot-operated pedal to control the brake action. The friction clutch is composed of two discs. When the stationary disc is engaged with the rotating one, generated friction reduces the vehicle speed (Husain, 2011).

The brake system in PUNCH project was got from an old formula student car, but accurate calculation had been done to prove the applicability of this decision. Four disc brakes with floating caliper were respectively installed in the front and rear. Other components included a brake pedal, a vacuum brake booster, a master cylinder and a brake fluid reservoir. A warning system for the failure of a brake circuit and the loss of brake fluid was also equipped (Atchison et al., 2011).

Suspension system

The suspension system of a vehicle connects the wheels and body. The behavior of suspension determines the wheel position and further influences vehicle dynamics. Vehicle handling characteristics during braking, accelerating, cornering or driving over rough terrain, are, therefore, highly dependent on the performance suspension system. For passengers, appropriate car suspension almost means safety and comfort.

There are various different kinds of suspension solutions available such as double wishbone suspension, MacPherson strut, trailing-arm suspension, semi-independent suspensions, etc. They respectively have their own advantages and drawbacks. Though many variation of suspension exists, two basic parts could be found in them, an elastic component and an energy dissipative component.

For PUNCH project, the suspension system should provide the driver with adequate safety; provide a comfortable ride and good handling performance; enable maintained steering control; ensure favorable vehicle responses and isolate the body from vibrations. After a series of comparisons, double wishbone suspension was decided to be applied on for the front. Finite element analysis in a worst case scenario was executed on all components, and the result proved the success of the design. The design of rear suspension remained unfinished. The recommendation from the PUNCH 11 team is to use a semi-trailing arm suspension system in the rear axle (Atchison et al., 2011).

4.1.6 Section discussion and conclusion

Environmental and economic issues keep pushing the automotive industry to develop clean, efficient and sustainable vehicles. And the rapid development of automotive technology makes the popularization of zero emission cars no longer a dream. At the Department of Applied Mechanics of Chalmers University of Technology, Professor Sven Andersson sensed the coming trend of electric vehicle and the potential market of a small, safe, light and low cost moped car. Thus, project PUNCH was initiated in 2010 and two teams of students has been working on it for years.

Significant progress has been achieved on the technical level. The powertrain team students has designed and selected the components of the entire driveline system of PUNCH. They successfully developed a less complex solution with great weight control, while the price problem could be further discussed. The frame team students not only finished the construction of CAD chassis, a full scale aluminum physical model was built in lab. In addition, vehicle crashworthiness simulation tests in four distinct modes: front, side, rear and rollover were respectively done in LS-DYNA. Great crash safety were proved in the front and rear tests, and modifications had been executed to enhance the strength of the side and roof. Although all the impact simulations were stayed in the theoretical level, i.e. no physical tests were actually carried out, tremendous reference value still could be obtained in their research.

However, despite the fruitful results from technical aspect, the application and potential user of this vehicle remains ambiguous. No specific function description could be found and very few user studies have been executed. In addition, vehicle ergonomics and anthropometry research was also quite insufficient. Finding the way out in the market is an urgent affair for PUNCH.

Trying to look into the developing markets can be a good opportunity. On one hand, the price level in developing areas is conducive to finding cheap vehicle components to achieve the low cost purpose. On the other hand, huge market potentials provide a piece of fertile soil for PUNCH to find its position. In addition, a clear definition of product function and market distribution could also be helpful to alter the existing solutions to actual specific requirements, and thereby reduce the potential risks or financial loss. China’s chaotic express delivery industry offers a hopeful market for PUNCH.

4.2 Express delivery industry

The environment of express delivery in China is fairly optimistic. The industry is experiencing an extremely rapid growth in the new century, especially the local enterprises. But meanwhile, the explosive and chaotic growth has exposed many serious problems which not only effect the satisfactory of customers but also concern the future survival of the private-owned companies. Turning future challenges to opportunities become the primary affairs for them. Thus, in this section, private-owned companies are selected as main study objects. Discovering the weakness and development trends of these enterprises would be helpful to direct later deign orientation.

4.2.1 Definition and workflow of express delivery service

Express delivery is a method of communication and transportation that serves to get articles like documents, parcels, and other goods from door to door within a definite period of time (Sokol, 2002). The core value of this service is the time sensitivity of the packages, often next day service. Express delivery service providers maintain control of every item and use management and technology to monitor their location throughout the delivery process (USITC, 2004). The industry has some large enterprises which integrate ground and air networks and provide a broad range of international or domestic door-to-door delivery services, as well as some small firms that compete in the domestic and local markets or specialize in certain freight delivery services (Sokol, 2002).

Express delivery service providers offer customers a comprehensive service process including organizing collection, checking information on the progress, providing proof of delivery, etc. All these services are supported by a robust system that involves air and ground transport, distribution centers, delivery, and the application of various technologies in every aspect of the business. The key stages of typical express delivery are illustrated in Figure 4.14 (OE Forecasting, 2011).

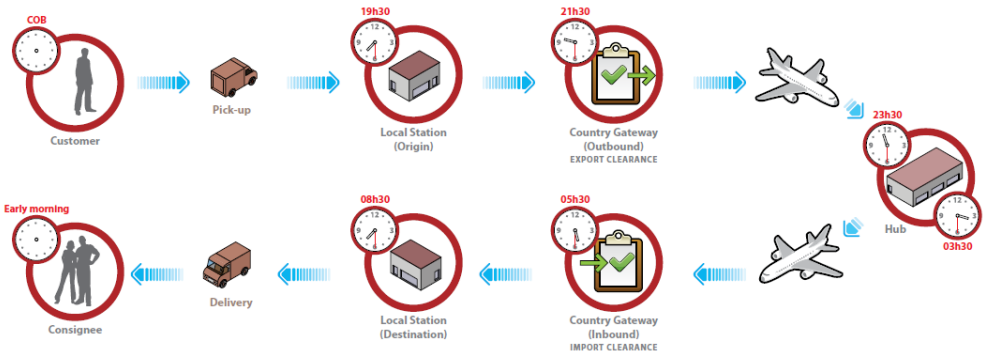

Figure 4.14 The key stages of a typical express delivery (OE Forecasting, 2011)

4.2.2 The development of express delivery services in China

In the last decades, Chinese express delivery industry has experienced an impressively rapid development. Although the growth rate of global economy slows down a couple of years before, Chinese express delivery industry still maintains a high-speed expansion.

According to the China Express Delivery Industry Report presented by Research in China (RIC), in 2013, express delivery enterprises obtain the annual sales revenue of over RMB 144.17 billion (approximately 16.64 billion euro). They completed the delivery of 9.19 billion mails and parcels, increasing by 61.6% year on year. Wherein, the revenue generated by intra-city business reached RMB 16.64 billion, jumping by 51% year on year; the inter-city business revenue reached RMB 82.9 billion, presenting a year-on-year rise of 30.5%; and the international and Hong Kong, Macao and Taiwan business revenue increased by 31.7% year on year to RMB27.07 billion (RIC, 2013). Nearly 100,000 outlets have been established; 121,000 legitimate motor vehicles have been registered; and about 1,000,000 people are employed national wide.

Data collected by State Post Bureau of China (SPBPRC, 2009-2013) also demonstrate this incredible development. In the chart on the left side of Figure 4.15, the revenue of express delivery providers are monthly displayed. Dramatic increases can be easily observed for a year on year comparison, whilst accelerated growth rates pull up the line chart progressively month to month. The sudden drops appear during January and February every year are caused by Chinese New Year, and the sharp rises on November in 2012 and 2013 are affected by the most influential “Double 11” online sales promotion. Compared with the statistics four years before, in 2013, the

entire industry enjoys a three times revenue growth and a five times business volume increase (bar charts in Figure 4.15). It could be predicted that if no severe industry environment changes happen in the near future, the development of express delivery in China would keep accelerating.

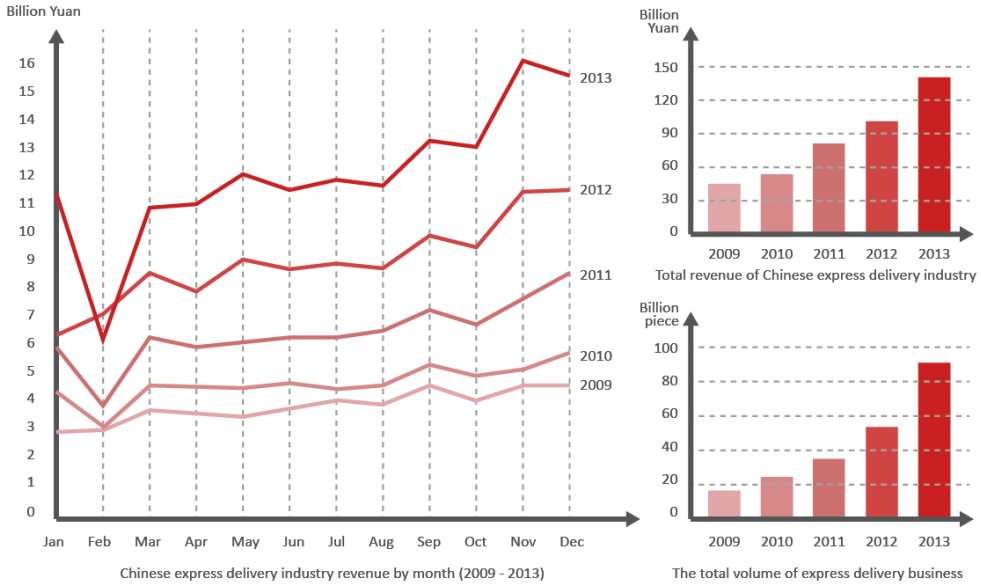

Figure 4.15 Statistics of Chinese express delivery industry (SPBPRC, 2009-2013)

4.2.3 Factors of industry prosperity

As the link between addressors and consignees, the prosperity of express delivery service does not stand out independently. It highly relies on the development of correlated industries and world financial condition. Oxford Economic Forecasting has proved that the increasing bidirectional promotion and integration between economy and express delivery industry (OE Forecasting, 2005). And obviously, besides economy influences, there are some other factors that prosper express business. Via PEST method, Long (2012) gives a macro-environmental explanations on the reason behind this high-speed expansion industry. Principles of PEST analysis method are presented first followed by specific analysis on Chinese express delivery industry. Some data are updated and reorganized to present latest situations.

PEST analysis

PEST is a framework of macro-environmental factors used in the environmental scanning component of strategic management. It can help to understand market growth or decline, business position, potential and direction for operations (CIPD, 2013). The basic PEST analysis includes four factors: Political factors reflect the degree of government intervention in the economy. Specifically, they include as tax policy, labor law, environmental law, trade restrictions, tariffs, political attitude, etc. Economic factors contain economic growth, interest rates, exchange rates and the inflation rate which have major impacts on how businesses operate and make decisions. Social factors refer to the cultural aspects. They include factors like health consciousness, population growth rate, age distribution, etc. which affect the needs for a company's products and how that company operates. Technological factors involve technological aspects such as research and development activity, technology incentives, automation and the rate of technological change. They determine barriers to entry, minimum efficient production level and influence outsourcing decisions. Moreover, technological shifts can influence costs, quality, and lead to innovation (HIA, 2011).

Applying PEST analysis in Chinese express delivery industry

1. Political factors

On October 2009, Chinese new postal law was officially issued, in which the juridical status of express delivery enterprises were accepted for the first time. In addition, principles of encouraging competition and facilitating development as well as management measures of safety were also announced. In the same year, Chinese “The Eleventh Five Years Plan” was promulgated. “Vigorously developing modern logistics” was clearly pointed out by the government. China Express Association (CEA) was quickly established and performed as a bridge and bond in

increasing the communication between government and companies. Meanwhile, CEA also helped to standardize the domestic industry and exploit foreign markets. In 2010 and 2011, new industry development indicators were kept promulgating by State Post Bureau of China. More detailed goals were presented in these documents, which indirectly proved that the express delivery industry was becoming more and more normative and standard.

2. Economic factors

Economic factors include two aspects, domestic economic environment and international economic environment.

According to The World Bank's data, China's Gross Domestic Product (GDP) has kept a steady increase in the recent years and reached 9.18 trillion dollars in 2013, presenting a year-on-year rise of 7.7%. Compared with the GDP in 2009, the number almost doubled in just four years. This speedy development of Chinese economy is partly driven by the cumulative prosperity of domestic e-commerce. In accordance with the report presented by China E-business Research Center (CECRC) (2014), Chinese gross e-commerce transactions have attained 1.02 trillion dollars in 2013, jumping by 29.9% year on year. It occupies over 11% of GDP, and the growth rate is almost four times faster than GDP increase. The explosive Chinese e-commerce brings enormous market space and business interests to the courier industry. Driven by macroeconomic, the volume and revenue growth of express delivery has all exceeded 24%, which is immensely higher than GDP growth rate over the same period. With the domestic economic recovery, consumer purchasing power would further increases; express delivery service industry would keep this rapid development.

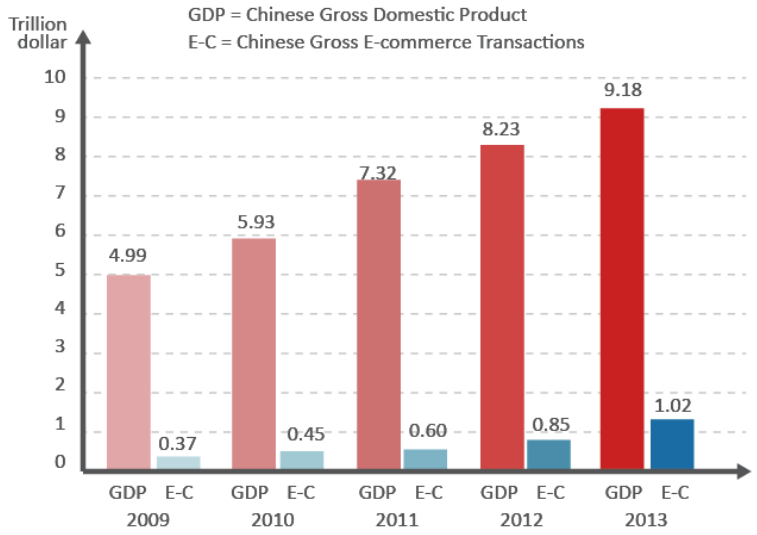

Figure 4.16 Chinese GDP and e-commerce growth in 2009-2013 (SPBPRC, 2009-2013)

On the other hand, world economy has been staring to recover from the financial crisis. Global GDP has realized a four years continuous increase since 2009. Most industries have achieved encouraging growths. According to the report from OE Forecasting (2011), revenues of express operators have grown more quickly than the value of European exports. Express delivery services help European companies to remain competitive by growing their exports and investments.

3. Social and cultural factors

From the perspective of express delivery industry, the social and cultural factors include two main aspects. The first is the change of consumer group. With the coming of the 21st century, the generation after 80s and 90s become the core consumer group. This group owns increasingly individual purchasing power as well as diverse personalities and demands. The development of e-commerce exactly caters to their desires and taste. The second point lies in the transformation of consumer behavior. Online shopping turns to a trend of chasing fashion and personality. Meanwhile, the high cost-effective product, convenience and accessibility fit the features of modern society.

4. Technological factors

With years of development of domestic logistics, technologies in transportation, warehousing, load and unload, containerization and informatization tend to mature. Meanwhile, rapid development of electronic information and communication technologies are also increasingly embedded into express delivery industry to further speed up the entire work process.

Moreover, WTO brings foreign companies' advanced information management system and well-equipped operating facilities into China, which facilitates Chinese enterprises to enlarge their investments in technology research, improve the quality of new products, and further develop their information management systems and shipment tracking system. In addition, with the growing importance of environmental protection, energy saving technology and better route management becomes imperative to achieve environmental friendly development.

4.2.4 Express delivery carriers in Chinese market

There are three main kinds of express delivery companies in China in terms of the property of enterprises, state-owned express delivery companies, private-owned express delivery enterprises and foreign express delivery companies. According to SPBPRC, in 2012, state-owned express delivery enterprises finished delivering 1.3 billion mails and parcels; foreign express delivery companies delivered about 100 million articles; and private-owned express delivery companies reached 4.29 billion. They respectively accounted for 22.8%, 1.8% and 75.4% of the entire business volume.

State-owned express delivery companies

EMS (Express Mail Service), CRE (China Railway Express) and CAE (China Air Express) are the only three state-owned express delivery companies in China. They are respectively in the charge of China Post Group, China Railway Corporation and China National Aviation Holding Company. Needless to say, due to the nature of China Post Group, EMS holds a leading position among the three.

Founded in June 2010, EMS is the largest integrated express and logistics service provider with the widest coverage and the richest products in China. The company recruits nearly 100,000 employees, owns 20,000 delivery vehicles and operates 45,000 business outlets. Its network covers all the cities, counties and towns in 31 provinces and reaches over 200 countries and regions. It not only engaged in domestic express and international express, but also contract logistics, and LTL (EMS, 2014).

Compared with other foreign or private-owned companies, EMS has many advantages. The accessibility is the most appreciative one. The wide range of coverage area could reach almost every corner in China within at most 8 days. Meanwhile, it offers next-day service with in over 100 cities. Additionally, in order to maintain the time efficiency, their outlets remain open even on statutory holiday and delivery service is offered every day. But their relatively high price directly excludes a large number of online consumers with less time sensitivity. By way of comparison, the charge of inter-city EMS service for a kilo package is almost four to five times as the price of private-owned enterprises. In addition, lack of flexibility and poor tracking system is also considered as the weakness of EMS.

Private-owned express delivery companies

Private express delivery enterprises occupy over 3/4 of the market share and keep expanding (RIC, 2013). According to estimation, over 8,000 private-owned companies have been established, and mainly locate in the developed coastal area. They not only control over 90% of intra-city business, but also accounted for over half of inter-city business. Among the 8,000 enterprises, six of them are relatively famous and accepted as industry leaders, including S.F. Express, STO Express, YTO Express, ZTO Express, Yunda Express and Best Express.

1. S.F. Express

S.F. Express is the undoubted leader in domestic private-owned companies. It is just second to EMS in network coverage and business scale. Ever since its establishment in 1993, S.F. Express has been committed to improving service quality and satisfying market demands. Besides domestic services, S.F. Express also extends its business to Hong Kong, Macau, Taiwan, America, Singapore, South Korea, Malaysia, Japan, Thailand, Vietnam and lately Australia. As of January 2014, S.F. Express has nearly 240,000 employees, 10,000 motor vehicles, 14 aircrafts and 7,800 service outlets in mainland China and overseas countries / regions (S.F.Express, 2014). Though in the same conditions, S.F. charges nearly three times as the other five private-owned leader companies, it remains the most popular choice, especially by business customers, for its extremely high efficiency, great safety and nice service attitude.

2. STO Express, YTO Express, ZTO Express, Yunda Express and Best Express

These five companies are usually called by a joint name "Four TO and one Yunda" (Best Express was formerly known as HTO), and represent second-line qualities in the industry. Except that STO Express was founded in 1993, the rest four were established around 2000. The business scale of STO, YTO and ZTO are quite close; they respectively own 6,000 to 8,000 service outlets with 100,000 to 150,000 employees. Yunda Express and Best Express have relatively small staff scales which recruit about 50,000 people each, but they run about 10, 000

outlets respectively. Though none of these companies has owned their own cargo plane yet, relying on cooperation with airline companies or foreign express enterprises, most of them could provide limited range of international express delivery services (STO Express, 2014; YTO Express, 2014; ZTO Express, 2014; Yunda Express, 2014; Best Express, 2014). Beside the similar company scale, the services, prices, coverage and market strategies offered by them are also fairly close. Thus, fierce market competitions always happen within this group.

3. Comparison among EMS, S.F. Express and "Four TO and one Yunda"

Figure 4.17 illustrates the number of employees and outlets of the six private-owned companies as well as the state-owned EMS. In the figure, extremely large number of service outlets could be observed owned by EMS to support its extensive coverage. Most of these outlets are actually not dedicatedly established but attached to thousands of post offices all over the country due to its firm nature.

The extraordinary number of S.F. employees is another eye-catching figure. Compared with Yunda or Best Express, S.F. owns fewer outlets but hires almost five times numbers of employees. In most industry, this phenomenon may equals to the symptom of low efficiency. On the contrary, in the field of express delivery, it means shorter delivery intervals and higher efficiency. According to the S.F. deliveryman interview result collected in field research, within the same service area, S.F. Express normally as three times the amount of couriers of other companies. The triple number indicates each of the deliverymen is in charge of a smaller area with fewer cargos, which allows them to deliver or collect the parcels in really short time.

Meanwhile, in comparison with the other five private companies, S.F. Express has put much effort into strengthening its infrastructure construction. Fourteen fully possessive cargo airplanes and thousands of well-conditioned motor vehicles allow the company no longer to coordinate their delivery process with others. S.F. could further control and reduce the time on the way. In addition, advanced information technologies and equipment are kept developing and bringing into practice in order to improve automatic operation and optimize the capacity of the whole service network. As a result, S.F. develops or purchases a series of informationalized products such as Smart Express Box, multifunctional scanner, portable receipt printer, etc. to monitor, track, and look into all the information generated in the transition process.

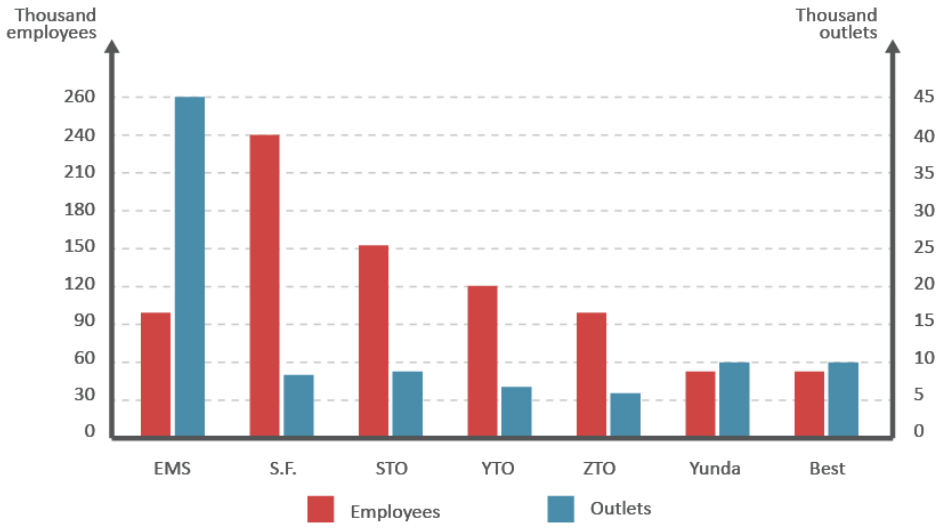

Figure 4.17 Comparison between express delivery carriers on number of employees and outlets

The most fundamental difference between S.F. Express and "Four TO and one Yunda" lies in their different business mode which directly influences the service quality and thereby impacts consumers' satisfactory. There are three major business mode in express delivery industry, including direct mode, franchise mode and mixed mode. Direct mode means that the company uses its own brand in the scope of services to set up a wholly-owned subsidiary or holding company. Franchising is known as the mode that franchisees of the company could pay and use the brand of franchisor. And mixed mode refers to the integrated use of direct and franchise mode. At present, S.F. Express is the only private-owned company applying direct mode; another company called ZJS Express uses the mixed mode; and the rest are all franchise mode.

Obviously, the popular franchise mode has many advantages. For the franchisees, joining a strong and highly reputable franchising company can avoid investment risk and get finance help. They could use the service marks,

product trademarks, patents and designs of the franchisor to quickly obtain market competitiveness. For the franchisors, capital brought by the franchisees can also relieve their financial pressure and realize rapid expansion (Wang et al., 2010).

Therefore, franchise mode becomes a dominant choice of China's private express delivery companies. But looking to the development of this mode in last ten years, the drawbacks of franchise mode become more and more obvious and the competitiveness of franchise companies are declining (CEA, 2010). A series of severe problems have been exposed, which is not just about customers' satisfactory issue, but matter the companies' future survival. More detailed discussion is presented in section 4.2.5.

Foreign express delivery companies

Before 2012, foreign investments were not allowed to operate domestic express mail services according to Chinese Postal Law due to the concern of national security. Therefore, foreign express delivery companies cannot get the domestic express business license, and had to change their layout strategy or directly quit from Chinese market. For example, UPS turned to high profitable market segments; FedEx put their efforts to accelerate the operating speed of international express mails; TNT shifted to focus on cross-border express delivery; and DHL directly sold its 100% of shares in three Chinese express companies in 2011 (RIC, 2013). In the beginning of 2012, State Post Bureau of China decided to gradually and partly open the domestic service market to foreign companies to perform the commitments made in WTO and to meet the trends of globalization.

Thus, the four global industry leaders, UPS, FedEx, TNT and DHL start to expend their business in China. Although in 2012, these companies only occupied 1.8% of the market volume, they accounted for 11.1% of the total industry revenue. That was because they occupied 75% of the most profitable international express business, which were about 30 million mails and packages daily (SPBPRC, 2012).

Compared with state-owned and private-owned companies, these international giants own much larger business scales, more advanced infrastructures and more superior business management and development strategies. Taking FedEx for example, its annual business revenue in 2013 is approximately 42 billion dollars, which is almost twice as China's entire express delivery industry revenues in the same year. FedEx owns more than 30 million employees, 634 aircrafts and more than 47,000 delivery vehicles worldwide (FedEx, 2013).Obviously, if direct competition happens, even the Chinese industry leader S.F. Express is too vulnerable to face the pressure from this kind of business magnate. This is one of the basic reasons why Chinese government used to close the domestic market to foreign investments.

Fortunately, though FedEx and UPS have got the permission to enter domestic service field, the service areas are limited to several main cities and still, not allowed to deliver mails and documents due to the safety concern. So most of the Chinese enterprises agree that opening domestic business to foreign investments in some cities would not significantly impact on the industry in short term; but the good quality, efficiency and safety from foreign companies could definitely shatter the original market pattern; and if one of the giants acquires one of the "Four TO and one Yunda" or starts price competition, EMS or S.F. would be unable to compete (Zuo, 2012).

Thus, for a long term consideration, Chinese express delivery enterprises, particularly private-owned companies, should treat the potential competition as a driving force and keep improving their own service capability and quality. In the meantime, learning advance business strategies, experience and technologies from these international giants are also essential for Chinese companies to optimize their management and be ready for the future.

4.2.5 Problems in Chinese private-owned enterprises

As mentioned in section 4.2.4, except S.F. Express and ZJS Express, the rest private-owned express delivery companies all use franchise mode. This mode has brought massive benefits to these companies during their early stage of development, but with their rapid extension, the rise of S.F. Express and the market access of foreign investments, a series of severe problems and drawbacks of this mode have been revealed gradually.

Low industrial concentration and low level of business management

Because of the low market access requirements, the number of express enterprise increases rapidly. These newly established companies are commonly in small business scales and have no brand awareness. Though some of those expend in a dramatic pace, this kind of expansion remains blind or shortsighted and runs without long-term development plan (CEA, 2010). Furthermore, a majority of private-owned express delivery companies stays in a family business structure. The old-fashioned management method restricts the further development of these small companies.

Multiple interests

Meanwhile, multiple interests behind the franchise model limit the development of middle or large scale companies. Future express industry is doomed to transfer from labor intensive orientation to labor, technology and capital orientation which requires large budget to purchase advanced vehicles, PDA, X-ray inspections, automatic sorting machine, monitoring aids, etc. However, the diverse interests of different franchisees make it difficult for the franchisors to execute large scale technological reform. In most cases, when the new proposal increase the current operation cost and no extra profits could be obtained in the short run, parts of the franchisees would place their revenue ahead of technical transformation, even their service quality (CEA, 2010). The slow pace of innovation implantation severely impedes the progress of Chinese local express delivery enterprises which can hardly face the competition from foreign companies.

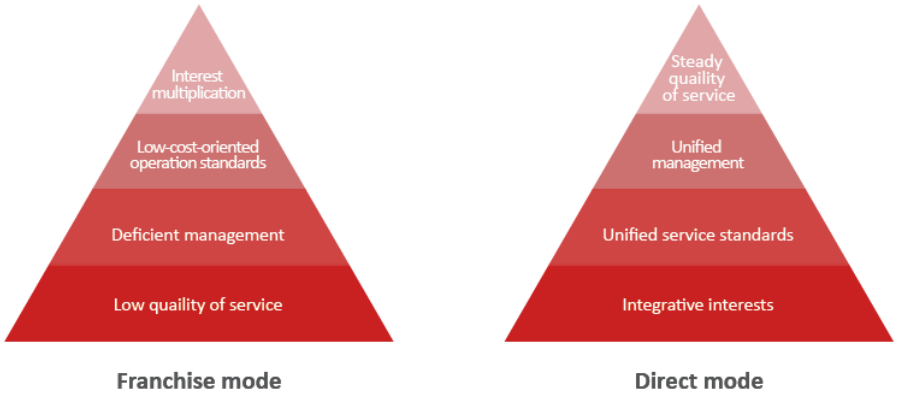

Figure 4.18 Comparison between franchise mode and direct mode (CEA, 2010)

Product homogeneity

Franchise model also aggravate the product homogeneity problem. Less communication and coordination among different franchisees and their limited service abilities makes it almost impossible to launch company-wide differentiated service for market segments. To maintain current profits and market share, low price competition seems to be the only effective means. Excessive low price directly increases the possibilities of bad service attitude, parcel delay, damage, loss, etc.; and thereby, form a vicious circle of low price and poor service (Lu, 2013).

Low quality of staff and poor service quality

Price competitions reduce the profit margin and further influence the quality of staff. More not well-educated labor forces are hired and less skill training is execute before they start service. Combined with the job nature of high-intensity physical labor, frequent staff mobility in private-owned companies are quite common. Moreover, with the entrance of foreign companies, the deficiency of specialized and professional employees becomes more and more evident. Laggard employing system and training system seriously hinders the development of industry (Ding et al., 2013).

As a result of unqualified employees, customers' complaints about local private-owned companies' service quality are fairly common. According to the data collected in March 2014 by State Post Bureau of China (Table 4.4), the top twelve companies with high complaint rate are all private franchise enterprises, in which the industrial leaders STO, Yunda and Best Express occupy three positions. State-owned company EMS is also not optimistic; it receives a rate of 17.76. By contrast, companies applying direct mode, such as S.F. Express and foreign companies enjoy a much better performance; they all control customers' unsatisfactory in a very low level with the highest TNT at 5.92, and UPS even reaches 1.2. Delivery service affiliated to E- business companies performs the best. But given that they only carry the goods for their parent firms, they have to ensure the safety and punctuality to avoid financial loss. So these companies are not discussed here.

The statistics clearly demonstrates the huge gap of service quality between most of Chinese companies and foreign enterprises. The rapid growth of market make the companies only focus on expanding number of outlets, the capital shortage problem accompanied and cost control rather than the improvement of service quality and consumer experience. Therefore, high risks of delay, loss or damage widely exist and their service attitude remains poor (Chen, 2011).

Company name	Overall complaint rate in March 2014	Among the overall rate		
		Delay	Loss	Service
Fast Express	91.56	32.80	19.13	23.92
Quanfeng Express	84.71	29.11	20.77	18.41
RFD Express	59.19	36.58	1.64	19.32
NEDA	46.67	18.89	10.00	11.67
ZJS Express	37.77	18.36	3.95	9.88
Unitop Sure Express	33.56	5.70	5.70	11.63
Yunda Express	29.91	15.60	4.58	7.96
TTK Express	28.50	13.63	5.36	7.13
Best Express	25.86	12.39	4.74	6.70
STO Express	22.59	6.81	4.51	8.24
Guotong Express	21.90	8.98	3.34	6.76
UC Express	20.31	8.12	3.07	6.09
EMS	17.76	8.26	2.09	5.88
Sino EX	14.93	14.93	0.00	0.00
ZTO Express	12.29	2.98	2.76	4.34
YTO Express	9.91	3.77	1.65	3.63
TNT	5.92	1.97	0.00	1.97
S.F. Express	4.07	1.05	0.41	1.65
Unitop Express	2.96	0.49	1.48	0.00
Suning	2.69	1.92	0.00	0.38
FedEx	2.40	0.40	0.00	0.40
China Air Express	2.19	0.00	2.19	0.00
UPS	1.20	0.00	0.00	0.40
Amazon	1.06	0.00	1.06	0.00
JD	0.70	0.30	0.07	0.30

Unit: the number of effective complaint/per million parcels

Leaders of private-owned express delivery companies	Other private-owned express delivery companies
State-owned express delivery companies	Foreign express delivery companies
E- business companies affiliated delivery service	

Table 4.4 The complaint rate of main express delivery enterprises in March, 2014 (SPBPRC, 2014)

No industrial standard

China Express Association (CEA) was established by the State Council of China in 2009. It aims to formulate standards of express delivery industry, strengthen the self-management of companies, provide information, training and other services, and promote the healthy development environment (CEA, 2012). But the actual effect of the association remains unsatisfied due to the short time after establishment and sophisticated industry condition. What's more, the industry association is not legally authorized to execute any punishment to the misconduct of members, which means even CEA notice the standard violations of certain company, there is very few thing that the association can do to solve the problems in a short term (Wei, 2012). The unhealthy condition not only encroaches on the interests of consumers, but also violates rights of stipulation compliers.

Turning problems to opportunities become the primary affairs for these private-owned companies. Therefore, in this project, problematical local private express delivery enterprises are selected as the study objects. Further field research would be executed within these companies and vehicle would also be designed based on the specific requirements that occur during these companies' daily operation. The final result aims to increase the industrial competitiveness of these private-owned express delivery enterprises so as to face the potential competition and market opportunity in future.

4.2.6 Trends of industry development

Understanding industry development trends could help to create reasonable solution to support Chinese express delivery companies.

Gradually switching the business mode from franchise to direct mode is the most prior trend. The success of S.F. Express which finished the transition in 2002 has already proved the superiority of direct mode. And latest news has shown that STO, YTO, Best and Yunda Express have started their direct management process. Though in transition process, fierce resistance from franchisees would be received, yet after the mode transition, problems like product homogeneity, unqualified employees, poor service quality, etc. could be smoothly solved (Ren, 2012).

Despite the transition of business mode, there are several universal developing trends in the express delivery industry. The first is mechanization and automation. The prosperous development of e-commerce brings unprecedented business volumes which increasingly exceed the expected workload of express companies. Obviously, traditional manual operation could hardly satisfy the current market requirements; more advanced automatic machines are deemed as a significant solution to raise the work efficiency and stability. Facilities like automatic sorting machines and specialized vehicles have already taken into practice in most of transit hubs, and in the near future, more advanced equipment is expected to be widely embedded into the industry.

Mechanization and automation cannot be achieved without informatization and intellectualization. The construction does not actually have to be high-end technical solutions. The optimized use of bar code, scan technology and internet could in fact significantly improve a company's warehousing, delivery management and customer service. Meanwhile, the rise of Internet of Things would further integrate information and propel the logistics system towards an informationalized orientation.

The last but not least, increasing awareness and interest in sustainable business practices is an unavoidable topic for stakeholders. Sustainability demands start to increasingly shape the market and therefore business success. In line with this, the reduction of carbon emissions and the insurance of employee health and safety become important responsibilities for express delivery enterprises (TNT, 2014).

4.2.7 Section conclusion

Due to the combined effect of political, economic, cultural and technical factors, the express delivery industry in China is experiencing an extremely rapid growth in the new century. Local companies are springing up like mushrooms after the rain and foreign investments are itching to enter the recently opened domestic service field. Most of the intra-city and inter-city business is currently dominated by state-owned and private-owned companies. But the services they provide are not that satisfying, the defects of these companies such as poor management, old-fashioned business mode, poor service quality, unqualified employees, etc. is gradually being exposed. These problems would become more obvious when facing the direct competition from international industry giants in future.

Challenge is opportunity. In this paper, problematical local private express delivery enterprises are selected as the potential clients. Using the design result combined with industry development trends like mechanization, automation, informatization, sustainability, etc., the project intends to provide reasonable solutions to support local companies, especially the private-owned enterprises to face and survive in the future.

4.3 Delivery vehicle

It is known to all that the express delivery industry highly relies on road, air or rail transportation. More specifically, express delivery transportation is achieved by using a variety of different transport tools, for instance, trucks, vans, aircrafts, high-speed trains as well as on-foot delivery.

To expense control and some other concerns, surface transport modes is used as long as it is possible, air transport is only applied where there are no other options available to meet the time limitation. For inter-city transportation, heavy trucks and trains are the main tools, while for intra-urban distribution, lorries, vans, electric vehicles, motorcycles, scooters and bicycles are major choices.

In this paper, vehicles take undertake the intra-urban delivery tasks are the main focus. They are in charge of the first or the last step of the transport process. The function, safety and efficiency of the vehicle could vastly influence the service quality and consumers' satisfactory.

4.3.1 Existing problems

As mentioned in last segment, though China's delivery companies are experiencing a tremendous development, numerous serious problems are gradually being exposed and imperil the future of the industry. Besides the issues listed in section 4.2.5, contradictions among policies, company interests and actual requirements also exist in the field of delivery vehicle.

The first problem is the lack of industrial standards of delivery vehicle. According to the regulations raised by local traffic administration of large or medium-sized cities, freight vehicles without special passes are not allowed to enter the city central areas in rush hours. Large express delivery vehicles, such as trucks, lorries and vans are therefore not permitted to drive in the restricted zone from 7 a.m. to 10 a.m. and from 6 p.m. to 9 p.m. This traffic restricted hours happen to be the business peak periods for the express companies. Since no dedicated-designed vehicle or other legal solution could be found to solve the dilemma, passenger cars like minibus or low cost MPV are unlawfully refitted to carry parcels. Small electric scooters, mopeds and three-wheeled bicycles are also massively applied to support the intra-city distribution. Although the problem seems to be temporarily solved, the delivery efficiency is actually vastly decreased. Lots of smaller vehicles have to be bought and more human recourses are devoted to daily works. The increasing operation cost directly affects service quality and influence customers' satisfactory (Yu, 2009).

Moreover, the illegal refitted passenger cars and overloaded scooters endanger the road safety of the local traffic system. According to a rough research by a famous Chinese web portal, Sina (2013), more than 50% of the road accidents in Suzhou, a second-tier city with 10.7 million populations, involve electric scooters or mopeds. Within the perpetrators and victims of these accidents, nearly one-third of them are express delivery employees. Overload, overspeed and aggressive driving are the primary inducements. Due to the franchise mode, the quality of the deliverymen is relatively low, and the salaries of them are linked to their workload. In order to deliver or pick up more goods, some of them would rather to run the risk of violating traffic laws. Since less of them have incidental insurance, if a traffic accident happens, they would have to suffer both health and financial loss, and also bring inconvenience to the consumer.

Figure 4.19 Deliveryman involved in a traffic accident

The third problem lies in the lack of explicit infrastructure which is provided for couriers to park their vehicles. The contradiction between legal parking and delivery efficiency usually puts the deliverymen in a dilemma. They have to rush during their on foot delivery to avoid getting fined for parking violations. In addition, the prohibition of delivery vehicles in some of the communities further makes the situation worse. Delivery vehicles have to park in the nearest road which not only influence the traffic condition but also increase the inconvenience of customers. Municipal transport planning authorities tried to use special licenses to protect the delivery vehicle from penalty, but this measure can do nothing to remit the traffic chaos brought by illegal parking. Dedicated parking facilities such as parking bays should be provided to solve this problem.

4.3.2 Government intention

According to the deputy secretary-general of China Express Association, State Post Bureau of China and other relevant ministries intend to introduce relevant specifications for the special delivery vehicle. A series of studies including vehicle speed, weight, mileage per charge, brake performance, appearance, material, safety criterions etc. have been executed. The result would be negotiated with express delivery companies and then published as industrial standards (He, 2011).

The issue of 'special pass' is another measure. State Post Bureau of China recently redefines express mails and parcels as communication media rather than cargos, and according to the related laws, residents' communication secrets and freedom is needed to be protected (Yu, 2009). This apparently changes the nature of express delivery vehicle from freight carrier to communication carrier. And thus, the prohibition for freight vehicle is no longer suitable and the modification of passenger car turns to legal. Therefore, some local governments start to gradually grant 'special passes' to some express delivery vehicle of several enterprises with integrity. And wider application is expected to be executed in future.

Figure 4.20 'Shanghai express special pass' (left) and government authorized delivery vehicle type, SAIC Motor MAXUS V80 (right)

Strengthening the management of electric scooters/mopeds is the third measure. As mentioned in section 4.3.1, traffic accidents involving electric scooters or mopeds have occupied over half of the total amounts. Though national standard sets their top speed at 20 km/h, most of the scooters and mopeds could reach the speed of 40 to 50 km/h due to illegal modification. Additionally, problems like overload, poor maintenance, overdue usage, etc. also commonly exist. In order to change the current situation, the State Council promulgated ''Notice on Strengthening Road Safety Work'; and local governments issued 'Notices on Further Strengthening the Management of Electric Bicycles'. All the electric scooters/mopeds should be registered at local traffic administrative department, and unqualified vehicles would be eliminated within a specified time limit.

4.3.3 Current local delivery vehicles

There are three major categories of intra-city express delivery vehicle in Chinese market, including electric scooters/mopeds, electric three-wheeled bicycles and refitted petrol MPV/minibuses. They undertake the 'the last/first kilometer' missions of the entire delivery process, i.e. pick up/delivery the parcels or mails from/to customer.

Electric scooter/moped

Since motorcycles are forbidden or limited to use in about 170 cities in China for safety and sustainable concern, electric scooters or mopeds become popular substitutions. They also become the most favorable choice for local delivery enterprises for their low price, low transportation cost, small size, flexibility and sustainability. They could easily reach almost every corner in Chinese cities without concerns about congested traffic condition. But they also inherit the defects from motorcycles such as bad weather adaption, low driving safety, low cargo safety, bad stability, etc.

Figure 4.21 'The king of Load' produced by Jiebao King

An electric scooter 'The king of Load' is select to represent this category, which is produced by Jiebao King Company. It is equipped with a 500w motor and a 48V battery pack, and could realize a continuous mileage over 60 kilometers. Hydraulic front suspension and wide motorcycles tires are also installed to keep a stable and comfortable ride. In order to carry more parcels than regular scooters, a special-designed foldable back seat and two cargo holders are place in the rear side. The price of the scooter is about RMB 2,300, in which RMB 500 is the battery price.

Electric trike

Electric trikes are the new favorites of express delivery industry. On one hand, the electric power helps to cut down the expense on energy consumption and save transportation cost. On the other hand, compared to two-wheeled vehicles, the extra wheel provides greater loading capacity and driving stability, and meanwhile keeps good flexibility and trafficability. But similarly, the drivers of most three-wheeled bicycles are exposed in the environment. Severe weather conditions would still highly affect their working efficiency. And then, some of the trikes remain the cargo security problem. The last but the most essential is that most of the first-tier and second-tier have already issued or are going to announce relevant prohibition or restriction regulations on this kind of vehicle because of their massive traffic violations and illegal operation.

Figure 4.22 The product of Jinguangcai (left) and the product of Haifeiyue (right)

Two kind of electric trikes are chosen as the representatives of this category. The one on the left is manufactured by Jinguangcai and the one on the right is produced by Haifeiyue. They have the same length and width of 2700mm and 960mm, and enjoy exactly same motor power (550w) and top speed (30km/h). The payload of both

vehicles is 400kg. The only functional difference lies in the design of cargo compartment. Jinguangcai's product has a closed lockable cargo compartment. The size of it is 1,400mm×950mm×920mm, and an extendable space is located on the roof. The steel cabin can provide a shelter for parcels and increase the cargo security as well. Haifeiyue's product has a 1,300mm * 900mm open cargo compartment. Compared with the previous one, it definitely has a lower weather adaption and cargo security, but the additional tipping components design can help to unload cargos. The price of Jinguangcai product varies from RMB 3,380 to 4,180 depending on the battery volume, while the price of Haifeiyue product is only RMB 1,600.

Low cost petrol MPV and minibus

Low cost MPV and minibus have their unique advantages. Compared with scooters and three-wheeled bicycles, they have much bigger load capability, mobility and horsepower, and provide a much better indoor condition and safety for passengers as well as cargos. In comparison with small freight vehicles, they enjoy much lower prices, even taking the illegal modification payments into consideration. And the most significant thing is that current traffic restrictions on freight vehicles could be evaded tactfully. However, the drawbacks of this type of vehicle are also quite prominent. Relatively large and bulky body influences the trafficability of the vehicle, which makes it hardly get into some narrow street in old neighborhoods. In addition, though the space inside is quiet large, yet the vehicle is not designed for cargo delivery purpose. Huge effects have to be paid during loading, arranging, finding and unloading process.

Wuling Sunshine Economic produced by SAIC Motor is select to represent this category. The dimensions of the car is 3885mm * 1600mm * 1860mm with a 2500mm wheelbase. The gross mass is about 1620 kg and able to carry 8 people in total. The max speed could reach 110 km/h with 7.4L fuel consumption. MacPherson struts is equipped as the front suspension and a leaf spring work in the rear. Except the basic automotive components, almost no additional function could be found in this car, even air-conditioner, airbags or disc player are not included. The price of the basic version is round RMB 29,800, and the most advanced version is RMB 50,500.

Figure 4.23 Wuling Sunshine Economic produced by SAIC Motor

4.3.4 Worldwide newly raised delivery vehicles

With the increasing needs of logistic industry, some foreign automotive companies have started to research and develop tailor-made express delivery vehicles. Though this kind of vehicle remains a new field, several concepts have already been realized and some of them have been put into practice. All of these newly raised vehicles are electric ones, which somehow reflect the main developing trend of this new automotive category.

