THE POTENTIAL FOR SHARED-USE VEHICLE SYSTEMS IN CHINA

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ABSTRACT

In the past, the majority of Chinese cities have developed with low-levels of automobile dependence, resulting in high-density centers that are well served by transit. However, a number of policies and factors are now in place that promote "motorization", resulting in increased automobile dependency in these cities. Increased personal automobile ownership in China is having a significant impact on the quality of human life in terms of land use, pollutant emissions, greenhouse gases, and energy supplies. Rather than embracing personalized automobile ownership that competes with traditional transit, China is well positioned to adopt an innovative mobility option: *shared-use vehicle systems*. The general principle of a shared-use vehicle system, often referred to as carsharing or station cars, is that individuals can access a fleet of shared vehicles (ranging from cars to bikes and scooters) on an as-needed basis, rather than using personally-owned vehicles for the majority of their trips. Shared-use vehicles offer the convenience of a private automobile and more flexibility than public transportation alone. There are many advantages to shared-use vehicle systems, including: 1) improving transportation efficiency by reducing the number of (private) vehicles required to meet total travel demand; as a result, vehicles spend less idle time in parking lots and are used more frequently by several users; 2) reducing individuals' transportation costs since vehicle expenses (e.g., payments, insurance, maintenance) are shared among all system users; 3) achieving energy and emission benefits when low-polluting vehicles (e.g., electric, gas-electric hybrid, natural gas) comprise the shared-use vehicle fleet; and 4) increasing transit ridership when individuals use shared vehicles via a direct transit linkage or indirectly because they are more conscious about modal choice in tripmaking (i.e., fixed auto ownership costs are typically converted to variable costs). For several years, the authors have extensively studied many models of shared-use vehicle systems in Europe and North America, creating a typology of systems. In this paper, a variety of shared-use vehicle system models are described and examined from the perspective of Chinese transportation and urban systems.

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1. INTRODUCTION

Over the last several decades, China has experienced tremendous economic growth. This growth brings many benefits to China; however, it also places serious challenges on China's social, environmental, and economic systems. As part of this economic growth, per capita income is increasing. Closely related to this rise in income is a rapid increase in motorization [1]. Indeed, in 1970, there were approximately 0.8 vehicles per 100 people in China. In 1996, this ratio increased to 1 vehicle per 100 people. It is projected to increase to 2.6 vehicles per 100 people by 2010 [1]. Although this ratio is low when compared to the U.S. (approximately 77 vehicles per 100 people in 1996), the growth potential is much higher.

This rapid increase in the number of cars poses both potential benefits and problems. The obvious key benefit is an increase in mobility and everything it brings: better access to education, wider employment and housing choices, access to shopping, and improved leisure [2]. However, there are many potential pitfalls, including traffic congestion, reduced air quality, and increased injuries and fatalities due to traffic accidents. This increase in motorization also has a significant impact on urban form. Like many cities around the world, the typical China city was originally developed with high population densities in centralized downtown areas. With motorization on the rise, there is usually a strong shift of people and industry away from urban centers to outlying areas: the so called "spatial decentralization problem" [1]. When this occurs, existing transit systems have a difficult time satisfying travel demand as it had in the past, forcing increased automobile use.

Unlike other developed countries, China is at the beginning of this new era of motorization and can take early measures to prevent over dependence on personalized automobile use. There are several measures that can be taken, including improved public transit systems and travel demand management programs. Another opportunity to consider is an innovative mobility option known as *shared-use vehicle systems*. Shared-use vehicle systems (SUVS) can be considered as an intermediate solution situated between public transit and private vehicle ownership. The general principle of a shared-use vehicle system, often referred to as carsharing or station cars, is that individuals can access a fleet of shared vehicles (ranging from cars to bikes and scooters) on an as-needed basis, rather than using personally-owned vehicles for the majority of their trips. Shared-use vehicles offer the convenience of a private automobile and more flexibility than public transportation alone. In addition, shared-use systems have the potential to complement existing transportation infrastructure (e.g., transit linkages and parking efficiencies) at significantly less cost than transit extensions, roadway expansions, and added parking structures [3].

There are many advantages to shared-used vehicle systems, including:

1) They can improve transportation efficiency by reducing the number of (private) vehicles required to meet total travel demand; as a result, vehicles spend a lot less idle time in parking lots and are used more often by several users;

2) Individuals can reduce transportation costs since vehicle expenses (e.g., payments, insurance, maintenance) are shared among all system users (Note: Many carsharing organizations in Europe and North America claim that significant cost savings are achieved by members whose corresponding private vehicle mileage is less than 10,000 annual kilometers);

3) An energy/emissions benefit is achieved when low-polluting (e.g., electric, gas-electric hybrid, natural gas) cars comprise the shared-use vehicle fleet; and

4) Transit ridership is increased when individuals use shared vehicles via a direct transit linkage or indirectly because they are more conscious in tripmaking and modal choices (i.e., fixed auto ownership costs are typically converted to variable costs with carsharing).

