

Interoperability Options for Shared-Use Vehicle Systems

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Different models of shared-use vehicle systems (SUVS) continue to grow worldwide, in particular in North America. SUVS models include carsharing, station cars, and other system forms. In general, these models coinstitute fleets of vehicles used by several different individuals throughout the day. As these systems continue to expand in number and size, the need for interoperability will increase. Furthermore, interoperability will play an important role with other transportation modalities as well (e.g., transit). There have already been several discussions on interoperability in carsharing; the general idea is to allow a user from one system to use a different system easily when traveling in a different area or on a different mode (in the case of transit). Interoperability will likely result in higher customer convenience and satisfaction and lead to greater market penetration of this and other forms of transit. A number of interoperability issues for SUVSs are examined in detail, taking into account the point of view of the customer, the operator, and the vehicle manufacturer. Issues such as reservation systems, vehicle access, billing, and insurance are addressed. Several technical solutions for interoperability are proposed, drawing on similarities in the arenas of electronic toll collection and automated banking.

Interest in carsharing and station cars, generally referred to as shared-use vehicle systems (SUVS), continues to grow worldwide as an attractive mobility alternative to personally owned vehicles. The general principle of SUVSs is that individuals can access a fleet of shared vehicles on an as-needed basis rather than use their personal vehicles for all trips. Advantages of SUVSs include better utilization of vehicles and land (leading to higher transportation efficiency), potential cost savings to the user, energy and emissions benefits, and improved access to established transit operations. For more information about the history and benefits of SUVSs, see Shaheen et al. (1) and Whitelegg (2).

BACKGROUND

Different operational models, market segments, and purposes exist for SUVSs. The predominant shared-use vehicle model is neighborhood carsharing, where users access vehicles placed at strategic neighborhood locations. Neighborhood carsharing is prevalent in Europe and growing rapidly in North America. Station car systems are another model, where vehicles are closely linked to transit stations to enhance access. Other SUVS models exist that combine dif-

ferent elements of neighborhood carsharing and station cars. A preliminary typology for categorizing different SUVS models was developed in 2002 (3).

One of the key factors in the growth of today's SUVSs is the application of intelligent transportation system (ITS) technologies. The penetration and impact of technology such as dispatching and reservation systems, smart card technology, onboard navigation and travel information, intelligent communication and tracking systems, and automated back-office billing systems have been described in detail (4). During the pioneering stage of SUVS development, many of these technologies were selected and applied based on a number of factors, including cost, system enhancements to the user, and ease of management. Many trade-offs have been encountered during these initial developments as described by Barth et al. (4), who address detailed issues such as vehicle selection, user-system interactions, user-vehicle interactions, and system operations.

As SUVSs continue to expand and multiply, the penetration of ITS technology use will only increase as manually managing larger fleets and more diverse user markets (e.g., one-way trip rentals) becomes more difficult with increased scale. Currently, approximately 56% of SUVSs in North America have some degree of ITS technology in their systems (5). With this growth, there will be an increasing need for interoperability among SUVSs and providers. Furthermore, interoperability will play an important role between SUVSs and other transit modalities. As described by Barth et al. (4), interoperability issues will be important from three points of view: the customer, the system operators, and the vehicle manufacturers.

Customer Interface

From the customer's perspective, it is beneficial for SUVS operators to provide a high degree of interoperability and consistency among various SUVSs, as well as with transit. A key example in this case would be a single access mechanism (e.g., smart card, key fob, or both) that could be used among many SUVSs and other mobility services such as transit and parking management. Billing could also be made uniform across many programs, so that one monthly bill is received rather than several from various organizations. Operational consistency among several systems is also key, so that customers do not have to relearn different operational procedures.

System Operations

It is inevitable that system operations will be different among SUVSs, depending on their functional model (i.e., purpose and location). Thus, it is difficult to introduce common operational practices across all models. Nevertheless, there is a strong need to measure

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SUVS effectiveness with a focus on modal connectivity, air quality, energy efficiency, economic viability, and insurance risks. Common operational practices could specify the minimum set of data collection required to document vehicle usage, net benefits, and claims histories. Such standard practices would allow for consistent determination and comparison of system effectiveness and the establishment of an insurance risk class for SUVs. As it turns out, insurance is one of the more difficult issues when one deals with interoperability. Another important issue is whether a system operator can achieve a return on cost for enabling interoperability in their system. This issue is addressed in the subsections on billing systems and on implementation and operational system costs.

Vehicles

Many automobile standards are already in place for safety, consistent operation, and interoperability of components. With the addition of shared-use onboard electronics, some standards will likely emerge so that automakers can produce vehicles that integrate easily and operate more consistently among many shared-use vehicle programs. For example, Honda's latest Civic Hybrid now has an interface connector for onboard monitoring and control electronics for purposes of carsharing (6). SUVs technology manufacturers could also benefit by adopting some uniform components for the growing shared-use vehicle market segment (e.g., smart card readers placed in vehicles).

In this paper, we examine various interoperability issues for SUVs. Interoperability methods in similar systems are first examined, followed by a discussion on key issues of success and potential barriers. Several interoperability methodologies are then proposed for shared-use vehicles systems, followed by a short discussion on next steps.