Mitsuoka LIKE-T3

Mitsuoka Motor is a forerunner of micro EV. The technologies and experiences obtained from previous projects are migrated to new and unique design of LIKE-T3. It is a three-wheeled EV with about 310 kg curb mass. Two seats are arranged side-by-side and a 1,050mm×900mm open or closed cargo compartment with 100 kg payloads is placed behind. LIKE-T3 has two type of battery capacity to be selected as option, 4.3kWh or 2.9kWh. Range is 60km/charge and 40km/charge respectively at the constant speed of 40km/h and takes six hours to charge from a normal household plug socket. LIKE-T3 has successfully obtained the type approval from Japan government for its high and stringent safety standard, and can be reached in the market at the price of RMB 60,000. A local delivery company Sagawa Express has implanted it into their daily service and proved its value in the practical use (EV world, 2012).

Renault Twizy Cargo

In June 2013, Renault announced a new version of its tiny EV Twizy, namely Twizy Cargo for hauling goods. Instead of previous tandem two-seater layout, the rear seat space was replaced with a 180-litre boot, accessed by a lockable rear door. It can accept loads of up to 75kg and mainly face the companies offering callout or takeaway services. Like the two-seater Twizy, the Cargo has a 17bhp motor that helps the 474kg vehicle to reach a top speed of 90 km/h. It has a range of around 80 km per charge and takes three and a half hours to charge from a normal household plug socket. The tiny size of 2,338mm×1,396mm×1,454mm allows the Twizy to be parked end-on into a space. The price of Twizy Cargo is about RMB 72,000 and could be directly ordered from Renault. Though Twizy Cargo is not technically an express delivery vehicle, it can be a really good reference for later design (Phillips, 2013).

Figure 4.24 Mitsuoka LIKE-T3

Figure 4.25 Renault Twizy Cargo

Toyota B-COM EV

Toyota Auto Body released a series of ultra-compact and ultra-efficient electric cars named COMS EV in 2012. It has two variants, the P-COM and the B-COM. B-COM is a single-seater delivery purposed version. It measures 2395mm in length, 1,095mm in width and 1495mm in height and weighs 420kg. A 5kW motor could provide a maximum speed of 60km/h and can travel 50 km on a single charge. A 150L boot (590mm×965mm×875mm) space or a 1,005mm×675mm cargo desk is located behind the driver seat to carry limited amount of cargos. The B-COM delivery would cost approximately RMB 47,000, but it is only available in Japan now (COMS, 2012).

eT! Concept

eT! Concept is a brand-new delivery vehicle. A think tank from Volkswagen, Deutsche Post and the Braunschweig University of Art has reinvented the standard delivery van from the tires up. This concept vehicle can drives semi-autonomously on voice commands and be steered by driver from the passenger side using a joystick. Two

space-saving, 130 hp electric wheel hub motors is placed on the rear axle, which free up room for cargo and can also accelerate to 50 km/h in just 9.2 seconds. It has a top speed of 110 km/h and a battery range of 100 km per charge. Of course, the most charming places of eT! Concept are its highly innovative and useful functions. According to the estimation by the developers, voice control and 'drive stick' helps the driver save up to 40 minutes on an average delivery round, which is extremely vital for this time-sensitive industry (Martian, 2011). Currently, the concept demo has been successfully tested, but when the product would starts its massive production remains unknown.

Figure 4.26 Toyota B-COM EV Desk (left) and B-COM EV Delivery (right)

Figure 4.27 Volkswagen eT! Concept

Navistar eStar

Navistar eStar is a medium-size electric delivery truck produced by a joint venture between Navistar and Modec. The design of it looks a bit futuristic, but it is actually a field-service workhorse. The power comes from a 70 kw electric motor and could reach a maximum speed of 80 km/h. The recharge could be finished in 8 hours on a Level 2 charger or in 20 min via exchanging battery pack. Up to 160 km range can be achieved per charge. The curb weight of eStar is 272kg, but it could bear the max payload of 2,500kg. The manufacturer suggested retail price of RMB 934,080 are very likely to scare off lots of buyers, but the American government decides to help offset the cost. More than 150 vehicles have been manufactured since 2007. Major customers include Tesco, FedEx, UPS & UKMail (Van Vlack, 2013; Korte, 2011).

Figure 4.28 Navistar eStar

4.3.5 Benchmarking

A benchmarking was made to analyze the existing local delivery vehicles and the new comers. Four practical-used vehicles (including government authorized MAXUS V80) and the five new electric products mentioned in the previous section were measured via six dimensions, including price, top speed, payload, curb mass, range per charge and vehicle size. The purpose is to find out the superiorities and weaknesses of the existing options.

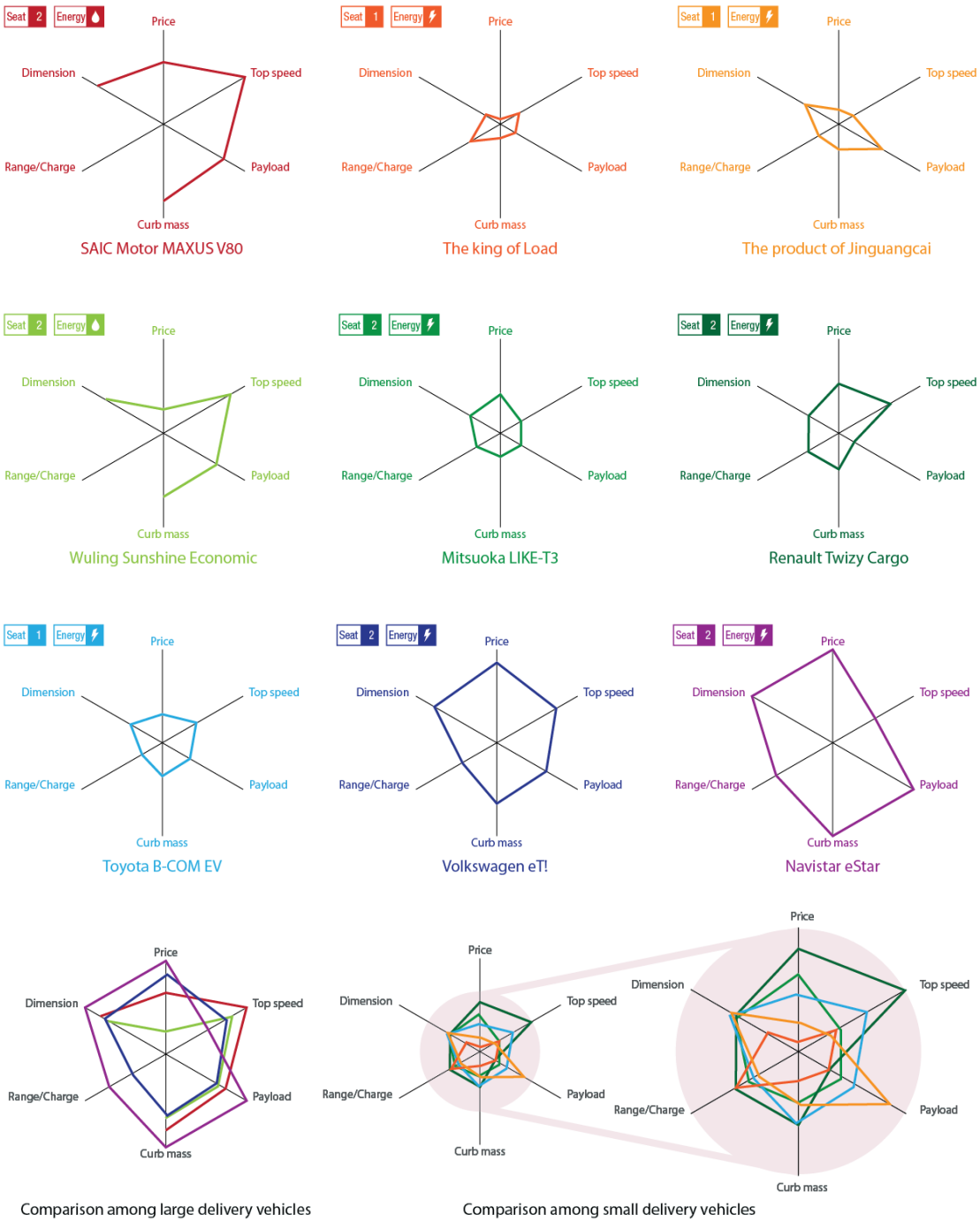

Figure 4.29 Benchmarking of the nine delivery vehicles

The nine vehicles formed two sets of comparison according to the vehicle dimension. The graph in the lower left corner shows the comparison among large delivery vehicles which include MAXUS V80, Wuling Sunshine Economic, Volkswagen eT! and Navistar eStar. This graph indicates that except price and top speed, the new electric products are able to cover most of the features of current products. The higher prices of the new design can be seen as the result of the implantation of high-tech solution or additional functions.

The graph in the lower right corner illustrates the comparison of the small vehicles. Big differences can be observed in three dimensions. Especially in the aspects of price and payload, newly designed vehicles are at least twelve times more expensive than the Jinguangcai electric trike, but could only carry merely one-third amount of cargos. It is obviously that these new small electric vehicles are not suitable for Chinese market.

To sum up, either a large-sized low-cost product with higher top speed or a small scale low-cost vehicle with good load capability could be potential developing orientations. Combined with the knowledge of local express industry, the fact of widely applied but dangerous overloaded delivery scooters and the intention of designing a small safe low speed vehicle of PUNCH project, low-cost small vehicle with reasonable payload is decided to be the project developing direction.

To further prove the validity of this decision, a matrix with a high/low price axle and a little/large payload axle were made as shown in Figure 4.30. It clearly demonstrates that most of the newly designed vehicles are concentrated in medium and high price region, while currently popular products are mainly distributed in low price area. Providing a small low-cost vehicle with reasonable payload are very likely to make up this market blank

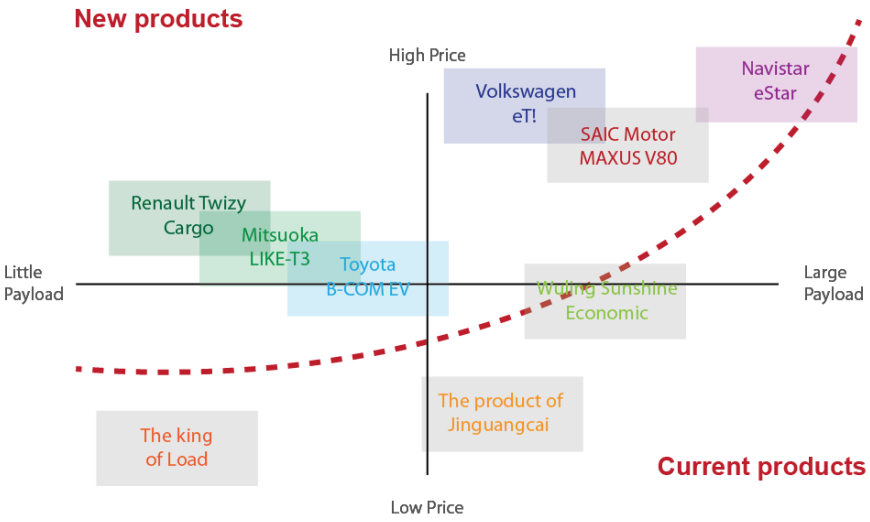

Figure 4.30 Benchmarking of the nine delivery vehicles

4.3.6 Express delivery vehicle developing trends

Except the trend of sustainable energy use in the express delivery vehicle mentioned in the beginning of 4.3.4, there are several other trends within the delivery vehicle design (Logistics Technology and Application, 2011).

1. High cost performance: There is a common phenomenon in most of the China express delivery enterprises, the capital shortage. Therefore, most of the companies would like to regard price as the primary factor during vehicle purchase though they understand the long-term benefits of better products with higher price. With further developments, the increasing demands of good quality vehicles would certainly gradually increase, but providing high cost performance products is always the wise choice.

2. Multifunction: In the past, freight vehicles design solely focuses on the driving performance, but increasingly fierce market competition generates higher demands on the service quality, security and convenience. Express delivery vehicles should provide relevant functionalities to increase the market competitiveness of their users.

3. Professionalization and customization: With the increase of specific function, the professionalization of express delivery vehicle would become more and more evident. But some companies might still not satisfy with the product or they have special requirements, business cooperation would create more unique and tailor-made products to fulfill the specific requirements.

4. Ease of assembly: As a high depletion product, maintenances should be executed frequently. The ease of assembly could reduce the cost and human resource for long-term consideration.

4.3.7 Express delivery vehicle design related legislations

Legislations of People's Republic of China should be obeyed during the design process. Since detailed vehicle properties have not been decided in this phase yet, regulations on both motor and non-motorized vehicle are studied. Relevant vehicle regulations are listed as below.

Road Traffic Safety Law of People's Republic of China (2013)

Chapter II Vehicles and Drivers

Section 1 Motor vehicles and non-motorized vehicles

Article 8: The state practices a registration system for motor vehicles. A motor vehicle shall be driven on reads only after it is registered with the traffic control department of a public security organ.

Article 18: Non-motorized vehicles required for registration according to law shall run on roads only after they are registered with the traffic control departments of the public security organs.

The types of non-motorized vehicles required for registration according to law shall be specified by the people's governments of provinces, autonomous regions and municipalities directly under the central government in light of the actual local conditions.

The external size, quality brake, handle -bar bell and night reflectors of a non-motorized vehicle shall be in conformity with the safety and technical standards for non-motorized vehicles.

Section 2 Drivers of Motor vehicles

Article 19: To drive a motor vehicle one shall obtain a motor vehicle driver's license according to law.

Chapter IV Provisions on Road passage

Section 2 Provisions on the passage of Motor vehicles

Article 42: When driving a motor vehicle on roads, the driver shall not exceed the maximum speed per hour shown by the speed limit sign. He shall keep the safety speed along the sections of roads without speed limit signs.

Article 48: The loaded cargo of a motor vehicle shall be in conformity with the verified loading capacity, and overload is strictly prohibited; the dimensions of the length, width and height of the loaded cargo shall not be at variance with the requirements of loading, and nothing loaded shall be littered on the way.

Article 49: Passengers carried by motor vehicle shall not exceed the verified number; passenger motor vehicles shall not be used for carrying cargoes in violation of regulations.

Article 56: Motor vehicles shall be parked at specified places. They are prohibited from being parked at the sidewalks, except for the parking berths delimited in accordance with the provisions of Article 33 of this law.

Section 3 Provisions on the passage of Non-motorized vehicles

Article 57: When riding a non-motorized vehicle on roads, the person shall observe the regulations on traffic safety. Non-motorized vehicles shall run in the bicycle lane; and where there is no bicycle lane, they shall run on the right side of the motor vehicle lane.

Article 58: When motor wheelchairs for the disabled and battery-powered bicycles run in the bicycle lane, their maximum speed per hour shall not exceed 20 kilometers.

Article 59: Non-motorized vehicles shall be parked at specified areas. Where no such parking areas are delimited, such vehicles shall be parked at places where the passage of other vehicles and pedestrians are not impeded.

Chapter VIII Supplementary provisions

Article 119: For purposes of this law, the meanings of the following terms are：

(3) “Motor vehicles” mean the wheeled vehicles driven or drawn by power sets on roads for carrying people, for transporting cargoes, or for special engineering operations.

(4) “Non-motor vehicles” mean such means of transport as are driven or drawn by man or animal on roads, and the motor wheelchairs for the disabled and electrically operated bicycles, which are installed with power sets but the designed maximum speed per hour, the light quality and the external size of which are in conformity with the relevant standards of the state.

Road Traffic Regulations of Shanghai (2008)

Chapter III Vehicles

Article 18: Municipal traffic control department of the public security should be involved in the development, security technology demonstration and performance appraisal of new types of vehicles.

Chapter IV Vehicle drivers

Article 23: Person driving a motor vehicle should hold a vehicle driving license of People's Republic of China. Person driving motor wheelchairs for the disabled or battery-powered bicycles should hold disabled vehicle operating license or battery-powered bicycle operating permit.

Article 24: Person applying a motor vehicle driving license shall have a city residence permit.

Chapter V Provisions on Road passage

Article 41: Non-motorized vehicles and vehicles with top speed under 60 km/h are not allowed to drive on elevated roads.

Non-motorized Vehicles Management Approaches of Shanghai (2013)

Chapter IV Non-motorized vehicle passage management

Article 32: Non-motorized loading shall comply with the following requirements:

(A) The loads on bicycles, electric bicycles, wheelchairs, motorized wheelchairs shall not exceed 1.5 meters high from the ground. The width of load shall not exceed 0.15 meter from the left and right handlebar. . The length of load shall not exceed the front wheels in the front and shall not exceed 0.3 meter from vehicle body in the rear.

(B) The loads on tricycle shall not exceed 2 meters high from the ground, 0.2 meter from vehicle body in both side and shall not exceed 1 meter from vehicle body in the rear.

(C) Load shall take reinforcement measures to prevent cargo from falling, floating, etc.

4.3.8 Section Conclusion

Today’s Chinese express delivery industry highly relies on surface transportation, but due to the flaws in relevant regulations and infrastructures as well as the national and industrial conditions, most of delivery vehicles used currently are either illegal-modified or illegal operated. Especially in intra-urban distribution, overloaded electric scooters/mopes, unlawful –used electric tricks and illegal-refitted MPVs/minibuses undertake almost all the business. The high traffic accident rate of deliverymen and the dilemma of express delivery companies have caught the attention of government, introducing standard delivery vehicle and issuing ‘special delivery vehicle pass’ is being discussed.

Meanwhile, automotive enterprises have already started their research and development on tail-made delivery vehicles. Mitsuoka LIKE-T3, Renault Twizy Cargo, Toyota B-COM EV, eT! Concept and Navistar eStar are five newly designed products and four of them are now available on the market. Compared with current popular products, these products can cover most of the required features and some of them could provide more advanced functions. However, all of the new solutions concentrate in high and medium price region. No low cost product with reasonable payload could be found. Moreover, these foreign company designed products could hardly meet the actually requirements and legislations in China.

Via a comprehensive consideration of China express industry, market blank and the intention of PUNCH project, a low-cost small electric vehicle with reasonable payload is assumed to be the developing direction of this paper. The developing trends of express delivery vehicle and relevant traffic regulations should be emphasized in the final design.

4.4 Sustainable Design

According to McLennan (2004), sustainable design is defined as “the philosophy of designing physical objects, the built environment, and services to comply with the principles of social, economic, and ecological sustainability.” The intention of it is to "eliminate negative environmental impact completely through skillful and sensitive design". Meanwhile, it also needs to balance the dynamic relationship between economy and society to achieve long-term effect.

Sustainable design is not the main purpose of this project, but it is one of the initial intentions of PUNCH project: using small light electric vehicle to replace the market demands of gasoline products in main cities. Bringing sustainable design thinking and principles into in this project could carry the spirit of project starters.

4.4.1 Problems in automotive industry

Automotive industry is one of the most prosperous global industries. The number of light vehicle is predicted to enjoy a three to five times’ increase worldwide in the next 50 years and the growth in developing countries might be even greater. Today, 96% world’s transportation systems are dependent on petroleum products, which occupy nearly 40% of the world’s oil consumption (McAuley, 2003). The tremendous growth would result in dramatic increases in global fuel demand, material requirements and air emissions. It is vital to significantly reduce the overall environmental impact of vehicles worldwide in order to achieve environmental sustainability in future.

4.4.2 Sustainable design in automotive industry

According to the data from the American Plastics Council (2001), 87.1% of a vehicle’s life cycle energy consumption happens in the “use phase”; 7.1% occurs in manufacture, and 4.8% appears in the end-life recovery. Use phase seems to be the undisputed leader of fuel consumption and further, key environmental impacts like air emissions also occur in this phase. Significant changes are urgently needed to alter the current situation.

Technical innovation is a part of solution. Changing design parameters can influence vehicle air emissions and energy consumption including alternative fuel, engine technologies, rolling resistance, drive train design, vehicle weight, etc. Vehicle weight reduction is the most crucial approach among the above. It can effectively reduce energy demand across all energy distribution elements. New and advanced lightweight materials like plastics or composites are going to overtake current metal-based infrastructure. Combined with hybrid or fuel cell engine technology, it is estimated that a factor of 3-5 efficiency can be reached, whilst realizing air emissions reduction as well. Easy disassembly is also important. Fewer materials and parts as well as mono-material construction can vastly improve the recyclability (McAuley, 2003).

In addition, there are some universal technical principles could be applied, for example, choosing low-impact materials such as local, non-toxic, sustainably produced or recycled materials, optimizing product manufacturing processes, planning the entire life cycle for products, etc. (Anastas, 2003; Hawken et al., 1999; Chris, 2006).

Shifting user behavior is another part of sustainable solution in use phase. Design interventions introduced in section 3.2.2 are also suggested by literatures to facilitate users’ sustainable behavior. Strategies like Eco feedback, personal norm reminder, competition, just-in-time prompt, habit Intervention, etc. have been applied into practice and acquired satisfactory result (e.g. Lockton, Harrison & Stanton 2008; Lilley 2009; in Lidman et al., 2010).

4.5 Chapter conclusion

At the Department of Applied Mechanics of Chalmers University of Technology, project PUNCH which is about a small, safe, light and low cost electric moped car has been going on for years. Fruitful results have been achieved on the technical level. Massive components research and development has been done and computer aided crashworthiness tests have been executed to prove the safety. However, the vehicle application and potential user of this vehicle remains ambiguous. No specific function description could be found and very few user studies have been made. Finding the way out in the market is an urgent affair for PUNCH.

Meanwhile, the express delivery industry in China is experiencing an extremely rapid growth in the new century. Local state-owned and private-owned companies dominate a majority of the intra-city and inter-city business. Nevertheless, the inherent defects of these companies are gradually being exposed with their rapid extension. With the open of domestic business, their low service quality, homogeneous products, poor service attitude, etc. could hardly face the direct competition from foreign express delivery companies.

Challenge is opportunity. Implanting PUNCH into China express delivery industry can be a good choice. On one hand, the price level in developing areas is conducive to finding cheap vehicle components to achieve the low cost project purpose. On the other hand, the huge prosperous but less developed delivery market provides a piece of fertile soil for PUNCH to find its position.

Due to the flaws in relevant regulations and infrastructures as well as the national and industrial conditions, most of the currently-used intra-urban delivery vehicles are either illegal-modified or illegal operated. Overloaded electric scooters/mopes, unlawful –used electric tricks and illegal-refitted MPVs/minibuses seriously endanger the safety of delivery drivers, parcels and local traffic system. The government has decided to introduce standard delivery vehicles to the industry to solve the dilemma.

Looking into current market, though there are several kinds of dedicate-designed delivery vehicles available, the new solutions all concentrate in high and medium price market. These foreign company designed products could hardly meet the actually requirements and legislations in China.

Via a comprehensive consideration of China express industry, market blank and the intention of PUNCH project, a low-cost small electric vehicle with reasonable payload is assumed to be the developing direction of this paper. Since most of the technical solutions were generate, this late market positioning is inevitable to induce a series technical modification. Though huge effects is required to be involved again, the new vehicle definition is believed to be more closed to actual requirements, and thereby reduce the potential risks or financial loss in future.

The influencing factors of this decision making in this chapter are listed in the following table. These factors could also be regarded as inspiration inputs for the final design.

Influencing factors

Section	Field	Specification
4.1.1	Electric and hybrid electric vehicle	The mature of electric and hybrid electric technology
4.1.2	Keywords of PUNCH	Small, safe, one-seat, eco-friendly, electric hybrid, low speed, producible, moped car, four wheels
4.1.3	PUNCH powertrain	The weight, size and price of powertrain elements
4.1.4	The use of separate frame	Ease of mounting and dismounting Ease of achieving strong and robust designs Isolation of noise Low cost and easy manufacturing process High vehicle height and cargo floor High vehicle structure vibration

	PUNCH frame architecture	PUNCH frame parameters Great crashworthiness The thickness distribution of frame
4.1.5	Steering, brake and suspension design	The type and relevant parameters of related elements
4.2.2	The prosperity of China's express delivery industry	Profitable market potentials
4.2.4	Express delivery carriers in Chinese market	Tremendous challenges/opportunities after opening domestic delivery business to foreign investments
4.2.5	Problems in Chinese express delivery enterprises	Poor infrastructure construction Low efficiency Low quality of staff and poor service quality Poor cargo safety
4.2.6	Trends of local express delivery industry	The transition to direct mode Mechanization and automation Informatization and intellectualization Sustainable business
4.3.1	Problems of express delivery vehicle	Illegal-refitted passenger vehicles, overload electric scooters, and overload illegal-operated mopeds three-wheeled High accident rate of deliverymen Less parking place
4.3.2	Government intension on vehicle development	The confirmation of their intention of developing standard delivery vehicle The issue of 'special pass' The strengthen electric scooter/moped management
4.3.5	Benchmarking	The requirement of a low-cost small vehicle with reasonable payload which is suitable for Chinese market
4.3.6	Express delivery vehicle developing trends	High cost performance Multifunction Professionalization and customization Ease of assembly
4.3.7	Express delivery vehicle design related legislations	Related articles

Table 4.5 Factors of this decision making in this chapter

5. Field research and analysis

This chapter describes contents of the field research carried out in Shanghai, China. Theories and methods mentioned in the previous chapters are implanted in practice, and the results of two rounds of user investigations and corresponding analysis are respectively displayed. These requirements and problems identified in this phase would be used in combination with the knowledgebase to serve for the later design phase.

5.1 Pilot study result

The first round field data collection started on 11th March and lasted for a week. There are two main purpose of this round research, including the collection of user, vehicle, cargo, task and environment information, as well as the verification of the existing situation in private-owned express delivery companies with previous literature studies.

Before the field research started, a pilot study was conducted to exam the effectiveness of the original research proposal. It was about giving a restrict-structured research table (almost the same as Table 3.1) to deliverymen from different private-owned companies; and followed by entire working hour observation on some of them. Two advantages were believed in this approach. On one hand, the relatively wide-covered results could serve as supplementary knowledge and verification materials for previous literature study; on the other hand, more suitable companies could be chosen for further observation study via the horizontal comparison of results.

However, after being tested by a courier from ZTO Express, the result was not really inspiring. Serious problems were exposed during the process, such as:

1. The questions were so detailed and redundant that over 25 minutes were required to fully complete.
2. All the deliverymen were extremely busy during daytime. It was impossible to stop to answer the question table. The only way was presenting the question orally, which was another reason for the overlong study time. And it also turned the questionnaire method to 'structured interview'.
3. Most of the required information was too common and basic for the subject, which made him easily lose interest to the interview.
4. Due to the long duration and low interest, the answers received were usually perfunctory and ambiguous.
5. The 'structured interview' could hardly reach deep user insights. Methods with triggers were required to obtain user's tacit need and latent needs.
6. The service area of the deliveryman only limited in Tongji University. The way courier worked in campus was significantly different from the typical door to door service mode. The structured table was not able to reflect the actual situation of him.

After the problems were detected, the methods used for the first round field research were modified. And the research strategy was also reconsidered. More specifically, the improvement included:

1. Use observation as the first and the dominating method for the first round user research. Trivial information would be observed instead of raising boring questions.
2. Semi-structured interview was introduced instead of questionnaire. Information which could not be observed in routine process but in the Table 3.1 or questions generated during observation would be asked during the work of deliverymen.
3. Deliverymen working in different types of service area, for example, school, residential area, business area, etc. were planned to be studied. The requirements generated by different ways of delivery should be all taken into consideration.

Since the integrated method of observation and semi-structured interview was moved to be the first method, the choice of subjects' companies was just based on the result of previous literature research and actually opportunity.

5.2 Observation and semi-structured interview results

After several time's attempt, three deliverymen respectively came from ZTO Express, YTO Express and S.F. Express accepted the request. Observations throughout their full working hours were given on 14th, 17th and 24th March 2014. It was really flattered that the S.F. employee could join this research because the stipulations in this direct business mode company were extremely strict. His participation enabled the author not only compare the situation within two homogeneous franchise companies, but also compare the actual distinctions between different business modes.

5.2.1 Subjects' information

Mr. Yan, Mr. Gao and Mr. Li are the three main subjects of this round research whose brief profiles are listed as below. Besides them, about seven deliverymen were more or less involved in the semi-structured interview, and an estimation of over 40 express delivery employees were observed during the research. Common features can be easily identified on them. A general picture of this group people is described here as well.

Mr. Yan

Mr. Yan is a 22 years old deliveryman from ZTO Express. After graduated from junior high school, he left his home town to Shanghai. He has been worked as a deliveryman for over a year, but the first six months were spent in another company, Yunda. His service area is about 0.1 square kilometer includes Tongye Commercial Building, Tongji postgraduate student dormitories, two old residential quarters and a relatively modern residential building. The outlet he worked for is about 1 km away from the first stop of his delivery route. The electric scooter 'The king of load' mentioned in section 4.3.3 is his delivery vehicle.

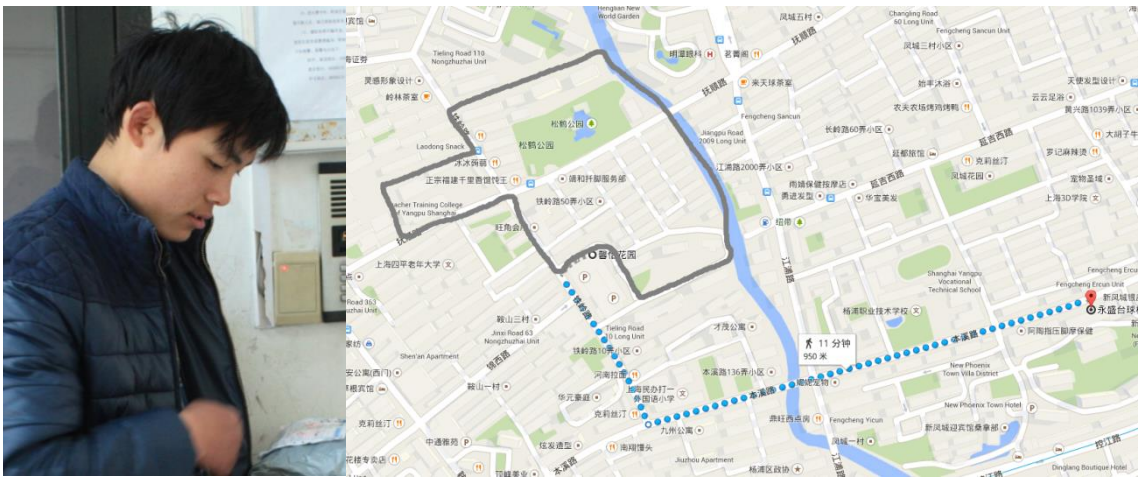

Figure 5.1 Mr.Yan and his service area

Mr. Gao

Mr. Gao is also 22 years old. He has only worked in the industry for six months. He is currently served for a modern business plaza called 'Hi-Shanghai' which is made up of three 21-floor business buildings and over 100 shops. Though the area of the plaza is not so big, the workload is really heavy on weekdays due to recent prosperous economy. An average of 10 minutes was spent on the 2.7km ride to the service area from outlet. The vehicle he uses is a poor-maintained 'Panther Sport', which looks almost the same as the 'The king of load'.

Figure 5.2 Mr.Gao and his service area

Mr. Li

Mr. Li is a 36 years old father of two kids. He used to start a small business in Henan Province after leaving his hometown Bozhou, Anhui several years before. However, the failure of business and the pressure from family made him turn to a job with stable income. He bought a minibus and joint S.F. express about half year before. As a large vehicle driver, he has to deliver or pick-up the big or heavy parcels of his outlets which cover a relatively bigger service area than others. Meanwhile, he also has an electric scooter given by S.F., which is used to deal with the business in his own responsible area, three business building and a small old neighborhood close to

Tongji University. The outlet he worked for is about 15 minutes' drive away from the service area, and traffic congestions happen all the time during the rush hours (shown in color yellow and red in Figure 5.3).

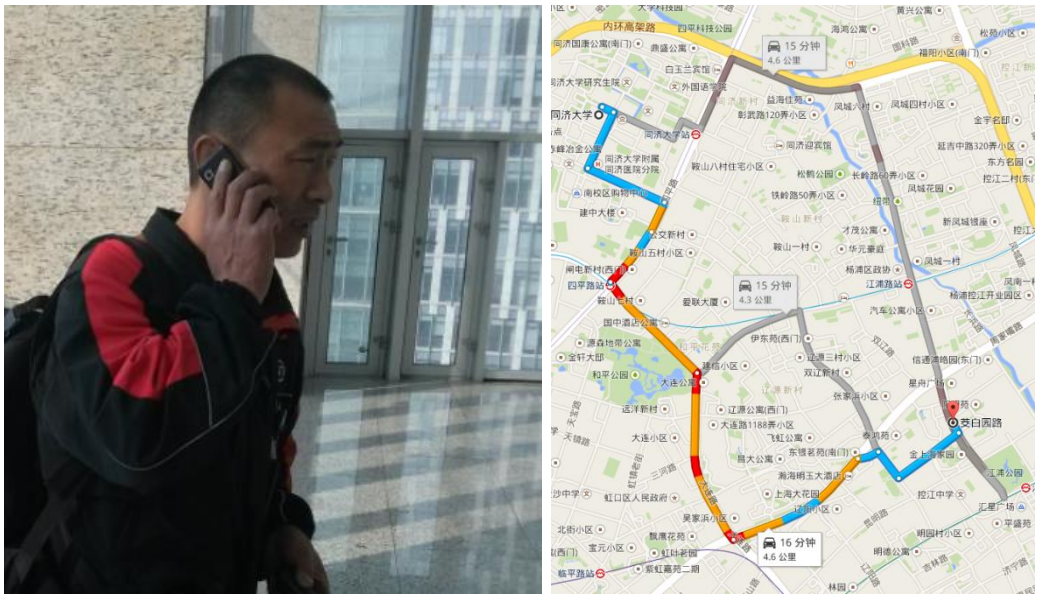

Figure 5.3 Mr.Li and his service area

A general picture of express deliverymen in private-owned companies

1. **Demographics information**

   Most all the deliverymen are young male due to this job's high demand of physical labor. Their age ranges from 18 to 40 and a majority of them are estimated younger than 25 years old. Almost none of them are local Shanghainese; they come alone from all over China trying to find their positions in this large city.

2. **Sociological traits**

   Many deliverymen started to go for a job once they finished China's nine-year compulsory education. Only a few of them have a diploma from high school or technical/vocational school. Various reasons were found to explain why they gave up their studies prematurely, for instance, the lack of interest, money issue, timeworn notion from family, the lack of local education resources, etc. The insufficient education somehow negatively influences their attainment, judgment, abilities of understanding and learning, world view and even life philosophy. Therefore, though their personalities are actually sincere and honest, some undesirable behaviors can be observed like using coarse words, dropping litters on street or some other violative/dangerous behaviors during service. Combined with the impression of dirty and sweaty, people regard this job as a low social status work in China. Not enough respects were given to their actual hard work.

   Comparatively speaking, employees from S.F. do have a higher quality and enjoy a much better reputation than others, which might be partly the result of strict company rules. They would collect trashes till they find a rubbish bin; they would use more polite words during talking and they would rather to walk for a small distance to smoke in the smoking room.

3. **Health conditions**

   Fatigue is the biggest enemy of deliverymen, extremely for those who are over 30 years old. They have to bend down thousands of times to pick up parcels on the ground, and go up and down hundreds of floors on foot every day. It is really common that in order to deliver a single parcel, a courier has to walk to the seventh floor and get down in some old neighborhoods without elevators. Combined with weather issue, fatigue greatly influences their service efficiency and attitude.

   Sleep deprivation is another problem. According to the interview, they work over 12 hours a day, from 8 a.m. to about 9 p.m. After diminishing the commuting time and meal time, only 6 to 7 hours are left for sleep, which certainly is not enough for massive physical labor works.

   The third is the smoking problem. Almost everyone is a smoker in the outlets they work. It becomes a popular method among them to release the working pressure. This problem not only endangers the safety

of parcels, but also threatens their own health.

4. **Career / job information**

Except S.F. Express, average of 12 hours per day are required from their work including weekends and holidays. Basically, they do not have any rest day until the coming of Chinese New Year. Comparatively, Deliverymen in S.F. have one day off every week, but still it seems not enough for their high workload.

The service areas they work in highly determine their workload. Average of 70 to 80 letters and parcels are delivered by a deliveryman every day, and in some busy area the number could reach 200-300. The number of the parcels they collect also varies in accordance to the area. Approximately 40-60 items can be picked up in general neighborhoods or business buildings, but in some area with online business dealer, three or four hundreds packages a day is not news.

The income of the deliverymen is mainly associated with the number of parcels they collect monthly. There are two ways to calculate their salaries depending on the type of their contracts. If a deliveryman works as an employee for the outlet franchisee, he could get a minimum wage round RMB 2,500 to 4,000 and a 10% additional bonus is added according to the gross revenue of parcels they collect. If a deliveryman works as a subcontractor of the franchisee, he would get RMB 0.5 to 1 reward on every parcel he delivered and all the revenue of picking up. S.F. Express only admits the first kind of contract due to their direct mode, but offers a more profitable way to calculate. RMB 4,000-5,000 is an average salary for deliveryman in 'Four TO and one Yunda', while S.F. employees could reach RMB 6,000–10,000.

Although the salary sounds not so bad, it can barely afford the living expenses in Shanghai. Combined with stressful working pace, employee turnover rate in these private-owned enterprises are quite high. According to Mr. Li, more than 20 people left S.F. in last half year.

5. **Attitude to current job and future plan**

Some of the subjects are satisfied with current job. They think working as a deliveryman is much freer than sitting in a small cubicle in office. They are able to control their time and enjoy certain level of autonomy as long as they finish the routine tasks.

While the others are relatively negative, they think their labor does not receive equivalent income and are tired from the repetitive endless work and low social status. They have to be trapped in this loath job for their lack of other skills or economic hardship, but sooner or later they would leave this industry.

No matter positive or negative attitude, 'money' and 'freedom' are the words they mentioned the most frequently.

5.2.2 Outlet study

Unlike the site selection of regular shops, the express delivery outlets are commonly located in some secluded streets. An outlet of 'four To and one Yunda' is literally an 80-100 square meter large place with many wire entanglement shelves and plastic crates marked with different destinations for sorting. The outlets in city center have a crew of 40-50 people and cover a range of no more than 10 square kilometer. In suburb area, they have a bigger delivery team and cover much wider. S.F. Express has a relatively denser outlets configuration to increase delivery and picking-up efficiency.

Figure 5.4 An outlet of ZTO Express

Each outlet is equipped with one or two trucks which are used to carry the parcels from the transportation hub. Several minibuses or cheap MPVs are used to carry the extra-large parcels or cargos over 10 or 20 kg according to company rules. The rest about 30-40 deliverymen use electric scooters/mopes to distribute the small parcels in their responsible areas.

5.2.3 Vehicle study

In the section 4.3.3, a product research and a benchmarking have been made to briefly understand the existing vehicles, but the information remains limited and need to be verified. In the field research, more detailed vehicle studies were executed to record vehicle data and user reflections.

Vehicle information

1. **Electric scooters**

   Generally, in companies like 'four TO and one Yunda', a deliveryman is required to prepare his own vehicle before joining an outlet. In some cases, the outlet owner may buy a scooter for the freshman, but RMB 500 would be deducted from his salary until paying off. Thus, various kinds of electric scooters or mopes could be found within one outlet. Unlike these franchise companies, S.F. Express cooperates with an electric vehicle producer, Luyuan, and manufactures a customized type of delivery scooter. These scooters have a uniform appearance but distinguished by mark number. Compared with those personal-owned scooters, vehicles of S.F. Express are all registered and commonly in well condition because of the regular maintenance. And after serving two years, these scooters would be eliminated and given to the employees freely.

Figure 5.5 Self-prepared scooter and S.F. customized scooter

No matter self-prepared or company customized vehicles, the primary features of them are quite similar, including:

• Overweight and overspeed. Although according to China's national standard GB 17761-1999 (1999), the design speed of electric bicycles shall not exceed 20 km/h and the entire vehicle weight shall be kept under 40kg, yet the actual vehicle weight is about 50-60kg due to the increasing mass of battery, and a top speed of 40-50 km/h can be reached after simple modification.

• Size: The vehicles are about 1,700-1,800mm long, 700mm wide and 900mm tall.

• Rear wheel drive: A hub motor is located in the center of the rear wheel providing kinetic power for the vehicle and the front wheel is connect to the handlebar to manipulate moving direction.

•Controller-concentrated handlebar: The controllers of almost all the vehicle functions can be found on the handlebar. On the left side, three buttons respectively controlling headlight, turning light and horn are place from top to bottom; while on the right side, an accelerated handle and a speed shifting button are placed. A simple HMI panel is located in the middle with information of battery, speed, frequency conversion, and turning direction displayed.

• Foldable cargo shelves and front basket: In order to carry more parcels than regular scooters, a special-designed foldable shelf/back seat and two cargo holders are place in the rear side. In addition, a 350 ×300×300 mm front basket is designed to store small personal effects . Metal-frame baskets are the

most common one, whilst more advanced waterproof lockable baskets are mounted on S.F. customized scooters.

• Remote control locks: Remote control locks are now widely applied on electric scooters as well. The buttons on the lock can disconnect vehicle battery but could not prevent from stealing.

• Long charging time: 6-10 hours are required for every charge. The charging is always done overnight and sometimes during lunch break if required.

Figure 5.6 Details of electric scooter

2. Modified minibuses

Since only one minibus had the author approached and a modified minibus is actually nothing special than an ordinary petrol vehicle, the study of it was not as detailed as the scooters. Only several essential points were recorded.

• The same as electric scooter, a deliveryman should prepare the vehicle before he join an outlet. Even S.F. Express follows the same rule as well, but an additional RMB 200 petrol allowance is given to the owner every month.

•The minibuses used for delivery are usually second-hand vehicles. The maintenance and vehicle conditions are commonly not so good.

• Except the driver seat and front passenger seat, the other seats are removed to place cargos. Therefore, the driver compartment and so called 'cargo compartment' are connected together, which seriously violates national standard GB T 3730.1-2001 and Road Traffic Safety Law of People's Republic of China

• Since all the rear seats are removed, both side door and back door can be used in loading and unloading, which somehow provide a little higher efficiency.

• The lockable storage places in the vehicle are perfect for personal effects and working material.

• Air-conditioner, radio, big soft seat and close driving compartment provide a very comfortable interior for deliveryman to have short rests.

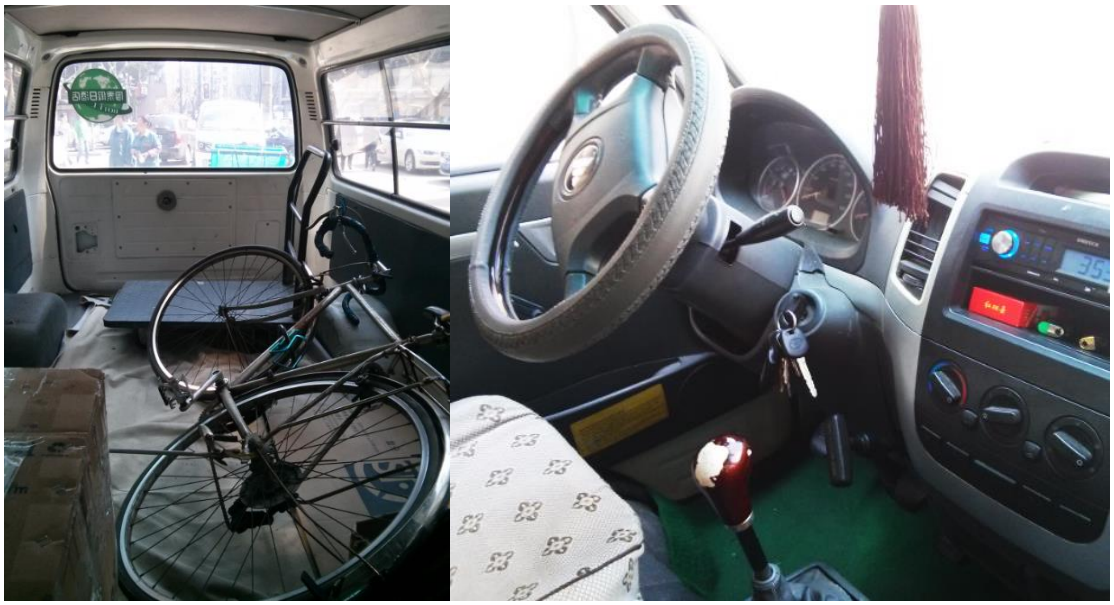

Figure 5.7 Details of modified minibus

Cargo arrangements

There are three places that the deliverymen can place the cargos, front basket, middle footboard and the rear foldable cargo shelves. Generally, parcels with fragile objects or parcels easy to be delivered are placed in the front. Medium sized boxes or a parcel bag are arranged in the middle and clamped by legs during driving. The iron cargo shelves is used to fix large boxes and big woven sacks. In some cases, the cargo height on the rear side is even taller than driver's sitting height.

Some deliverymen choose to mount a 880×600×450mm blue plastic basket on the rear which is believed to provide a more stable ride and effectively prevent the cargos from damage or missing; while most of the others are not willing to use it because the volume of basket limits space and highly reduce the flexibility during loading.

Figure 5.8 Cargo arrangement

Reflections on existing vehicles

The special design of rear cargo shelves shows that the manufacturers of these electric scooters are trying to integrate some appropriative components to improve their vehicles' performance on freight carrying, but still these vehicles are not designed for express delivery purpose. Likewise, though modifications have been made on passenger minibuses, the inherent design still brings many inconveniences to the driver. A dozen of problems or dissatisfactions appearing in existing vehicles/situations have been identified and reflected by both deliverymen and the author, and are listed as following.

1. **Overload**

   Overload is an inevitable problem for express delivery enterprises. Since electric trikes are not allowed to use in big cities and legal freight vehicles are forbidden to enter center areas in rush hour, overloaded scooters seem to be the only choice for them to maintain the business. A maximum payload is 75kg for the current delivery scooter, but the actual load is much heavier than that. The deformations of cargo shelves can be seen on many scooters, and excessive wear and tear can also be observed on brakes, tires, body and some other components.