For further information on the history and benefits of shared-use vehicle systems, see, e.g., [4, 5, and 6]. Over the last several years, there has been a proliferation of shared-use vehicle systems around the world. Many of these systems reflect different business models and purposes; nevertheless, they have common elements such as a shared fleet, transit linkages, and advanced technologies. This rapidly growing field is addressed at many major transportation conferences (e.g., Transportation Research Board Annual Meeting, ITS World Congress, etc.) and has even spawned several dedicated conferences that encourage practitioners, researchers, and enthusiasts to gather to discuss shared-use vehicle system practices and approaches. Shared-use vehicle systems are often described with various terms, emphasizing key attributes such as: "flexible fleet services", "short-term car rental", "time-shared vehicles", "instant rent-a-car", "commuter carsharing", "station cars", and "transit-based carsharing".

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The authors have been studying shared-use vehicle systems for many years, focusing on the design of SUVS models, implementation of pilot operations (see e.g., [5, 7]), developing management techniques, and analyzing the impacts of these systems (including success factors and market barriers). With the proliferation of these systems in Europe and North America, the authors have recently developed a shared-use vehicle system *typology* in order to more consistently characterize and evaluate various models and systems [8]. In this paper, the authors briefly review several shared-use vehicle models in place today followed by a short description of the SUVS typology. Next, the potential for SUVS in China is considered in light of China's transportation and urban systems.

2. SHARED-USE VEHICLE SYSTEM MODELS AND TYPOLOGY

Generally, there are three basic shared-use vehicle system models. They include neighborhood carsharing, station cars, and multi-nodal shared-use vehicles. Recently, the first two models have started to develop from their original visions, largely due to advanced technologies (e.g., electronic and wireless communication systems) that facilitate system management and vehicle access. Thus, the initial carsharing and station car concepts have evolved to include common elements of each model (e.g., commuter carsharing). The authors also explore the multi-nodal approach below.

2.1. The Neighborhood Carsharing Model

The current concept of *neighborhood carsharing* started most aggressively in Europe fifteen years ago. Carsharing efforts emerged primarily from individuals who wanted the mobility benefits of automobiles but could not justify vehicle ownership costs, parking, and other associated expenses. As a result, several carsharing organizations were initiated, consisting of a few vehicles used by a group of individuals. Several of these early carsharing organizations failed for various reasons, but many grew beyond the initial grassroots, neighborhood-based program stage. Today there are many successful carsharing organizations in many cities [4]. For a recent listing of these carsharing organizations, the reader is referred to several active web sites that focus on carsharing activities, such as http://www.carsharing.net and http://www.ecoplan.org/carshare.

Today's typical carsharing organization places a network of shared-use vehicles at strategic parking locations throughout a dense city (see Figure 1a). Members typically reserve shared-use vehicles in advance. At the time of the rental, the user gains access to the vehicle, carries out his/her trip, and returns the vehicle to the same lot he/she originally accessed it from. Participants pay a usage fee (typically based on time and mileage) each time a vehicle is used. The carsharing organization as a whole maintains the vehicle fleet (including light trucks) throughout a network of locations, so users have relatively convenient vehicle access throughout their neighborhoods and business areas. Usually there is also a small monthly subscription fee or a one-time deposit or both.

Internationally, carsharing organizations are the most prevalent shared-use vehicle system. Vehicles are most often placed in residential neighborhoods; less frequently, they are located in downtown business areas and rural locations. To summarize, the premise of carsharing is simple: Short-term usage and vehicle costs are shared among a group of individuals. Lots are located so carsharing users can conveniently access vehicles for tripmaking. Often carsharing results in increased transit ridership (as well as other alternative modes, such as biking), as users become much more conscious of the individual costs of each automobile trip.

2.2. Station Cars

Another shared-use vehicle system model is known as "station cars". The station car concept has been implemented internationally, but has been most actively tested in the United States [9]. Since 1998, six station car programs were launched in the U.S. Today, there are just two remaining on the east coast [3]. The earliest and predominant station car model consists of a fleet of vehicles deployed at passenger rail stations in metropolitan areas that are used by rail commuters primarily on the home- and work-end of a trip. The majority of these systems were initiated by rail transit operators seeking to relieve parking shortages and increase transit ridership. Historically speaking, station cars did not focus on shared use by multiple individuals, but traditionally on enhanced transit connectivity. Thus, a common characteristic of many station car programs is a relatively low user-to-vehicle ratio in contrast to carsharing. In the mid-1990s,

however, several experiments began to test shared-use practices as part of the station car concept (particularly in Asia through the integration of electronic and wireless technologies).

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b: schoolschoolschoolhomehomehomeofficeofficeofficeschoolschoolschoolhomehomehomeofficeofficeofficeSTATIONSTATION

Figure 1. Basic Shared-Use Vehicle System Models. a: Neighborhood carsharing model; b: Classic station car model; c: Multi-nodal shared-use vehicle model.

A typical station car scenario is depicted in Figure 1b. When station cars are placed at major rail stations along a commuting corridor, they can serve as a demand-responsive transit feeder service on both ends of a commute (see [10]). For example, a user can drive a station car from home to a nearby transit terminal, parking it at or near the station while at work. The user then commutes by rail or bus to their destination. After arriving at their destination station in the morning for work, a second station car could be rented to travel from the station to their office, and during the day the individual also might use that same vehicle to make business and personal trips. In the evening, the user again drives the station car to travel from work to the station. At the end of the transit commute, this same individual takes another station car to drive home. In this scenario, "reverse" commuters often use the same dedicated station car for their station-work/station-home trips. Furthermore, business and personal trips could also be made by other users during the day when the vehicles would otherwise sit idle at a station [11].

2.3. Multi-Nodal Shared-Use Vehicles

A more generalized shared-use vehicle system is one in which the vehicles are driven among *multiple* stations or nodes to travel from one activity center to another. Such systems may be located at resorts, recreational areas, national parks, and corporate and university campuses. For example, a user may arrive by rail or plane, then rent a shared-use vehicle to drive from the station or airport to a hotel, as depicted in Figure 1c. Later on, the same individual may travel from the hotel to a shopping mall or a tourist attraction. In this way, the trips are more likely to be *one-way* each time in contrast to the typical roundtrips made in a traditional station car or neighborhood carsharing program. Users share vehicle costs and usage, similar to

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carsharing.

Because there are many more one-way trips in a multi-nodal scenario, the number of shared-use vehicles at each station can quickly become disproportionally distributed among the nodes [12, 13, and 14]. At different times throughout the day, some stations will have an excess of vehicles while others will have a shortage. As a result, it is sometimes necessary to *relocate* vehicles periodically each day so that the system operates efficiently and (most) users' travel demands are satisfied. Multi-nodal systems could also be directly linked to transit, although they have not been traditionally. An advantage of a multi-nodal system is that vehicle trips can be "one-way" versus "two-way" only. One-way rental introduces significant flexibility for users but management complexities, including vehicle relocation. Advanced technologies can make multi-nodal systems much easier to manage and cost effective as well.

2.4. Shared-Use Vehicle System Typology

To more consistently characterize and evaluate various SUVS models, a typology was developed for categorizing different shared-use vehicle system models, ranging from neighborhood carsharing to station car systems [8]. This framework is illustrated in Figure 2. The primary purpose in creating this formal structure was to aid policymakers, researchers, and practitioners in describing, contrasting, and analyzing (e.g., environmental and social benefits) shared-use vehicle models/approaches in this rapidly changing field. Developing a structured framework also helps to clarify key terms and their usage. In addition, it identifies existing and evolving models along the shared-use vehicle continuum, key attributes, and success factors. As described earlier, the predominant shared-use vehicle model is neighborhood carsharing. At the other end of the spectrum are station cars, where vehicles are closely linked to transit stations to enhance access. Some of the more innovative shared-use vehicle service providers today are combining elements of both traditional carsharing and station cars, forming what are called "hybrid" models. For further information on this typology, see [8].

3. THE POTENTIAL FOR SUVS IN CHINA

As described earlier, China is undergoing a rapid increase in automobile numbers, posing both potential benefits and problems. Vehicle costs are declining and per capita income is rising, fueling this increase. Without counter measures, China will suffer from many automobile-related problems, such as heavy traffic congestion, poor air quality, and increased injuries and fatalities due to traffic accidents. There is also worldwide concern, as automobile-related greenhouse gas emissions (e.g., CO_2) would also increase.

China is well positioned to embrace various types of shared-use vehicle systems. We consider the advantages of several SUVS models below:

***Neighborhood Carsharing*—**Much of China's urban population lives in large apartment complexes in centralized locations within the city. In many cases, shopping, education, and work are close by, eliminating the need to own a personal vehicle. However, there are cases when an automobile would be very useful: perhaps to shop in another area of town or to visit friends. Such non-recurrent trips can easily be accomplished with shared vehicles. An apartment complex could pool costs and own a small fleet of vehicles (of different types) to provide mobility on an as-needed basis.