   In addition, as mentioned before, electric scooters are only in charge of small or medium sized parcels during delivery; extra-large parcels or cargos over 10 or 20 kg are carried by minibus. But in the picking-up process, if a deliveryman, especially those who works as a subcontractor, receives an overweight package, facing the inducement of considerable profits, he would not transfer the business to others but try to transport the heavy load by himself.

   The increasing overload problems have got the attention from the government. With the execution of the national wide "Notice on Strengthening Road Safety Work" (see section 4.3.2), strict control is to be carried out really soon. But how to solve the delivery problem without overload becomes a new topic for private-owned enterprises, and the answer still remains unknown.

2. **Overspeed**

   Like overload problem, overspeed and aggressive driving phenomenon widely exists in express deliverymen too. Their overloaded scooters ride about 30 km/h on the road and sometimes even speed up to catch up with customers. The high accident rate mentioned in section 4.3.1 has demonstrated that they are becoming the road killers and accident victims at the same time.

   According to Mr. Yan, Mr. Li and Mr. Gao's manager, an average of one or two traffic accidents happen annually within an outlet. And according to a rough search on Baidu Map, there are 1,785 express outlets in total in Shanghai. If 1.5 is set as the annual traffic accidents number of each outlet, express deliverymen are involved in at least 2,678 accidents yearly, i.e. an average of 7.34 accidents happens on then every day in Shanghai. And this is just a conservative estimation; the real situation may be much more severe.

   Moreover, almost none of the deliverymen use a helmet to protect them during driving. As they explained, it is really uncomfortable to keep the head long time in this airtight protector, and some of the recipients may feel odd and uneasy when facing a man in helmet. The absence of protection makes the result of accident even worse.

3. **Driving performance**

   Even not in the overload situation, the improper weight distribution of cargos can easily cause the imbalance of these two-wheeled vehicles as well. The scooter might keep leaning to a certain direction which is fairly dangerous when passing uneven surface or going downhill.

4. **Insufficient battery**

   The overload problem also influences battery consumption. The 48V battery package can theoretically support a ride over 100km per charge, while the maximum range a deliveryman goes every day is no more than 20km. Even so, they still need to charge the scooter once or twice a day. Except the problem of aging battery, the heavy load as well as frequent starting and brake consume more power than normal situation.

5. **Legality**

   No matter the scooter or the minibus drivers, they all have the experience of being stopped by the police and got a ticket from RMB 20-200. They are certainly aware of the illegality of their vehicles or overload behavior, but nothing they could do to solve the contradiction between legislation and work. Since the companies are not over the fine, they have to suffer the financial loss by themselves.

6. **Economic benefits**

The gradually increasing petrol prices raise the operating costs of the minibuses. “Although I could earn RMB 7,000-8,000 per month, the monthly fuel cost is about RMB 1,500. Combined with the annual car insurance fee and regular maintenance, I could hardly afford this vehicle anymore” said Mr. Li. The electric scooter deliverymen also try to save their cost on electricity as well. They tend to charge at companies rather than at home so that the outlet owner would pay for the electricity expense.

7. **Vehicle stealing**

The anti-theft function is one of the essentials that the deliverymen concern the most. Not only because the price of a scooter is close to their half month’s salary, but also the parcels they sometimes left on the vehicles may have a great value, for instance, a simple piece of paper in a regular envelope may be a contract and worth over a million RMB. Though the remote control lock is used together with regular ring locks, vehicle stealing cases still take place again and again. In addition, instead of entire vehicle, some thieves turn to steal the most value part of the vehicle, the portable battery pack, which is more secluded to be discovered.

8. **Cargo protection**

It is not practicable that a deliveryman bringing all the parcels climbs to the 7th floor just to do a single delivery. In most cases, they have to leave bags and boxes of stuff on the vehicle and rushes up and down stairs to reduce the unguarded period. But anyway, the left parcels give access to burglars, which causes parts of the missing problem.

The other parcels loss problem is induced by unstable cargo arrangement shown in Figure 5.8. Parcels’ frequent dropping out during driving was observed in the three days. If not noticed by the deliverymen, the cargo is unlikely to be found again.

Weather is also a crucial factor for cargo safety. Although in rain and snows days, deliverymen would use raincoat to cover their parcels. Water still inevitably invades the packing material and cause damage on non-waterproof objects inside. And sometimes strong wind can blow away envelopes or other light stuffs

9. **Flexibility**

Although after loading, the width of the scooter is about 1,000mm, it still enjoys a high flexibility especially in some narrow lanes in old neighborhoods. It can pass through many shortcuts and is allowed to get into some new residential estates with strict management. On the contrary, the big size of minibus excludes itself from many areas. It is either too big to fit into the small street or forbidden to enter private estates. The deliverymen have to carry the extra-large or heavy cargos to walk for a long distance to reach the recipients.

10. **Parking**

Mr. Li parks his minibus in a small piece of open area in front of Bohai Bank which is a client of him and allows him to do so. But more often, the minibus drivers have to face the parking problem as mentioned in 4.3.1. They have to park their motor vehicles in the nearest road and rush during on foot delivery to avoid getting tickets.

Comparatively, parking space is not a big problem for the smaller scooter, but the design of the parking components is a common issue. Almost all the scooter drivers complain that the short middle supporting foot often makes the vehicle lean too much to the left. After loading certain amount of goods, the scooter is more easily to fall down due to the elevated center of gravity. And though the rear supporting feet can provide a more stable vehicle position, the location of it is too bad and requires a very large force to lift it. What’s more, the hard spring on it could not provide a smooth parking process; the vibrations generated during lifting and putting down usually cause the loose of rubber ropes which fix the cargos.

11. **Comfort**

The seat cushion is relatively hard. It is uncomfortable when sitting for a long time. And often, the sitting postures of deliverymen are twisted in order to leave space for parcels on the footboard or rear shelf, which also increase their fatigue.

12. **Ingress and egress**

After loading on the medium footboard and rear shelves, getting on and off the scooters becomes extremely difficult. In most cases, deliverymen search help from their companions or drop footboard cargos on the ground first then get off. The later behavior might have chances to cause parcel damage.

Expectations

Exceptions on a new generation of electric delivery vehicle were also given by the subjects during the study. Parts of it are the suggestions to the current vehicle, whilst the rest come from the description of their ideal products.

1. Have enough space for cargos.
2. Protect the driver and cargos from bad weather.
3. Use electricity as energy.
4. Have a more durable battery package (not necessary to be a dismountable and portable one).
5. Drive without motor vehicle driving license.
6. Get the permission and authorization from government.
7. Be cheaper than RMB 5,000 or let the companies buy for deliverymen like what S.F. Express do right now.
8. Be smaller than minibus for parking consideration.
9. Keep the flexibility as scooter.
10. Equip stronger wheel rims and wider tires.
11. Improve the design of both supporting feet.
12. Add turning lights and brake lights in the rear side. And increase the illumination of the headlight.
13. Delete unusual or not understandable information on the HMI panel.
14. Use tipping components to help to load and unload cargos.

5.2.4 Cargo study

The features of the delivery objects, cargos, also have a great influence on the entire delivery process. Understanding the properties of cargos and existing situations during cargo transportation is beneficial for designing a more suitable delivery vehicle.

Cargo properties

There are two main types of the cargos, documents and packages. Documents are always enclosed in the special-made envelopes with delivery companies' logo printed on, while the form of packages varies with the objects inside. Generally, they can be different sized corrugated paper, plastic bag or bubble wrap covered boxes or other geometries. The weight of them also differs a lot, but deliverymen with scooter only deal with the ones under 10kg or 20kg according to different companies' rules. Most of the parcels are not waterproof, and some of them are not well-packaged to resist severe extruding, jolting or falling.

Figure 5.9 Different packages of parcels

Existing situation during cargo transportation

A series of activities combine into the entire procedure of distributing or collecting parcels. Generally, it contains six main aspects, sorting, loading, driving, unloading, delivering and collecting. The following part focus on the deliverymen using scooter in franchise private-owned express delivery companies first, facts of deliverymen in S.F. Express or minibus drivers are conclude in the last paragraphs of this section.

1. Sorting

In the sorting process, relatively small packages together with documents are gathered and place into woven bags according to their destination. Different woven bags symbol different areas which are decided by the deliveryman according to his convenience. The order of the parcels placed in the bag is according to their address, i.e. the sequence of delivery. Things to be delivered earlier are placed on the top, while the later one to give out lies on the bottom.

20-50 parcels are usually enclosed in one bag which weighs about 15-30 kg and has a maximum size of 1,200×800×300mm. After finishing bagging, the deliverymen would tie or tape the woven bag. Sometimes, one or two parcels may be left out, they have to unfasten the tie and order again.

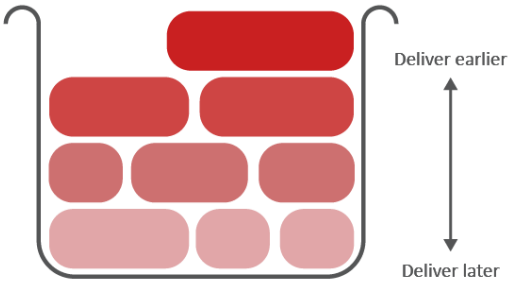

Figure 5.10 Cargo sorting

2. Loading

The woven bags together with several relatively large parcels are fixed on the rear foldable cargo shelves. The placement of big cargos only concerns their sizes rather than address. Proper sized boxes are place on the cargo holders on both sides first to increase the area of thrust surface, and then larger and heavier bags would be laid on them. After that, rubber ropes or bicycle tubes are used to bind and tighten all of these cargos to the scooter. The rest parcels or bags are put on the footboard with the help of other courier and clamped by driver legs during driving. Usually 2-5 woven bags and 4-12 boxes can be carried each time.

Several problems are identified in this phase.

- The 15-30kg the woven bags are actually much heavier than the boxes. Placing them in a higher place needs lots of efforts
- Some big boxes may fairly empty inside. The heavy bag weight on them can easily causes deformation and damages the object inside.
- Placing the heavier cargos on higher place also raise the height of vehicle's center of gravity and makes the scooter wobble more fiercely during loading
- The process of fixing cargos with rubber ropes or bicycle tubes is really time-consuming and the effect is less than desirable.

Figure 5.11 Cargo loading

3. Driving

The problems occurred during the loading are extended to the driving process. With the movements of vehicle some problems are even magnified

- The deformation of the lower boxes become more severe, which may not only cause the damage of objects inside, but also change the weight distribution and lose the rubber ropes.
- The high center of gravity and unbalanced weight distribution reduce the stability, flexibility and other performances of the vehicle.
- When meeting uneven terrain such as bumpy surfaces or deceleration strips, the loosen ropes caused by box deformation increase the risks of dropping out.
- The cargos on the footboard may cover some information on the HMI panel, and the volume of rear cargos can influence the view of other drivers driving behind.
- After loading, the scooter drivers do not have accurate judgments on the entire width.

Figure 5.12 Problems during driving

4. Unloading

Most of the deliverymen tend to find a place to store some later-delivered parcels first. They unload all the goods and reorganize the bags and boxes on the vehicle. The whole unloading process is relatively violent. After the deliverymen unfasten the rubber ropes, some cargos directly fall on the ground one after another. The same as loading, lots of efforts is required to remove the higher big heavy woven bags.

Figure 5.13 Problems during unloading

5. Delivering

Although the packages inside a woven bag are placed according to delivery sequence, after the bumpy driving and violent unloading, the order starts to be somehow disrupted. When the deliverymen begin delivery, they still need some time to find certain package.

As the parcels are gradually delivered out and combined with the inappropriate behaviors like dragging bags during walking or going upstairs/downstairs, the order inside the woven bag is completely disrupted. The 'turnovers' of leaving out become quite often and more time is needed to find a specific parcel in the mess, as shown in Figure 5.14.

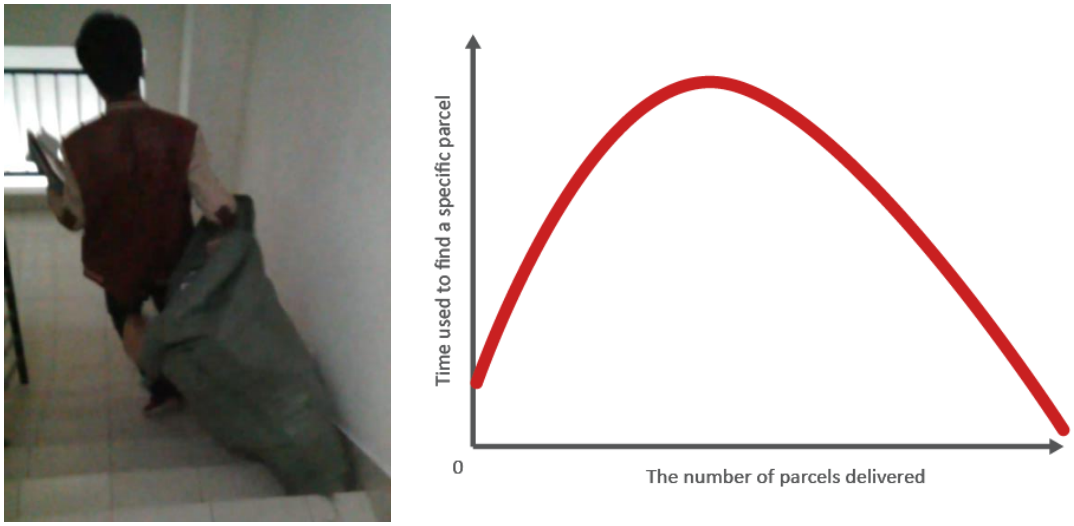

Figure 5.14 The relationship between 'time to find a parcel in bag' to 'number of parcels delivered'

In addition, different deliverymen have different ways to deal with the documents; some of them just mix the envelopes with small cargos, and arrange according to the address; while some others collect them and put on the side of the woven bag together. The first method may cause the damage while another might be easily forgotten by the couriers and leads to the leaving out 'turnovers' as well.

Another problem lies in the delivering phase is the security of cargos. As mentioned before, a majority of the deliverymen tend to find a place to temporarily store their later-delivered goods, and in most cases, they leave the rest parcels on the vehicles during delivery. In order to prevent the cargos from thieves, sometimes they turn to the doorkeepers and securities for help, or they choose to park the scooter in the range of a monitor. However, in most conditions, these methods cannot be approached; cargo is still in the unguarded situations.

Figure 5.15 Unguarded parcels

6. Collecting

The collecting process is almost the reverse order the delivery. The number of parcels collected is highly dependent on the service area. Due to the temptation of profits, no matter how many parcels a deliverymen receive or how heavy the parcels are, he would try to transport them all back to the outlet by himself. The same as the sorting phase, small cargos and envelops are enclosed in the woven bags, but without ordering by address.

The deliverymen with scooters in S.F. Express almost have the same process, but they only carry about one-fifth to one-third amount of the cargos as the franchise deliverymen in order to realize a much higher motility and delivery efficiency. Instead of the woven bags, they use a company customized waterproof large knapsack to contain envelopes and small packages, and put it on their back or on the footboard during driving. Due to the strict company rules, during the delivering or collecting process, the parcels are either in the knapsack on their back or held in their hands, no inappropriate behaviors happens at all. But the way they transport large parcel boxes is the same as other companies and left the parcels unguarded on the vehicle is also a big problem for them.

Figure 5.16 Deliverymen of S.F. Express

Cargos delivered by minibus are either extra-large or over 10/20kg. Cargos' position on the bus also arranged according to the address. The things to be sent out earlier are placed closed to the rear door and the last one to deliver is arranged close to the driver. Both rear door and side doors can be used to finish unloading. And a platform cart is used to help during delivering and collecting process.

5.2.5 Other carrying articles

Besides cargos, deliverymen also carry some other articles with them to support their work. These articles can be mainly divided into three categories, delivery supplies, tools and person effects.

1. Delivery supplies

Delivery supplies include envelops, plastic bags, blank express waybills and receipts. Needless to say, envelops and plastic bags are used to pack customers' documents and articles.

A waybill is actually a contract between a sender and the company, and a receipt for the recipient. A waybill usually has several sheets; taking FedEx for example, it includes a sender's copy, a manifest billing copy, an origin copy, a customs copy, a destination copy and a recipient's copy. Different copies are saved by different subjects, the sender, the picking-up outlet, the destination outlet, the deliveryman and the recipient.

Chinese express delivery companies usually use a waybill with 4-5 sheets. After a deliveryman gets the recipient signed on a waybill, he should carefully keep the receipt sheet for later scanning. It is a crucial evidence for him to show that he has finished this delivery in time. At the end of the day, by comparing the number of parcels he should deliver and the number of the receipt in hand, the deliveryman can know if any parcel is missing or left out.

2. Tools

Tools refer to the objects that help the deliverymen in finishing certain tasks. Generally, a deliveryman carries the listed things in their vehicles, several ball pens, a knife, tapes, a small electronic scale, raincoat and a portable scanning gun. The stuff in S.F. express are required to additionally bring a small multi-functional waist bag, a portable receipt printer and the big knapsack with them, and wear in company's uniform. As a minibus driver, a fire extinguisher is obliged to place in the vehicle.

3. Personal effects

Besides the regular personal belongings like a cellphone, a wallet and keys, most of the deliverymen have packs of cigarettes and a lighter with them. And due to the nature of work, a bottle of water and small snacks are also necessary for them.

Figure 5.17 Delivery supplies and tools

5.2.6 Environment information

The environment issues also vastly influence the delivery activities. Two categories of environmental factors are discussed here, weather and climate as well as traffic and road condition.

Weather and climate

Monsoon climate of medium latitudes are mainly distributed in the region north of the Qinling - Huaihe River, where Beijing, Tianjing and many other industrial cities are located. Monsoon climate of medium latitudes are known for its warm and rainy summer as well as the cold and dry winter. And with the growing heat island effect, the highest temperature have reached an astonishing level, 40℃ for many times, and the rainy days are also greatly increased.

Subtropical monsoon climate is the major climates of China's eastern and southern coastal areas. Famous economical cities like Shanghai, Nanjing, Guangzhou, Shenzhen and hundreds of medium and small size cities are all located in these areas. While enjoying the same hot and rainy in summer as northern cities, the winter is much more wet and humid. The annual rainfall of these areas is over 800 mm, and frequently suffers from the typhoons coming from the Pacific.

Therefore, as a long-time outdoor work, the hardships of the deliverymen can be easily imaged. As Mr. Yan said, "In order to withstand the cold, gloves, masks, hats and knee pads have to be worn throughout the winter. Though it is incontinent and still cannot resist cold, it is much better than the inescapable hot in summer." Rainy days are also the enemy of them, besides the incontinence they brought to the delivery process, the acid rain water also endangers their health.

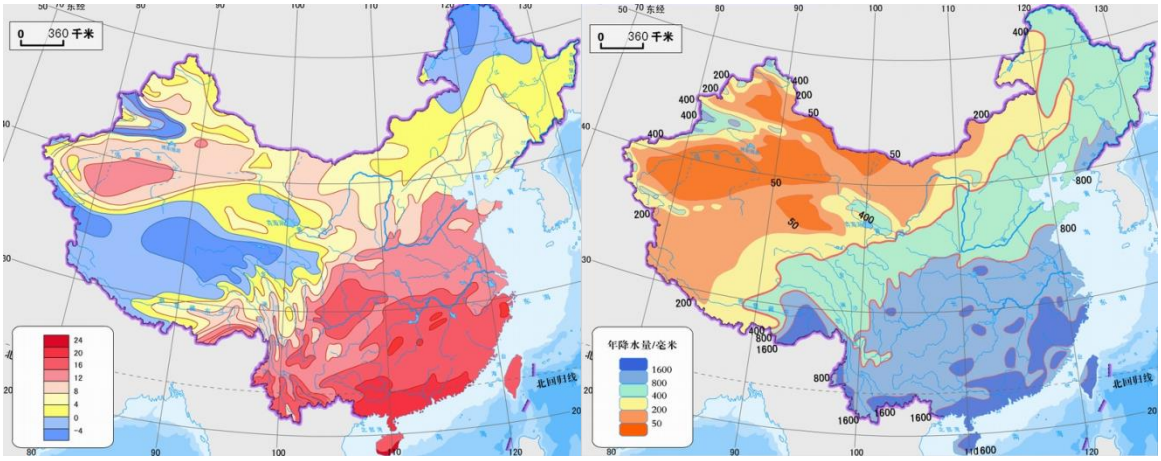

Figure 5.18 The annual average temperature (left) and annual average precipitation of China (right)

Figure 5.19 Deliverymen working in summer, winter and rainy days

Road and traffic condition

The road condition vastly influence the deliverymen's driving comfort. Although most of main roads in cities are relatively new and flat, the road conditions in small streets and lanes are still not satisfying. Breakages and bumps are pretty common, and some sections are left muddy. Solid vehicle structure and good suspensions have to be provided to meet the situation.

Figure 5.20 Road condition in small streets and lanes

The traffic conditions are also closely related to the delivery efficiency. In a majority of big cities, the situations are not optimistic. Besides the large-scale severe traffic jam in rush hours, long time congestions also exist in some small ranges. In addition, some traffic restrictions such as restricted zone, one-way streets, roadblock, etc.

limit the passage of road vehicle as well. According to the vehicle passage capability research done by Zhang (2013), the common width of the non-motorized vehicle lane is about 2,000mm and distances between roadblocks in some motor vehicle restricted zone ranges from 1,440 – 1,700mm. And considering that the delivery vehicles have to go through the narrow street in old neighborhoods, ensuring great mobility is quite essential for the design.

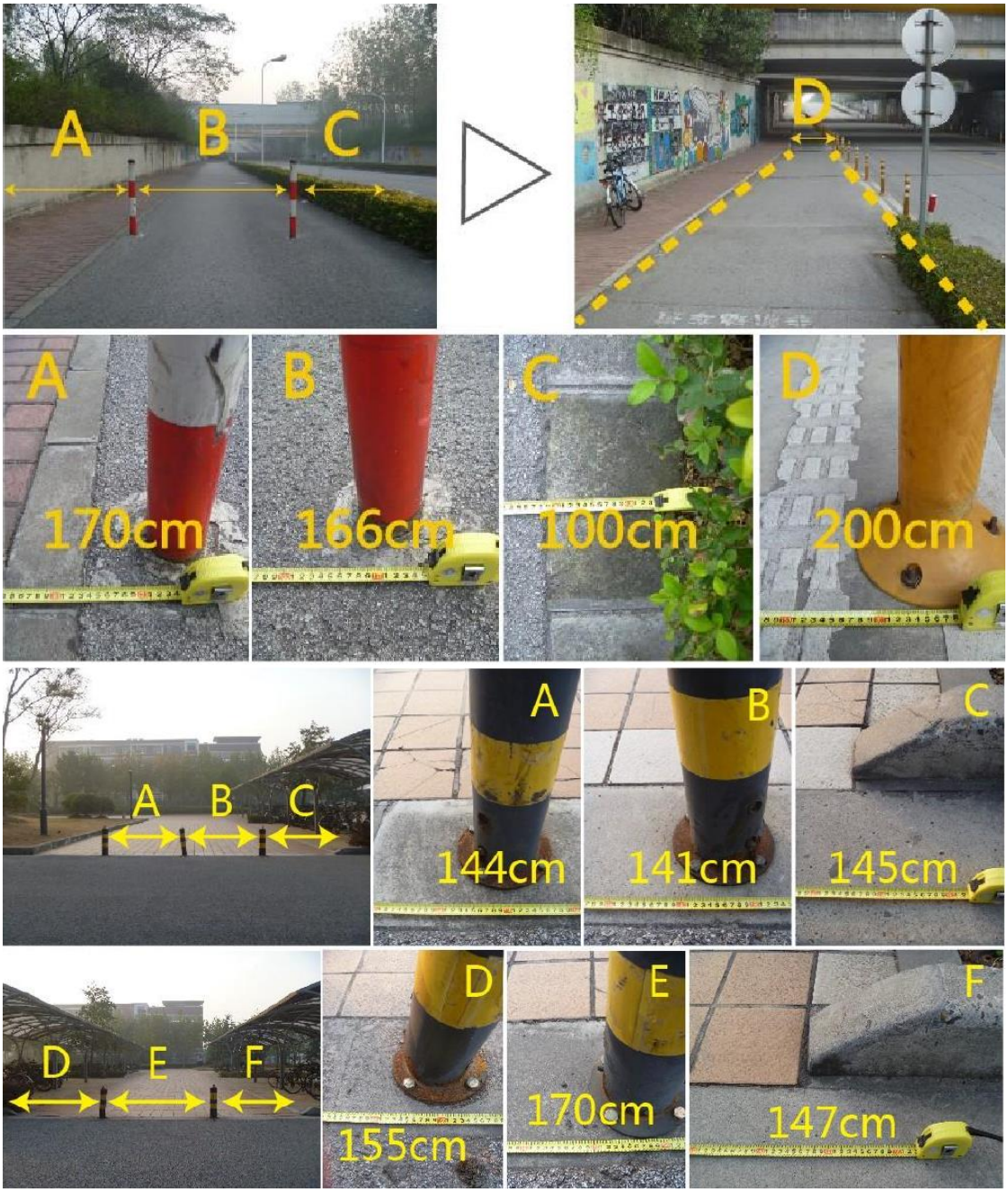

Figure 5.21 Vehicle passage capability research (Zhang, 2013)

5.3 Delivery activities analysis

After got the information from the first round research, activity-centered design theories are implanted to process the data. Norman's activity theory could effectively classify the information in accordance with different activities and hierarchical levels, and quickly eliminate unvalued information. Undesired behaviors can be discovered and analyzed via The Theory of Interpersonal Behavior. Influencing factor behind these unexpected behaviors would be sorted in line with the three dimensions in the model, and the sketchy solutions can be proposed

As mentioned before, the entire express delivery process is made up of a series of activities, including sorting, loading, driving, unloading, delivering, collecting, etc. Besides the inherent defects of the vehicles or cargos, a majority of the reasons of current unsatisfying service quality are actually because of the problems existing in the delivery process. In the following segments, activity-centered design thinking is used to figure out the reasons of the less satisfied situation. Undesirable behaviors are identified and the inducements of the behavior are analyzed for later design.

5.3.1 The workflow of Chinese private-owned express delivery companies

Before starting to study the activities, the workflow of Chinese private-owned express delivery companies should be understood. In section 4.2.1, an illustration of key stages of a typical express delivery is displayed, but it is a general image of the industry working procedure and more close to the express delivery workflow in European countries.

After processing the information gathered from research subjects, a flow chart illustrating the stages of China's inter-city and intra-city delivery process is done as shown in Figure 5.22. The entire workflow can be seen as the combination of three phases. In the first phase, deliverymen use electric scooters to pick up the parcels from the customers and carry them to a local outlet. Then in the second phase, the parcels from different local outlets are transported to a local sorting center by trucks; inter-city cargos would be pick out and send to a transshipment hub or a destination's sorting center, while intra-city articles would be transport to some other local sorting center or directly ship to the destination outlet. The third phase is actually the reverse order of the first phase; deliverymen in destination outlet would distribute these parcels and get consignees signed on the receipts.

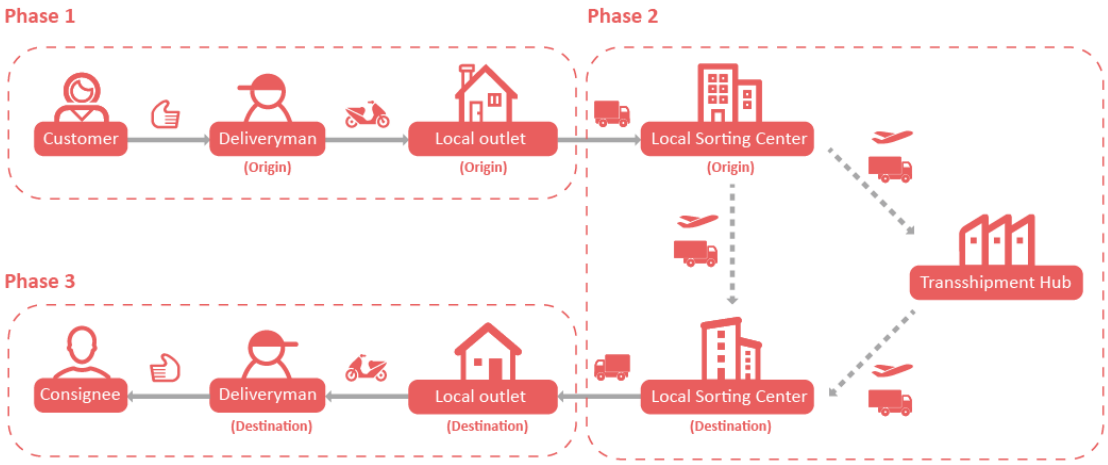

Figure 5.22 The key stages of a Chinese domestic express delivery

Since the intra-city delivery vehicles are used in phase one and three, more detailed workflow within these two phases are looked into. Figure 5.23 is a detailed illustration of the daily workflow of a franchise company. It can be observed that massive parcels are overnight transported to the local sorting center by air and road. In the early morning, trucks carry all these parcels to the corresponding outlets, and rush back and park at the sorting center to avoid morning restricted hours. After a series of activities of sorting and loading, deliverymen start to send out these parcels from 9:00 a.m. and have to finish before 13:30 p.m. or 14:00 p.m. according to different companies' rules. Meanwhile, around 10:30 a.m., the trucks start to carry another batch of goods to the local outlets. These goods are actually tardy ones due to the delayed flight or congested road traffic, so the amount of them is usually much less than the previous batch. After a short lunch break, the deliverymen begin to deliver these "tardy goods" at 14:30 p.m., after that, they spend about four hours to collect parcels from senders and transport then to the outlet. At about 20:30 p.m., after all the deliverymen get back with their "harvests", all the collected parcels would be sorted, packaged and moved on the trucks, which travel back to the sorting center for the next day's air or surface transportation.

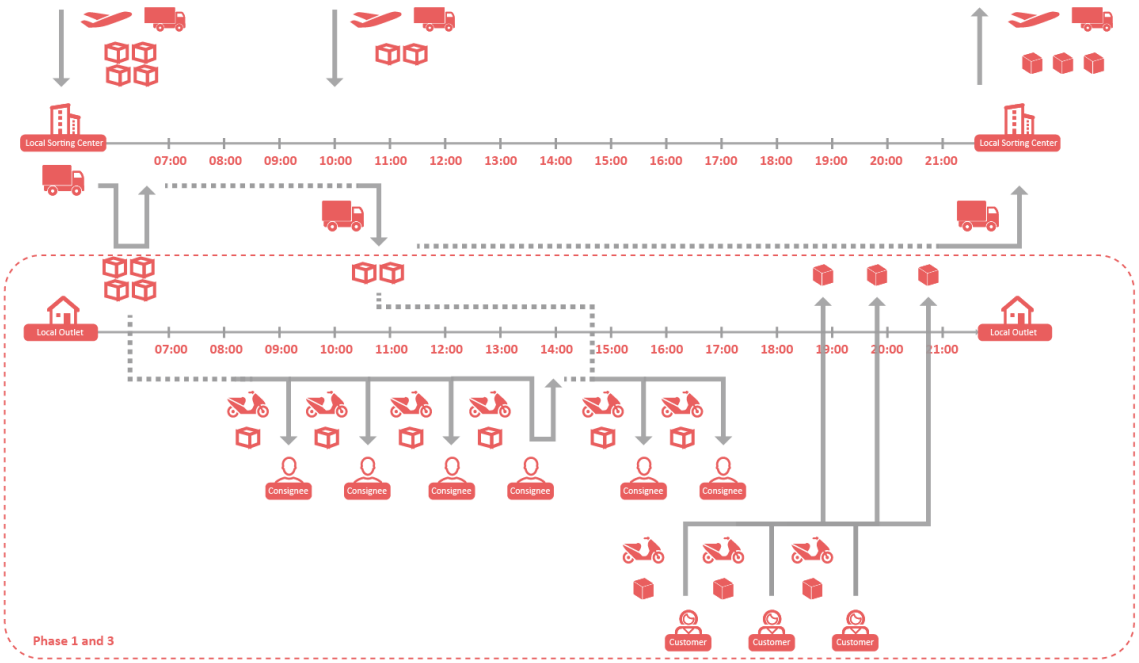

Figure 5.23 A detailed illustration of the daily workflow of a franchise company

Figure 5.24 shows a diagram of the daily workflow of S.F. Express. Basically, this direct mode company follows the same structure as the franchise ones but works in a more efficient ways. The differences mainly reflect in three aspects. The first is more batches of cargos are transported to the local sorting centers and local outlets in a day. This is because of the solid infrastructure construction S.F. has made mentioned in section 4.2.4. The massive amount of morning cargo can be well split by more turns of air/road transportation in the previous day. Via the precise control of the fully-processed fourteen cargo airplanes and thousands of well-conditioned motor vehicles, the company is able to capture the most important value in this industry, time efficiency. Second, it can be observed that the S.F. trucks are able to get in the city area during the morning rush hours. This is actually because S.F. Express has got the license from road and transport authority of Shanghai due to its good reputation. The third is that the S.F. deliverymen do the delivery and picking-up at the same time. According to Mr. Li, there is a 'two hours-one hour' stipulation in the company, which means that a deliveryman should finish delivery a batch of parcel in two hours; and after get the message or call from a sender, a deliveryman should go and pick up the parcels within one hour. Therefore, for example, a parcel customer delivered at 9:00 a.m. can reach the outlet at latest 11:00 a.m., and then be placed on the truck left at 13:30 p.m.; it is very likely that the parcel are able to leave the sorting center at 16:30 p.m. instead of the midnight or next day's early morning. The only defect of this system is its high operation cost, but the fact has indicated that a majority of customers are willing to pay for the high efficiency and parcel safety.

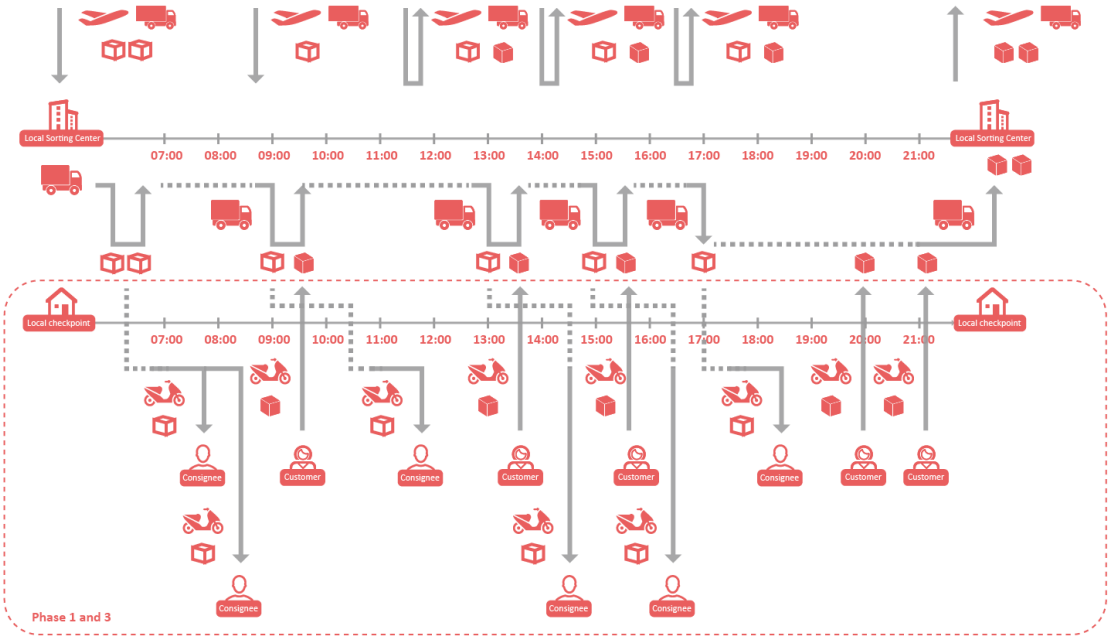

Figure 5.24 A detailed illustration of the daily workflow of S.F. Express

5.3.2 Activities in express delivery workflow

After understanding the daily workflow, deliverymen's routine activities are studied, including sorting, loading, driving, unloading, delivering, collecting, communicating, etc. Norman's activity theory (see section 2.2.2) is used combined with the HTA to disassemble activities to tasks, actions and behaviors, and The Theory of Interpersonal Behavior (see section 2.2.2) is applied to find out the influential factors of the undesired behaviors. Deliverymen with scooters are the main subjects in this phase, minibus drivers are temporarily not considered in these segments.

Activity 1 - sorting

Deliverymen start their work around 8:00 a.m. every morning. The first thing they do after arriving at the outlet is beginning to sort the parcels brought by the trucks in the early morning. The sorting activity contains three primary tasks including scanning parcels, sorting parcels and bagging parcels. The purpose of scanning a parcel is to create a digital record in company's system to show that this parcel is received by the outlet and ready to be delivered by certain deliveryman. Then they would roughly categorize the parcels in accordance to their address by putting them in different positions. After that, woven bags are used to enclose the small packages and documents, while large parcels are left aside waiting for loading. The detailed actions involved in the three tasks are listed in Figure 5.25. In some situations, they may do scanning task and sorting task at the same time. The sorting activity also occurs in the other time when they receive a new batch of cargos, i.e. round 14:30 p.m. for franchise companies' deliverymen, and about 10:30 a.m., 13:00 p.m., 15:30 p.m. and 17:00 p.m. for S.F. employees. An average of two hours is spent on sorting activity every day; this period is relatively time consuming and could not bring any profits to them.

Bad behaviors are observed concentrating in their 'putting down/aside' actions. Instead of handling with care, most of the deliverymen in franchise companies rudely throw the parcels on purpose, even including the ones marked with 'fragile objects'. By using The Theory of Interpersonal Behavior, this inappropriate behavior can be viewed as a combined result of negative attitude, the absence of roles, poor habit and less external constraint. Since the outlet owner would pay for the damage of the parcels instead of them, deliverymen's evaluation of behavior outcome is incorrect, which make them hold a wrong attitude towards the improper behavior. In addition, the outlet owner's acquiescence of this behavior and the imitation of other deliverymen make this phenomenon even worse. And the most important inducement is the lack of external constraints. In the contrary to the franchise employees, S.F. stuff treats the parcels with much more care because of the strict rules in the company. Since both of the intention factors and habit factors are moderated by the external facilitating conditions, the rigorous company management plays the strongest role in restricting their behavior.

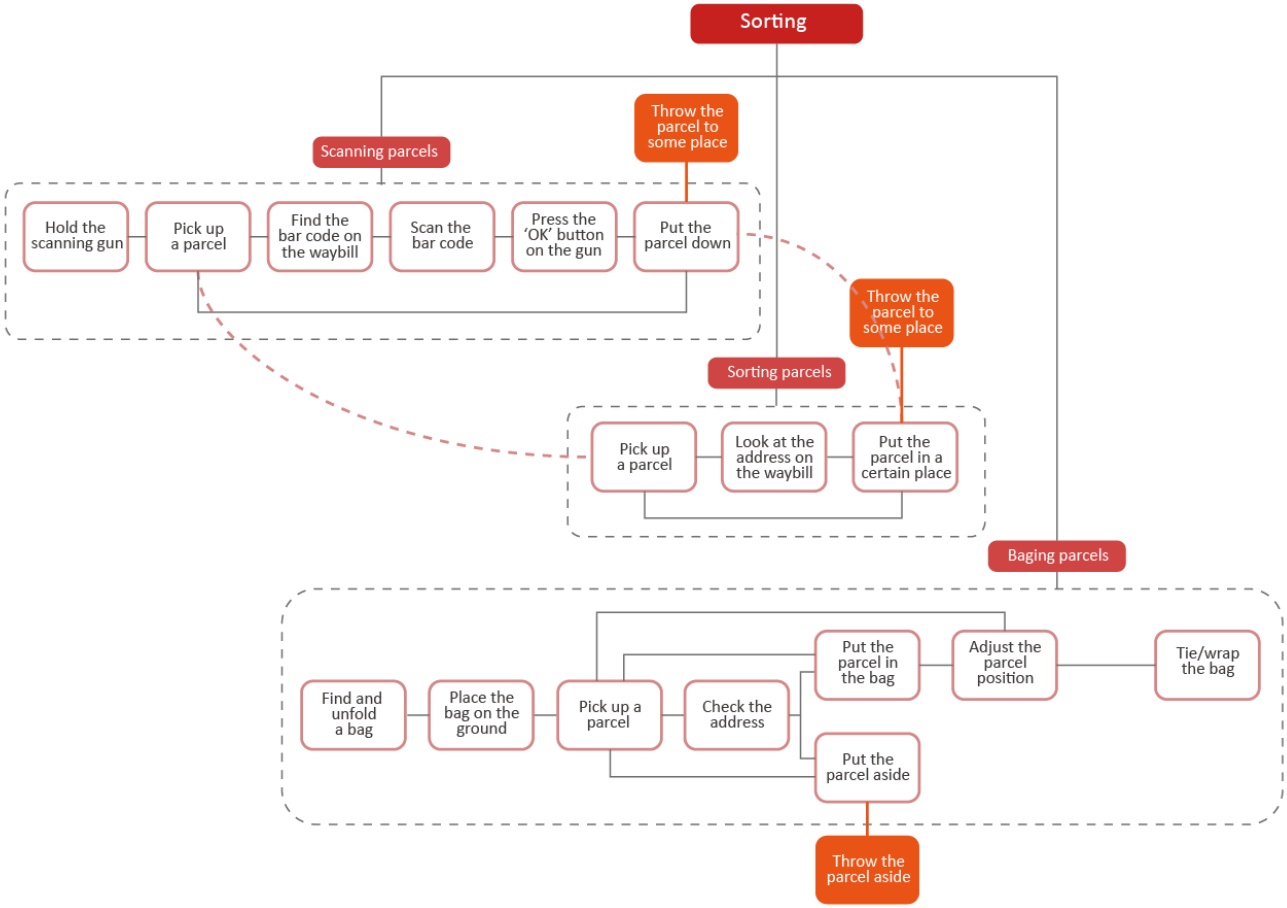

Figure 5.25 Tasks and actions in sorting activity

It is really hard to alter deliverymen's attitude, roles or a company's management through this project. And the repetitive, long, boring and unprofitable sorting process seems to gradually become a channel for them to vent working pressures. Reducing the process and time period of sorting might a good choice to minimize the inappropriate behaviors.

Activity 2 - loading

After finishing the sorting process, the deliverymen start to load their vehicles. At first, they park their vehicle out of the outlet and release the cargo shelves in the rear side. And then, woven bags and large parcels are carried close to the vehicle and place on the ground. Articles are chosen to place on the vehicles one after another, and positions are kept adjusting according to their size. Rubber ropes are constantly used to fix cargos on the vehicle. Once the rear side loading is done, the rest cargos would be placed on the footboard or for front basket.

Although more actions are involved in the loading process, less undesired behaviors are observed except the same 'dropping' problem as the sorting process. Since the negative attitude, the absence of roles and poor habit of the deliverymen has not been altered, it can be assumed that the changed working context influence the behavior. The unstable two-wheeled vehicles actually make the deliverymen to be more carefully during loading in order to avoid the scooter from falling due to the rude behavior or unbalanced weight. It is really interesting to realize the defect of the tools actually becomes the constraint to the users, and facilitates desirable behaviors.

However, these good behaviors are established on the sacrifice of time. A deliveryman spends nearly one hour a day to cope with his shaky scooter and sometimes still have to face the result of its falling on the ground. Improving the stability and loading capability to reduce these unnecessary time consumption are no doubt the developing direction of the later design, but meanwhile utilizing the features of the vehicle to get rid of the undesired behavior is also equally essential.

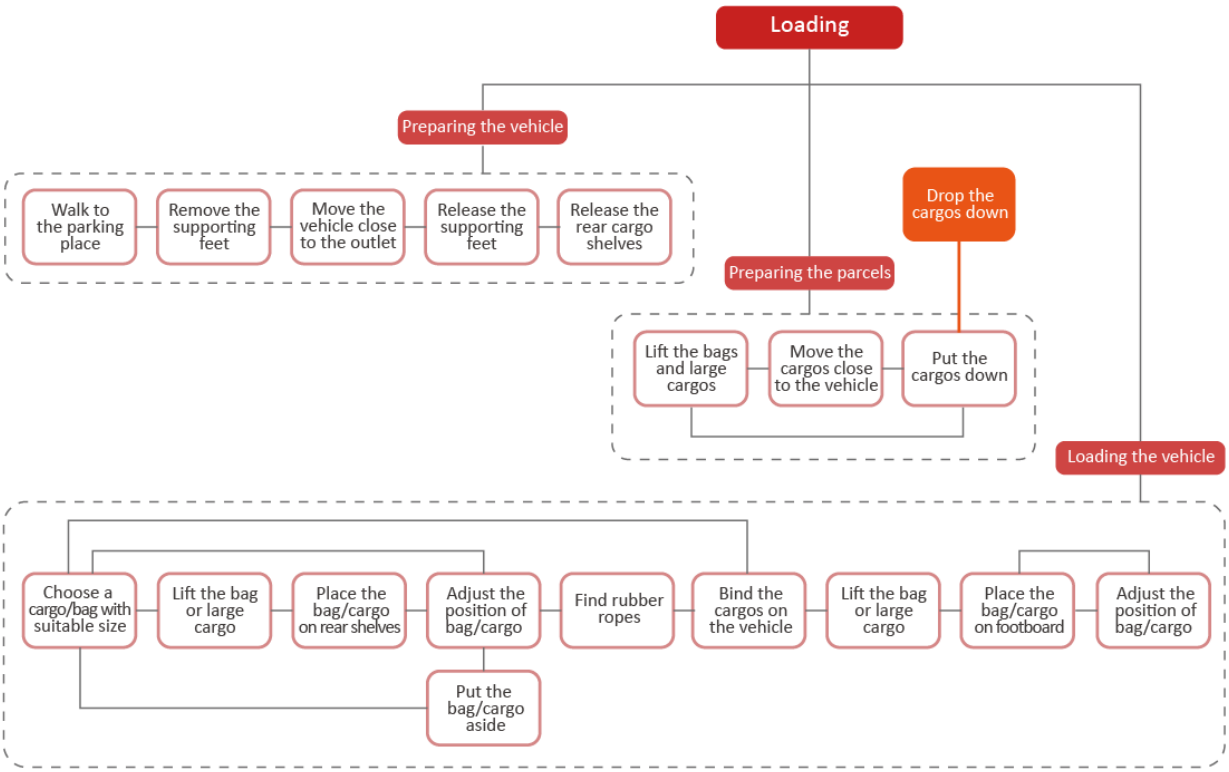

Figure 5.26 Tasks and actions in loading activity

Activity 3 - driving

Driving is an essential activity in express delivery procedure. It realizes the parcel transportation among the outlet and customers. Actions and behaviors during the driving activity are illustrated in Figure 5.27, and many undesired behaviors can be identified in the diagram.