One of the main problems of personalized automobile ownership in China is that vehicle costs are too high for many lower income households. As described above, one of the key advantages of carsharing is lower user cost. By establishing carsharing systems in high-density areas, personal mobility can be enhanced at a much lower cost. Motorization already has a significant equity impact among various segments of the Chinese population; carsharing can potentially lessen this inequity.

In the U.S., SUVS also have the potential to enhance the mobility options for low-income households, however this is often not a primary objective of U.S. SUVS programs [3]. Most studies show that the majority of carsharing members in Europe and North America are highly educated and professionally employed. Barriers to low-income households include initial processing fees and limited credit history required by most carsharing organizations. In China, governmental support should be considered to lower potential barriers for new carsharing initiatives.

***Station Cars*—**Over the last several decades, China has put more emphasis on transit systems than on expanding roadways. Transit use is already quite high in China (compared to the U.S.). Nevertheless, transit use can still be increased by providing station cars between high-density residential areas and transit stations.

Similarly, station cars should also be placed between rail/bus stations and high-density industrial regions. As Chinese cities continue to expand, it may be more cost effective to support station cars rather than developing a higher density of transit stations. Again, station cars can provide a crucial link between transit and origins/destinations. An environmental benefit can also occur when station cars are electric vehicles; since station car trips are typically shorter, range limitations of electric vehicles would be mitigated.

Shared-UseVehicle Systemsnodes placed at transit stationsconnections at trip starts/ends*Station Cars*purely services commute tripswith non-commute tripsshort-term non-commute tripshybrid designsdistributed nodes without transitinter-nodal travel allowed*Carsharing Organizations*no inter-nodal travel allowedcampus setting (day-use)resort/park settingbusiness use (mostly)•*corporate campus•academic campus•national parks•gated communities•resorts•city visitors*residential use (mostly)•*classic carsharing organizations•fleet vehicles•classic station cars•enhanced station carscommuting usenon-commuting usenon-commuting use*

Figure 2. Shared-Use Vehicle Classification System

***Multi-Nodal Shared-Use Vehicles*—**There is a recent trend in China (like other international cities) to create academic and corporate campus-like settings where buildings themselves occupy very little land compared to surrounding green space [1]. These settings are ideal for multi-nodal shared-use vehicle systems, where stations can be established in high activity centers (i.e., the buildings) and vehicles can travel between these stations. In this case, the vehicles do not need to be full-size automobiles, they could be smaller "neighborhood" vehicles or even scooters. As with station cars, electric vehicles may fit well here since trip distances are short, and it is possible to reharge vehicles when they are idle at stations. Further, municipal planning offices in China have created specific growth centers or expandable small settlements within major metropolitan areas. Thus far, 14 have been identified in and around Beijing, and approximately

20 are located in and around Shanghai [1]. These settlements or "new towns" can be made more self-sustaining with the implementation of multi-nodal shared-use vehicle systems.

For neighborhood carsharing and multi-nodal systems, dramatic increases in parking efficiency can be realized. In contrast to personalized automobile ownership, fewer parking spaces are required to support the same level of mobility. Chinese cities have developed with high density in mind, with less than 10% devoted to roads and parking [15]. As increased automobile use occurs, it will be a difficult and costly to add more parking throughout the city. Supporting neighborhood carsharing and multi-nodal systems may be more cost effective.

In terms of vehicle production, there is currently an effort underway in China to develop a low-cost national car (the "China Car") that can be used by much of the population [1]. During the development of this car, it would be advantageous to incorporate carsharing features (e.g., keyless access, telematics, etc. see [16]) so that they could readily be used in any type of shared-use vehicle system in the future.

4. SUMMARY

To summarize, shared-use vehicle systems could offer a flexible mobility alternative to China as it wrestles with increased automobile use and its associated problems. Many automobile-related problems can be alleviated such as parking constraints, user costs, air quality, and transit access. Several shared-use models can be employed, extending from neighborhood carsharing to station cars.

Shared-use systems have a high potential for success in China for several reasons. The Chinese city is at the beginning of a new era in terms of automobile usage without any deep-rooted notions of personalized ownership. It would be easier for people to adopt the concept of increased mobility at a lower cost than personalized auto ownership. Further, China has the strength of governance that would enable it to establish supportive automobile use policies [1]. To ensure widespread integration of the SUVS alternative, China's national, regional, and municipal governments should consider incorporating shared-use vehicle systems into their comprehensive development and traffic management plans.

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