In the task of 'starting the vehicle', sometimes a deliveryman is hard to get on the scooter and reach a comfortable driving posture due to the cargos on the footboard and rear shelf. Moreover, parcels on the footboard are very likely to be dropped on the ground in this process and lead to potential damage. These medium and rear loads also influence driver's egress behavior. Since nearly 30-40 times getting on and off actions have to be done every day, it is really important to prove an easy ingress and egress situation in the later design.

In addition, in the starting and parking tasks, since most of the intervals between parking and next starting behavior is only about 1-5 minutes, most of the deliverymen are disinclined to lock and unlock the vehicle for the inconvenience, although they concerns a lot about the cargo and vehicle safety. Despite the fact that they try to let doorkeepers to look after the vehicle or park the scooter under the monitor, thieveries still happen frequently.

If most of the undesired behaviors in the starting and parking tasks can be imputed to the poor design of vehicles, the improper actions during the scooter driving have to blame on drivers' inappropriate intention and the nonfeasance of legal constraints. Various traffic violations point to the deliverymen's less consideration of the behavior outcomes, and the universality of these dangerous behaviors within this group indicates the lack of regulation of the relevant government department. Obviously, in this project, there is nothing could be done to change the current traffic supervision. In order to protect the safety of driver during the potential accidents, providing enough crashworthiness of the vehicle seems to be the only solution.

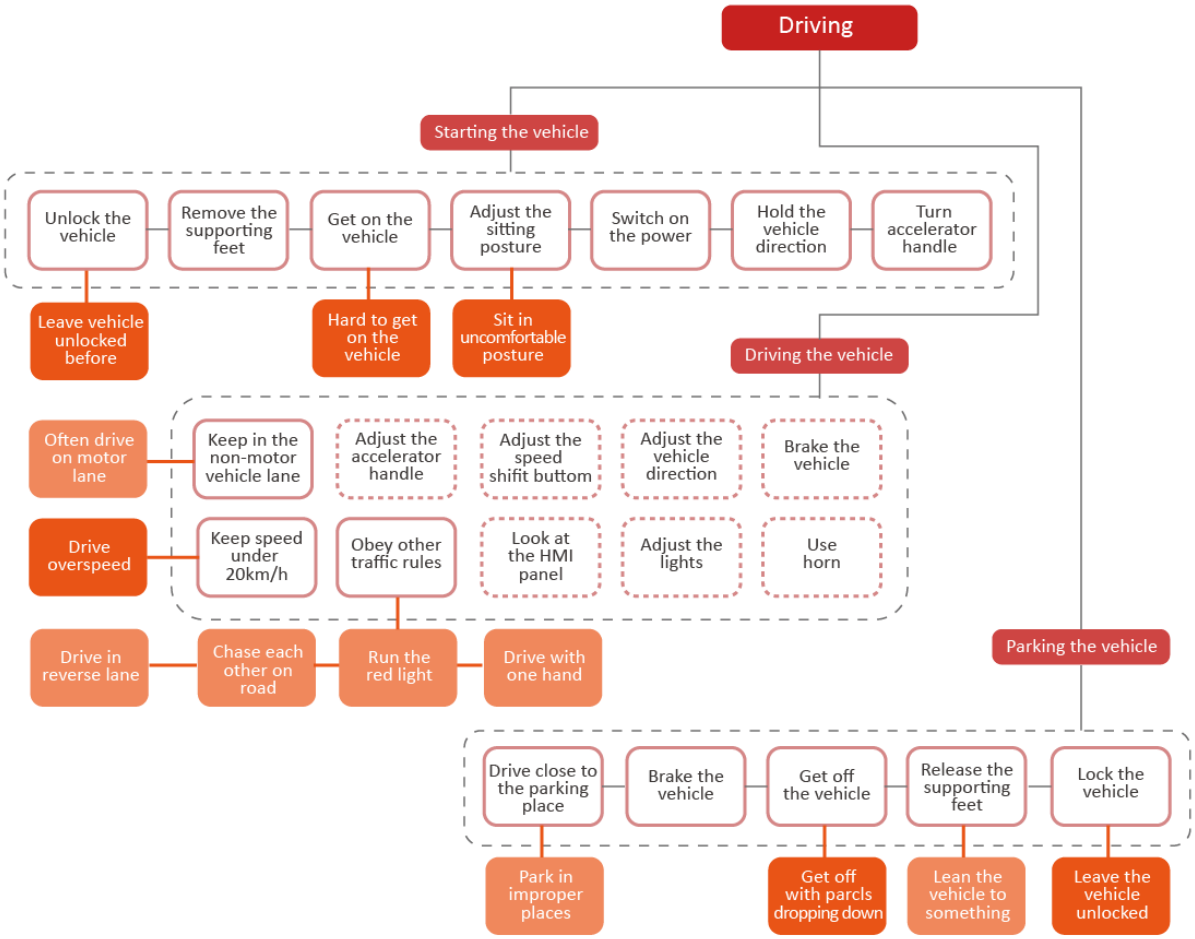

Figure 5.27 Tasks and actions in driving activity

Activity 4 – unloading

There are two kinds of the unloading activities depending on the real situation. As mentioned before, most of the deliverymen tend to find a temporary place to store some later-delivered parcels. In this case, they would unload all the parcels on the vehicle then followed by a lite sorting process. Parts of the cargos are moved to the storage place and the rest would be reloaded on the scooter. Another type of unloading activity is defined as 'partly unloading' which commonly occurs during the delivering process. After a deliveryman finds the parcels to send, they would be picked out and gathered aside. The process of both types of unloading is illustrated in Figure 5.28.

The influencing factors of the improper behaviors like 'dropping cargos' and 'left the cargos unguarded' in this activity are quite alike the ones in the previous activities, so no more repetition is done here. Cutting unnecessary procedures, reducing operation time period and using vehicle features to limit these behaviors are the solutions.

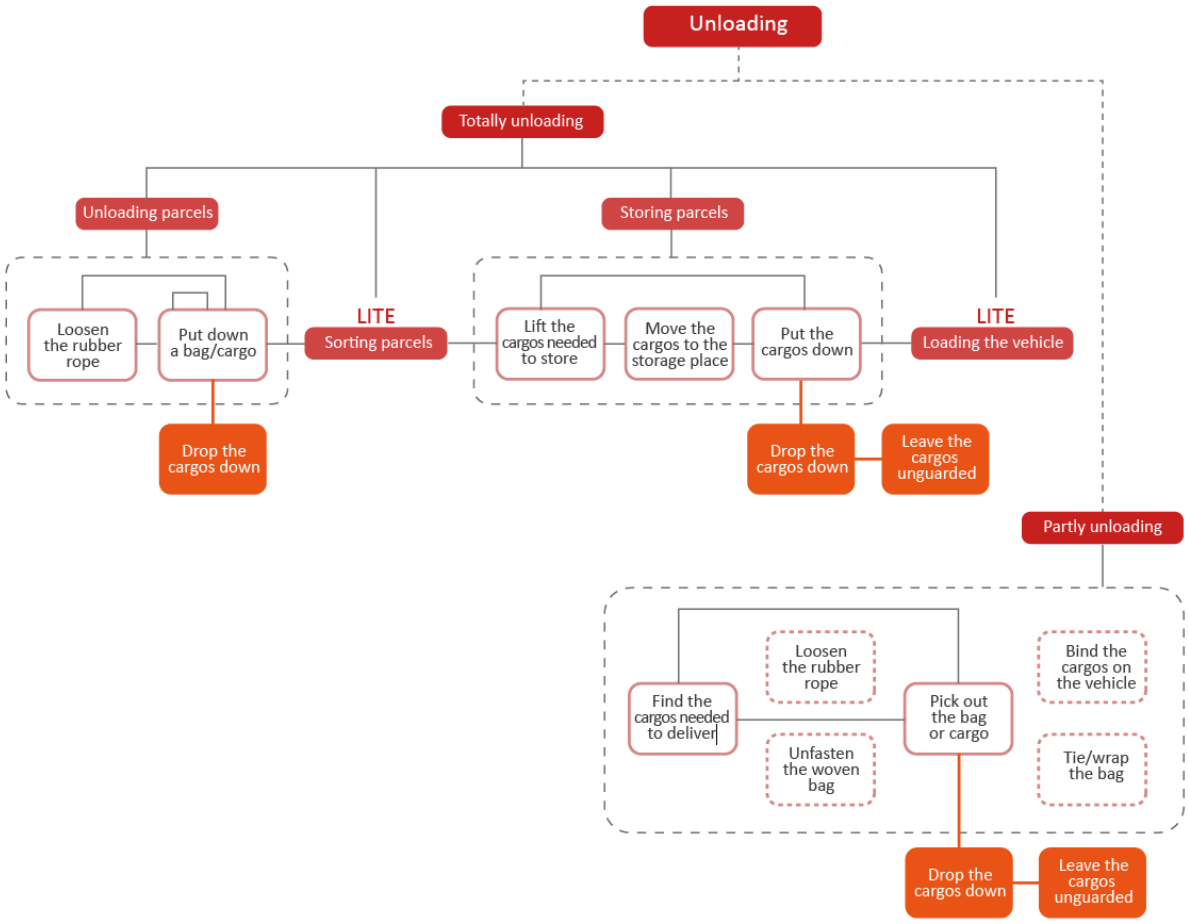

Figure 5.28 Tasks and actions in unloading activity

Activity 5 – delivering

Delivering is the one of the most essential and flexible activities during express delivery process, of which the procedure varies a lot depending on different service area. Except signing process, there seems to be no fixed tasks combination could be found among various delivery activities, but several interesting patterns have been observed during the research.

1. Delivery pattern 1 – for high-rise commercial buildings

To cope with the concentration of companies in commercial buildings and their high requirements of time efficiency, a typical delivery pattern is developed and widely applied by the deliverymen. By using a top-down delivery sequence, this pattern is able to finish over 50 parcels within one hour, and can massively save the stamina of the deliverymen. Though in many procedures, cargos are left unguarded; business employees' relatively high qualities the monitors all over the place somehow reduce the risk of theft.

The detailed delivery actions are included in Figure 5.29. Briefly speaking, in this method, a deliveryman would take all the parcels of the building to a cargo elevator. He would stop at the floors with large parcels and quickly move the big boxes to lobbies with the elevator door open. After reaching the highest floor which locates the companies to deliver, parcels of the floor would be picked out and respectively sent out. Then, Stairs are used to get down instead of a lift to save the waiting time. Every floor he reaches, he would check the lobby first, and then searches the small parcels in bag, until they are all delivered.

Three types of undesired behaviors can be found out in the diagram. The first type is still the 'dropping', 'kicking' and 'dragging' problems which are combined results of negative attitude, the absence of roles, poor habit and less external constraint. The second is the 'leaving' behaviors. Though leaving the cargos unguarded is proved to be an inevitable problem during the delivery process, in this case, the deliverymen seem to leave the parcels in too many places, for example, on vehicle, in lobbies, in stairwell, in corridor and at door. Even without

considering the security risks, leaving a large number of parcels in five places is also very likely to lead to omissions. Unlike the first type of behavior, the deliverymen fully understand the outcome of the behavior and are willing to find much better solutions; the external factors like the lack of temporary storage place, the pressure from business customers and their limited physical energy dominate these 'leaving' behaviors. The last type of undesired phenomenon is the abnormal relationship between 'times to find a parcel in bag' to 'number of parcels delivered' mentioned before. This can be simply understood as the result of defect of the woven bag together with their first type of improper behaviors.

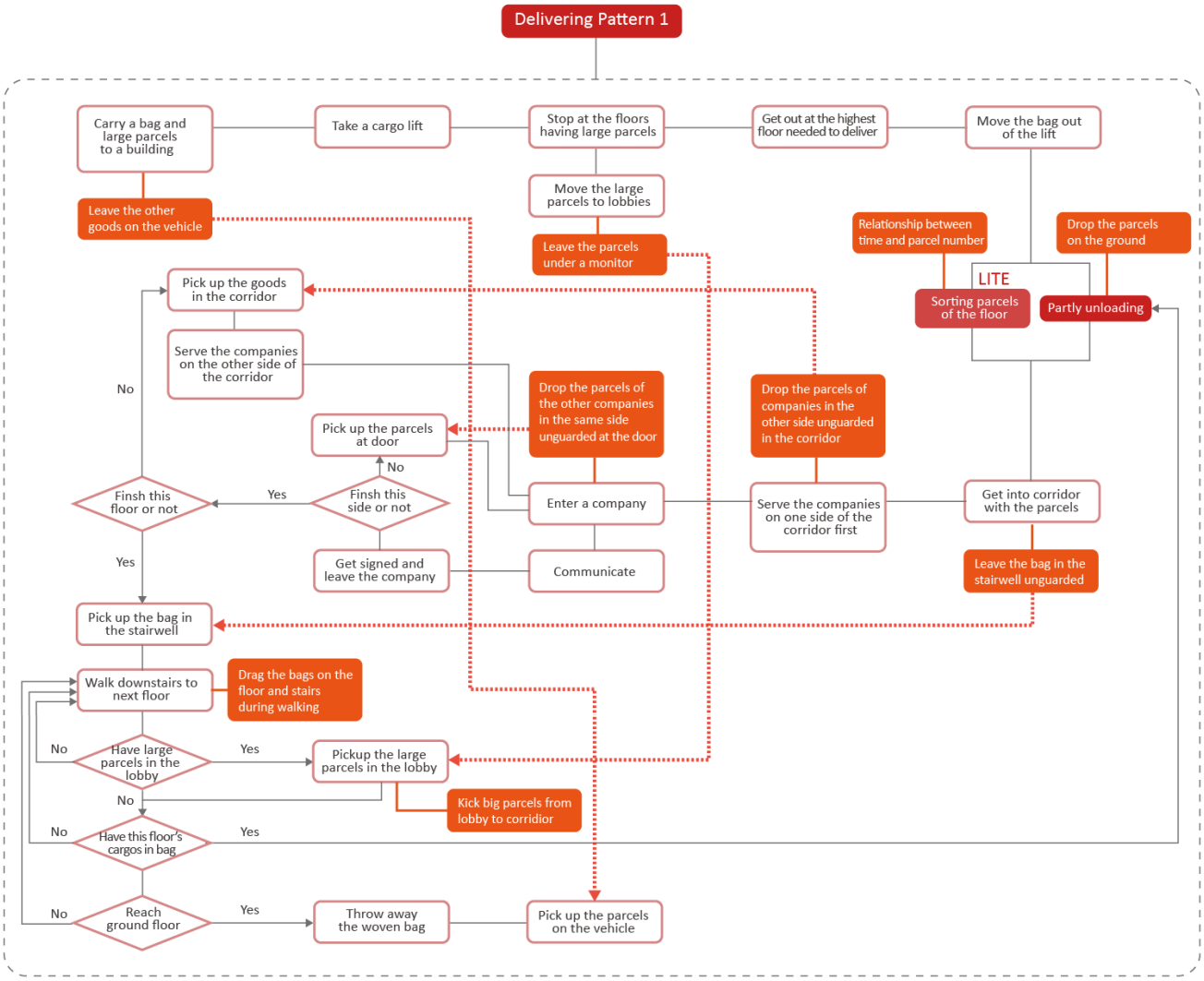

Figure 5.29 Actions in delivery pattern 1

2. Delivery pattern 2 – for resident neighborhoods

Pattern 2 could be commonly observed during the delivery in most resident neighborhoods. It involves lots of time and energy, because the destinations of parcels are relatively dispersive and in some old housing estates without lifts, the deliverymen have to get up and down floor frequently. What's more, sometimes the consignee may not at home during weekdays, a lot of communication and negotiation have to done. Thus, it is the most unwelcome pattern to the deliverymen.

But surprisingly, less improper behavior has been observed in this pattern. This is partly because of the less 'putting or picking' behavior is involved, and partly due to deliverymen's intention of establishing a good image in consumers' mind. But in a few cases, the continuous physical exertion and extreme weather may influence the service attitude of them. Therefore, though less intervention could be done to change this delivering pattern, a comfortable environment within the vehicle could be offered instead to help the deliverymen recover from massive physical output.

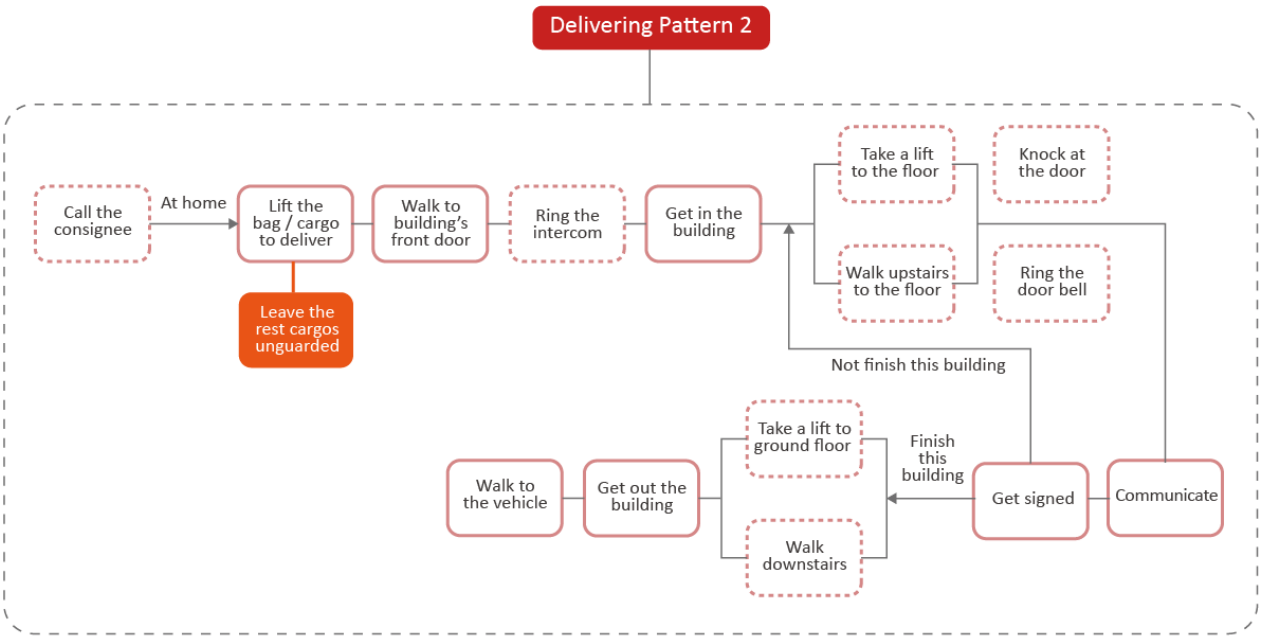

Figure 5.30 Actions in delivery pattern 2

3. Delivery pattern 3 – for colleges and some resident neighborhoods

The third kind of delivery pattern is often used in colleges or some modern resident estates with restrict management. Generally, the doorkeepers of these areas refuse the deliverymen to enter the residential building. The consignees usually are informed by a call or a message, and go outside the block or certain dedicated place to meet the deliverymen.

Though very less labor is involved in this pattern, the deliverymen still don't like this pattern, because they lost the initiative in this process and have to spend really long time in waiting.

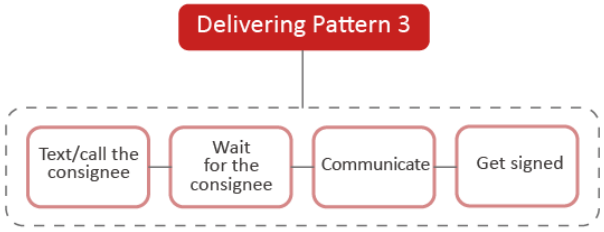

Figure 5.31 Actions in delivery pattern 3

Overall speaking, delivering activity is a really important element in the entire express delivery process. This activity lasts a very long time in their routine work and is not very profitable concerning the vast physical exertion they have made. Some undesired behaviors have been found in different delivering patterns and a majority of them are induced by either their negative attitude, the absence of roles and poor habit or insufficient facilitating conditions. Although some behaviors cannot be diminished by the design of vehicle, providing a comfortable interior environment and some auxiliary tools may indirectly help to alter or reduce the undesired behaviors.

Activity 6 – collecting

No matter for the deliverymen working as outlet employees or as subcontractors, collecting is the most enjoyable time period of a day. Using a vivid metaphor, they are the 'fishermen' on the scooters, and the amount and size of the 'fish' they get determines their income. Three tasks are involved in this process, including receiving order, visiting sender and collecting parcel. After getting a phone call from a sender, or for the S.F. staff, receiving a message in the scanning terminal, a deliveryman would note down his/her address and arrive at the place in certain hours. For some regular customers, the deliverymen would come at a set time to pick out parcels. The sender is required to let the deliverymen check the objects to send first to avoid hazardous articles, and then fulfills the waybill and pays for the express fee according to parcels' weight. Later, the deliveryman should bring the parcel back to the outlet and sort it according to the destination.

Two kinds of undesired behaviors can be identified in collecting activities including bad driving behavior and the 'leaving' behaviors which are all mentioned in the other activities. Thus, no more discussion would be done here.

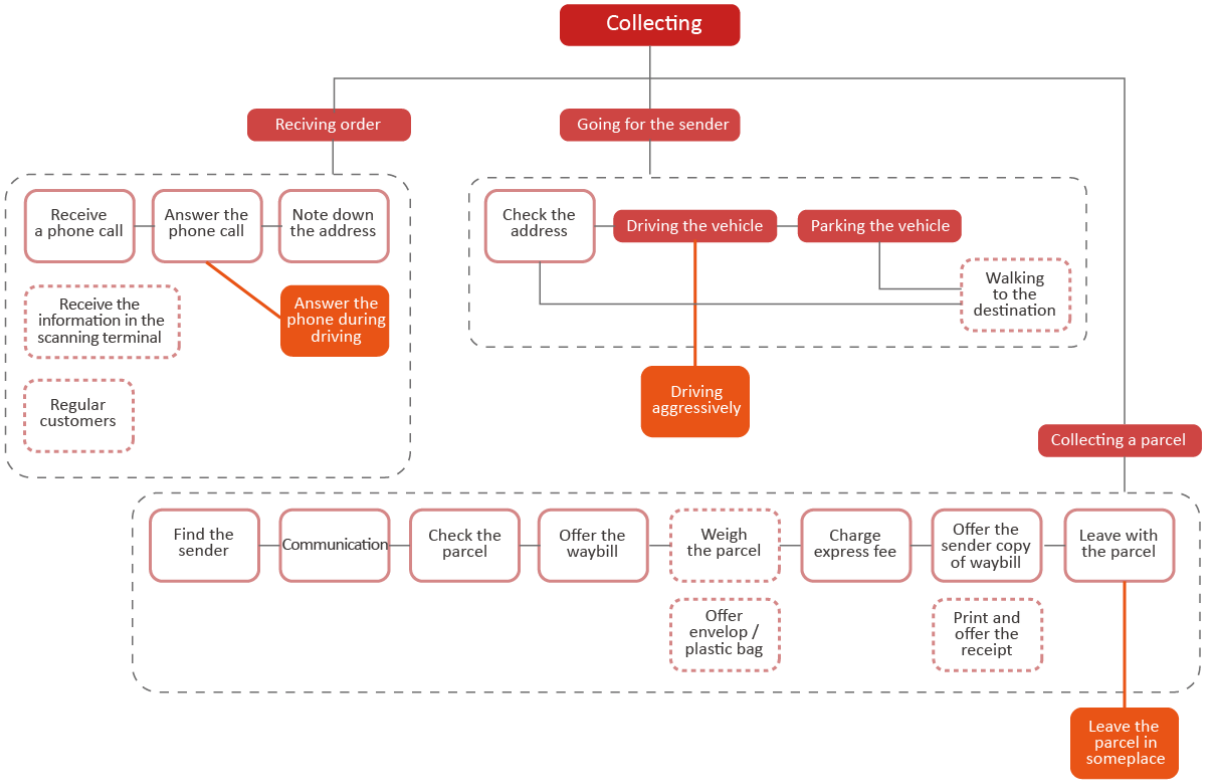

Figure 5.32 Tasks and actions in collecting activity

Activity 6 – communicating

Some other activities are also involved in the express delivery. For example, communicating is a crucial part of the delivery process. In delivering pattern 2 and 3, consignees are all informed by call or message in advance of the delivering activity; and in collecting process, it becomes a primary means to reach the deliverymen. In order to cope with the busy business, some of the deliverymen even bring two cellphone during work. The average monthly mobile phone fee for a deliveryman is around RMB 200 and they have to pay this bill by themselves. Answering the phone during driving is the only bad behavior could be found in this activity, but it can be simply avoid by the application of Bluetooth equipment.

5.3.3 Segment Conclusion

Overall speaking, though various activities and changing real situations make the job look relatively flexible, lots of iterations in the HTA diagrams proves that it is actually a kind of prolonged repetitive work. Combined with the labor-intensive job nature, poor staff quality, vehicle defects and other external conditions, a series of undesired behaviors happens inevitably in its activities.

The following table encloses all the undesired behaviors appears in the activities, and categorizes them into three types according to their influencing factors. The enlightenments of these behaviors are also attached which are integrated in the later design

Type	Activity	Undesired behaviors	Influencing factors	Other inducements	Enlightenment
1	Sorting	Throw/drop the parcels	Inappropriate intention Less external constraints	Time consuming Less profitable	Reduce activity process and time period Improve vehicle stability and loading capability Utilizing vehicle features to constrain undesired behavior
	Loading				
	Unloading				
	Delivering				
	Driving	Drive aggressively			Improve vehicle safety
2	Driving	Leave vehicle unlocked Get off with parcels dropping down Lean the vehicle to something Hard to get on the vehicle Sit in uncomfortable posture	Vehicle defects		Provide dedicated design for delivering purpose
	Unloading	Leave cargos unguarded		Time consuming Limited physical energy	
	Delivering				
	collecting				
3	Driving	Park in improper place	External factors		Provide suitable vehicle size
	Delivering	Leave cargos all over		Limited physical energy	Provide dedicated design for delivering purpose
	Collecting	Answer the phone during driving			Solve via applying Bluetooth technology

Table 5.1 Undesired behaviors and their reasons and enlightenments

5.4 List of requirements

After the activity analysis, a requirement list is made to summarize the information got in the first round field research and the HTA. All the inspiring findings are listed in the 'specification' column with the potential requirements extracted and noted aside. The full contents of the list could be found in Appendix III, while the main requirements are shortly concluded as below. All the user requirements got in this step would be used in the second round field research to test the validity and importance of them, while the hard requirements would be directly adopted and interpreted in the later design.

User requirements:

1. Use pure electricity as energy.
2. Provide sufficient battery capacity.
3. Provide suitable charging time.
4. Equipped solid vehicle structure, good suspensions, stronger wheel rims and wider tires
5. Control the vehicle dimensions for flexibility, mobility, traffic condition and parking concern.
6. Add turning lights and brake lights in the rear side and increase the illumination of the headlight

7. Improve the vehicle security.
8. Protect the vehicle from thieves.
9. Improve users' social status via exterior design
10. Drive without motor vehicle driving license
11. Design closed driving compartment to protect driver from bad weather.
12. Provide comfortable driving posture.
13. Enable convenient ingress and egress.
14. Provide lockable storage places for delivery supplies, receipt copies, tools and personal effects.
15. Provide sufficient payload and cargo space.
16. Protect cargos from bad weathers, thieves and extruding, jolting or falling.
17. Enable deliverymen to arrange cargos' position according to size and delivery sequence.
18. Help to reduce activity process and time period
19. Improve the vehicle stability during driving, loading and unloading.
20. Provide dedicated-design ancillary products to assist delivery activities.
21. Provide longer service life.
22. Get the permission and authorization from government

Hard requirements:

1. Utilizing vehicle features to constrain undesired behavior
2. Separate driver compartment and cargo compartment
3. Provide fire equipment.
4. Control the high speed of vehicle

5.5 Questionnaire – user requirement validation

This questionnaire was sent out on 18th March as the second round field data collection. The main purpose of designing this questionnaire is to exam the validity of the requirement list, evaluate the importance of the listed requirements and collect some simple ergonomics data such as stature and mass to support the later design. Different from the first round research, this round data collection is more qualitative-oriented. 25~40 samples were initially considered as the proper amount, while 21 were eventually retrieved. All the samples came from the same YTO outlet close to Tongji University, which is deemed as the limitation of this research. But considering homogeneity of the franchise delivery companies and various sources inputs during the first round data collection phases, this limitation was not supposed to be so influential.

5.5.1 The execution of questionnaire

In the pilot research, a restrict-structured research table was tested but the result remained unsatisfied due to its redundancy, time consuming and deliveryman's really busy work. Thus, in order to obtain a better result, only two types of questions were used in this questionnaire. The first was blanks filling, which was used to collect participants' information about age, gender, stature, mass and the ownership of motor vehicle driving license. And the rest were all single-choice questions with requirements listed and the same five options: totally agree, agree, slightly agree, don't care and disagree. Maximum 5-10 minutes were estimated to finish the entire paper. In addition, with the help of the YTO outlet manager, all the questionnaires were collected the day after sending out, which means all the samples could have enough time to fill the questions.

5.5.2 The results of blank filling questions

Since the collection of simple demographic and anthropometric data is planned to be carried out in the later phase as well, yet, the data got in this step is just displayed here, more data processing would be done later.

1. As state before, all the deliverymen in this round research are males.
2. 18 deliverymen provide their information of motor vehicle driving license. Seven of them have while the rest eleven do not.
3. The results of age, stature and mass are listed as below.

Age	- 20	1/11	21-25	7/11	26-30	1/11	31-35	2/11	36 -	1/11
Stature (cm)	- 160	1/20	161-165	3/20	165-170	7/20	171-175	6/20	176 -	3/20
Mass (kg)	- 55	3/19	56-60	5/19	61-65	3/19	66 - 70	3/19	71 -	5/19

Table 5.2 The results of age, stature and mass

5.5.3 The results of single-choice questions

Most of contents of the single-choice questions are actually interpreted from the requirements identified in the previous round of field research. After a sample reads these interpretations, he/she should pick the most suitable answer according to his own experience from the five options: totally agree, agree, slightly agree, do not care and disagree.

During the analysis phase, different scores are given to the five answers, with 3 points for 'totally agree', -1 points for 'disagree', and the rest are done in the same manner. After marking all the samples' answer together, average scores of every question are calculated. The higher the average score is, the more universal and important the requirement represents. The result of the research is shown in Table 5.3 and would be further analyzed in section 5.6.

Score	3	2	1	0	-1	-1~3	Sum/21
Requirement interpretation	Totally agree	Agree	Slightly agree	Do not care	Disagree	Average score	Sum
The battery of my electric scooter is not sufficient.	7	2	7	2	2	**1.5**	20
The loading capability of my scooter is not sufficient.	13	0	2	2	4	**1.76**	21
The legal top speed of 20km/h is too slow for express delivery.	9	2	1	2	5	**1.42**	19
My electric scooter is easy to be stolen.	16	1	1	0	1	**2.63**	19
My electric scooter is unstable during usage.	12	4	2	2	1	**2.14**	21
The cargo load affects my riding posture and leads to discomfort and fatigue.	7	7	5	0	1	**1.95**	20
It is hard to estimate the overall width of electric scooter with load	6	4	5	1	4	**1.35**	20
My electric scooter cannot protect me very well in traffic accidents.	15	1	5	0	0	**2.48**	21
The illumination of vehicle light is very important during night.	12	2	3	3	1	**2**	21
The sorting, loading, unloading and delivering activities are time-consuming	13	3	2	1	0	**2.47**	19
It is very laborious to load on my electric scooter	7	5	6	3	0	**1.76**	21
It is difficult to get on and off my scooter after loading	8	3	6	3	1	**1.67**	21
It is necessary to provide a stuff to record information after a sender calls.	4	6	4	3	1	**1.5**	18

It is hard to carry an extra-big or overweight parcel by my scooter during collecting	13	2	3	0	3	**2.05**	21
My scooter is not able to prevent the cargos from theft.	16	2	1	0	1	**2.6**	20
There should be some space to put personal belongings and delivery supplies on my scooter.	10	6	1	2	1	**2.1**	20
It is necessary to bring some boxes, bubble wraps, etc. to help clients with less well-packaged parcels.	5	5	2	5	2	**1.32**	19
Leave parcels within ranges of monitors is safe.	12	7	2	0	0	**2.48**	21
Even the parcels is arranged according to delivery sequence before, some still are left out during delivery.	3	5	6	1	5	**1**	20
I am afraid other deliverymen lose the parcels I collected, which make me lose customers.	11	5	1	3	0	**2.2**	20
I often smoke.	8	0	2	3	6	**1.05**	19
My electric scooter cannot give me and parcels enough protection in bad weather.	11	6	1	2	0	**2.3**	20
Hot, cold, rainy or snowy weather greatly influence my delivery efficiency.	16	4	1	0	0	**2.71**	21
Fatigue caused by hot, cold, rainy or snowy weather influences my service quality	8	9	2	0	2	**2**	21
A good delivery vehicle should be flexible enough to handle in small space	11	3	4	0	2	**2.05**	20
My electric scooter going not well in a poor road conditions	5	5	5	3	2	**1.4**	20

Table 5.2 The results of single-choice questions

5.6 Kano analysis

The user requirements tested in the questionnaire could be roughly divided into four levels according to their average scores shown in Table 5.2. The first level requirements fall in the ranges from 2.40 to 3.00. Obviously, these requirements are the most universal and essential ones among the deliverymen and should be satisfied within the new design. These requirements can be regarded as the one-dimensional attributes in the Kano Model, because apparently they are not the most fundamental requirements such as vehicle's ability of mobile or load, but the lack of the requirement corresponding functions has already caused users' dissatisfaction.

The second level of requirements is within the range of 1.90 – 2.39. Comparatively speaking, these requirements receive less degree of agreement than the previous one, but most of the samples still hold a relatively sympathetic attitude. Most of these requirements can be deemed as the attractive attributes in the Kano Model. Though no severe user satisfaction may be caused by the absence of the corresponding functions, the new product should try to cover as much of these requirements as possible.

The third and the forth categories of requirements respectively have their average scores within 1.40 – 1.89 and 0.00 -1.39. The relatively low scores of these requirements can be either because a major of the samples hold an indifferent attitude to the requirement interpretation, which is fairly close to the indifferent attributes in the Kano Model; or opposite viewpoints widely exists within one items and lowers its average score, which belongs to the reverse quality.

Therefore, the requirements tested in the questionnaire are all accordingly categorized as shown in Table 5.3. Some other requirements in section 5.4 are also included here.

Must-be quality	One-dimensional quality	Attractive quality	Indifferent quality	Reverse quality
Vehicle required basic capabilities	Protect driver from bad weather	Improve the vehicle stability during driving, loading and unloading	Improve users' social status via exterior design	Drive without motor vehicle driving license
Delivery required basic capabilities	Protect the vehicle from thieves	Provide comfortable driving posture		Provide dedicated-design ancillary products to assist delivery activities
Get the permission and authorization from government	Protect the cargos from thieves	Add turning lights and brake lights in the rear side and increase the illumination of the headlight		Enable deliverymen to arrange cargos' position according to size and delivery sequence
	Ensure vehicle security	Provide lockable storage places for delivery supplies, receipt copies, tools and personal effects		Provide longer service life.
	Help to reduce activity process and time period	Protect cargos from bad weathers and extruding, jolting or falling		
	Provide sufficient battery capacity	Control the vehicle dimensions for flexibility, mobility, traffic condition		

		and parking concern		
	Provide sufficient payload and cargo space.	Enable convenient ingress and egress.		
	Use pure electricity as energy	Provide suitable charging time		
		Equipped solid vehicle structure, good suspensions, stronger wheel rims and wider tires		

Table 5.3 The results of Kano analysis

5.7 Persona

A frictional character named Mr. Chen is created to symbolize the deliverymen group, especially the deliverymen in franchise companies. The facts, behaviors and vehicle requirements of Mr. Chen are all displayed in Figure 5.33.

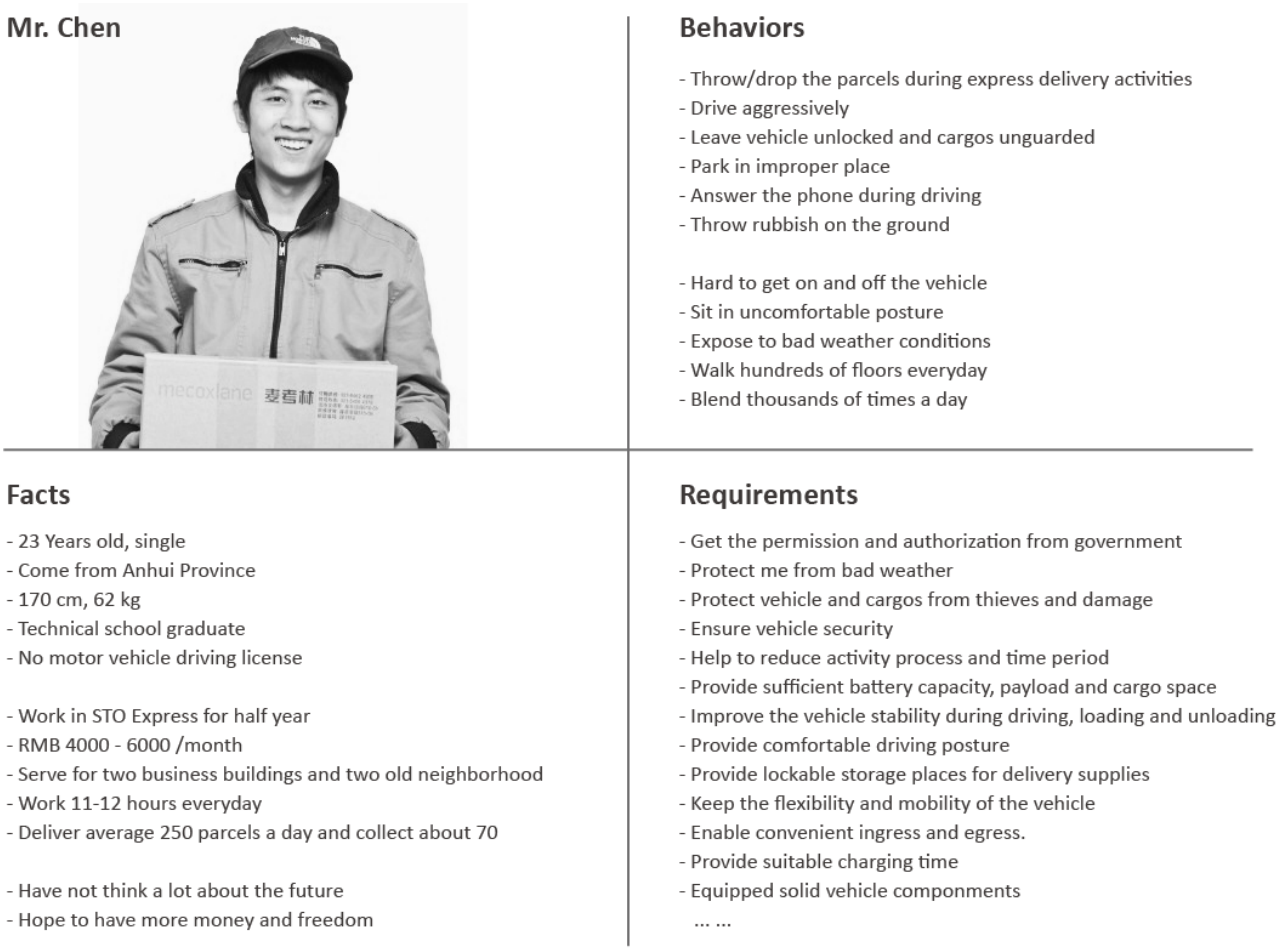

Figure 5.33 Persona

5.8 Chapter Conclusion

Two rounds of user field research and two rounds of data analysis are included in this chapter. In addition, in order to obtain a better result of the field research, a pilot study was executed ahead to test the effectiveness of the research proposal.

In the first round field data collection, an integrated method of observation and semi-structured interview was applied to collect the information of user, outlet, vehicle, cargo, other carrying articles and environment. Three deliverymen were followed throughout their working hours and over 40 delivery employees were involved. A general picture of the deliveryman group were generated and used for the construction of persona. Two kinds of delivery vehicles were detailedly studied; user's reflection and expectation were recorded. The problems occurred on cargos were also studied according to six major delivery activities. The features of other carrying articles were also noted as requirement for analysis phase. Additionally, the differences between deliverymen in franchise companies and S.F. staff were pointed out and the reasons of the distinction were traced.

In the first round data analysis phase, all the inputs in the previous stage were organized by two methods, activity analysis and list of requirements. In the activity analysis, the observed results were treated as a series of delivery activities; all the tasks were disassembled to actions, and undesired user behaviors were identified, analyzed and categorized. The factors behind these undesired behaviors were figured out and design interventions would be applied in the ideation phase. Meanwhile, the list of requirements further processes the discoveries of the previous round data collection; requirements were extracted and waited to be evaluated.

The main purpose of the second round research was to confirm the universality of the requirements got in the first round of data analysis, and to collect incidentally collect some simple anthropometric data. Thus, to the quantitative consideration, the form of questionnaire was utilized and sent to an outlet to do the test. 21 answers were retrieved finally. An average score of each requirement interpretation was calculated and prepared for the later analysis.

The second round research aims to access the importance of these requirements. Therefore, Kano analysis was implanted, which classified the requirement into five categories according to their average scores. The later design would try to cover as much the must-be attributes, one-dimensional attributes and attractive attributes as possible. Meanwhile, the construction of persona helped to well conclude all the traits of the user and also served for the later ideation phase.

Overall, this field research phase is an essential fundamental for the design phase. User-centered design methods were used to reveal deliverymen's unmet requirements, while activity-centered design thinking was applied to discover possible constrains to standardize behaviors. Both discoveries would be reflected in the design phase.

6. Ideation

This chapter describes the process of the creative ideation phase. In the early concept development stage, three concepts are generated according to the list of functions. Then the three concepts were respectively evaluated by Pugh Matrix and Krippendorf's experience dimensions. After the evaluation, one concept is selected for further development.

6.1 Early concept development

The early concept development was carried out during the field research phase in Shanghai, China. After received users' requirements and combined with the constrains for user behavior and enlightenments got in the theories and knowledge base, the function of the new delivery vehicle were decided in the stage, and then the product form were started to discuss. Due to the time limitation, no brief sketch was able to generate in this stage, but some pictures with design intentions was collected instead to do the user evaluation.

6.1.1 List of functions

This list of functions aims to describe the functions that a new deliver vehicle has to be able to perform. All the functions come from seven main aspects, including user requirement, behavior constraint, legislation, market, technology, ergonomics and sustainability. A weight scales from 1 to 5 are given to every function to illustrate its level of importance. Except the user requirement aspect, the weight of other functions is judged in line with author's estimation of the benefits from the function's outcome.

1. User requirement aspect

The function list within user requirements aspect is almost the same as the of Kano analysis. The result could be seen in Table 5.3.

2. Behavior constraint aspect

Function	Weight
Utilize vehicle features to constrain undesired behavior	4
Provide dedicated-design ancillary products to constrain undesired behavior	4
Provide fire equipment	5
Control the high speed of vehicle	4

3. Legislation aspect

Function	Weight
Separate driver compartment and cargo compartment	5
Be able to register as motor/non-motorized vehicle	5
Be in conformity with the verified loading capacity	5
Be unable to take extra passenger	5
Prevent cargo from falling, floating or littering on the way	5

4. Market aspect

Function	Weight
Provide high cost performance	4
Enable customization	3
Provide multifunction	3
Ease of assembly	3
Provide reasonable payload	4
Use sustainable design and manufacture	2
Ensure driver safety	5

5. Technology aspect

Function	Weight
Use electricity as energy	5
Solve the high vehicle height and cargo floor problem	2
Solve the structure vibration problem	3

Ensure the frame's crashworthiness	5
Provide battery cooling system	5

6. Ergonomics aspect

Function	Weight
Adequate vision from seating position	5
Fit different body sizes	4
Perception of being safely seated	3
Fit user's cognitive understanding	4
Load/unload cargos ergonomically	5
Offer flexibility to adjust working environment to driver's own needs	2

7. Sustainable aspect

Function	Weight
Own light vehicle weight	3
Enable easy disassembly	3
User fewer materials and parts as well as mono-material construction	3
Use low-impact materials	3

Table 6.1 List of functions

6.1.2 Three concepts

After clarifying the required functions of the product, three concepts were generated to translate the product functionalities to forms. These concepts are required to integrate the technical attributes of the PUNCH projects and coordinate with the actual requirements. Since the time was really limited in this stage, all the concepts were respectively presented with four pictures showing the primary features of the concepts instead of sketches. All the pictures were meant to not only display the functionalities of the product but also shows the aesthetic characters of the concepts. In order to get rid of the influences from picture tunes or qualities, all the images were processed to be black and white.

Concept 1

Concept 1 is a more scooter-shaped-oriented proposal. It keeps the steering wheel and seat features of the existing delivery scooter so that the deliverymen would be able to quickly handle the new vehicle. And also the scooter ergonomics is kept in this concept, of which the driver sets quite straight and is able to get on and off the vehicle conveniently. The differences lie in the additional semi-opened driver compartment and the four-wheeled design. The windshield and roof are able to provide the driver some level of protection from bad weather, while the four wheels definitely vastly increase the vehicle stability during the loading, unloading and driving activities.

Figure 6.1 Concept 1

Concept 2

Concept 2 can be viewed as an intermediate form of a scooter and a small motor vehicle. The relatively complex steeling wheel design allows the driver to receive more vehicle feedbacks, and the larger seat with backrest and shoulder protection provides more driving comforts and safety. Instead of the separate pieces of windshield and roof, an integrated piece is applied instead to provide better driver vision and shade. The wheels are also larger and wider, and a closed cargo compartment can be faintly observed. Compared with the previous concept, the overall design of concept 2 tends to be more robust forceful but less flexible and familiar.

Figure 6.2 Concept 2

Concept 3

The third concept is definitely a small motor vehicle-oriented proposal. It can be deemed as a small electric motor vehicle. The steering wheel and the seat design are very close to the regular one. The driving compartment is totally closed with doors on the sides, while a closed cargo compartment is placed behind. Driver's ergonomics in the vehicle is the same as in the current vehicle with the body leans backwards and legs stretch forwards to reach the pedals. Safety and comfort problems are very likely to be solved by this design, but the cost problem seems to be a big issue for this concept.

Figure 6.3 Concept 3

6.2 Concept evaluation

There are two aspects required to be evaluated within this three concepts. One is the how many required functions could be realized by the each concept, and another is how the vehicle forms of the three concepts influence users' judgments. In order to receive precise reflections, two methods were applied evaluate the generated concepts

6.2.1 Pugh Matrix

Pugh matrix is selected to evaluate three concepts' realization of the required functions. All the functions in the function lists are listed in the leftmost column with weight aside. The delivery scooters used currently are selected as the reference and score '0' point in all criterion. If a concept helps to improve the existing situation of a criteria, '+1' point would be marked, otherwise, '-1' point would be got; if none changes happens, the '0' point would be kept. Some of the items are marked as 'N/A', which means these criterion are unable to be judged in the current phase. Three total scores are calculated afterwards, and the one with the highest score can be viewed as the most promising solution.

The result of the Pugh Matrix can be found in Appendix V. The three concepts respectively get 21, 48 and 47 points. In practical terms, the differences between concept 2 and 3 are mainly focus on the interior aspect, quite similar exterior features lead to the close score in many aspects. On the contrary, concept 1 has a significant difference in the windshield and roof design. The semi-opened driver compartment and cargo compartment still cannot entirely protect the driver and cargos from bad weather and solve the theft problem, which dramatically reduce its score. Thus, via the Pugh Matrix, concept 2 and 3 are selected as the potential development directions.

6.2.2 Krippendorf's experience dimensions

Krippendorf's experience dimensions are used to identify users' attitudes to the three concepts. Since only visual perception is involved in this stage, it can also be regarded as the exploration of vehicle form and user experience. Via this method, author aims to get some clues for the later form exploration. Four test papers each with the same 13 pairs of antonymous adjectives are distributed to 17 deliverymen. They are required to mark at the most suitable positions in each scale according to their actual feelings on their vehicle or the imagination of the three concepts based on the given pictures. The three concepts are assumed to have the identical load capabilities and the same road performance, so that the true judgments of the vehicle form are able to be obtained. The one getting most appreciations would be picked out, and synthesizes with the result of the Pugh Matrix to decide the direction of further development. The research table is enclosed in Appendix VI, and the results are listed as below.

The evaluation of own electric scooter

Adj.	-3	-2	-1	0	1	2	3	Adj.	Average	StDev
Unstable	0	1	4	2	5	2	3	Stable	0.71	1.52
Fragile	0	1	2	7	1	4	2	Robust	0.65	1.41
Bulky	1	1	2	4	3	6	0	Flexible	0.47	1.50
Low quality	0	1	1	6	9	0	0	High quality	0.35	0.84
Cheap	1	0	5	6	3	2	0	Expensive	-0.06	1.21
Common	0	2	7	4	4	0	0	Exclusive	-0.41	0.97
Boring	1	1	4	6	3	1	1	Exciting	-0.06	1.39
Load less	0	3	1	1	4	3	5	Load more	1.06	1.80
Inconvenient ingress	2	1	3	0	6	3	2	Convenient ingress	0.41	1.85
No cargo protection	3	3	3	3	3	1	1	Cargo protection	-0.59	1.75
Uncomfortable	1	4	4	2	5	1	0	Comfortable	-0.47	1.42
Dangerous	0	6	1	7	1	2	0	Safe	-0.47	1.33
Overall-bad	0	1	4	2	8	2	0	**Overall-good**	0.35	1.13

Very large distribution Large distribution Small distribution Little distribution

Table 6.2 Krippendorf's experience dimensions' result for own scooters

At the beginning of the test, the participants are told to mark the first dimension table according to their experience of their own electric delivery scooters. It is a warm-up test and also set a potential reference for their later concept evaluation. The result is displayed in Table 6.2. It could be observed that the average scores of all the answers are concentrate in a small range from -0.59 to 1.06, which could be understood as most of the participants hold a relatively conservative attitude at first and intend to set a neutral reference for the later evaluation. But most of the choice varies significantly from person to person which reflects on the relatively high values of standard deviation. The load capability, ingress and egress as well as the cargo protection are the three most diverse items. The load capability can be understand as some participants try to compare the scooter with the minibus and give a low score, while some thinks the current load is sufficient for the delivery activities and offer a better score. The reason of ingress and egress may lie in that some of the subjects realize the problems brought by the cargos on footboard while the rest have not remind out that in the short research period. The reason of the diverse choice of cargo protection remains unknown, but as the lowest score of the entire table, it partly demonstrates that improve cargo protection is an essential part of the design.

The evaluation of concept 1

Adj.	-3	-2	-1	0	1	2	3	Adj.	Average	StDev
Unstable	0	1	1	1	3	4	7	Stable	1.71	1.49
Fragile	0	1	1	5	3	2	5	Robust	1.12	1.53
Bulky	1	3	6	1	4	1	1	Flexible	-0.35	1.57
Low quality	0	0	1	5	5	5	1	High quality	1.00	1.03
Cheap	0	1	1	1	4	8	2	Expensive	1.35	1.28
Common	0	0	0	3	4	3	7	Exclusive	1.82	1.15
Boring	0	0	2	2	5	6	2	Exciting	1.24	1.16
Load less	1	2	2	0	5	2	5	Load more	0.88	1.94
Inconvenient ingress	0	2	2	1	3	6	3	Convenient ingress	1.06	1.63
No cargo protection	0	1	1	2	3	5	5	Cargo protection	1.47	1.46
Uncomfortable	0	0	0	2	4	4	7	Comfortable	1.94	1.06
Dangerous	0	0	1	2	2	6	6	Safe	1.82	1.20
Overall-bad	0	0	0	0	7	7	3	**Overall-good**	1.76	0.73
Favorite choice for	**7**	**deliverymen**								

Very large distribution Large distribution Small distribution Little distribution

Table 6.3 Krippendorf's experience dimensions' result for concept 1

After the evaluating their own vehicle, four pictures of concept 1 (Figure 6.1) are displayed. The participants are required to give their judgments base on their visual perception and imagination. The result of the concept 1 is shown in Table 6.3. Comparatively speaking, concept 1 have achieved a large score increase on all the dimensions except 'bulky/flexible'. The four wheels and larger body makes the subjects doubt its mobility and flexibility. The phenomenon of high values of standard deviation still exists and becomes more severe than the previous. Load capability and ingress/egress problem is till the focuses, and the contradictive opinions also widely exist in fragile/robust and bulky/flexible. An overall score of 1.76 is given to this concept and most of the participants agree with the result. Seven of the seventeen subjects choose this option as their most favorite choice because of its familiar handlebar design and the low-cost looking.

The evaluation of concept 2

Concept 2 receives a higher score in a majority of criterions than the concept 1 except load capability, ingress and egress and comfort. Some subjects think that the closed cargo carbine limits the volume of load, and the semi-closed driver compartment increase the difficulty of get in and off the vehicle. Their attitudes towards the decrease of comfort remain unclear. It might be caused by the sequence of research paper. Compared with the previous two evaluations, the values of standard deviation is much less than. But still the main contradictions locate in the load capability, ingress/egress problem and flexibility. Though a better score 1.82 points has been got, only three deliverymen choose this concept as their favorite one. The rest are actually satisfied with the

exterior design of the vehicle, but unreadable steering wheel design confused them, and although the holding shape of seat increase their feeling of safety, it also greatly influence the ingress and egress activities.

Adj.	-3	-2	-1	0	1	2	3	Adj.	Average	StDev
Unstable	0	0	1	1	3	4	8	Stable	2.00	1.19
Fragile	0	0	0	1	5	5	6	Robust	1.94	0.94
Bulky	1	3	1	4	3	5	0	Flexible	0.18	1.62
Low quality	0	0	0	1	5	10	1	High quality	1.65	0.68
Cheap	0	0	0	2	2	7	6	Expensive	2.00	0.97
Common	0	0	0	3	2	5	7	Exclusive	1.94	1.11
Boring	0	0	1	2	5	4	5	Exciting	1.59	1.19
Load less	1	2	2	1	6	3	2	Load more	0.53	1.72
Inconvenient ingress	0	2	2	2	6	3	2	Convenient ingress	0.71	1.49
No cargo protection	0	0	0	3	4	8	2	Cargo protection	1.53	0.92
Uncomfortable	0	1	0	1	3	5	7	Comfortable	1.88	1.32
Dangerous	0	0	0	0	5	5	7	Safe	2.12	0.83
Overall-bad	0	0	0	0	6	8	3	**Overall-good**	1.82	0.71
Favorite choice for	**3**	**deliverymen**								

Very large distribution Large distribution Small distribution Little distribution

Table 6.4 Krippendorf's experience dimensions' result for concept 2

The evaluation of concept 3

Adj.	-3	-2	-1	0	1	2	3	Adj.	Average	StDev
Unstable	0	0	0	0	0	9	8	Stable	2.47	0.50
Fragile	0	0	0	0	3	3	11	Robust	2.47	0.78
Bulky	2	1	1	1	4	7	1	Flexible	0.71	1.81
Low quality	0	0	0	2	1	4	10	High quality	2.29	1.02
Cheap	0	0	0	1	2	2	12	Expensive	2.47	0.92
Common	0	0	0	0	4	3	10	Exclusive	2.35	0.84
Boring	1	0	0	2	0	7	7	Exciting	1.88	1.53
Load less	1	2	1	1	3	6	3	Load more	0.94	1.83
Inconvenient ingress	1	0	1	3	4	7	1	Convenient ingress	1.00	1.41
No cargo protection	0	0	0	0	0	11	6	Cargo protection	2.35	0.48
Uncomfortable	0	0	0	0	1	6	10	Comfortable	2.53	0.61
Dangerous	0	0	0	0	0	8	9	Safe	2.53	0.50
Overall-bad	0	0	0	0	0	9	8	**Overall-good**	2.47	0.50
Favorite choice for	**7**	**deliverymen**								

Very large distribution Large distribution Small distribution Little distribution

Table 6.5 Krippendorf's experience dimensions' result for concept 3

Except flexibility, emotion feeling, load capability and the ingress/egress problems, concept 3 gets very high scores in the rest criterions, and the subjects' opinions of those are relatively concentrated, which reflects on the low standard deviation values. Again the closed driver and cargo compartments influence users' judgments, and

bigger chassis and wider wheels make the vehicle looks a little bit bulky. But most of the subjects really admire the comfortable seat and the great weather-resisted design. Seven of the seventeen participants select concept 3 as the best choice, the only concern of it is its expensive price. As one of the subject said, unless the company pay for or partly pay for the vehicle, he would never dream of using it as a delivery tool.

The comparison of three concepts

The line chart in Figure 6.4 shows the result of the four evaluations. Overall speaking, all the concepts somehow improve the existing situation, in which concept 3 is the best one and receive the highest overall score. However, in three scales, the three concepts only obtain a very little improvement, or even receive a less score than the existing products.

The first is the criteria of bulky/flexible. Concepts 1 and 2 all have a lower score than the existing products. Due to the similarity of the elector scooter and its extra roof and two wheels, concept 1 looks obviously heavier and bulkier than the original product. The low score of concept 2 might lie in its solid and strong lines and mechanical feelings. Thus, although concept 3 looks much bigger, the sportive seat, steering wheel and exterior looking combined with subjects' impression of motor vehicle; they offer a little higher score than the existing product. Therefore, the sportive looking should be kept and enhanced in the concept refinement phase.

The second is the load capability problem. Though all the deliverymen want their cargos away from thieves and bad weathers, the semi-closed or close cargo compartment design makes them doubt a lot about the vehicle payload, which clearly reflects on the low scores on all the concepts. Offer enough protection to the cargos, and meanwhile let the user feel vehicle's sufficient load capability can be further discussed.

The last problem lies in the ingress and egress difficulty. Applying four-wheeled design obviously slove the problems brought by the cargos on the footboard, but the wider vehicle body definiatly increase the difficulty of getting in and out. In addition, the separate chassis PUNCH use may significantly increases the vehicle height and further aggravates the problem. Solving this problem is also important of the later design.

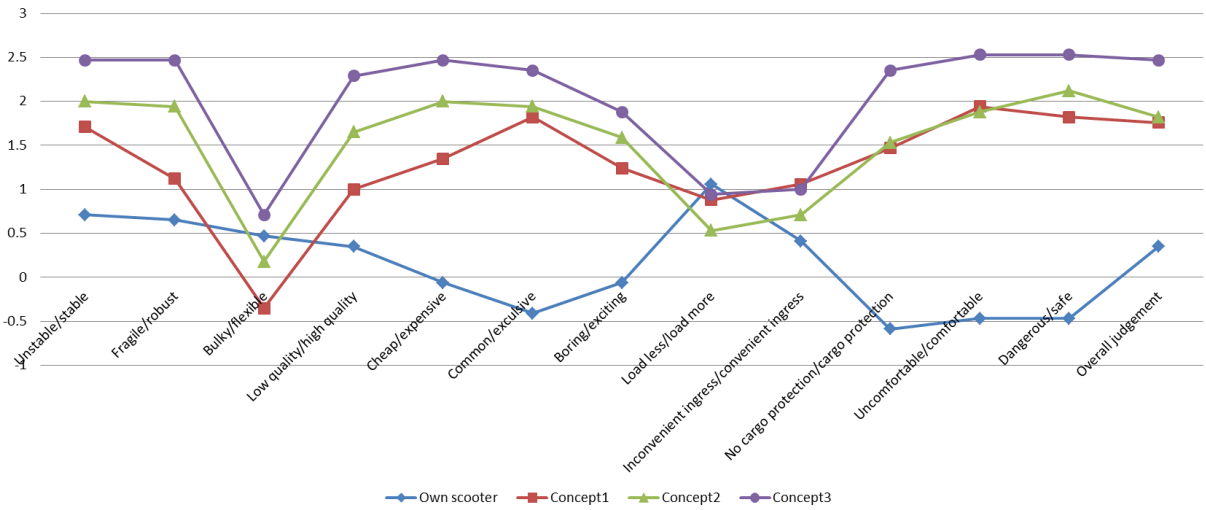

Figure 6.4 The comparison of three concepts

Concept selection

In the Pugh Matrix, concept 2 and 3 are selected as the potential development directions. And in Krippendorf's experience dimensions, concept 3 got the highest score in most of the criterion and got seven subjects' favors. Therefore, after synthesizing the results of the Pugh Matrix and Krippendorf's experience dimensions, concept 3 is selected for further development. Meanwhile, the defects found in this concept are required to be improved in the concept refinement phase. More specifically, the matters need attention for concept 3 contains:

1. Try to fulfill as much functions in the list of functions as possible.
2. Integrate sportive elements
3. Find solutions for the load capability problem
4. Find solutions for the ingress and egress problem
5. Take driver's cognitive ergonomics into consideration.
6. Reconsider the vehicle nature to fit existing legislations and standards
7. Try to control the vehicle cost.

8. Take the vehicle's market distribution into consideration.
9. Find extensive usage for the vehicle if possible.

6.3 Chapter conclusion

After finish the literature study and field research, a list of functions is created with all the gathered information including user aspect, behavior constraint aspect, legislation aspect, market aspect, technology aspect, ergonomics aspect and sustainable aspect. Three concepts are briefly generated based on the functions and respectively evaluated.

Pugh Matrix is the first evaluation method. It aims to exam the three concepts' realization of required functions. After scoring and calculating, the three concepts respectively get 21, 48 and 47 points. Krippendorf's experience dimensions table is the second method used in the evaluation. The purpose of this phase is to identify users' attitudes to the three concepts. Since only visual perception is involved in this stage, it can also be regarded as the exploration of vehicle form and user experience. The research results indicate that concept 3 is the most promising choice.

After synthesizing the results of both methods, concept 3 is chosen as development direction of the rest project. Nine matters need attention is raised for this concept, and would work as a guideline in the concept refinement phase.

7. Concept refinement

The chapter describes the development process of the selected concept, including package design, PUNCH modification, modification evaluation and form exploration. Many essential decisions of the finial product are made in this chapter.

7.1. The layout of vehicle package

Differing from the regular vehicle design process, the delivery vehicle design in this project has to start from the vehicle package. It is due to the concern of two essential requirements of this project; one is the high demand of load capability, which means sufficient space is obliged to leave for the cargos; another is vehicle's flexibility and the mobility, which requires smaller vehicle dimensions to fit the China's urban context. These two contradictive requirements push the vehicle package layout to be the most essential issue of the concept refinement. In addition, the package layout should try to couple with the existing frame of PUNCH as much as possible so that most of the generated technical solutions could continue to be used.

7.1.1 The volume of the cargo compartment and payload of vehicle

As mentioned in section 5.2.4, a deliveryman in a franchise company often carries 2-5 woven bags and 4-12 boxes in their morning delivery activities. Since much less cargos are required to be delivered in the afternoon and deliverymen in S.F. Express carries much less than the franchise ones, yet 2-5 woven bags and 4-12 boxes are set as the target volume of the vehicle.

According to the field research, the maximum dimensions of a loaded woven bag could reach 1,200×800×300mm. The size of boxes actually varies a lot, but in order to facilitate calculation, the size of a box is assumed to be 500×450×400mm. In addition, due to the limited load ability of the scooter, a function relationship is assumed to exit between the number of bags and cargos which shows in Table 7.1. The total required volumes in the four conditions are respectively calculated and also enclosed in the table.

Woven bag number	2	3	4	5
Box number	12	9	6	4
Total volume (L)	1,656	1,674	1,692	1,800

Table 7.1 The total cargo volume in four hypothetical conditions

The fourth condition of 5 woven bags and 4 boxes occupies the most volumes. Therefore, 1,800L is selected as the volume of target cargo compartment. And as mentioned in the section 5.2.4, the mass of each loaded woven bag is around 15-30 kg. If all the cargos are assumed to have the same and mean density, and then a maximum load of 187.5kg can be calculated. Therefore, the vehicle's payload should be at least higher than this number added the driver mass.

7.1.2 Driver ergonomics

After clarify the volume of cargo compartment, the dimensions of driver cockpit is required to be defined. The simple anthropometry data collected with the questionnaire and Krippendorf's experience dimensions would be processed in this section. And the ergonomics knowledge displayed in the theoretical framework would be used to decide driver's posture in the compartment.

The result of anthropometric data collection

The result of the anthropometric data collection with the questionnaire could be seen in section 5.5.2. In this section, it would be organized and analyzed together with the data got in the experience dimensions. The results are listed as following.

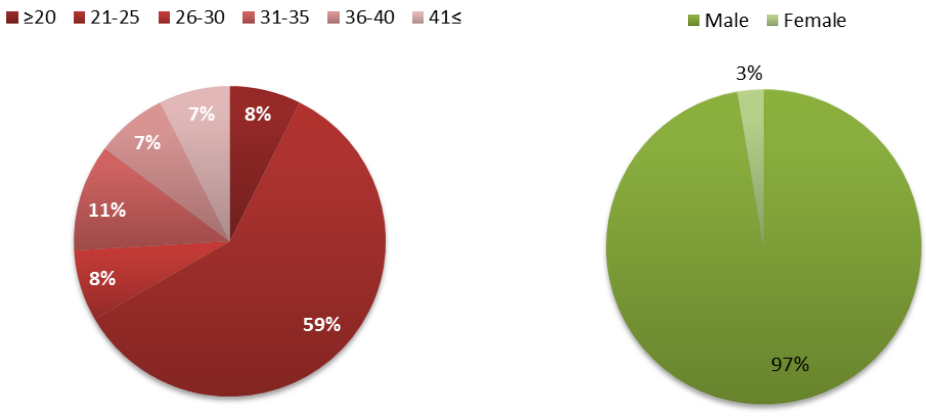

Figure 7.1 Participants' age and weight distributions

1. Age

27 deliverymen's age has been recorded. The distribution of their age is illustrated in Figure 7.1. It can be observed that nearly 70% of the delivery practitioners are under 25 years old. The requirement of strong physical labor of this job greatly determines this phenomenon.

2. Gender

Figure 7.1 also shows deliverymen's gender distribution. Among all the 37 participants, only one of them is female. This is also greatly influenced by this career's nature.

3. Stature and weight

37 participants' statures and weights are shown in Figure 5.2. The data of the solo female sample is marked in the blue dot, and the rest red rhombuses are male samples. It can be observed that the weight of the samples varies from 52kg to 81kg, and their statures are in the range of 165cm to 180cm.

Compared with the stature and weight statistics of 18-60 years old males recorded in GB10000-88, these deliverymen's data are all distributed in the relatively high percentage place. In addition, totally four samples exceed either 95-percentile height or 95-percentile weight. This phenomenon might be due to the job requirement, but also it is definitely related to the outdated national standard. As mentioned in the ergonomics theories, the stature of today's adult male is at least two centimeters higher than 20 years ago, and their five centimeters longer waistline also indicates they are much heavier than before.

Therefore, in order to make up the defects of the old statistics, 5-percentile male to 99-percentile male data are decided to use at first, which is shown as the red dotted line frame in Figure 4.2. But after considering the potential extensive usage of the vehicle, the range of 5-percentile female to 99-percentile male is finally chosen to include more users, which is illustrated in the red solid frame in the figure.

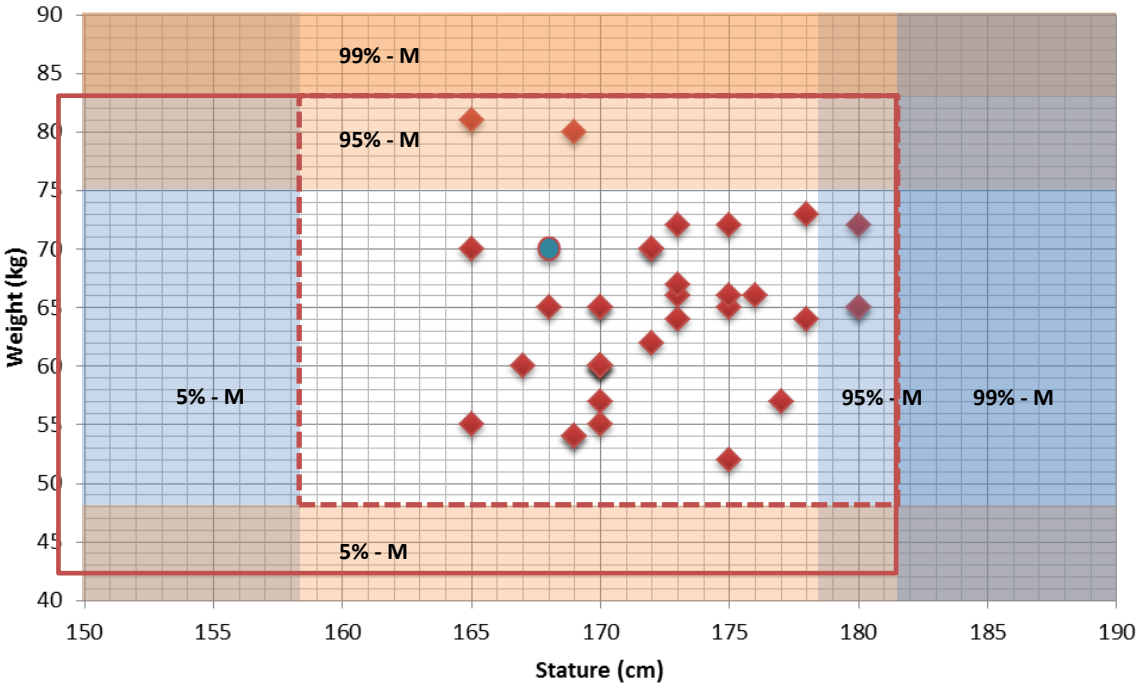

Figure 7.2 Participants' age and weight distributions

Driver posture

Driver's driving posture is highly related to their safety and comfort. As mentioned in 2.3.1, Society of Automotive Engineers (SAE) has presents a method in their recommend practice J4004 to calculate the positional relation among seat and vehicle hand and foot controls. But this method is limited to analyze the vehicles with foot pedals, for those non-motorized vehicles, it is no longer suitable.

Differing from the motor vehicle driving posture, deliverymen on their scooter sit relatively straight which is pretty close to normal sitting posture. Compared with the motor vehicle driving posture, the scooter posture requires much less space in horizontal direction but more on the vertical way.

In this project, the scooter driving posture is ultimately selected as the driver posture for the new delivery vehicle. There are four reasons for this choice.

1. Due to the flexibility and the mobility concern, the vehicle dimensions should be strictly controlled, especially the length and width of the vehicle. The scooter driving posture's much less requirement of space in horizontal direction and effectively helps to reduce the vehicle size,

2. Comparatively, the more straight sitting posture offers much more convenience on ingress and egress the vehicle, which is really essential for the delivery activities.

3. Though the regular vehicle driving posture is much more comfortable than the scooter one, deliverymen's driving duration is really short, maximum 15 minutes. It is not necessary to sacrifice vehicle mobility and convenient ingress/egress for short-time comfort.

4. All the deliverymen are familiar with this posture, which could reduce their learning costs after getting the new delivery vehicle.

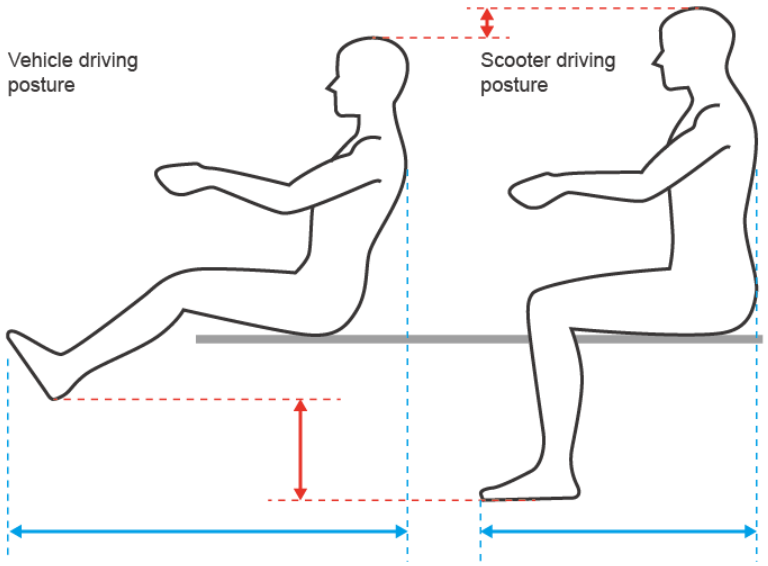

Figure 7.3 The comparison between vehicle driving posture and scooter driving posture

Cognitive Ergonomics

Since the scooter's straight posture is selected as the driving posture of the vehicle, the foot controls such as accelerator and brake pedals have to be transferred to the places within the operation range of hands.

A potential solution of this problem is keeping the scooter's handlebar design in which almost all the vehicle function controllers are concentrated, including an accelerated handle, a speed shifting bottom, lights bottoms, a horn bottom, two brake cranks and a display pane. There are three advantages of keeping this design. The first is this solution has been tested by practice, and it does well handle the vehicle steering tasks. Second, keeping the scooter handlebar design could cater the mental models of the deliverymen, which helps them quickly adapt to the new vehicle. The last but not least, among the 37 participants who joined the field research or evaluation research, 22 of them does not have motor driving licenses. Providing a motor vehicle operation system is doomed to exclude a large number of users, which goes against the purpose of this project. Therefore, a scooter like operation handlebar would be used in the new design.

7.1.3 The nature of new delivery vehicle

It is really essential to define which category does the new delivery vehicle belongs to before starting the form exploration process. Either motor vehicle or non-motorized vehicle should all be designed under the frame of existing standards and get approved by the local traffic and road administration.

Since driving posture and steering system of the vehicle would continue to use the design of the scooter's, and the more users without motor vehicle driving license are intended to be included, it can be helpful to define the coming new vehicle as a non-motorized vehicle.

According to Road Traffic Safety Law of People's Republic of China (2013) mentioned in 4.3.7, non-motorized

vehicles contain those which are installed with power sets but the designed maximum speed per hour, the light quality and the external size of which are in conformity with the relevant standards of the state. And according to Road Traffic Regulations of Shanghai (2008) and Non-motorized Vehicles Management Approaches of Shanghai (2013), the local government has authority to approve special types of non-motorized vehicles after a series of examinations. Therefore, it is theoretically possible to register the new delivery as a non-motorized vehicle once it meets the hard requirement from the legislations.

There are three major advantages of defining the new design as non-motorized vehicle.

1. As mentioned before, no motor vehicle driving license is required to use this vehicle which can significantly include more users.
2. The vehicle can efficiently avoid the traffic congestions in motorways during rush hours.
3. The vehicle is able to enter the motor vehicle restricted areas which can vastly increase the delivery efficiency.

The hard requirements brought by this decision include:

1. Maximum speed of 20km/h
2. Limited external size (unable to find related regulations, but the dimensions of electric tricks can be an important reference)
3. Run in the bicycle lane or the right side of the motor vehicle lane.
4. Park at specified areas.
5. Forbid to drive on elevated roads.
6. Load related regulations (see section 4.3.7, Non-motorized Vehicles Management Approaches of Shanghai, Chapter IV, Article 32)

7.1.4 The layout of driver cockpit and cargo compartment

After clarify the driver anthropometry, driving posture and the target volume of cargos, the vehicle package is briefly done as shown in figure 7.4. Driver sits in a quite straight posture in the front side of the vehicle and a 1,800L cargo compartment is located behind him. And according to the legislation, a partition is placed in the middle to separate the driver cockpit and cargo compartment. Since the design would be coped with the punch frame, the detailed dimensions of both compartments have not decided yet, which would be defined in the next section.

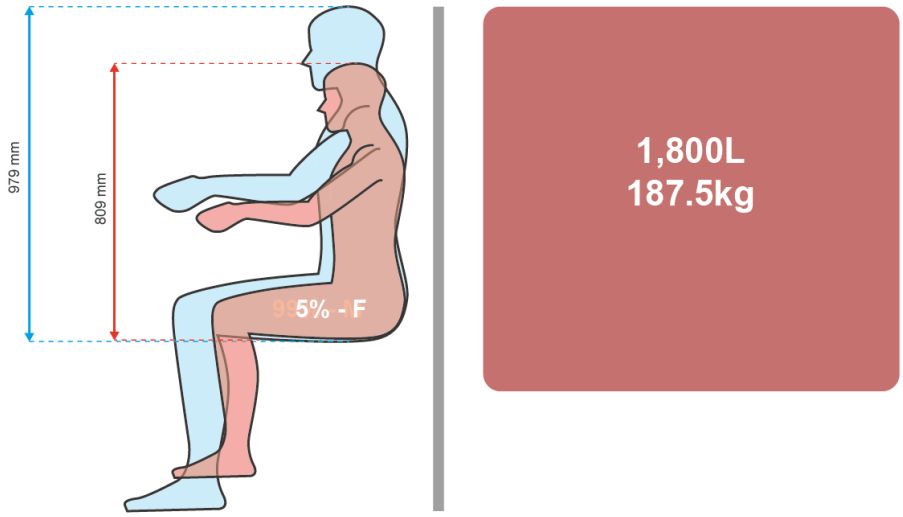

Figure 7.4 The brief package of the new delivery vehicle

7.2 The modification of PUNCH

As introduced in Chapter 4.1, the PUNCH project was carried out in a technical nature. Although almost all the technical solutions had been made, the distribution of the vehicle remained blurry. In this project, the solid literature study and field research has filled these blanks for PUNCH, but with the implantation of actual user requirements, some of the existing technical results have to be altered or temporarily put aside according to the real situation. The changes were all negotiated with mechanical experts to ensure the technology realizability and accessibility.

7.2.1 The adjustment of vehicle powertrain

As clarified in the list of functions, solo electric power would be used in the new delivery vehicle. Therefore, a new electric powertrain exactly like the one shown in Figure 4.2 would be applied on the vehicle. It consists of four main parts, including energy storage, electric machine and drive, coupling devices and wheels. Although the original powertrain is abandoned, the battery pack design and the selection of electric motor are intended to be kept. The eight $LiFePO_4$ batteries produced by M2 Power and the brushless electric motor HPM5000B made by Golden Motors are able to provide sufficient power to meet the output requirement.

Compared with the hybrid solution, there are several advantages of applying a pure electric powertrain in this project.

1. Electric powertrain involves much less components than the hybrid one, which significantly reduces the vehicle cost and design difficulty.
2. Less components contribute to reduce the vehicle mass and release more space for the driver and cargos
3. With the increasing price of petrol, and considering users' charging behavior, using electricity as power could vastly save usage expense for the deliverymen.
4. Electric vehicle fits the developing trends of the vehicle industry, especially the delivery vehicle industry.
5. The zero emission vehicles are more environmental friendly.

7.2.1 The adjustment of vehicle frame

As mentioned in section 4.1.4, a separate frame has been designed and manufactured by PUNCH team. The frame structure is 2860mm long, 1000mm wide and 1341mm high excluding ground clearance. Front, rear, side and rollover crashworthiness have all been simulated with the speed varied from 24.8km/h to 50km/h. Optimistic results have been obtained in most of the simulations, and unsatisfied designs have been all modified.

Since the vehicle's brief package has been decided, it is put into the vehicle frame to test the adaptability. The result is illustrated in Figure 7.5 in which three problems can be observed. First, the frame height is not sufficient. Apparently, the one-seater frame was designed for regular motor vehicle driving posture. After the driver sitting straight, it can barely satisfy the 5-percentile female data. The second problem is the lack of cargo space. It is also due to the initial design intention of carrying people rather than goods. Third, the wheelbase of frame seems too long, which may vastly influence vehicle's steering capability. Very rich "crash zones" have been left on the front and rear side to prove vehicle's crashworthiness performance. But since the top speed of the new design has been set at 20km/h rather than 50km/h, it is theoretically possible to reduce the length of the front and rear sides' frame side members.

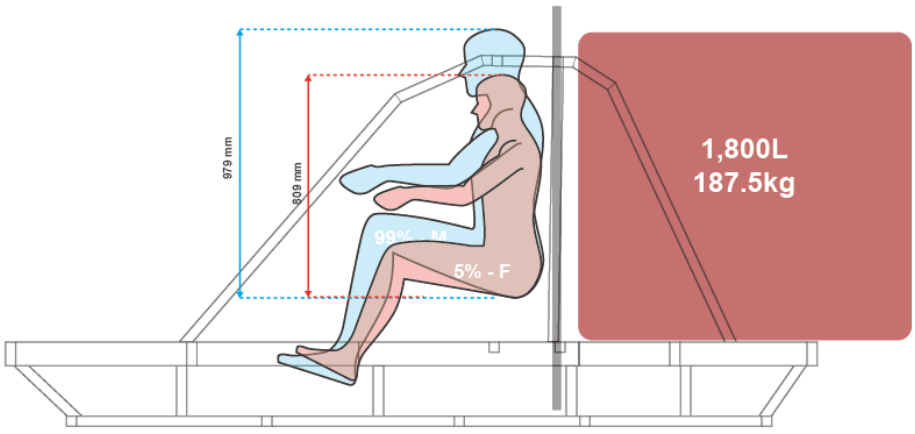

Figure 7.5 Place the brief package to the existing frame

The trike mentioned in section 4.3.3 is selected as the reference of the new design for its great load capability and flexibility. The length of the trick is 2700mm, which is fairly close to the entire length of the original PUNCH frame. But comparatively, the wheelbase of the trick is much shorter due to the forward placement of the rear wheels.

Based on the reference data, modifications have been made on the existing frame. The length of the wheelbase is cut to 1720mm, which is 180mm shorter than the previous design and 34mm longer than the Renault Twizy. The space of front and rear crash zones are all diminished to increase flexibility. The height of driver compartment is vastly increased to fit for the 99-percenile male data plus adequate clearance from roof, while the width of the cockpit is slightly reduced to cope with the straight posture and provide enough space for cargo compartment. The structure width is kept to ensure driver's safety from side crashes. Detailed parameters of the new frame are listed in Table 7.2, whilst the illustrations of modification can be seen in Figure 7.6.

Parameter	Unit	Specification
Length	mm	2300
Frame Structure Width	mm	1000
Estimated Vehicle Width	mm	1200
Height	mm	1540 (+140 of ground clearance)
Wheelbase	mm	1720
Top speed	Km/h	20

Table 7.2 Detailed parameters of the new frame

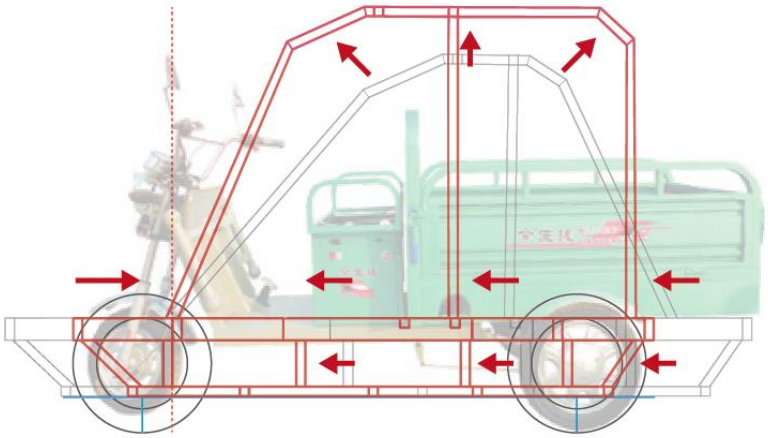

Figure 7.6 Illustration of modifications

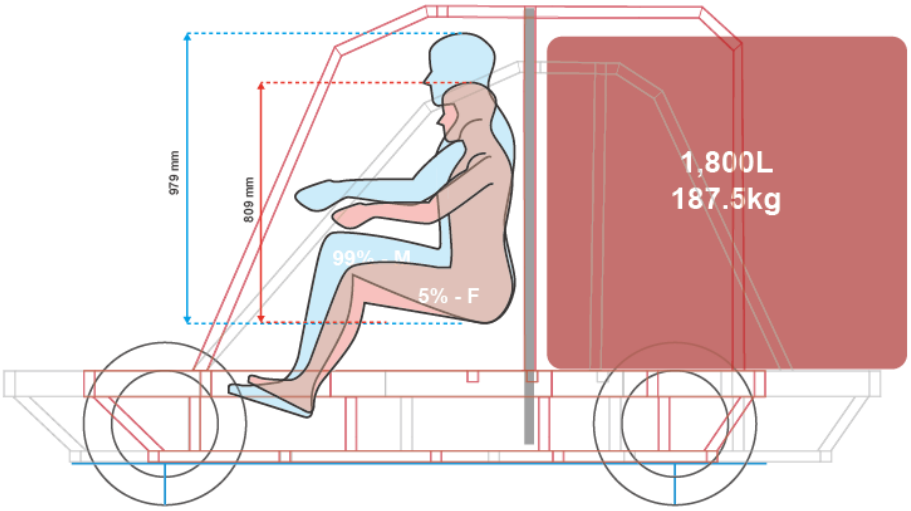

Figure 7.7 The detailed package of new delivery vehicle

Figure 7.7 displays the detailed package of the new delivery vehicle. It can be observed that a part of cargo space is left outside the frame on purpose. It is actually a semi-closed cargo compartment solution, which supposes to design an extractable cargo desk at the rear that can adjust the length according to the actual volume of load. The semi-closed design enables the possibility of room expansion, while the limited length of cargo desk can restrict the load volume under the maximum value of 1,800L. There are several advantages of applying this solution

1. According to the result of Krippendorf's experience dimensions, in the same circumstance, the semi-closed cargo compartment design looks enjoying a bigger load capability than the closed ones, which is very appreciated by the users.
2. The target volume of 1,800L is actually the extreme condition. Generally, a deliveryman's routine work volume is more or less lower than this number. The extractable cargo desk enables the delivery adjust the entire vehicle length according to every time's real circumstance to maximize vehicle's mobility and flexibility for each delivery activity.
3. The semi-closed cargo compartment is able to somehow provide protection to the parcels.

However, the drawbacks of this design are also obvious. First, the theft problem is still left to be solved. And the second, the semi-closed compartment still cannot entirely protect the cargos from bad weather conditions. Third, since the cargo compartment is relatively big, it is hard to reach the innermost parcels after lading. These three problems are needed to be solved in the later design.

7.2.2 The digital modeling of the adjusted frame

After finish the modifications of the original frame, Autodesk Alias is used to model the adjusted frame. The new frame and the later design of the new vehicle are named PUNCH-DMV for convenience, which means 'the delivery modified version of PUNCH'.

The PUNCH-DMV keeps the placement of cross frame members of the original design and only changes the dimensions of the side members. The crashworthiness of the frame was initially intended to be tested via FEM and simulation as well, but due to the limited project time and this process's less relevant relation to this project's main purpose, an expert evaluation is carried instead to access the safety and reliability of the frame. All the changes of PUNCH would be negotiated with the experts in Mechanical Department, Chalmers, and their suggestion would be taken to ensure the feasibility and accessibility of the PUNCH-DMV.

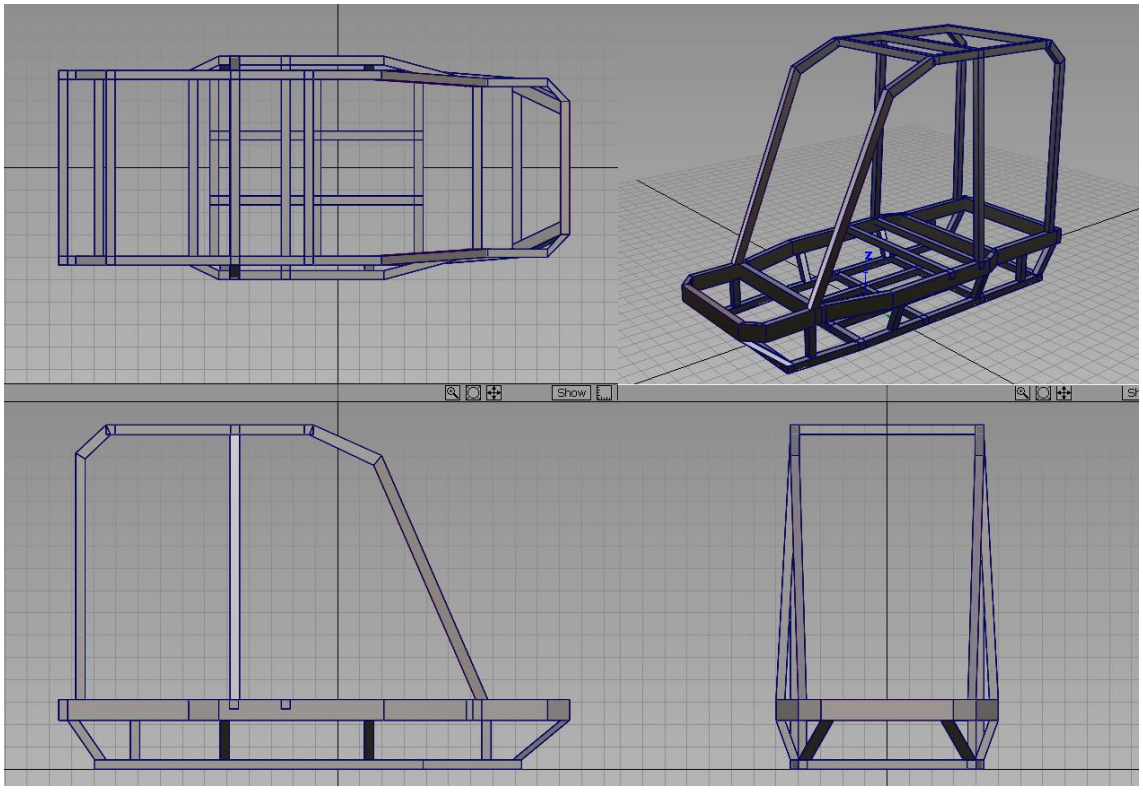

Figure 7.8 The digital modeling of the adjusted frame

7.2.3 The expert evolution of PUNCH-DMV

Professor Sven Andersson, the originator of PUNCH project and Sergej Abyzov, a master student of Automotive Engineering Master's Program are involved in the new frame evaluation. After they access the vehicle package, new powertrain design and the frame modification of PUNCH-DMW, several suggestions have been given on the new design.

Vehicle powertrain

Sven and Sergej approve the changes of powertrain system and agree that the electric powertrain it more suitable for this small one-seater delivery vehicle due to its light weight, less components and less occupied space. Three suggestions are given by them for the new design.

1. Use two hub motors on the rear wheels instead of the brushless electric motor HPM5000B. A hub motor is an electric motor that is incorporated into the hub of a wheel and drives it directly. The application of hub motors in PUNCH-DMV could release the space between two rear wheels, and reduce the sprung weight to ease vibration.

2. Place the battery pack in the safest place. There are two things required to remember during the design of an electric vehicle, protect the driver and protect the battery. Since driver compartment is usually well-protected from crashes, place the battery under the driver seat is a feasible solution.

3. Use narrower but bigger wheels than the ones used in previous PUNCH project. Since much less vehicle weight should PUNCH-DMV have, narrower ties can be used to increase the flexibility of the vehicle. Meanwhile, the higher vehicle height does not go well with the 13 inches rims, 14 inches wheels should be chosen for the aesthetic concern.

Vehicle frame

It is difficult to judge the vehicle crashworthiness just depends on the observation. If precise conclusion is required, digital simulations on the frame have to be done. However, since the new frame is pretty similar to the original one, according to Sven and Sergej, it can be assumed that the PUNCH-DMV owns some level of safety.

A modification has been point out by the experts. Two bars are added at the partition place and form a cross to further enhance the frame strength. And since the crash zones of the front and rear have been diminished, increasing the thickness of the front and rear frame members can be a potential solution. The thickness distribution of the original frame can be found in 4.1.4, while the thickness of the new is illustrated in Figure 7.9. The green area has a constant thickness of 3mm to protect the driver compartment from intrusion, and the yellow area has a constant thickness of 2mm to absorb the front and rear impact energy.

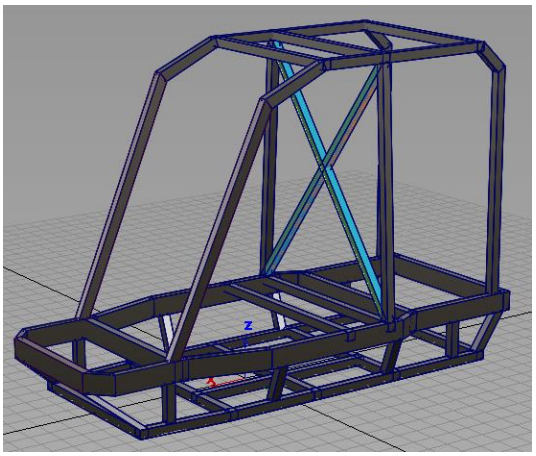

Figure 7.8 The modification of PUNCH-DMV frame

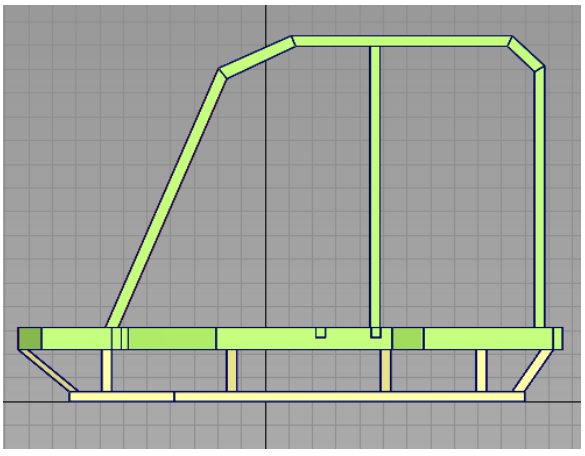

Figure 7.9 Thickness distribution of PUNCH-DMV frame

Steering system

Since scooter's handlebar design would be kept in PUNCH-DMV, more efforts are very likely to be required from the driver during turning. A power assist steering is suggested to be installed to help the driver with steering. Hydraulic or electric actuators increase controlled energy to the steering mechanism, which makes the driver only need to provide modest effort regardless of conditions. In addition, the forces acting on the front wheels can give driver an ongoing sense of how the wheels interacts with the road, i.e. the "road feel".

Suspension

The original estimated vehicle width of PUNCH is 1,500-1,600mm, but according to the field research result, distances between roadblocks in motor vehicle restricted zone ranges from 1,440 – 1,700mm, and the width of non-motorized vehicle lane is about 2,000mm. It is obvious that the original vehicle width is not suitable for the Chinese urban context.

The type of the suspension is a key factor which determines the overall width of the vehicle. In order to achieve an ideal width of 1,200mm, MacPherson struts and trailing arm suspensions are recommended to be used as the front and rear suspensions.

The MacPherson strut is one of the most widely-used suspensions in small and medium sized vehicles nowadays. It offers plenty of available space between the columns which allows better accommodation of vehicle components than other kinds of suspensions, especially in small cars. Furthermore, it is also a typically cheap solution with no bad performance, which is perfect for low cost vehicles. A trailing-arm suspension is also a simple cheap suspension with good packaging properties. It leaves sufficient space between the two arms which are really appreciative for small vehicles. A further benefit of this design is its good anti-dive and anti-lift properties. Stable ride is able to be provided to the driver (Atchison et al., 2011).

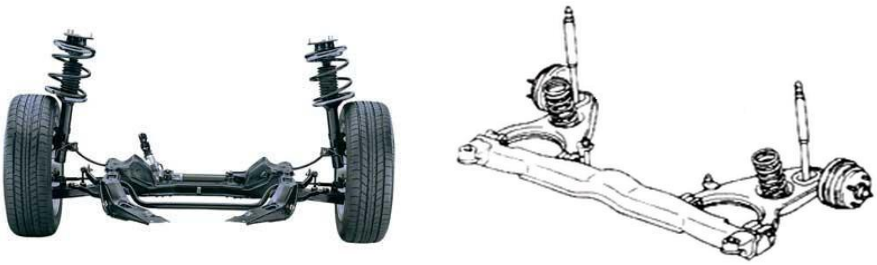

Figure 7.10 MacPherson strut and trailing-arm suspension (Atchison et al., 2011)

7.3 The visualization of PUNCH-DMV

After the PUNCH-DMV getting approved, visualization process is started to explore the form of the vehicle. Three methods are applied in this phase; a mood board is used to collect images in a composition to represent the intended visual aspect of the new PUNCH-DMV. Sketching and CAD modeling are applied to quickly explore and visualize the product. The following sections would mainly focus on the process and contents of these methods, while the results with detailed explanation would be presented in chapter 8.

7.3.1 Mood board

The mood board in this project was used to extend the selected concept. The sportive feelings, desired functions, forms and user traits are expressed via a series of images. It intends to concisely express the sportive, solid, accurate, functional and reliable feeling that the final vehicle should possess. A form connection between the expression of the mood board and the final product should be reflected in the vehicle exterior and interior.

Figure 7.11 Mood board

7.3.2 Sketching

The sketching is concentrated on the form design of vehicle exterior and interior as well as the realization of functions. The elements in the mood board, the pictures of selected concept, the functions required from user are integrated to form several proposals. The process of finding suitable forms, expressions and functionality of the vehicle mainly involves five sections.

1. Small thumbnail size sketches with rough vehicle profiles are developed quickly to identify interesting overall shapes.
2. Relatively detailed sketches are made on pre-printed papers with the frame's left, right and front view to ensure the concepts fit for the modified frame and ergonomics. The sample of underlay pre-printed paper can be found in Appendix VII.
3. Vehicle perspectives are drawn to reflect the surface transitions. Some details are added to reflect the realization of required functions.
4. Some of the sketches are colored with markers to reflect the color, material and surface treatment of different components.
5. More details are provided and the using context is also added in this phase.

Three different form concepts are done in this phase. They are evaluated by the author according to their aesthetic feeling, conformity with the mood board, the realization of functions, technical feasibility, ergonomics, potential market performance, and fitness of user favorites. The third concept is finally selected as the appearance of the final product.

Specification / full score	Concept 1	Concept 2	Concept 3
Aesthetic feeling / 5	3	4	4
Conformity with the mood board / 5	3	5	5
Realization of functions / 5	5	3	5
Technical feasibility / 5	5	5	5
Ergonomics / 5	5	4	5
Potential market performance / 3	2	2	3
Fitness of user favorites / 3	2	3	2
Total / 31	25	26	29

Table 7.2 The evaluation of vehicle form concepts

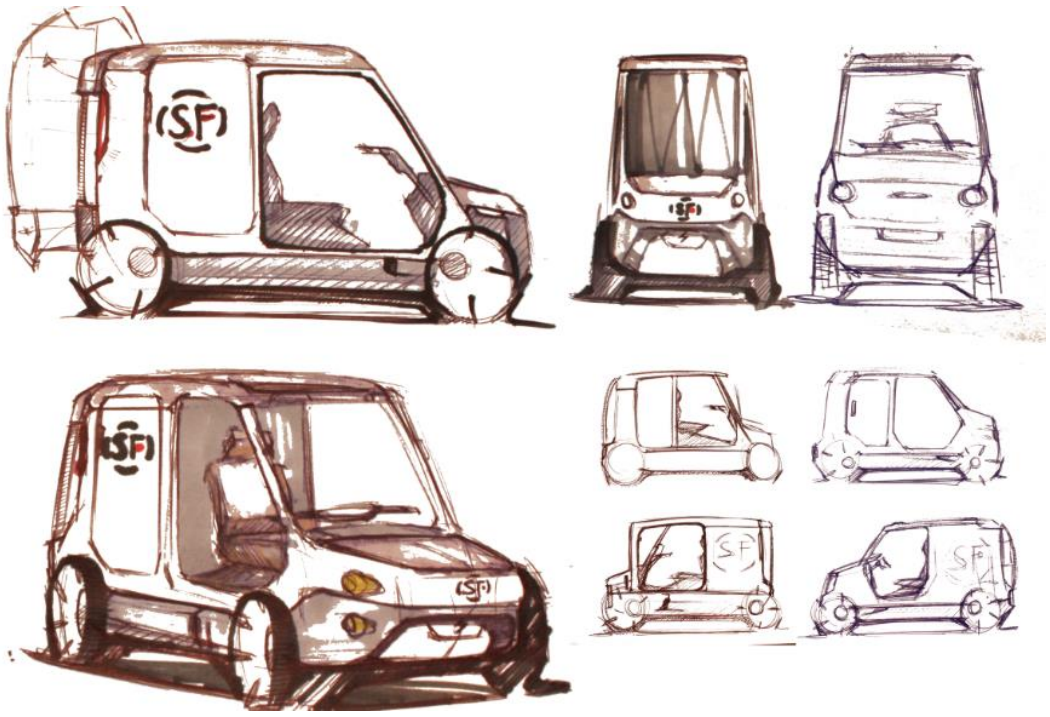

Figure 7.12 Form concept 1

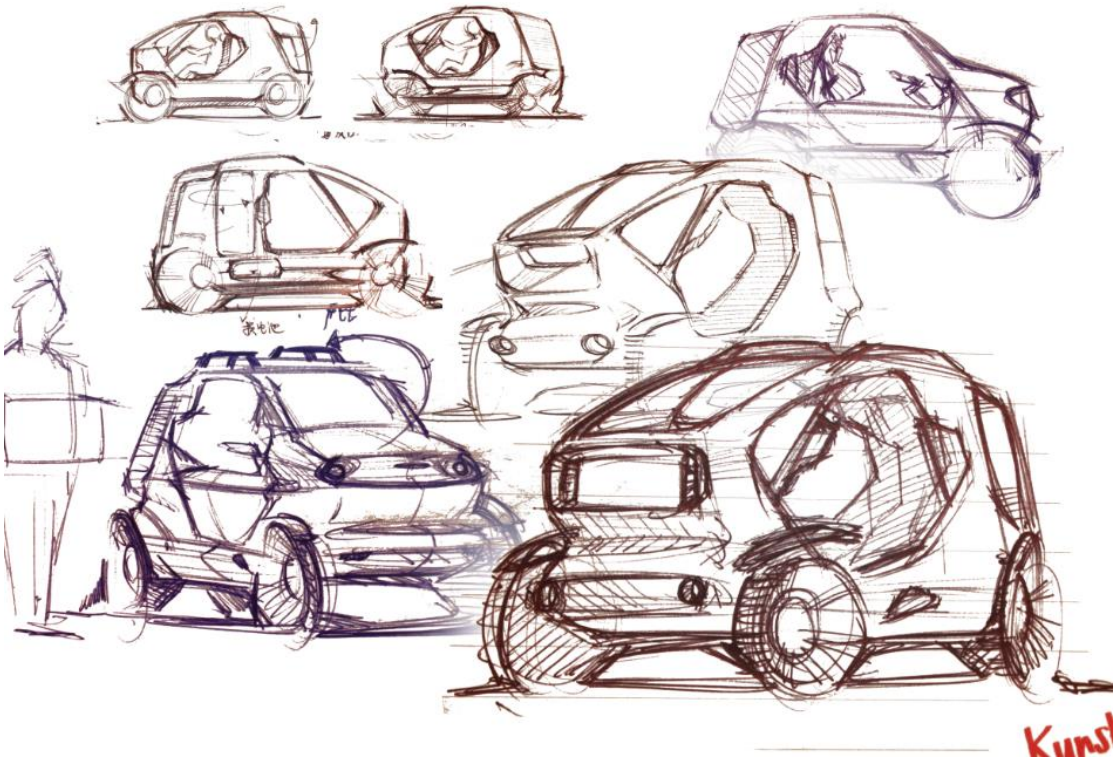

Figure 7.13 Form concept 2

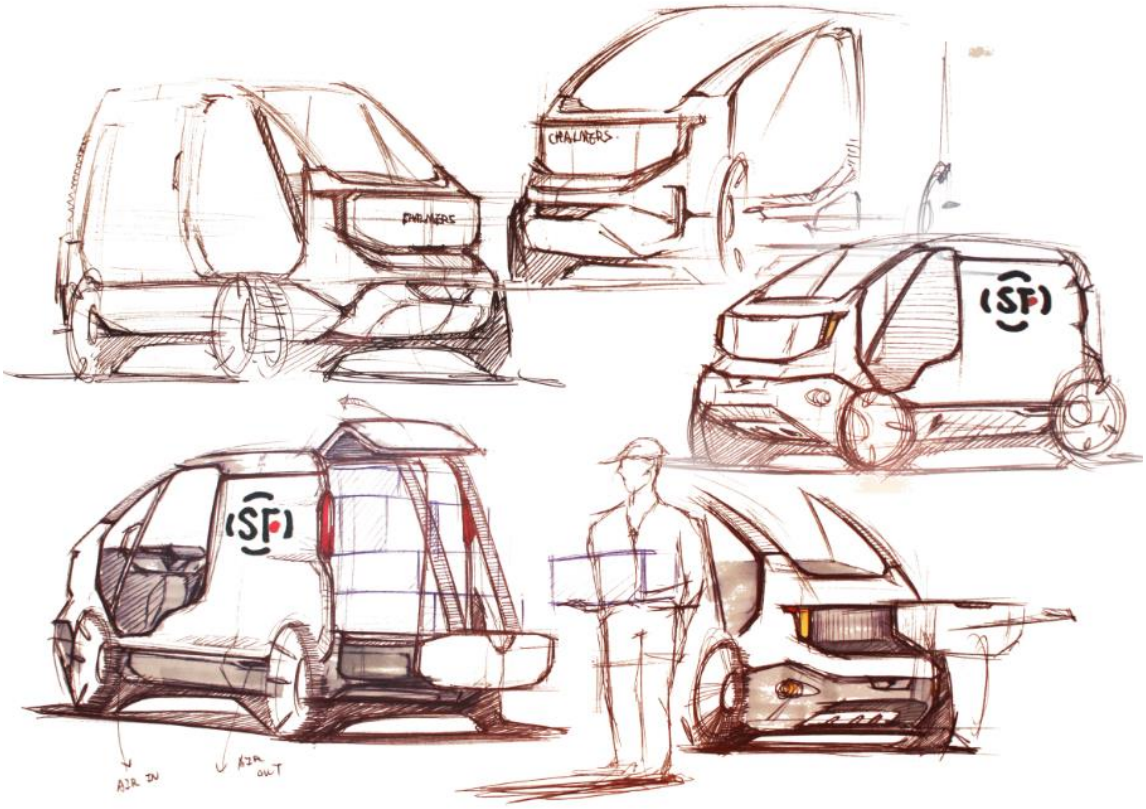

Figure 7.14 Form concept 3

7.3.3 CAD

The modeling process starts once after the sketching phase is done. In this project, two kinds of modeling software were involved in the digital model construction. A plug-in of Rhino called T-splines was used in the initial modeling stage to explore the profile of the vehicle as shown in Figure 7.15. The frame package made in Illustrator is imported into Rhino and a brief model is made to match the 2D profile.

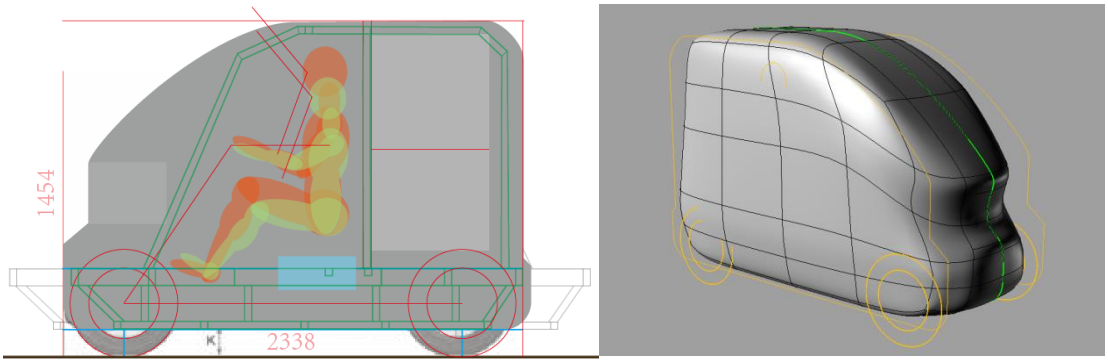

Figure 7.15 Brief model in T-spline

Then, Autodesk Alias was applied to model all the details of both interior and exterior. The model is try to couple the design in the sketch, and reflects all the embedded functions. After that, a render, Keyshot, combined with Photoshop was used to form the final renderings.

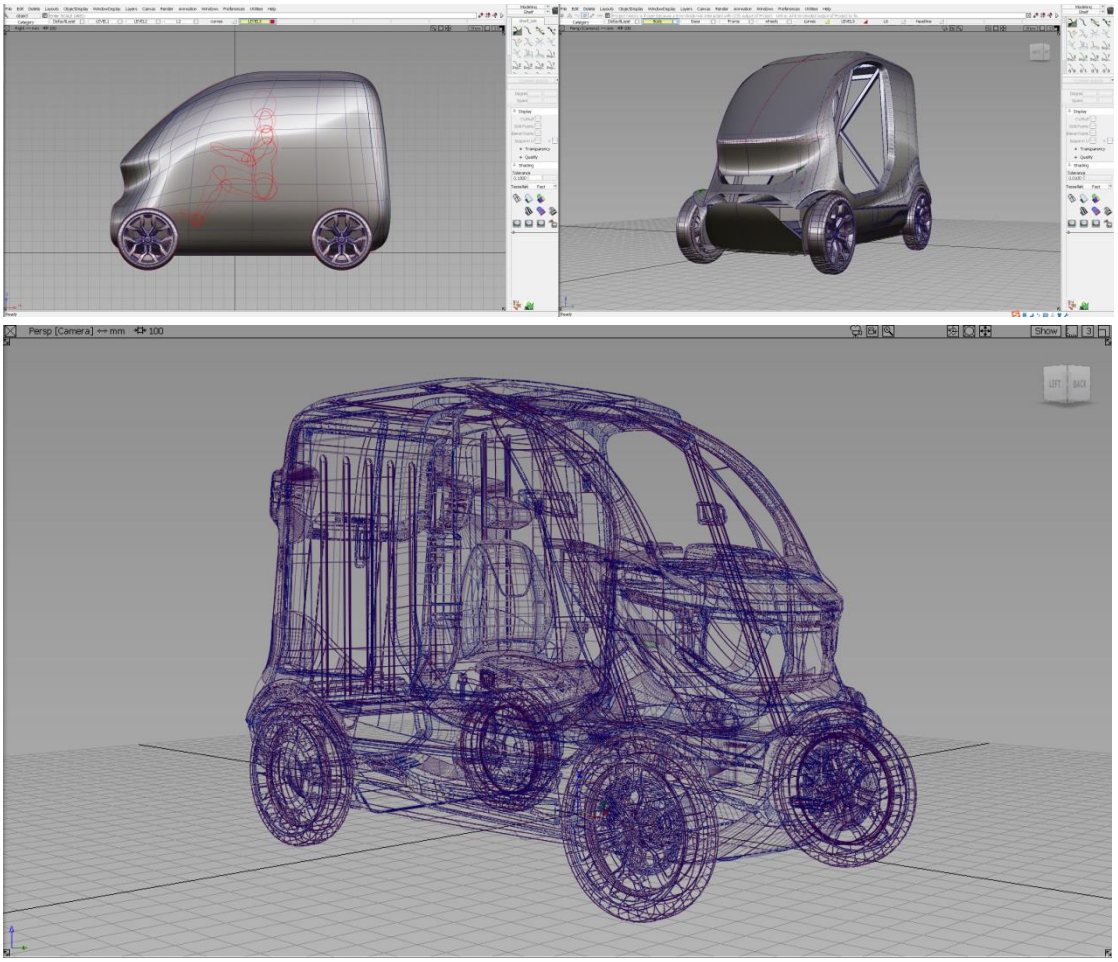

Figure 7.16 Final model done by Autodesk Alias

7.4 Chapter conclusion

The concept refinement process includes four main phases, i.e. defining the package of PUNCH-DMV, modifying the original PUNCH design, evaluating the modification and visualizing the final concept.

Due to the contradiction between the requirements of large cargo compartment and small flexible vehicle dimensions, deciding the vehicle package becomes a crucial and primary precondition before staring the concept refinement. After a series of calculations and decision making, a rough package layout is constructed with the listed decisions made.

1. 1,800L is selected as the volume of target cargo compartment with maximum 187.5kg cargo load.
2. 5-percentile female to 99-percentile male anthropometric data is chosen to be applied in the PUNCH-DMV.
3. The scooter driving posture is kept for it requires much less space, and the design of scooter handlebar is also remained for the vehicle steering.
4. PUNCH-DMV is defined as a non-motorized vehicle.

Then, the rough vehicle package is implanted to the original frame. Obviously, the PUNCH frame is not suitable for the different driving posture and much large cargo space. Modifications have to be made on the initial design. The wheelbase and vehicle dimensions have all been altered and a semi-closed cargo concept is generated to solve the conflicts between load capability and vehicle mobility. Meanwhile, a change is also made on the powertrain system; an electric transmission path is applied instead of the original hybrid one.

All the modifications have been evaluated by the experts in the Mechanical Department, Chalmers. Suggestions in the field of powertrain, frame, steering system and suspension are given by them, including:

1. Use two hub motors on the rear wheels instead of the brushless electric motor.
2. Place the battery pack under the driver seat.
3. Use narrower but bigger wheels.
4. Add a pair of cross bars in the partition place.
5. Change the thickness distribution of the frame.
6. Use a power assist steering.
7. Use MacPherson struts and trailing arm suspensions as the front and rear suspensions.

After the evaluation, the visualization process is started to explore the form of the vehicle. Mood board, sketching and CAD are used as the main methods to develop and visualize the product. After a simple form evaluation done by author, the form concept 3 is selected as the final design.

8. Final concept

This chapter presents the final concept design and end result of the master thesis project. The form, function, ergonomics, technical aspects and product strategy of PUNCH-DMV are respectively explained.

Figure 8.1 The final concept of PUNCH-DMV

8.1 Form design

The final design of PUNCH-DMV is shown in figure 8.1. Overall speaking, it owns a very strong visual appearance which precisely reflects the sportive, solid, accurate, functional and reliable feelings expressed by the mood board. Though lots of quadric curved surface is applied in the exterior, the massive application of plastic material and reasonable surface segmentation could help to vastly reduce the vehicle cost.

8.1.1 Vehicle dimension

As defined in section 7.2.1, the dimensions of PUNCH-DMV frame is 2,300mm long, 1,000mm wide and 1,680mm high with ground clearance. After mounted on the vehicle body, the length reaches 2,600mm with the width of 1235mm and height of 1730mm.

Figure 8.2 The dimensions of PUNCH-DMV

Figure 8.3 The size comparison among PUNCH-DMV, Twizy, Smart for two and Wuling Sunshine

The Figure 8.3 provides a more vivid comparison among PUNCH-DMV, Renault Twizy, Smart for two and Wuling Sunshine. It can be observed that PUNCH-DMV enjoys a similar width with Twizy, but it is 260mm longer and 276mm taller, which is fairly close to the data of a Smart for two. Compared to the Wuling Sunshine, the most common illegal-modified minibus for delivery, PUNCH-DMV is much smaller in size. The strict -controlled vehicle dimensions enable the new PUNCH to drive as a non-motorized vehicle in the bicycle lane, fit into many narrow delivery contexts with its mobility and flexibility and occupies relatively less space during parking.

8.1.2 Exterior form design

The vehicle exterior design intends to express the sportive, solid, accurate, functional and reliable feelings which are displayed in the mood board.

The entire exterior mainly consists of three parts, the roof and top-hinged liftgate part, the medium body segment as well as the chassis. Obviously, the body segment is the dominant part of the vehicle. Instead of the flat and straight elements in most of the freight vehicles, relatively complex quadric surfaces are applied, which create more dynamic and sportive feelings than the straight ones. The slightly convex but tense surfaces in the two sides let user generate some powerful and solid associations and increase their trust to the vehicle functions. On the contrary, the design of the subdominant part, chassis, integrates more straight and stiff lines. The intention of this design is to demonstrate the durable, robust and stable traits of the chassis. The different style between the dominant and subdominant segments forms an appropriate interesting contrast within the vehicle, but not too dramatic to lose harmony. As the subordinate part, the design of the roof and top-hinged liftgate follow the style of the vehicle body, which makes the entire upper body looks quite uniform.

The proportions of these three parts are not actually decided by the author. It is determined by the frame structure. In order to obtain a better effect of ingress and egress, the height of the subdominant part is just slightly higher than frame's side members, which is approximately one-fourth the height of the medium body segment. Aesthetically speaking, the proportion is not very ideal, but in order to achieve a better functionality, the appearance has to sacrifice in this case.

Figure 8.4 The exterior form design

8.1.3 Interior form design

Compared to the sportive and complex vehicle body design, the interior of PUNCH-DMV is calmer and more concise, which aims to concentrate the driver and steady their nerves during driving. The form of it is less symmetrical than the exterior design, because more functions are integrated and distributed in the not big compartment.

The driver seat and dashboard are the dominant parts of the interior. The form of the seat is quite simple. The large plump surfaces on it offer the user a direct feeling of comfort and safety. The well-controlled shape could perfectly fit the ergonomics of human body, but not too much to influence the ingress and egress activity. The dashboard form design is also quite concise. The shape of knee bolster is formed according to the driving posture, which leaves enough spaces for their legs but not sufficient for cargos. It is actually a constraint aiming to protect them from the potential injury brought by improper-placed parcels during crash.

The subdominant parts of the interior consist of the steering handlebar as well as the storage bin and cup holder segments. The shape of the handlebar follows exterior design style. The dynamic but muscular shape tends to express the good capabilities and controllability of PUNCH-DMV. Comparatively, the look of the storage bin and cup holder segments is much clam. Similar to the design of the chassis, the application of more straight elements intends to provide a durable, functional and robust impression to the user.

The rest components in the driver cockpit are the subordinate parts, including rearview mirrors, seat belts, parking brakes, overhead components, etc. The forms of these stuffs follow the calm and concise style which aims to express the functional feeling while not distracting the attention of driver.

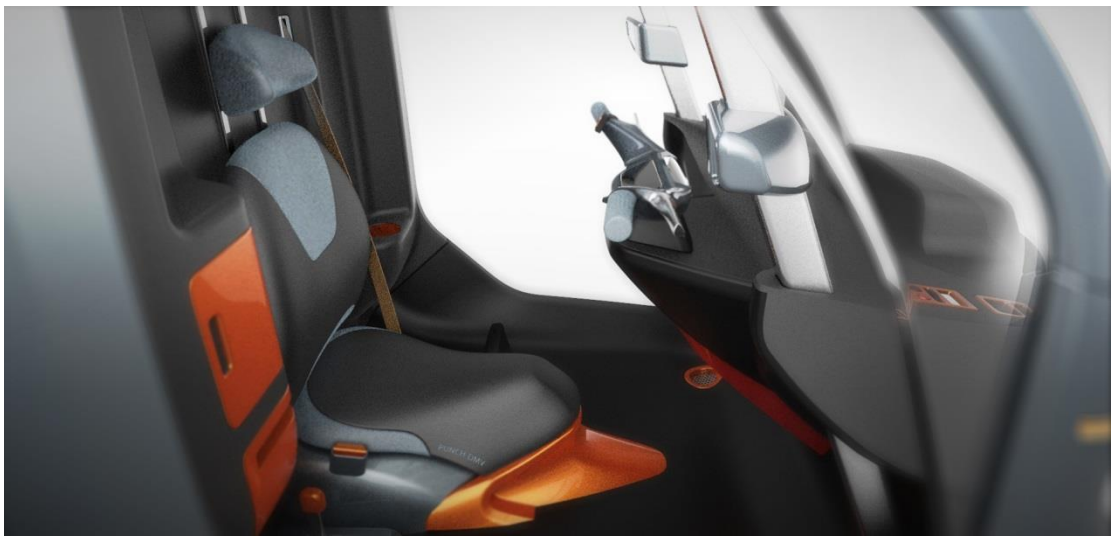

Figure 8.5 The interior form design

8.1.3 Material selection

The selection of material is highly related to PUNCH-DMV's weight, cost, manufacture and sustainability. Using fewer and lighter materials can significantly reduce the curb weight of the vehicle, and therefore increase the battery range for per charge. And applying less or mono material construction can vastly reduce the manufacture difficulties and ease the recycle process after the vehicle ends it service life. Two major materials which build up over 80% of the vehicle exterior and interior are discussed here.

The first is aluminum alloy. As mentioned in the knowledge base, the main material used for the frame is the tubular aluminum 6063-T6 type. It is perfect for its low weight, sufficient resistance, cheap price, accessibility and good welding characteristics. Besides the frame, aluminum material is also used in the roof component, the extractable cargo desk and other stressed members. It can perfectly undertake the cargo weight while less increase the weight and manufacture cost, which is really admired in this small one-seater.

Another material is polypropylene, also known as PP, which is a reasonably economical engineering plastic used in a wide variety of applications in lots of industries and our daily lives. This material is used in most of PUNCH-DMV components of body, chassis and interior instead of the common-used heavy metal sheets. It is famous for its light, tough and flexible, and it has good resistance to fatigue. Considering the out-door nature of the vehicle, the melting point and degradation condition of the polypropylene are quite essential parameters.

The melting point of commercial isotactic PP ranges from 160 to 166 °C, which is relatively safe of being exposed to the hot summer in China, but it is liable to chain degradation when presenting in sunlight. Therefore, for external applications, UV-absorbing additives must be used when manufacturing the material (Cacciari et al., 1993).

Polypropylene material is just starting to be applied in the automotive industry. Toyota Me.We, launched in 2013, is the first one to apply this material in the vehicle body, which makes it weigh 200kg lighter than a normal steel same-sized vehicle. The cheap, environmentally responsible, and fully recyclable traits of it make it won universal praises. And the application this material is considered as a potential developing orientation for the future industry (Top Gear, 2013).

In all, both of the two applied materials all own the desired characters of low weight, cheap price, good accessibility, sufficient performance and easy manufacturability. The application of these materials is believed to be positive to achieve the high cost-performance market positioning of PUNCH-DMV.

Figure 8.6 Aluminum alloy, polypropylene and Toyota Me.We

8.1.4 Color trim and customer branding

The PUNCH-DMV shown in Figure 8.1 is actually a STO version of it since the character of the persona is a STO employee. The painting of the vehicle should vary according to the owner companies, but there are several general principles of the vehicle color and texture selection should follow during customer branding.

1. The medium body segment, i.e. the dominant part of PUNCH-DMV should be painted in line with the major color of a company's CI system. The color should be able to provide enough brand identity and form a proper contrast to the brand logo printed on both sides of the body. Car paints with good quality should be selected, and a layer of glossy glaze is intended to put on the paint. Though it might increase the vehicle cost, the beautiful high-quality looking of the vehicle can contribute to promote the brands image of an enterprise, and provide the customers a kind of professional feeling.

2. The chassis should keep the plastic's original grey tone or be painted to black. The selection of the dark color for this part has two purposes. One is to form a contrast to the dominant part and makes it more conspicuous. Another is that the darker and less glossy looking of the undercarriage in correspondence with its straight form language could further increase the feeling of robust, functional and reliable. The bottom piece of the chassis should use a slightly lighter or darker color than the rest part, which is used to indicate that it could be disassembled during vehicle maintenance

3. The roof and top-hinged liftgate part should also use a dark color, but the surface treatment is required to be close to the vehicle body. The smooth but dark roof intends to express the feeling of high quality, durable and robust.

4. The rear semi-closed cargo compartment should also be paint into black. This is not just for the user feeling, but also because this segment must be always worn and dirty.

5. The interior is designed in the grey tune as well, which is believed to be benefit for the driver to concentrate and steady their emotions on the road. It can be deemed as one of the design interventions that prevent the driver from dangerous driving behaviors. In addition, the same to the cargo compartments, the semi-closed cockpit should also be relatively dirty, darker components can effectively reduce user's negative feelings.

6. A bright color can be given on some interior details to illustrate some interior functions. It is quite

eye-catching and recognizable in the dark tone which allows the diver to reach in a really short time. This is a clever way to keep driver's attention on the road. And since the main vehicle material is plastic while over half of the deliverymen are keen on smoking, the place with a fire extinguisher is marked in red. The warning color enables the diver to react quickly if an emergency happens.

Figure 8.7 PUNCH-DMV in S.F., YTO and STO paints

8.2 Functions

All the functions that PUNCH-DMV has are listed in this section. Some of these functions are designed to fulfill the user requirements, while the others are interventions aimed to alter undesired user behaviors. The functions are presented according to the delivery activities identified in the field research. Although the vehicle is not directly involved in the some of activities, the design is still somehow able to change the current undesirable situation.

8.2.1 Driving related functions

Driving related functions includes all the design served for a better driving activity, including the design of lighting system, wheels, semi-closed cockpit, windshield, steering handlebar, driver seat, etc. The brand-new design offers the driver a totally different driving experience and vastly improves their comfort, safety and efficiency.

Light system

The vehicle lighting system is made of four pairs of lights at exterior and a dome lamp, and they all use LEDs as light sources. Two "7 shape" large headlights are located in the front site. They are used to illuminate the road condition and mark the vehicle width at night. They also indicate the turning direction when driver steering. It can be observed from both front and side, which can easily attract the attention of other driver or pedestrians.

Figure 8.8 Vehicle lighting system

Two high beams are mounted just under the headlights. Since the vehicle is only used in the urban context, the brightness of these two beams is far weaker than the ones on the regular motor vehicle. It is just slightly stronger than the headlight and works as the supplements when meeting bad weather conditions.

A pair of large taillights is placed on the rear site as the normal vehicles. They would lights up during night, at brakes or on turning. It can be observed from both front and side, and together with the headlights, they demonstrate the length of the vehicle.

Two small but strong flashing lights are mounted at the end of the extractable cargo desk. After the desk is moved outside and placed on parcels at night, these two light would automatically keep flashing to remind the people surrounded of vehicle's laden length.

A dome lamp is designed at the roof above the driver. It is used to illuminate the interior space at night time. The switch of it is just aside, which enable the driver to easily turn it on and off.

Wheels

As suggested by the experts, narrower but bigger wheels are used in PUNCH-DMV for its less vehicle weight and aesthetic concern. A front wheel is made of a 14 inches aluminum alloy rims and a 120-80-14 motorcycle tire, while a rear wheel is composed by a 350W brushless non-gear hub motor and a 120-80-14 motorcycle tire as well. The application of hub wheels significantly reduces PUNCH-DMV's sprung mass, which helps to provide a smooth and flexible ride to the driver. And also, it releases the space between rear wheels for cargos load.

Semi-closed cockpit and windshield

As all of the subjects in the field research expect, the design of the semi-closed cockpit is able to shade the driver in bad weather conditions, protect the driver from accident to some extend and provide a comfortable place to rest during their breaks. This design could effectively reduce or release driver's fatigue and increase their service efficiency.

A convenient ingress and egress is also provided by PUNCH-DMV. Since the vehicle applies a separate frame and a large ground clearance is required due to the bumpy road condition in China, the cockpit floor is 480mm above the ground. In order to make up the technical defects, a step with 300mm higher than the ground is designed on each side of the chassis to help the driver get in and off.

The design of the windshield of PUNCH is also quite interesting. Besides the big piece between the A pillars, two subsidiary pieces are mounted on both sides which are marked in orange color in the left picture of Figure 8.9. It is because the head of the vehicle is slightly narrower than the rear site, in order to prevent the air turbulence or rain drops from front enter the cockpit during driving, these two subsidiary pieces are designed to steer the air flow.

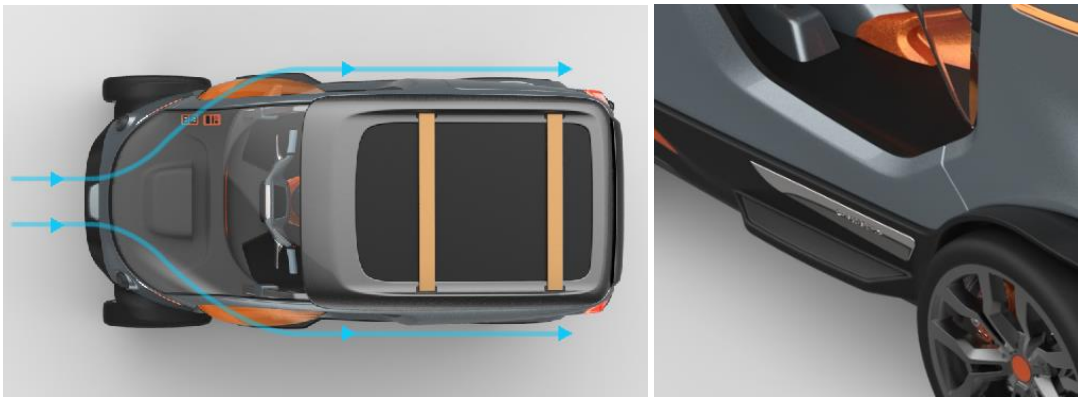

Figure 8.9 The design of windshield and step

Handlebar

The handlebar design of PUNCH-DMV is quiet close to the one that used in current delivery scooter. The controllers of all the driving related functions are gathered on it. On the left hand side, a red button controlling the headlights and high beams are placed over an orange horn button, while on the right side, an accelerated handle and an 'air conditioning' adjustment are placed. A pair of aluminum brakes is placed in front of the handles, and a display panel is located in the middle.

The information shown in the display panel is illustrated in Figure 8.10. Except that the vehicle speed is indicated

by a mechanical pointer, the rest information are displayed via LED indicator light, including the working condition of battery, speed, turning direction, lighting system, 'air conditioning', safety belt and lock system. The icons of the information are quite understandable, and their placement is arranged in line with the existing scooters to match users' mental model. The sizes of the icons are also adjusted to make sure that they could be easily observed during driving but not too large to distract the driver.

Figure 8.10 The design of handlebar and HMI panel

Driver seat

The driver seat has shown in Figure 8.3. The form of this seat merges the features of both vehicle seat and scooter seat. The shape of the cushion where the driver sits on is very close to the seat design of some large scooters or motorcycles. Rather than sitting with legs together, PUNCH-DMV driver places his/her legs apart just like the motorcycle drivers do. Though less comfort might be provided by this posture, it is believed that it may be a better solution for quick ingress and egress, because the convex and narrow sitting surface keeps the driver on rather than in the cushion. Since the maximum continuous driving period of a delivery is just 15 minutes, it is believe that no significant discomfort or fatigue would be brought by this design. But for the time issue, no evaluation test has been done to evaluate the actual effect of this design; all the contents above are based on reasonable inferences.

Except the seat cushion, the headrest and backrest design is very similar to the regular vehicle seat. They are used to support driver's neck and waist during driving. Since the space in the cockpit is quite compact, the seat cushion can only adjust vertically, while the headrest and backrest are able to adjust back and forth, upwards and downwards.

Other driving related functions/design

Besides the functions listed above, there are several functions/design available to facilitating deliveryman's driving behavior.

1. Since most of the deliverymen do not willing to wear a helmet for its discomfort and odd looking, a safety belt is equipped aside the driver seat. If a driver does not fasten it during driving, an indicator light on the display panel would be on with slight beep sound made. It is a persuading intervention which aims to remain the user of safe driving, but since the driving period of a deliveryman is usually very short and PUNCH-DMV is categorized as a non-motorized vehicle, it is feasible for them to drive the vehicle without the seat belt fasten.
2. A parking brake is designed at the right side of the driver seat. The driver could use it to facilitate parking in some undulating terrains.
3. Since the size of the windshield is quite big, a piece of visor is available at the roof to avoid direct sunlight during driving.

4. Two concave spaces are created close to driver's head, which aims to provide enough visual field for the user.

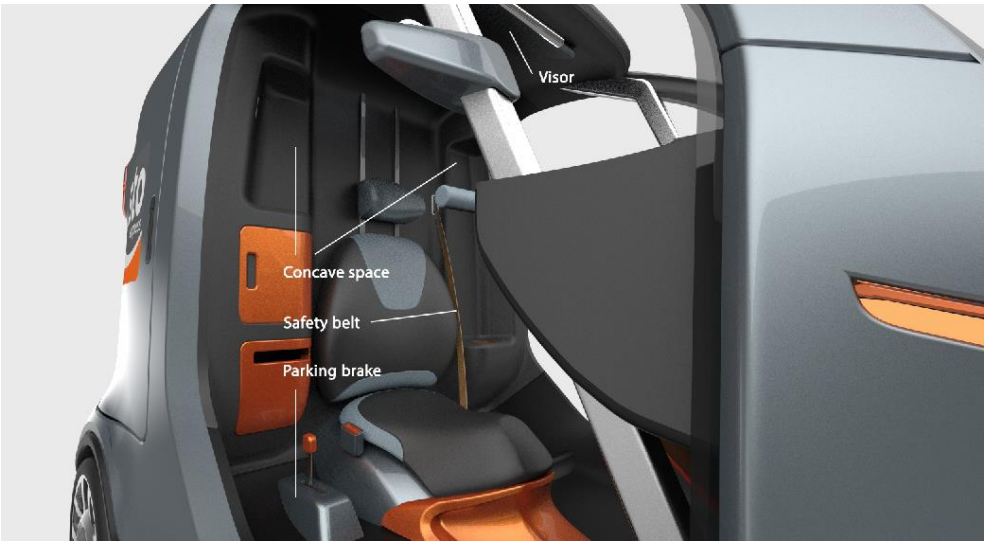

Figure 8.11 Other driving related functions/design

8.2.2 Loading/unloading related functions

There are four places that allow the deliverymen to store the parcels, including the driver cockpit, roof, closed cargo compartment and semi-closed cargo compartment. The parcels are loaded to these four locations in line with their different features. Figure 8.12 illustrates the layout of the four places in the vehicle.

Figure 8.12 The layout of cargo storage places in the vehicle

Driver compartment

The driver compartment provides very limited space (about 7 liters) for the temporary storage of parcels. The function of this storage place is actually very close to the front basket of the delivery scooters. Fragile objects or small parcels ready to be delivered can be placed left to the driver seat. A short baffle is designed to prevent the parcels from moving during driving, as shown in Figure 8.13.

Roof

The aluminum alloy made roof is designed to carry the overlength cargos only. When a parcel is too long to fit into any of the rest storage rooms, it can be placed on the roof and fastened by two wide fixing bands. Each band is 900mm long in total and controlled by a strong clockwork spring mounted on the left end. When the roof is unladen, about 750mm of band is exposed. The limited length of these bands is actually a forcing intervention. Since the vehicle is relatively high, in order to keep a low center of gravity for stable riding, the number of the cargos on roof should be strictly controlled. With the constraint from bands, the deliverymen are unable to overlay more parcels and therefore ensure the road performance and safety of the vehicle.

Figure 8.13 Cargo space in cockpit

Figure 8.14 An overlength parcel on roof

Closed cargo compartment

The closed cargo compartment is right behind the driver cockpit with a door at the right side of the vehicle. The dimension of it is 972mm long, 772mm wide and 1,112mm high. The gross volume of it is 834L, and the actual load volume is about 700L. The closed compartment design can perfectly protect the parcels from bad weather or theft.

Customization

The intention of designing this cargo compartment is to carry documents and small or middle-sized parcels to replace the function of woven bags. Slide rails are mounted every 110mm on the left and right cabin walls and different size of plastic drawers are applied to hold the cargos. The users are allowed to customized this compartment, i.e. they can choose the different number and size of the plastic boxes according to their real needs, for example, for those who have to deliver various areas but with less parcels for each place, they could choose to use five 200mm high boxes; for those who want to separate the documents and cargos, they could use a 100mm box for dedicated use and place the parcels in two 400mm drawers for instance.

Figure 8.14 The close cargo compartment and plastic drawer

Delivery sequence

Similar to the woven bag, the driver can use the plastic drawer to organize the parcels in accordance with their delivery sequences. Different drawers symbolize different areas. Parcels to be delivered earlier are placed close to the door, while the later ones are put near the rear cabin wall. In addition, the user can also adjust the vertical positions of boxes according to their area location or weight.

The simplification of activities

The most significant advantage of designing these drawers lies in its effects of simplifying the sorting, loading and unloading activities. Figure 8.15 displays a desired HTA of a combined sorting and loading activity after the application of these plastic drawers.

The user first takes the drawers from the vehicle and places them on the outlet ground. During the scanning, the deliveryman should check parcels' address as well and put them into different boxes according to their

destination. After the quick sorting, parcels would be reorganized within the drawer in line with their delivery sequences. And finally all the drawers with cargos would be put back to the closed cargo compartment. Compared to the previous HTAs of the two activities shown in Figure 5.25 and 5.26, the new sorting and loading activity involves much less process. Only 4 tasks, 21 actions and 3 repetitive loops are contained in the new procedure, while 6 tasks, 35 action and 10 repetitive loops is required when following the old ones.

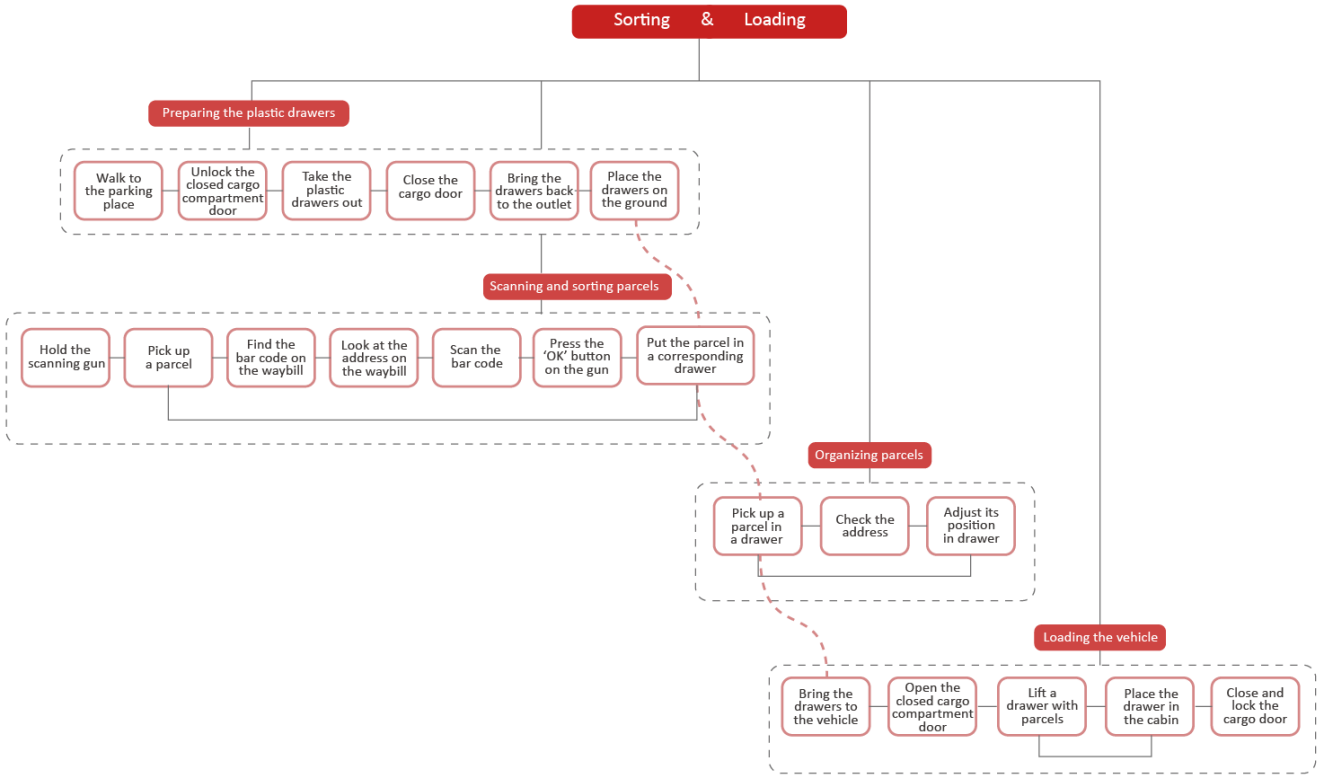

Figure 8.15 The new HTA of sorting and loading activity

The same consequence also happens in the unloading activity. After importing the new design, the actions required in the activity are vastly reduced. Since the deliverymen are on longer required to find a temporary place to store later-delivered parcels, the complex and time consuming 'totally unloading' activity is entirely eliminated. And the 'partly unloading' activity is also become much easier to execute.

Overall, the HTAs have demonstrated the theoretical superiority of the new design. Under the condition of the same goal, the new activities involve far less tasks and actions, and therefore possess much better delivery efficiency.

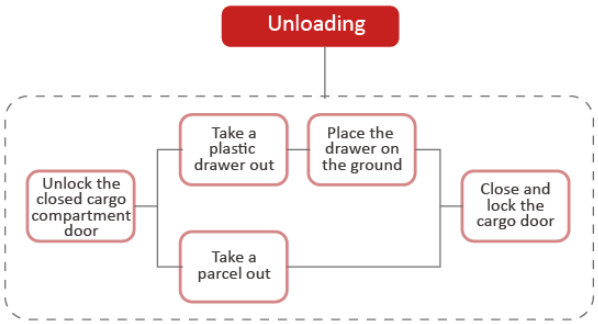

Figure 8.15 The new HTA of unloading activity

The alteration of undesired behaviors

The design of these plastic drawers also contributes to alter users' undesired behaviors. During sorting, loading and unloading activities, less 'put down/aside' actions is involved which can effectively reduce the happening of 'throw and drop' behaviors. And during the delivering activity, especially for the delivery pattern 1, the deliverymen are no longer able to drag the parcels on the floor or stairs during walking. In addition, as a part of

the vehicle components, the users are very likely to prize these plastic drawers and pay more attention during their usage. Therefore, the application of this design can also be deemed as a persuading intervention to change improper behaviors.

Semi-closed cargo compartment

The semi-closed cargo compartment is designed at the rear site of the vehicle. It consists of an extractable cargo desk, a top-hinged liftgate and cabin walls. It is a place to store large parcels to deliver or from collection. The user could first draw cargo desk out, adjust the angle of liftgate if necessary, then place on the cargos, and fix the lockable bands at last. The design of the fixing bands is exactly the same as the one on the roof and the length of them are calculated to resist overload.

The dimension of this cargo compartment is designed according to the target volume and relevant regulations. According to Non-motorized Vehicles Management Approaches of Shanghai (2013), the loads on tricycle shall not exceed 1 meter from vehicle body in the rear site. As a similar product, the design of PUNCH-DMV chose to obey this article. Therefore the maximum length of the extractable cargo desk is assumed to be 1,000mm away from the rear, with its 815mm width, 1,150mm height and 265mm additional length of the cabin, the gross volume of the compartment can be calculated as 1185.6L, and the actual load volume is estimated to be approximately 1000L. Combined with the 700L closed cargo compartment and cargo space on roof and cockpit, the target volume of 1800L is fulfilled.

The advantages of designing this semi-closed cargo compartment have listed in section 7.2.1, including giving user the feeling of a bigger load capability and maximizing vehicle's mobility and flexibility. But the drawbacks of this design are also obvious; first, the theft problem is still left to be solved; and the second, the semi-closed compartment still cannot entirely protect the cargos from bad weather conditions.

The first problem is solved by the implant of a small monitor on the right side of the vehicle. As the field research indicates, most of the deliverymen feel safe when the cargos is in the range of a monitor. This small camera would keep working as long as the cargo desk is on load. The video information would be stored in a flash disk in the cockpit, and renew very three hours. Once a deliveryman realized the happening of theft, he should pull out the USB and send to the police for help.

The second problem is fixed by an attachment, a plastic compartment cover. When the bad weather comes, the deliveryman is able to find it in the vehicle and lay this waterproof material outside the cargos to protect them from rain, wind or snow.

Figure 8.15 The design of semi-closed cargo compartment

8.2.3 Delivering/collecting related functions

Although a vehicle is not directly involved in the delivering and collecting, via some specific design features, PUNCH-DMV is still somehow able to facilitate these two activities. These features mainly reflect in two aspects, providing enough space for delivery supplies and tools as well as ensure the vehicle/cargo security.

Front drawer for delivery supplies and tools

In order to leave more space for parcels, most of the scooter deliverymen are unwilling to bring so many delivery supplies and tools with them. So they are often unable to provide the customers necessary materials to help them with the improper-packaged parcels, and therefore increase the risks of cargo damage.

In PUNCH-DMV, a front drawer is provided to dedicatedly store some delivery supplies. It is located between the two headlights and possesses the space of 45L. Envelops, plastic bags, small boxes, blank express waybills, bubble wraps, tapes, etc. could be stored in this room, and the deliverymen could choose the suitable ones to bring before they go for delivery or collection.

Figure 8.16 The design of front drawer

Room for a luggage cart and a plastic semi-closed compartment cover

In order to reduce the physical labor of transporting cargos from the vehicle to recipients or from senders to the vehicle, a luggage cart is also equipped on board. It is placed in an 80L room under the extractable cargo desk. The users could use it to carry large, heavy boxes or a plastic drawer of the closed cargo compartment. The plastic semi-closed compartment cover mentioned in section 8.2.2 is also stored in this room.

The equipment of the luggage cart is extremely useful for those who serve for business buildings, i.e. the deliveryman applying delivering pattern 1. Using the luggage cart combined with the plastic drawer can effectively prevent all the three categories of undesired behaviors in this pattern.

1. ‘Leaving’ behaviors: In this pattern, the deliverymen leave the parcels in five different places unguarded, which is really easy to lead to delivery omissions or cargo losses. Though they fully understand the risk of these behaviors, the lack of temporary storage place, the pressure from business customers and the massive physical exertion of carrying large heavy bags leave them no better choices. But with the combined usage of the cart and drawer, they can realize a quick movement among the customers with much less physical exertion. The convenience brought by this design cuts down the advantage of leaving parcels, and therefore reduce the necessity of performing these behaviors.

2. ‘Dropping’, ‘kicking’ and ‘dragging’ behaviors: Since the ‘leaving’ behaviors are vastly diminished, the corresponding ‘dropping’ and ‘kicking’ behaviors should be reduced too. And with the application of luggage cart, the feature of the product turns the improper ‘dragging’ behavior to the desired one.

3. The abnormal relationship between ‘times to find a parcel in bag’ to ‘number of parcels delivered’: As mentioned in 5.2.4, although the packages inside a woven bag are organized before, with the bumpy driving, violent unloading, dragging during delivery and the soft flexible nature of woven bags, the order inside the woven bag is often disrupted. A lot of time is needed to find a specific parcel in the mess, and delivery omissions happen from time to time. But within the new scenario, three of the four inducement of this phenomenon is removed. The deliverymen are able to obtain a constant efficiency during their entire delivery process.

Figure 8.17 The design of luggage cart room

Waybill receipt container

Section 5.2.5 has mentioned the importance of a receipt copy of the waybill. It is a crucial evidence for the deliveryman to show that the recipient has received the parcel in time. Therefore, a waybill container is designed on the dashboard to collect the receipts. It is about 90mm high and locates in a perfect place where the driver could reach easily but away from rains or winds.

Remote lock

A remote lock is used to control all the locks on the vehicle, including the lock of vehicle power, the lock of closed cargo compartment, the lock of the fixing bands of semi- closed cargo compartment, the lock of front drawer and the lock of rear cart room. Just by pressing one key on the remote controller, the user is able to lock or unlock these five places at one time.

8.2.4 Other functions/design

Besides the functions mentioned above, the vehicle has embedded several other functions/design as listed below.

1. The charging port: Vehicle's charging port is located in the front sit between the two high beams. It is a rear-hinged plastic component and could be opened during charging.

2. Cup holder, storage bin and rubbish bin: The cup holder is on the left interior column, and the storage bin and rubbish bin are on the right one. They are used to carry some personal effects or rubbish generated during delivery.

3. Socket and radio: A socket together with a radio is mounted on the right side of the dashboard within driver's reach. The user is able to charge his cellphone via the vehicle for frequent communication.

4. Outfalls and oblique floor: Rain water or snow can invade the cockpit due to its semi-closed design. Therefore, the floor of the driver compartment is designed to lean about 3 degrees forward, and two out falls is located in front to drain away water.

5. 'Air-conditioning': The 'air-conditioning' in this vehicle is constructed based on the battery cooling system. It helps to heat the cockpit in winter and blow wind to driver in hot days. The principle of this system would be described in section 8.4.

6. Fire extinguisher: A fire extinguisher cell is placed in the center of the knee bolster and marked in red. It is essential to take a fire extinguisher on-board due to vehicle's plastic material and users' smoking habit.

Figure 8.18 Other functions/design

8.3 Ergonomics

Section 7.1.2 has presented the selection of anthropometric data and driving posture. This section would follow this topic with more specific data and add some analysis on loading ergonomics. Most of the discussion would focus on the physical ergonomics aspect since the cognitive ergonomics is not the key point of this project and has already discussed in section 7.1.2.

8.3.1 Driver posture

Figure 8.19 illustrates the driving posture of the 99-percentile male and the 5-percentile female. The anthropometric data are acquired from the national standards GB10000-88: Human dimension of Chinese adults and GB/T 13547-92: Workspace body dimensions of Chinese adults. Statistics of sitting height, buttock-popliteal depth, popliteal height and functional reach depth are picked out and applied in the design.

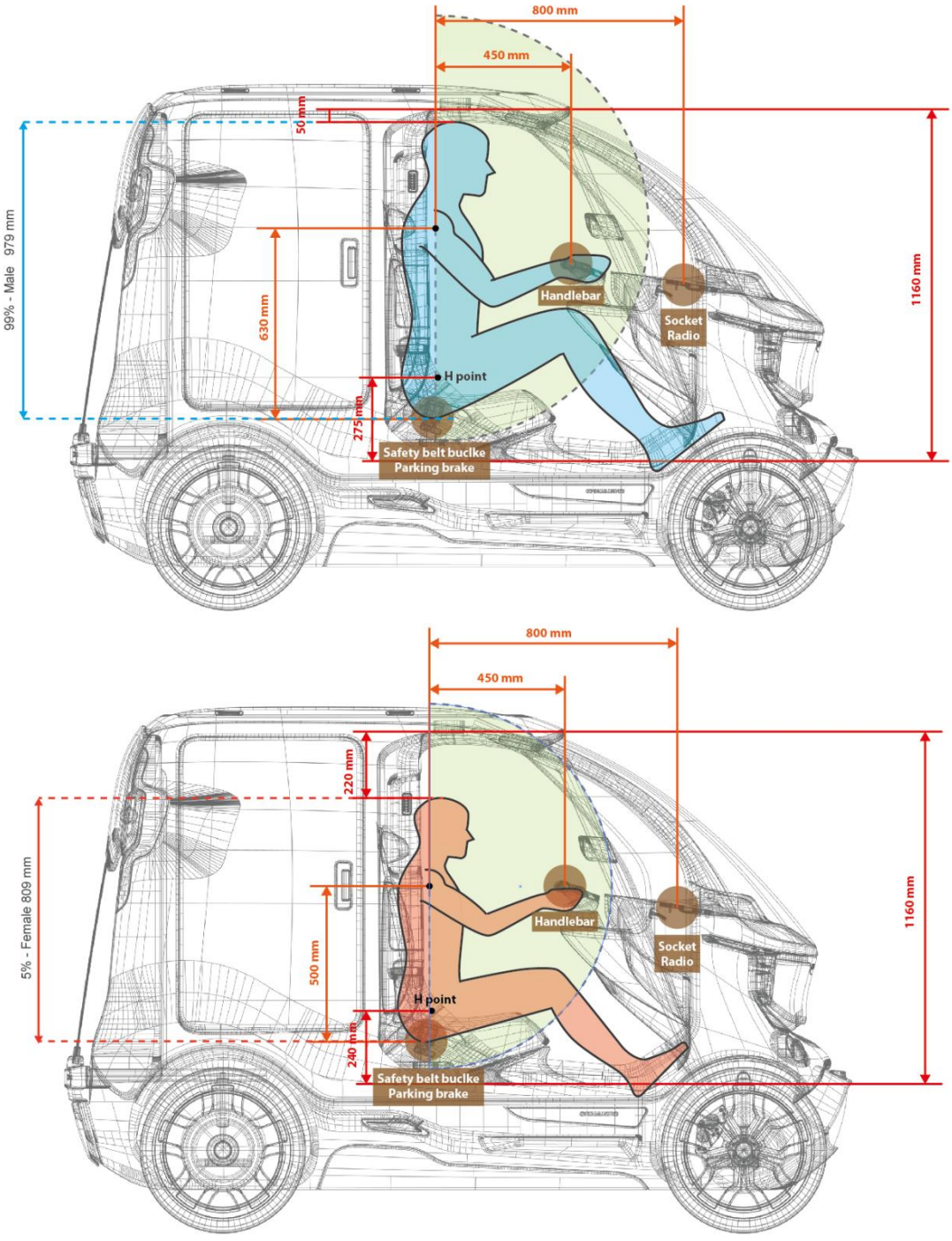

Figure 8.19 Driving posture of 99-percentile male and 5-percentile female

It can be seen that PUNCH-DMV is able to include these two kinds of the extreme user in the cockpit. Their H-point are respectively 240mm and 275mm above the ground, and they are all able to sit in the right position and have a relatively nature posture. But there are two unsatisfying points that appear in the illustration.

The first is the roof clearance of the 99-percenile male is not so sufficient. Only 50mm is left for him, which is very likely make the driver head hit the roof during bumpy road condition. To avoid this situation, tall drivers could properly move the backrest forward and lean their bodies backwards a little which is fairly close to the regular motor vehicle driving posture.

The second is the view field of 5-percentile female might be blocked by the dashboard. This problem is really easy to solve. Just by raise the height of seat cushion, short drivers are also able to obtain good view of road.

8.3.2 Workstation

According to their importance to the vehicle, the controls can be separated into 3 categories: primary, secondary and auxiliary. Primary controls in this vehicle include the accelerator, brakes and the parking brake; the secondary include the seatbelt, horn, indicators and lights; and the rest controls such as radio, sockets, 'air-conditioning', etc. are auxiliary ones. The first controls must be placed within the most suitable and comfortable range of the driver, and then the secondary controls. Auxiliary controls can be place out of driver's the functional reach depth when a user is in the driving posture.

The green areas in the Figure 8.19 demonstrate the functional reach range of the driver. It can be observed that in both extreme conditions, the placement of the entire primary and secondary controllers are included in the green space, and the auxiliary ones are also can be easily reached the driver lean towards to the front. Overall, the workstation ergonomics is fairly good in this design.

8.3.3 Ingress and egress

As mentioned in section 8.2.1, a step with 300mm above the ground is mounted on each side of the chassis to facilitate the driver's ingress and egress activity. Without the help of steps, it is very difficult for the driver to directly enter the cockpit with 480mm high floor and 50mm addition height of compartment threshold.

Figure 8.20 displays the estimated effect of the steps with the 99-percentile male and 5-percentile female data. It can be seen that these two extreme users are all able to step on the steps easily and then get in or off the driver compartment.

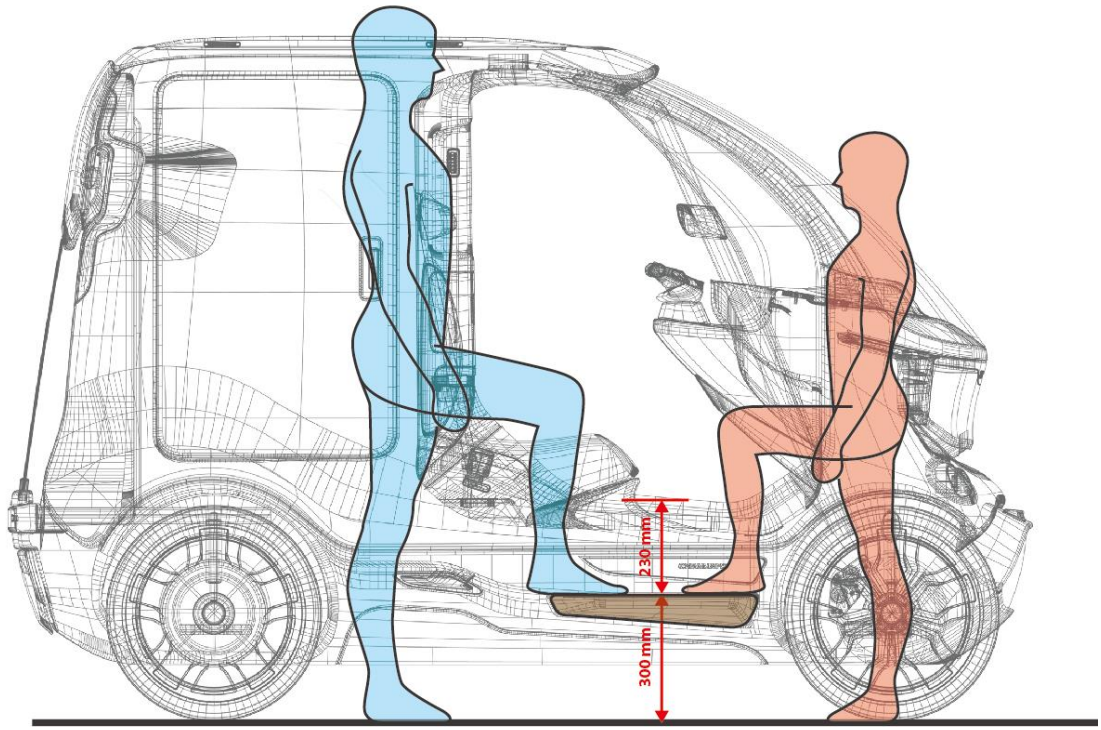

Figure 8.20 Ingress and egress ergonomics

8.3.4 Loading/unloading

As a delivery vehicle, providing a good loading/unloading ergonomics enjoys no less importance than designing a suitable driving posture. It can immensely reduce deliverymen's physical exhaustion and diminish their fatigue. Figure 8.21 illustrates the loading/unloading ergonomics with 99-percentile male and the 5-percentile female's stature and functional reach depth statistics. Three cargo places are respectively tested, including the closed cargo compartment, semi-closed cargo compartment and roof.

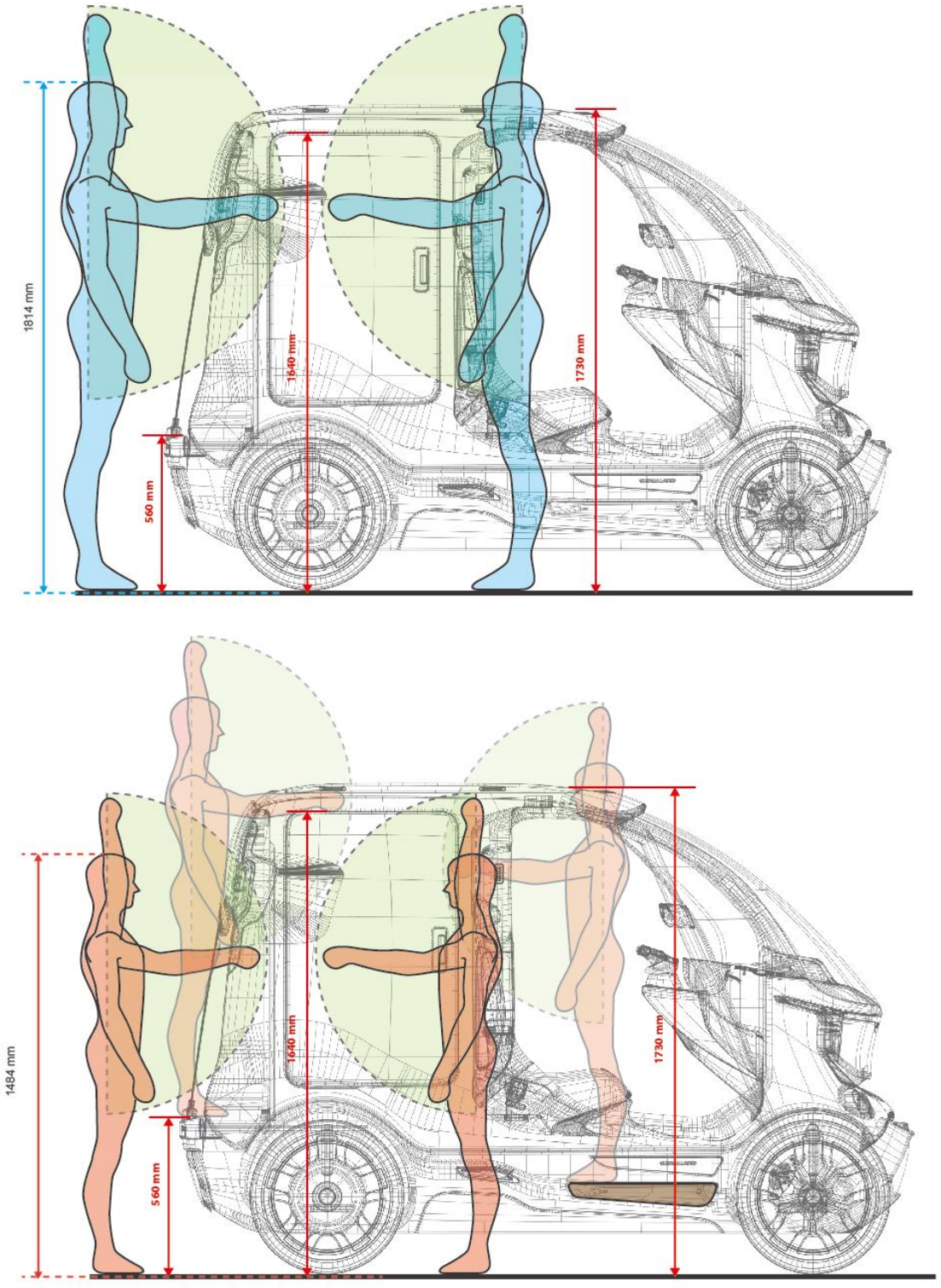

Figure 8.21 Loading ergonomics

The highest point of the closed cargo compartment is 1,640mm, which is just 75mm lower than the maximum reach range of the 5-percentile female. There can be some difficulties for the 1,484mm tall women to take the plastic drawer out or put in during the usage. But since in the actual scenario, very less women is involved in the express delivery industry, and for those rare women deliverymen, they should be quite large and strong to undertake the massive physical work. Therefore, it can be assumed that this problem would not influence so much on the practical usage of PUNCH-DMV. For those short users, they could choose to store the heavier drawers at a lower place and put the lighter or smaller ones on top to remit the problem.

The ergonomics of rear semi-closed cargo compartment is quite friendly. The two extreme users can all use the top-hinged liftgate easily, and reach the extractable cargo desk by just bending a little.

Regarding the roof space, for tall users, there would not be big problems; while for the short users, it is relatively difficult to place and fasten the cargos for them when standing of the ground. The steps on the chassis and the cargo desk on the rear can be used to facilitate this activity, but it is quite dangerous to do so. But again, in the reality, almost all of the deliverymen are young males. This phenomenon is less likely to happen. Even so, searching help from others is the most reasonable and feasible option.

8.3.5 Others

In addition to the items state above, the ergonomics of the front drawer and luggage cart room are also worth to notice during design. The bottom of drawer where an opening slot locates is 690mm from the ground, which is a perfect height for all covered users. Via a straight standing posture or only bending a little, a deliveryman can easily reach it.

While the opening slot of the luggage cart room is relatively low, its 380mm height forces the user bend over a lot to reach the objects inside. Extremely for tall users, it might be tough for them to repeat this action. But in the reality, the frequency of take out or put back the luggage cart or plastic compartment cover is not that often, approximately 2 to 4 times a day, which is still considered as an acceptable frequency for the users.

8.4 Technical aspects

The technical aspects mainly concern the validation of the form and functions to ensure that the design solutions are feasible. In this section, the shaping techniques of body, the assembly of the vehicle parts and frame, the layout of mechanical system and the special designed battery cooling system are introduced.

8.4.1 Shaping techniques of body

The main shaping technique of plastic body components is injection molding. It is the most common methods in polypropylene product manufacturing, since the material's high melt flow rate can easily fill the mold during production process. The related techniques of blow molding and injection-stretch blow molding are also used. Via these methods, complex shapes can be easily formed and produced in very low cost, which is quite essential for this project.

The primary method used to shape the vehicle aluminum components is foundry. Aluminum foundry alloys are remelted again and cast in the desired shapes. This method can provide product with excellent and consistent metal quality as well as low level of impurities and trace elements. It has already widely used in automotive industry to manufacture wheels, chassis components, cylinder heads, etc. Though the cost of aluminum foundry is relatively high, very limited components is required to be shaped via this method. Therefore, the overall cost is still can be well-controlled.

8.4.2 Assembly of the vehicle

The plastic body parts are expected to be fitted into each other by snap joints. Since most of the plastic components are not essential to stress undertaking, load carrying or impact absorption, snapping each other together is supposed to be the most efficient way to finish the assembly process. In addition, because of the uniform material of the components, the snapped body can be melted down and recycled as whole without complex disassembly after its life ends, which is desired in regards of sustainability.

Screws are recommended to use when mounting the plastic body pieces on the frame or fit the metal stressed members into plastic ones. Brackets can be pre-molded on the plastic body parts or press formed on the metal parts to fix the components and facilitate the assembly process. During disassembly, these parts would be separated manually from the frame, categorized according to material and melted down respectively. The

mounting points of the frame are roughly illustrated in Figure 8.23. The eight points at the lower of the frame is used to fit the plastic chassis, while the ten upper ones are used to mount the dominant body. The two points on the aluminum bars in front fixed the dashboard, and the four under the roof connect the metal piece on top.

Figure 8.22 The explosive view of PUNCH-DMV

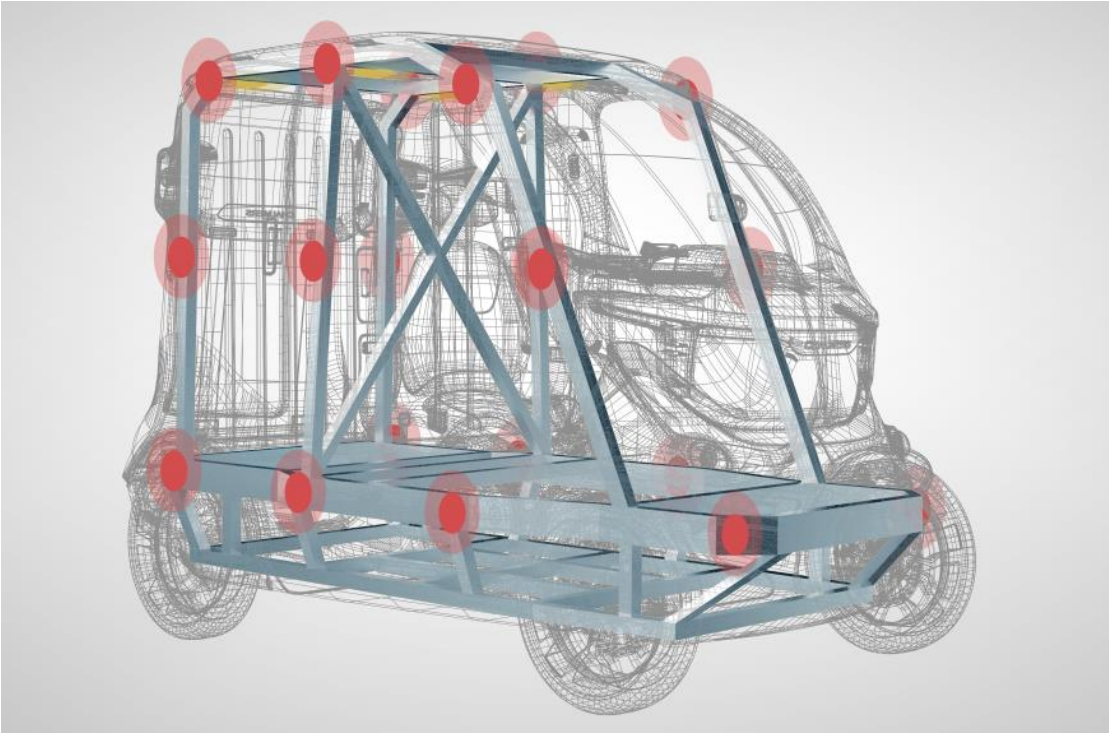

Figure 8.23 The mounting points on frame

8.4.3 The layout of mechanical systems

A brief layout of the mechanical system is shown in Figure 8.24, which displays the space configuration and occupation of powertrain, brake, steering and suspensions.

The powertrain system is marked in red, which mainly consist of a battery package and two hub motors. The battery is placed right under the driver seat where a low center of gravity could be achieved and a maximum protection could be provided during crashes. User's operation on accelerator handle would be interpreted by the control unit and determine the power output of the vehicle. The brake system is shown in yellow. Two oil press brakes are mounted on the front wheels, and two rear brakes are integrated in the hub wheels. The green region illustrates the components of steering system. The motion on the handlebar is transferred to steering column, enhanced by a steering power assist and reflects on the front wheels. In addition, the vehicle can also use the different speed of rear wheels to facilitate the turning performance in some areas. The space occupation of suspensions is demonstrated in blue. As suggested by the experts, MacPherson strut and trailing arm suspensions are respectively applied on the front and rear site.

Overall speaking, the application of suitable mechanical solutions tremendously contributes to save the space inside the vehicle. Most of the components are integrated or gathered around the four wheels and much space is left for cargos and delivery supplies. In addition, less mechanical components also helps reduce the sprung weight of the vehicle to provide a smoother vehicle performance; as well as diminish the cost of PUNCH-DMV to realize its low-cost market positioning.

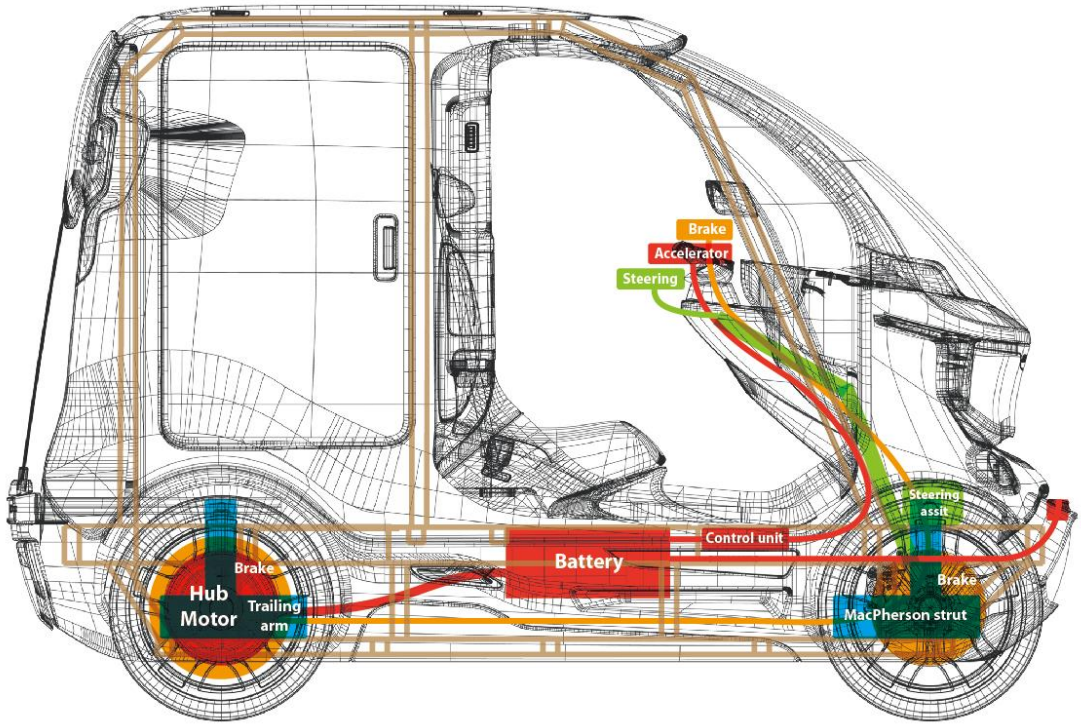

Figure 8.24 The layout of mechanical systems

8.4.4 Battery cooling system

A special designed battery cooling system is equipped to reduce the temperature of battery pack and provide an additional function, heat the cockpit or blow wind to driver during driving, i.e. the so-called 'air-conditioning' function.

This function is realized by the design of alternative air ducts and two valves. After the wind comes into the inlets located in the center of the high beams, it would path through an air clean system where dusts and water drops are removed. And then, the clean air reaches the first valve which is control by a rotary knob on the handlebar. According to driver's choice, the valve would close the upper front air duct, or let both upper and lower ducts open.

In the condition of upper front air duct closed, the air would pass the lower front air duct and reach the battery. It would be heated up by the high temperature of the battery and vented out. The second valve is located behind

the battery; in this condition, it would have a linked movement with the first valve and open the upper rear air duct. All of or part of the warm air, depending on driver's choice, could follow the ducts and effuse close to driver's head. The long path of the rear ducts can effectively heated driver's back area and provide a more comfortable interior environment in cold days. But there is no specific evaluation on the quality of the heated air, for the safety concern, another air cleaning system is mounted on the rear path to filter the air again.

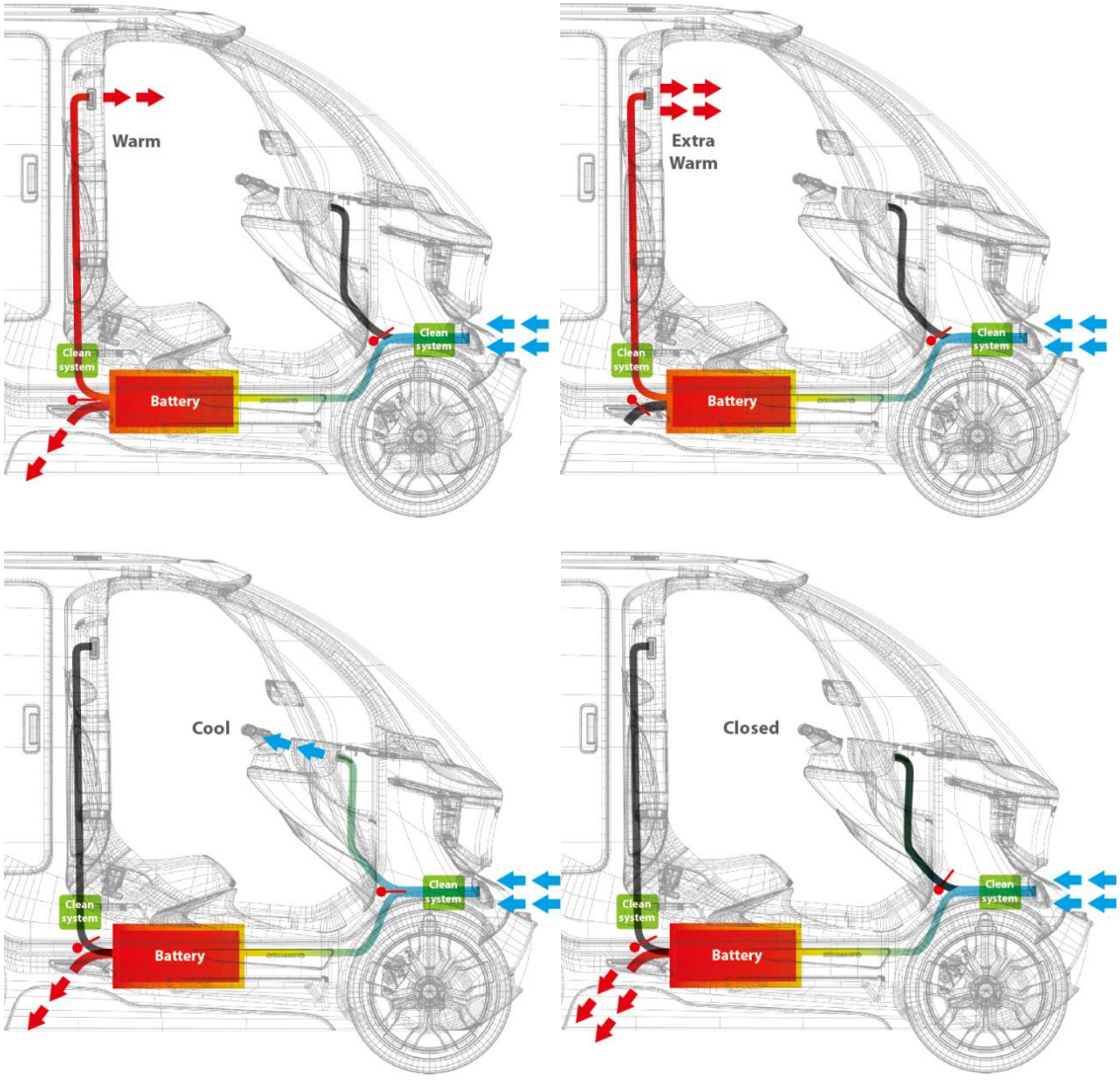

Figure 8.25 Battery cooling system

In the hot days, the driver could switch the valve and let the air go through both upper and lower ducts. Wind would go pass and be accelerated by the twisted and narrow tube, and blow towards driver's face to relieve the hot feeling. The second valve would correspondingly close the upper rear air ducts and let the rest air pass through lower tube and be vented at the exhaust outlet on both sides of the chassis. The user is also able to switch off the system by using the valves to shut down both rear and front upper ducts. All the air would go through the battery to acquire the maximum cooling performance.

Unfortunately, this function is only available during driving. And it might not able to fully work during extremely hot days, since the battery requires much air to take away more heat. But still, since the driving period and distance is not much, it can be assumed that there would be no severe impacts when PUNCH-DMV is in its regular usage.

8.5 Product strategy

This section presents a brief product strategy for the distribution of PUNCH-DMV, which involves an estimation of retail price, the positioning of market strategy and the prospect of vehicle's extensive application. It is quite essential to take these stuffs into consideration during the design phase to facilitate the success of future product.

8.5.1 Price

For a complex product, it is really hard to estimate the cost of the entire product, because it involves various materials, different manufacture methods, diverse component suppliers, unpredictable labor inputs and uncertain transportation cost. Though the design of PUNCH-DMV tries to involve less different material, simplify the mechanical components and apply easy manufacture and assembly techniques to achieve the low cost aim, the complexity of the products still makes it quite hard to directly define a possible price range.

Therefore, in order to obtain a rough vehicle price, a much intuitionistic method is used. Since vehicle's manufacture and distribution process would all be finished in China, several local products with similar features were found, and their prices are used as essential references for PUNCH-DMV's pricing. The current delivery-used electric scooter, trike and minibus are also included

Name	Dimension (m)	Main exterior material	Payload (kg)	Curb weight (kg)	Battery (V)	Price (RMB)
PUNCH-DMV	2.60*1.24*1.73	Plastic	270	N/A	8*12V	N/A
The king of Load	N/A	Plastic	75	N/A	4*12V	2,300
Jinguangcai	2.70*0.95*1.65	Steel	400	150	4*12V	3,380
Wuling Sunshine	3.89 * 1.60 * 1.86	Steel	8 people	1620	N/A	29,800
Qita	2.10*0.90*1.50	Plastic	150	200	4*12V	15,600
Minkun Minibus	2.280* 1.200* 1.5	Steel	300	350	4*12V	11,800
ZH golf	2.30*1.20*1.71	Plastic	300	410	6*8V	18,000
Hubin	2.40*1.20*1.50	Plastic	320	400	4*12V	11,000

Table 8.1 Parameter comparison among PUNCH and other vehicles

Figure 8.26 Qita, Minkun Minibus, ZH golf and Hubin

The price of the four comparable product ranges from RMB 11,000 to RMB 18,000, with their dimension slightly smaller than PUNCH-DMV. Qita and Hubin are the two most similar ones; they all use plastic as major material and shares relatively complex appearance. Especially for Qita, it seems to be well-design and manufactured for its exquisite details. Therefore, the price of PUNCH-DMV might be close or slightly higher than the Qita. On the other hand, Wuling Sunshine, the current delivery-used petrol minibus, is RMB 29,800. As a much smaller and simpler product, the new vehicle should be much cheaper than it. Taken these factors together, the retail price of PUNCH-DMV might range from RMB 15,000 to RMB 18,000.

In comparison to the current-used products, the new PUNCH does have a relatively high price; it is almost seven times more expensive than a scooter or five times dearer than an electric trike. However, when compared it to the tailor-made express delivery vehicles made by foreign automotive companies, significant price advantage

would immediately come out. Figure 8.27 shows PUNCH-DMV's positions among the existing products; it can be observed that PUNCH-DMV is the cheapest one but with the most payload performance among the newly designed small delivery vehicles. Though it is more expensive than the scooters and trikes, the dedicated design for requirements can make up the defects and provide better experiences and efficiency to users.

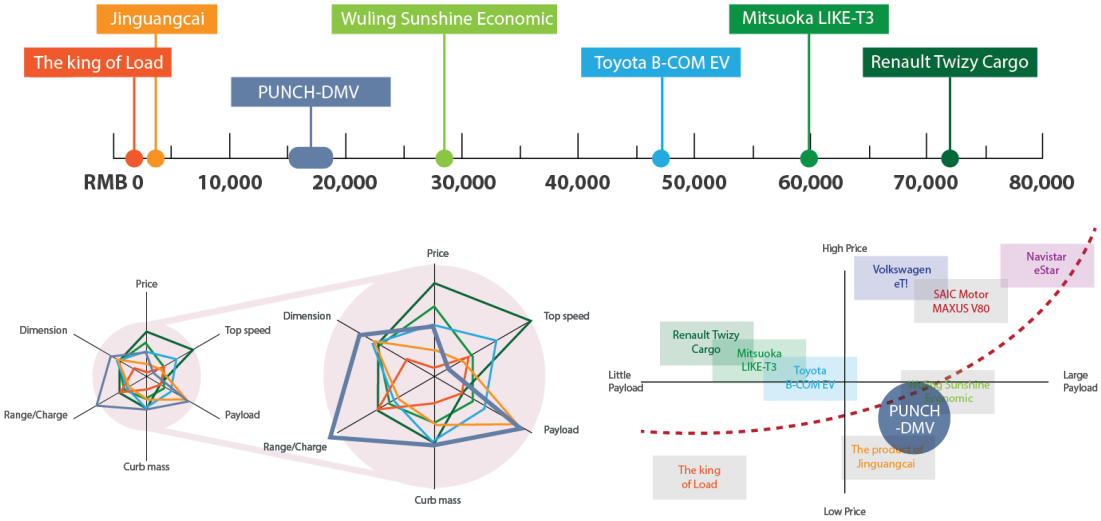

Figure 8.27 The market position of PUNCH-DMV

8.5.2 Market strategy

Though the price of PUNCH-DMV is the cheapest one in the new products, it is still unaffordable for those deliverymen with quite low salaries. As mentioned in the field research, in deliverymen's mind, the expected price of an ideal delivery vehicle is less than RMB 5,000. Obviously, PUNCH has greatly exceeded this line. But it does not equal that the new design is unable to enter the market, on the contrary, the business mode transition of the private-owned express delivery enterprise and the policies from the government open a huge market for the new PUNCH.

Opportunities from local express delivery industry

As stated in section 4.2.6, the most prior trend of the local express delivery industry is switching from franchise model to direct mode. STO, YTO, Best and Yunda Express have all started their direct management process, and it can be predicted that in the near future, more and more companies would join the mode transition. After the companies retrieve the rights from franchisees, they are able to control and unify the rule and management and therefore provide a better service quality to complete with each other or the foreign or state-owned enterprises.

Instead of letting the deliverymen preparing the vehicle by themselves, a company in direct mode, such as S.F. Express, is very likely to purchase and unify the vehicle for a better brand image and uniform service quality. This is the key breakthrough for the distribution of PUNCH-DMV. Compared to individual customers, corporate clients owns enough capitals and be willing to invest for things that facilitating the development of the company. Obviously, the customer branding feature and advance delivery related functions can effectively help the company raise its corporate image and service quality, and more care about the deliverymen can reduce their physical labor, increase their loyalties and diminish employee turnover rates. In addition, the good quality and much longer service life of PUNCH-DMV is able to save the expense in maintenance and repeated procurement. If the vehicle can seize the opportunity of the coming model transformation trends, big market occupancy is expected to be obtained.

Opportunities from industrial association and government

Obtaining the support from the government is another potential strategy that PUNCH-DMV could apply. As mentioned in section 4.3.2, China Express Association, State Post Bureau of China and other relevant ministries are planning to introduce some specialized delivery vehicles as industrial standards. The design would be based on studies of vehicle speed, weight, mileage per charge, brake performance, appearance, material, safety criterions etc., and the result would be negotiated with express delivery companies.

Since solid research has been before PUNCH-DMV is design, it is a great opportunity for the new PUNCH to try to get the support from the government. Being selected as an authorized product can not only acquire massive

market occupation; the large numbers of orders may also reduce the cost of a single product. In addition, the government may issue some allowances with the vehicle to promote the popularization of the product.

8.5.3 Extensive application

Trying to explore the extensive application of the vehicle is also quite essential for the development of the product. There are two main orientations including in this exploration, launching the product to broader markets, or discovering the extensive usage of the vehicle.

Broader markets

Before the field research, several semi-structured Interviews were actually conducted to Chalmers students from various countries or regions in Asia and Europe. The content was about the express industry and the vehicles used in their home city. Since no influential result regarding vehicle design is obtained, it was removed from the design phrase.

However, the retrieved information is quite inspiring in this phase. Almost all the interviewees stated that vans are the primary vehicles used for delivery in their countries; smaller vehicles are also applied as supplementary products to cope with some narrow areas. Delivery petrol scooters are pretty common in Italy, Taiwan, Ireland and Japan, while bicycles are used in Hungary, France, German and Greece. In Sweden, a trike is used to carry mails and small parcels. None PUNCH-DMV similar products has been mentioned in the research, which might indicate that there are plenty of potential markets desiring to explore. The perfect size of PUNCH can fit into small narrow streets in old older city sections, and it is clean, safe, multifunctional and efficient which can perfectly replace the scooters, motorcycles or bikes. It is definitely worthwhile to try to extend it usage out of Chinese urban context.

Extensive usage

Discovering the extensive usage of the vehicle is another direction could go. Some services close to the features of express delivery can be explored, such as flower delivery, food delivery, barrelled water delivery, etc.; or it can be extended to some occupations that requires to use a functional vehicle to carry tools and materials, for example, repairman, retailers, outdoor workers, etc.

Different version of PUNCH-DMV could also be developed to better serve the actual requirements, for instance, combining the two cargo compartment into a bigger one to get more room, designing a fully closed cargo compartment for better cargo protection, etc.

8.6 Chapter conclusion

The final design of PUNCH-DMV owns a very strong visual appearance which precisely reflects the feelings of sportive, solid, accurate, functional and reliable. The dimension of the vehicle is well-balanced between the requirement of large payload and the constraints from context. And the advantages of applied material, polypropylene and aluminum alloy, help to achieve the aimed market positioning of PUNCH-DMV.

The design of vehicle functions starts from two intensions, fulfilling the user requirements and altering undesired user behaviors. A majority of the functions concentrate in facilitating user's driving and loading/unloading activities, while some others try to intervene in the delivery process to reduce deliverymen's physical exhaustion and change improper behaviors.

Ergonomics is born in mind throughout the project. The design of driver posture, workstation, ingress/egress and loading/unlading posture can all fit the body dimensions of 5-percentile female and 99-percentile male.

The shaping methods of injection molding and foundry are selected to respectively manufacture the plastic body pieces and aluminum components. Snap joints are pre-design on the plastic pieces for convenient connections, while screws are recommended to use when mounting between different materials. A special designed battery cooling system can reduce the battery temperature as well as act as an 'air-conditioning' when required.

The retail price of PUNCH-DMV might range from RMB 15,000 to RMB 18,000. Though it is much lower than the other new products, it still greatly exceeds individual user's expectation. But with the mode transition of many franchise companies and the government's increasing intension of designing standard delivery vehicles, great opportunities are displayed in front of PUNCH-DMV. The author believes that this well tailor-designed delivery vehicle can obtain big market occupancy, and even extend its usage to other industries or a broader market.

9. Concept evaluation

The chapter presents the evaluation of the final concept and a description of the strong and weak aspects of the design according to the evaluation result. The evaluation is conducted base on the requirement list obtained in Chapter 6.

9.1 Final concept evaluation

The concept evaluation was planned to have three sections. In the first section, the final design should be checked with the list of requirements raised in section 6.1 to exam its fulfillment of desired functions. In the second section, an easy mockup is planned to be built to verify the ergonomics design. The third stage intends to include another round of Krippendorf's experience dimensions to obtain user's feedback on PUNCH-DMV's form design. But unfortunately, due to the limited project time, the evaluation only finishes the first step.

9.1.1 Evaluation via list of functions

The design of PUNCH-DMV is checked by the function list. If the function is fully realized, a 'Y' would be marked on the rightmost column; if the function is assumed to be fulfilled but required further evaluation or test, a 'Y*' is used instead; otherwise an 'N' is placed in the blank. If a function remains unknown or uncertain, an 'N/A' is marked standing for 'not available'. The evaluation result is listed as below.

1. User requirement aspect

Function	Check (Y/N)
Vehicle required basic capabilities	Y
Delivery required basic capabilities	Y
Get the permission and authorization from government	Y*
Protect driver from bad weather	Y
Protect the vehicle from thieves	Y
Protect the cargos from thieves	Y
Ensure vehicle security	Y
Help to reduce activity process and time period	Y*
Provide sufficient battery capacity	Y
Provide sufficient payload and cargo space.	Y
Use pure electricity as energy	Y
Improve the vehicle stability during driving, loading and unloading	Y
Provide comfortable driving posture	Y*
Add turning lights and brake lights in the rear side and increase the illumination of the headlight	Y
Provide lockable storage places for delivery supplies, receipt copies, tools and personal effects	Y
Protect cargos from bad weathers and extruding, jolting or falling	Y
Control the vehicle dimensions for flexibility, mobility, traffic condition and parking concern	Y
Enable convenient ingress and egress.	Y*
Provide suitable charging time	N/A
Equipped solid vehicle structure, good suspensions, stronger wheel rims and wider tires	Y
Improve users' social status via exterior design	Y*
Drive without motor vehicle driving license	Y*
Provide dedicated-design ancillary products to assist delivery activities	Y
Enable deliverymen to arrange cargos' position according to size and delivery sequence	Y
Provide longer service life.	Y*

2. Behavior constraint aspect

Function	Check (Y/N)
Utilize vehicle features to constrain undesired behavior	Y
Provide dedicated-design ancillary products to constrain undesired behavior	Y
Provide fire equipment	Y
Control the high speed of vehicle	Y

3. Legislation aspect

Function	Check (Y/N)
Separate driver compartment and cargo compartment	Y
Be able to register as motor/non-motorized vehicle	Y*
Be in conformity with the verified loading capacity	Y
Be unable to take extra passenger	Y
Prevent cargo from falling, floating or littering on the way	Y

4. Market aspect

Function	Check (Y/N)
Provide high cost performance	Y
Enable customization	Y
Provide multifunction	Y
Ease of assembly	Y
Provide reasonable payload	Y
Use sustainable design and manufacture	Y
Ensure driver safety	Y

5. Technology aspect

Function	Check (Y/N)
Use electricity as energy	Y
Solve the high vehicle height and cargo floor problem	Y
Solve the structure vibration problem	Y*
Ensure the frame's crashworthiness	Y*
Provide battery cooling system	Y

6. Ergonomics aspect

Function	Check (Y/N)
Adequate vision from seating position	Y
Fit different body sizes	Y*
Perception of being safely seated	Y*
Fit user's cognitive understanding	Y
Load/unload cargos ergonomically	Y*
Offer flexibility to adjust working environment to driver's own needs	Y

7. Sustainable aspect

Function	Check (Y/N)
Own light vehicle weight	Y
Enable easy disassembly	Y
User fewer materials and parts as well as mono-material construction	Y
Use low-impact materials	Y

Table 9.1 The checklist of functions

9.1.2 Comments on evaluation results

Except the charging time, all the requirements are fulfilled or assumed to be fulfilled via the design. Therefore, it can be inferred that the design of PUNCH-DMV is relatively successful in meeting the desired functions. However, this checklist evaluation is just on the theoretical level. The actual result of the uncertain is required to be verified via more evaluation methods or even practice.

For example, the items of 'provide comfortable driving posture', 'enable convenient ingress and egress', 'fit different body sizes', 'perception of being safely seated' and 'load/unload cargos ergonomically' are urgently to be evaluated by physical models, mockups or at least simulation software like 'JACK'.

Vehicle's exterior, interior and aesthetic experience design such as 'improve users' social status via exterior design', have to be confirmed by another round of user research, probably applying Krippendorf's experience dimensions again to test user's visual perception feeling of the vehicle.

'Be able to register as motor/non-motorized vehicle', 'get the permission and authorization from government' and 'drive without motor vehicle driving license' are just the intentions and aims of this design. Though all the design is trying to match the legislations and standards of being a non-motorized vehicle, it still cannot influence so much on the judgments from local related administrations. The product's legality and definition should ultimately follow the decision made by authorities.

Regarding the items of 'provide suitable charging time', 'provide longer service life', 'help to reduce activity process and time period', 'solve the structure vibration problem' and 'ensure the frame's crashworthiness', the result of them could only be retrieved after the execution of more technical research and development; and some of the results might be only obtained in product practice.

However, overall speaking, though there are many functions required to be further tested or evaluated, the design of PUNCH-DMV can still be accepted as a good solution to the problem. It realizes almost all the required functions generated in the research, and perfectly fills the market blanks.

10. Discussion

This chapter is the project discussion, includes author's thoughts on the entire project. The discussion also includes some recommendations on further development for the final concept.

10.1 Discussion on project

It has to be admitted that as an extensive project of PUNCH, designing this specialized vehicle involves much more cross-disciplinary knowledge than planned. Tons of literatures are required to understand, and so many inputs from various fields mix and conflict with each other. It is sometimes hard to well organize the information and control the overall progress of the thesis. Though the final results of the thesis seems to be fine, there are lots of things deserved to notice when facing similar projects in the future.

10.1.1 Process

The actual project execution is quite different from the planning report written at the beginning of the project. The research parts occupied more time than expected. As mentioned above, it is due to the underestimate of the required knowledge. In this project, a huge knowledge base is required to be built before staring the field research, including ergonomics, UCD, ACD, research methods, sustainable design, express delivery industry, delivery vehicle, PUNCH project, technical aspects, relevant laws and regulations, context, etc. Massive time is spent on collecting, analyzing and organizing the literature, which certainly delays and shortens the period of the later process.

In addition, the field research in Shanghai was initially not included in project initiator, Ralf Rosenberg's plan. The entire project was assumed to be built on literatures, author's knowledge of large Chinese cities and online investigations made in Gothenburg. But after a brief scanning on the online data, very less record of deliverymen's working conditions could be found and very less similar researches has been ever made. Therefore, in order to get the first-handed material to have a much convincible result, solid user research has to be done. So three unscheduled weeks have been spent in Shanghai and hundreds of hours were devoted to observation, interview and spreading questionnaires.

Luckily, the overall project process is still quite fine. Though as mentioned in last chapter, two evaluation phases are missed. Since all the design is constructed on solid research results, it can be assumed that the final deliverable has the capabilities to meet users' requirements and facilitating desired delivery activities.

10.1.2 Methodology

An integrated design research methodology and various methods have been applied in the project. Some are directly used; some are adjusted according to real needs and some are own creations. The effects of the different methods are discussed below.

The integrate approach of UCD and ACD

Personally speaking, this created hybrid approach is really useful throughout the project. It is unnecessary to pit two different approaches against each other and choose the theoretically better one. Integrating the advantages of both approach and making them counteract the inherent defects of each other is obviously a better plan. The mixed approach allows the author to look at facts from different perspectives, and produce better solutions. For the future projects owning the same features like thesis, i.e. starting from established technical results or coping with users with undesired behaviors to some extent, this approach is worthy to be transplanted.

UCD methods

The requirement gathering and developing methods mainly refer to the observation, interview, requirements list, questionnaire, persona, etc. applied in the field research phase. They are used to either discover the observable and explicit requirements, or extract and analyze user's tacit and latent needs. Overall speaking, the effects of those methods are quite delightful. It not only reflects on the long list of functions concluded at the beginning of the design phase, but also demonstrates by the positive feedback from users. Especially when retrieving the requirement verification questionnaires, many participants thought the contents of the research paper was very professional and did reflect some aspects they hard to express or notice.

ACD method

Though the adjusted HTA is the only pure ACD method in this approach, the role of it is very important. It is slightly altered according to Norman's activity theory to achieve better connection to The Theory of interpersonal behavior. The comparison between the required action and actual behavior can let the author quickly find the unexpected ones and traces them back to the main inducing factors. Quick judgments are made according to the different antecedents to see whether they can be altered by the vehicle design or not. Then proper interventions are introduced to try to realize the changes. Overall speaking, the effect of the ACD method is satisfying as well. The undesirable findings are all able to be reflected in the design phase, and measures have been integrated in the final design to prevent improper behaviors while not influencing too much on the required functions.

Design and visualization methods

In comparison to some other students' thesis, less design methods is involved in this project. Many quite popular and common methods like brainstorming, rapid prototyping, morphological matrix, etc. are excluded from the project. There are three main reason of only applying very limited design developing methods. The first is the tight project schedule. Since a lot of time has been spent on literature study and field research, the time on concept development has to be strictly controlled. For those design methods which are quite time-consuming but not have a guarantee of better outcomes, they were directly moved out of discussion. Second, the author is in charge of the project solely. Some design methods require more people for various inputs, which are obviously not suitable for this project. Even involving some other people to the design phase, their limited understanding of the project and user may not contribute a lot on the final result. The last reason is that the design phase was actually carried out with the field research in parallel. The time in Shanghai is not sufficient enough for finishing each phase one by one; some quick ideas must be generated once after the user providing valuable information. Therefore, not much design and visualization methods can be found in this paper, but it is believed to be not so influential to the generation of a high quality final deliverable in this project.

10.1.3 Final result

Due to the tight schedule, the final result was finished in two and half weeks, including the CAD modeling and rendering. Though the time is really limited, the finial deliverable was controlled in a satisfactory level. Required functions are all realized by the design, and meanwhile, it enjoys good aesthetic feelings to some extent. Mechanic and market solutions are also raised, though required to be further verified.

Form design

The vehicle form does transfer most of the desired feelings given by the mood board. The form of it looks quite solid, durable, functional and reliable, and the same time, have some sportive and dynamic details. In addition, the color, material and surface treatment successfully express its high quality attributes.

However, according to some limited reflections from author's friends, the bulky feeling still exists in the new design. The proportion might be the inducement of the problem. The height of PUNCH-DMV is much longer than a regular vehicle while the length is a little shorter, which makes it looks like a cube, especially from the 45 degree angles from front and rear. Moreover, the size of headlights and high beams are designed even smaller in proportion to leave enough space for the front drawer. That might make the car looks wider than it actually is. Combined with these two proportion problems, the bulky looking therefore generates.

Functions

Vehicle functions are the highlight of the project. It mainly involves three categories which are respectively facilitating the driving, loading/unloading and delivering/collecting process. Driving related functions include the design of the light system, wheels, semi-closed cockpit, windshield, handlebar, driver seat, safety belt, parking brake, visor, etc. Functions belong to this category focus on ensuring occupant's safety during the driving, most of which are designed for fulfilling the requirements rather than change the results brought by the undesired behavior passively. The loading/unloading functions involve the design for four loading positions, driver cabin, roof, closed cargo compartment and semi-closed cargo compartment. They respectively carry the fragile, overlength, small and large cargos, and perfectly replace of the scooter with better solutions. These functions integrate more design interventions for promoting the happening of desired behaviors or reducing number of actions with improper behaviors. The delivering/collecting related functions include the design of front drawer, luggage cart room, waybill receipt container and remote lock. All of them can be regarded as different level of interventions that changing user's behaviors. Besides these, some other functions are designed to make the user to achieve better comfort.

Overall speaking, all the design are successfully built on the research and owns theoretically value to change the exiting situation. Though the actually result of these design are obliged to be tested by practice, it still can admit the superiority of new-designed PUNCH.

Ergonomics

Since the nature of the occupation, the ergonomics problems of the 5-pencetile women is not actually so influential to the user group, while the problems with 99-percentile male are required to pay attention to. Within the five ergonomics aspects raise in Chapter 8, the driving posture is one needed to be solved in future. Though a tall driver is able to adjust their position to achieve a so-so siting posture, it is still not an admiring solution for the users with increasing stature in future. More space is required to leave over their head to achieve better safety. And if possible, lower the height of the driver compartment floor is a good way to make all the users to

achieve more convenient ingress and egress, but it is relatively complex and requires cooperation from technical solution of the frame design.

Technical aspects

Though the design initially tries to keep as many existing solutions of PUNCH as possible, with the implantation of user requirements and behaviors, the alternation of some of the solutions seems inevitable. Despite the bidirectional adaption of ACD, the TCD nature of PUNCH project has doomed that the technical design without the involvement of user is more or less contradictive to the actual requirements. Although the technical solutions provide in this paper might not be practically the most perfect one for the PUNCH-DMV, they still reflect the key attributes of why they are selected, for example, release the space in the vehicle, diminish cost, reduce sprung weight, etc. If the technical solutions are required to be optimized in future, these values still required to be obeyed and reflected in the new choices.

Product strategy

Great opportunities are displaying in front of PUNCH-DMV because of the transition of local express delivery companies and increasing intention of standardizing the express delivery industry from industrial association and government. The strategies raised in Chapter 8 are based on these backgrounds, and structured to be convincible. But the actual consequence of applying the strategies is not guaranteed, it also depends on some other factors which might not identified in this paper, and the relevant administrations enjoy the final decision and interpretation

10.1.3 Evaluation

There are three rounds of evaluation happen in the entire thesis project, which respectively happened in the ideation, concept refinement and final concept evaluation phases. The first two phases play significant roles in pushing the project going forwards, and the last one is used to test the effects of the final proposal.

Concept evaluation

The concept evaluation happens in the ideation phase. Three concepts presented in pictures were tested by the users to see which should be the development direction of the project. It was a quick and clear way to illustrate potential design, and really retrieve good results. And according to users' feedback, they all think it is quite interesting to finish the questionnaire like this. For the tight projects in future, this method is recommended to be implanted for quick but not dirty result.

Form evaluation

The form evaluation was in the concept refinement phase. Three different vehicle designs were created and evaluated by a simple table. Though it did not sound as scientific as the concept evaluation and it was done by author's subjective judgment, it is a good way to quickly screen and obtain a no bad result of the project. For a phase with very limited time, it is an appreciated method to facilitate quick decision.

Final product evaluation

The concept evaluation was planned to have three sections, including checking the list of requirements, building an easy mockup and testing user's feedback on PUNCH-DMV's final design. But unfortunately, due to the limited project time, the evaluation only finishes the first step. Though this checklist evaluation has proved the superiority of the new design is on the theoretical level, the actual result of the design remains uncertain and is required to be verified via more evaluation methods or even practice.

10.2 Recommendation

This paper presents a brief image of the concept which has been verified to a certain extent, but there is still a lot of work to be done in order to transfer the idea into a real product. This section describes some actions that is required to be taken to move the project forward. All the recommendations are given based on the final concept presented in the chapter 8.

1. Some detail adjustments should be given to the vehicle form design, especially the front face part to make it looks less bulky.

2. Increase the height of the vehicle to obtain enough clearance between driver head and the vehicle roof, which aims to make tall drivers to achieve a better siting posture.

3. Some technical solutions should be developed to lower the cockpit floor to facilitate driver's ingress and egress activity.

4. Exam the technical solutions raised in this paper to see their feasibilities and suitability. If necessary, new solutions fitting the core value of the design are required to be proposed.

5. Displaying the solutions to local companies, Chinese Express Delivery Association or other relevant administrations is good way to get their feedbacks on the concept. The attitudes from the authorities can reflect the potential market distribution of the solution.

6. Build physical models, mockups or at least use simulation software like 'JACK' to exam the ergonomics design of this vehicle.

7. Vehicle's exterior, interior and aesthetic experience design is recommended to be confirmed by another round of user research, probably applying Krippendorf's experience dimensions again to test user's visual perception feeling of the vehicle.

11. Conclusion

The chapter presents the conclusions of the entire report.

11.1 Conclusion

Project ‘PUNCH’ has been carried out in Applied Mechanics of Chalmers for years. It is a typical TCD project which means that almost all the technical solutions of it were developed with less involvement of the end user. There is no clear definition of the application of the vehicle and there is very little user requirement and ergonomics research executed during the process.

When Ralf Rosenberg, the initiator of this project, traveled to Shanghai, China in 2002, he accidently found a potential market distribution of ‘PUNCH’. Many undesired but interesting illegal vehicle overload situations caught his attention and he thought it might be beneficial to implant the ‘PUNCH’ to the Chinese market. Therefore, the industry with widely overload phenomenon, express delivery, is selected as the main focus of the project. Its tremendous growth and unqualified services offer a huge market potential for the development of PUNCH.

In order to have a deep understanding of the user, a field research under the guidelines of a mixed UCD and ACD approach was conducted on March 2014. Users’ requirements were captured and their undesired behaviors were also recorded. A series of methods had been applied to extract and conclude the obtained data, and a list of functions was generated to compose all the required functions of the new vehicle from various aspects. Several concept development methods and visualization methods were executed to transform the intangible needs and constraints to vehicle form, while some evaluation methods were applied to exam and evaluate the results from different design phases.

The final deliverable is presented via CAD model. The form design of the vehicle intends to express the sportive, solid, accurate, functional and reliable feelings, while the vehicle function design aims to interpret all the required functionalities got in the research phase. Users’ both physical and cognitive ergonomics traits are also taken into account in every delivery related activities. The selection of material and the intended mechanical solutions are based on the cost concern and technical feasibility. And at last, several suggestions on vehicle market strategy are raised for reference.

The final result has been evaluated by the list of functions raised before and the result is quite satisfying. Though there are many aspects required to be further developed or evaluated, the design of PUNCH-DMV can still be accepted as a good solution to the problem. It realizes almost all the required functions generated in the research, and perfectly fills the market blanks.

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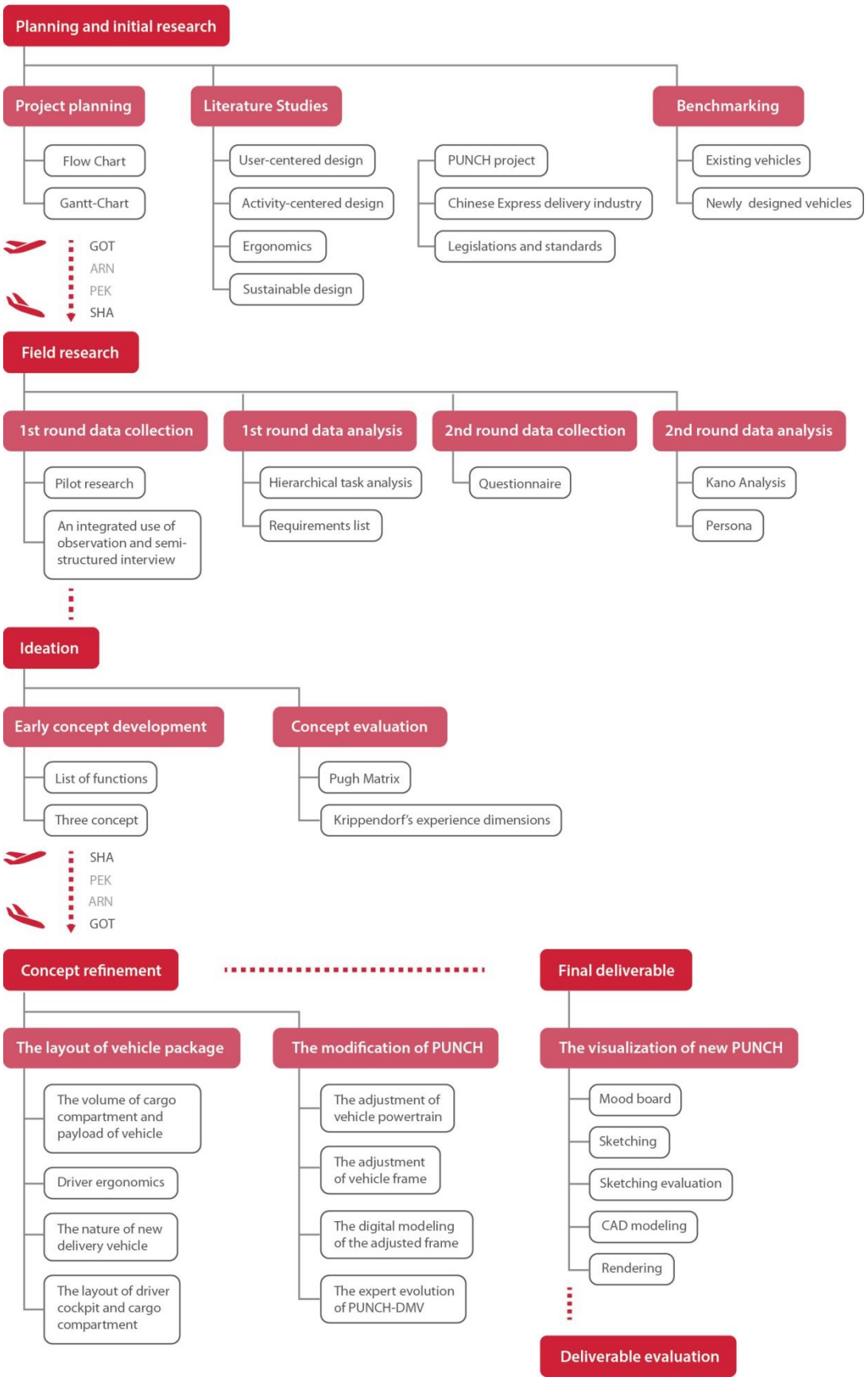
13. Appendix

Appendix I. The flow chart of the project



Appendix II. The Gantt-Chart of the project

Task	Start	Finish	Week																	
			7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Delivery market research	2 / 5	2 / 14																		
Technical Research	2 / 15	2 / 26																		
Review & writing	2 / 27	3 / 5																		
Planning user research	3 / 6	3 / 11																		
User research	3 / 12	3 / 22																		
Data analysis	3 / 23	3 / 27																		
Review & writing	3 / 28	4 / 4																		
Ergonomics research 1	4 / 5	4 / 9																		
Concept development	4 / 10	4 / 15																		
Concept evolution	4 / 16	4 / 20																		
Review & writing	4 / 16	4 / 22																		
Concept development	4 / 23	4 / 30																		
Ergonomics research 2	5 / 1	5 / 4																		
Review & writing	5 / 5	5 / 10																		
Digital Modeling & Rendering	5 / 11	5 / 31																		
Visualization	5 / 25	5 / 31																		
Review & writing	6 / 1	6 / 10																		
Presentation Preparation	6 / 11	6 / 13																		
Preparation	6 / 14																			

Appendix III. List of requirements

Section	Field	Specification	Potential requirement/demands
5.2.1	User	The distance from the outlet to service are	Sufficient battery
		The coverage of service area	
		Fatigue, long working hours, bend down frequently	Reduce the physical labor during delivery activities
		Low social status	Improve social status via exterior design
		Relatively low income	Control the cost
5.2.2	Outlet	Limited parking place	Suitable vehicle size
5.2.3	Scooter	Deliverymen-owned scooters in franchise companies	Adjust the cost according to the company nature
		Company-provided scooters in direct mode companies	
		Two years' service life	Longer service life
		Long charging time	Suitable charging time
		Overload	Sufficient payload and cargo space
		Overspeed	Control the high speed of vehicle
		Imbalance	Stable driving
		Vehicle stealing	Prevent the vehicle from thieves
		Cargo protection	Prevent cargos from thieves and bad weather
		Flexibility	Enough flexibility
		Ingress and egress	Convenient ingress and egress
	Modified minibuses	Connected driver compartment and cargo compartment	Separate driver compartment and cargo compartment
		Lockable storage places	Provide lockable storage places for personal effects and working material.
		Comfortable interior for short rests	Provide air-conditioner, radio, big soft seat and closed driving compartment
		High petrol consumption	Save energy cost
	Expectation		Drive without motor vehicle driving license
			Get the permission and authorization from government
			Equip stronger wheel rims and wider tires
			Add turning lights and brake lights in the rear side and increase the illumination of the headlight
			Delete unusual or not understandable information on the HMI panel
5.2.4	Cargo	Not well-packaged to resist severe extruding, jolting or falling	Protect the cargos from extruding, jolting or falling
		Lay the cargos in the bag according to address	Properly arrange cargos' sequence of delivery
		Place heavy cargos in a higher place needs lots of	Properly arrange cargos' position on the vehicle

		efforts	
		Deformation and damages	
		Higher vehicle's center of gravity and makes the scooter wobble	
		time-consuming process and less desirable result	Less time consuming
		Drivers lose judgments on vehicle width after load	Have a clear indication of vehicle dimensions
		The abnormal relationship between 'time to find a parcel in bag' to 'number of parcels delivered'	Keep the efficiency during delivery
		Leave the cargos unguarded	Prevent cargos from stealing
5.2.5	Other carrying articles	Delivery supplies	Provide space for delivery supplies
		The receipt copy of waybill	Provide space for receipt copies
		Tools	Provide space for tools
		Personal effects	Provide space for personal effects
5.2.6	Environment	Hot/cold/rainy climate	Closed driving compartment
		Bumpy roads	Solid vehicle structure and good suspensions
		Traffic conditions	Control vehicle dimensions
5.3	Activities	Throw/drop the parcels	Reduce activity process and time period Improve vehicle stability and loading capability Utilizing vehicle features to constrain undesired behavior
		Drive aggressively	Improve vehicle safety
		Leave vehicle unlocked	Prevent the vehicle from stealing
		Get off with parcels dropping down	Arrange suitable cargo space Convenient ingress and egress
		Hard to get on the vehicle	Convenient ingress and egress
		Sit in uncomfortable posture	Provide comfortable driving posture
		Leave cargos unguarded	Prevent cargos from thieves
		Park in improper place	Control vehicle dimensions
		Leave cargos all over	Provide dedicated design for delivering purpose
		Answer the phone during driving	Solve via applying Bluetooth technology

Appendix IV. Questionnaire table

Express Delivery Vehicles Questionnaire

Age: _____ Gender：_____ Statue: _____cm Weight：_____kg

Driver license: Yes / No

1. Demand Investigation

Please mark in the best suit space, for example:

	Totally agree	Agree	Slightly agree	Do not care	Disagree
Delivery is a tough job	√				

Notice: The 'electric scooter' in the questionnaire refers to the product which you are using, or you have used.

	Totally agree	Agree	Slightly agree	Do not care	Disagree
The battery of my electric scooter is not sufficient.					
The loading capability of my scooter is not sufficient.					
The legal top speed of 20km/h is too slow for express delivery.					
My electric scooter is easy to be stolen.					
My electric scooter is unstable during usage.					
The cargo load affects my riding posture and leads to discomfort and fatigue.					
It is hard to estimate the overall width of electric scooter with load					
My electric scooter cannot protect me very well in traffic accidents.					
The illumination of vehicle light is very important during night.					
My electric scooter seldom receives professional maintenance.					
The sorting, loading, unloading and delivering activities are time-consuming					
It is very laborious to load on my electric scooter					

	Totally agree	Agree	Slightly agree	Do not care	Disagree
It is difficult to get on and off my scooter after loading					
It is necessary to provide a stuff to record information after a sender calls.					
It is hard to carry an extra-big or overweight parcel by my scooter during collecting					
My scooter is not able to prevent the cargos from theft.					
There should be some space to put personal belongings and delivery supplies on my scooter.					
It is necessary to bring some boxes, bubble wraps, etc. to help clients with less well-packaged parcels.					
Leave parcels within ranges of monitors is safe.					
Even the parcels is arranged according to delivery sequence before, some still are left out during delivery.					
I am afraid other deliverymen lose the parcels I collected, which make me lose customers.					
I often smoke.					
My electric scooter cannot give me and parcels enough protection in bad weather.					
Hot, cold, rainy or snowy weather greatly influence my delivery efficiency.					
Fatigue caused by hot, cold, rainy or snowy weather influences my service quality					
A good delivery vehicle should be flexible enough to handle in small space					
My electric scooter going not well in a poor road conditions					

Appendix V. Pugh Matrix

Criteria	Basline	Weight	Concept 1	Concept 2	Concept 3
Adequate vision from seating position	0	5	0	0	-1
Be able to register as motor/non-motor vehicle	0	5	N/A	N/A	N/A
Be in conformity with the verified loading capacity	0	5	N/A	N/A	N/A
Be unable to take extra passenger	0	5	0	0	0
Delivery required basic capabilities	0	5	0	0	0
Ensure driver safety	0	5	1	1	1
Ensure the frame's crashworthiness	0	5	0	1	1
Get the permission and authorization from government	0	5	N/A	N/A	N/A
Load/unload cargos ergonomically	0	5	N/A	N/A	N/A
Prevent cargo from falling, floating or littering on the way	0	5	1	1	1
Provide battery cooling system	0	5	1	1	1
Provide fire equipment	0	5	N/A	N/A	N/A
Separate driver compartment and cargo compartment	0	5	0	1	1
Use electricity as energy	0	5	0	0	0
Vehicle required basic capabilities	0	5	0	0	0
Control the high speed of vehicle	0	4	N/A	N/A	N/A
Drive without motor vehicle driving license	0	4	N/A	N/A	N/A
Ensure vehicle security	0	4	1	1	1
Fit different body sizes	0	4	0	0	0
Fit user's cognitive understanding	0	4	0	-1	0
Help to reduce activity process and time period	0	4	N/A	N/A	N/A
Protect driver from bad weather	0	4	0	1	1
Protect the cargos from thieves	0	4	0	1	1
Protect the vehicle from thieves	0	4	N/A	N/A	N/A
Provide dedicated-design ancillary products to assist delivery activities	0	4	N/A	N/A	N/A
Provide dedicated-design ancillary products to constrain undesired behavior	0	4	N/A	N/A	N/A
Provide high cost performance	0	4	-1	-1	-1
Provide sufficient battery capacity	0	4	N/A	N/A	N/A
Provide sufficient payload and cargo space.	0	4	N/A	N/A	N/A
Use pure electricity as energy	0	4	0	0	0
Utilize vehicle features to constrain undesired behavior	0	4	N/A	N/A	N/A
Add turning lights and brake lights in the rear side and increase the illumination of the headlight	0	3	1	1	1
Control the vehicle dimensions for flexibility,	0	3	0	-1	-1

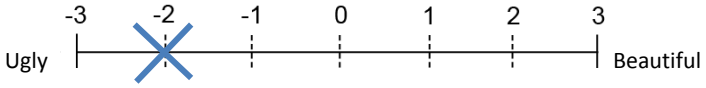
mobility, traffic condition and parking concern					
Ease of assembly	0	3	N/A	N/A	N/A
Enable convenient ingress and egress.	0	3	0	0	-1
Enable customization	0	3	N/A	N/A	N/A
Enable deliverymen to arrange cargos' position according to size and delivery sequence	0	3	0	0	1
Equipped solid vehicle structure, good suspensions, stronger wheel rims and wider tires	0	3	0	1	1
Improve the vehicle stability during driving, loading and unloading	0	3	1	1	1
Own light vehicle weight	0	3	-1	-1	-1
Perception of being safely seated	0	3	0	1	1
Protect cargos from bad weathers and extruding, jolting or falling	0	3	0	1	1
Provide comfortable driving posture	0	3	0	1	1
Provide lockable storage places for delivery supplies, receipt copies, tools and personal effects	0	3	N/A	N/A	N/A
Provide longer service life.	0	3	1	1	1
Provide multifunction	0	3	N/A	N/A	N/A
Provide suitable charging time	0	3	N/A	N/A	N/A
Solve the structure vibration problem	0	3	N/A	N/A	N/A
Use low-impact materials	0	3	N/A	N/A	N/A
User fewer materials and parts as well as mono-material construction	0	3	N/A	N/A	N/A
Improve users' social status via exterior design	0	2	0	1	1
Offer flexibility to adjust working environment to driver's own needs	0	2	0	1	1
Solve the high vehicle height and high cargo floor problem	0	2	N/A	N/A	N/A
Use sustainable design and manufacture	0	2	N/A	N/A	N/A
Total score			**21**	**48**	**47**

Appendix VI. Krippendorf's experience dimensions table

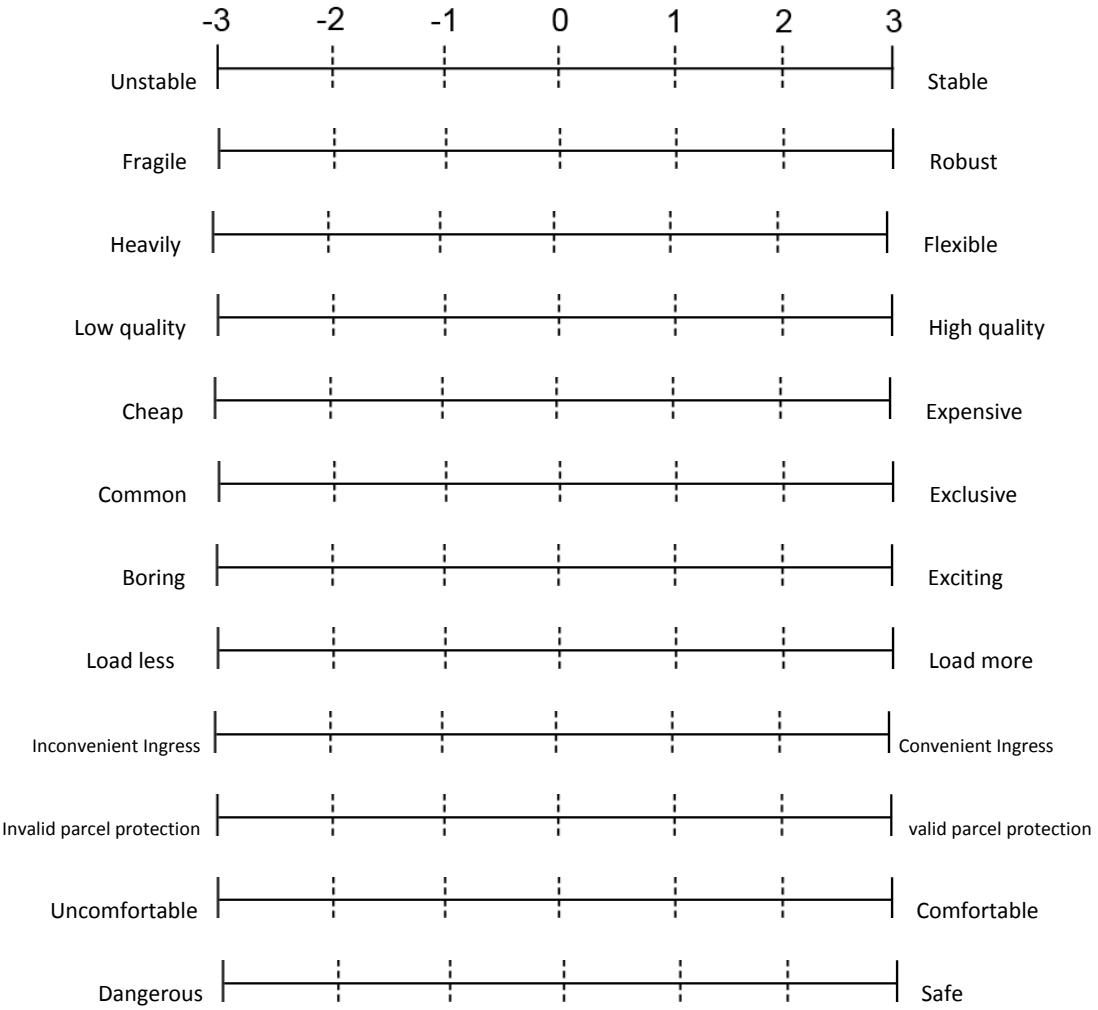
Age: _____ Gender：_____ Statue: _____cm Weight：_____kg
Driver license: Yes / No

Existing Vehicles Survey

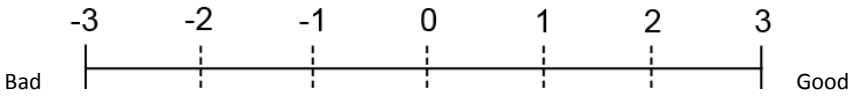
Please score for the following features based on the vehicles you are using now. 0 represents a compromise, 3, -3 means fully coincidence, and so among the options. For example:



Please complete the following scores:



Please give an overall evaluation



Vehicle concept survey

Concept 1：If there is a new express vehicle includes features as following, you think it is:

Please complete the following scores:

	-3	-2	-1	0	1	2	3	
Unstable								Stable
Fragile								Robust
Heavily								Flexible
Low quality								High quality
Cheap								Expensive
Common								Exclusive
Boring								Exciting
Load less								Load more
Inconvenient Ingress								Convenient Ingress
Invalid parcel protection								valid parcel protection
Uncomfortable								Comfortable
Dangerous								Safe

Please give an overall evaluation

	-3	-2	-1	0	1	2	3	
Bad								Good

Concept 2：If there is a new express vehicle includes features as following, you think it is:

Please complete the following scores:

	-3	-2	-1	0	1	2	3	
Unstable								Stable
Fragile								Robust
Heavily								Flexible
Low quality								High quality
Cheap								Expensive
Common								Exclusive
Boring								Exciting
Load less								Load more
Inconvenient Ingress								Convenient Ingress
Invalid parcel protection								valid parcel protection
Uncomfortable								Comfortable
Dangerous								Safe

Please give an overall evaluation

	-3	-2	-1	0	1	2	3	
Bad								Good

Concept 3：If there is a new express vehicle includes features as following, you think it is:

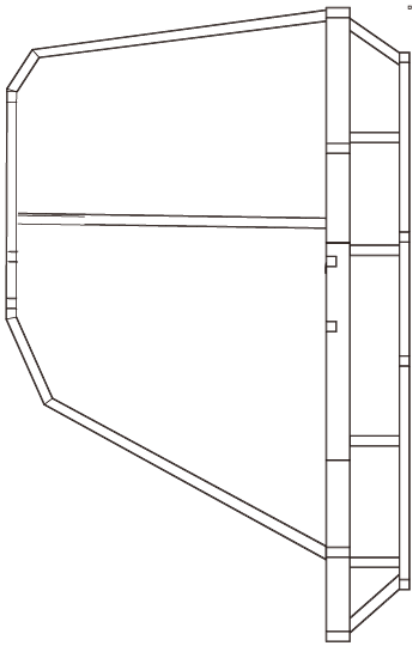
Please complete the following scores:

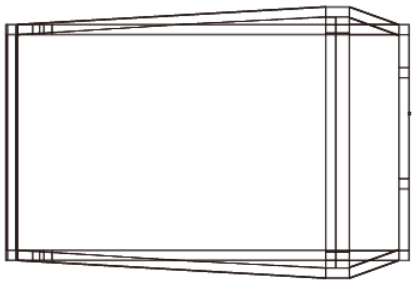
	-3	-2	-1	0	1	2	3	
Unstable								Stable
Fragile								Robust
Heavily								Flexible
Low quality								High quality
Cheap								Expensive
Common								Exclusive
Boring								Exciting
Load less								Load more
Inconvenient Ingress								Convenient Ingress
Invalid parcel protection								valid parcel protection
Uncomfortable								Comfortable
Dangerous								Safe

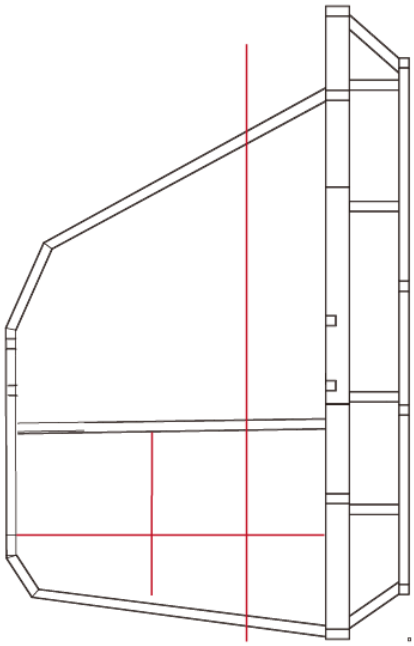
Please give an overall evaluation

	-3	-2	-1	0	1	2	3	
Bad								Good

Appendix VII. The sample of sketching paper







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