INTEROPERABILITY IN SIMILAR SYSTEMS

It is advantageous to examine similar systems that have first established themselves independently, and then later have developed interoperability methodologies as the systems have expanded. Two examples have been investigated: banking automated teller machine (ATM) networks and electronic toll collection (ETC) associated with U.S. toll roads. ATM networks developed and refined their interoperability techniques 20 years ago; ETC began some degree of interoperability approximately 10 years ago, and the process is still being refined.

Bank ATMs

Bank ATMs first emerged in the late 1960s as money-dispensing machines for specific banks. ATMs quickly became popular with both customers and bankers due to their convenience and low cost compared with using human bank tellers. The desire to use ATMs at other locations (i.e., away from the "home" bank) was immediate, leading to the development of ATM networks. At the time, banks took advantage of the advancing communication/computer technology of the time and formed shared ATM networks, essentially connecting their ATMs together. Today, ATMs are pervasive and nearly all bankcards can be used successfully at any ATM. There are still issues of bank ATM fees charged to customers for using other ATM networks, but it is possible to perform bank transactions worldwide.

The ATM interoperability process follows several steps, illustrated in Figure 1 (7). In this scenario, a user walks up to an ATM for which the ATM owner (Bank A) and the card issuer (Bank B) are different; however, both are members of one common regional network:

1. The user inserts ATM Card *b* (issued by Bank *B*) into ATM *a* (owned by Bank *A*), then enters a personal identification number (PIN).
2. ATM *a* sends a transaction message [that includes the identification (ID) number of User *b*] to Bank *A*'s host computer.
3. The host computer determines that the user is from another bank in the network, then sends a query to the network switch for authorization.
4. The network switch receives this query, determines the proper bank ID, and forwards the query to the proper bank (Bank *B*).
5. Bank *B* authorizes the transaction and posts the debit to the cardholder's account according to the information stored in its user account database; an authorization message is sent back to the network switch.
6. and 7. The confirmation message is relayed from the switch to Bank *A* and then on to ATM *a*.
8. The user receives cash.

To make this process work, various standards and protocols have been developed for the ATM process such as magnetic stripe coding, card readers, and messaging (i.e., queries and authorization). Importance is placed on security and reliability since these are financial transactions. The human-machine interface process does not have specific standards, but most ATMs have approximately the same sequences of data entry. It is important to note that ATM interactions must occur quickly (i.e., in real time) so that a user doesn't have to wait a significant period of time to complete his or her transaction.

Electronic Toll Collection

ETC is another similar area that began applying technology locally and then later expanding to allow interoperability between different

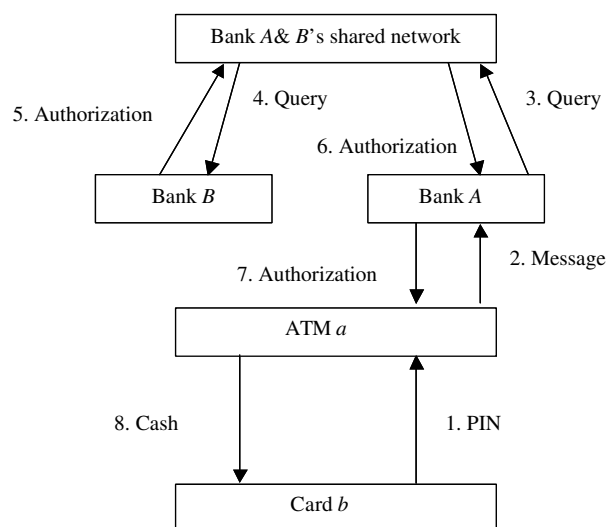


FIGURE 1 Bank ATM interoperability process.

toll agencies. Roadway toll collection continues to grow in the United States and more and more organizations are using electronic “transponders” that don’t require a driver to stop and manually pay a toll. Instead, the transponder-equipped vehicle can travel near an antenna at normal speeds and the toll is automatically debited from the customer’s account. Later, the customer and toll road operator settle the account using standard billing practices.

At least two major ETC consortiums have developed in recent years so that customers can use their transponders at different ETC facilities, operated by different toll authorities. This includes the EZPass system on the U.S. east coast, consisting of 12 toll authorities in Delaware, Maryland, Massachusetts, New Jersey, New York, and Pennsylvania (8). Another example is California’s FasTrak system, which covers five toll authorities throughout the state (9). To handle interoperability, the toll authorities in each of these systems adopted a principle of “reciprocity.” They initially reached an agreement on a common technology specification for the transponders and antennas; in the case of FasTrak for example, Caltrans drafted a compatibility specification for automatic vehicle identification (AVI) equipment, which was written in Title 21, Public Works, Chapter 16, the California Streets and Highways Code of Regulations. The transponders themselves are owned by the participating toll authorities, each of which has a unique three-digit agency code in the transponder ID or “tag.” Each tag is valid on the entire system and each agency separates “home” agency transactions from “away” agency transactions. Away agencies are billed for tolls generated by users on other roads and remit payment to the billing agency. They in turn debit the user’s account. The accounts are all owned by the agencies and they settle up daily, weekly, or monthly to process “away” transactions. This method has worked successfully for some time; however, it does require that each agency perform this post-processing on a daily basis. There is now movement in this arena to move toward a centralized “clearinghouse” model: all agencies report their transactions to an independent clearinghouse that then does the work of sorting and processing “away” transactions. The motivation for the clearinghouse method is lower cost and simplicity.

Another interoperability issue in the ETC arena is the method of how to handle stolen or invalid transponders. Each agency in the consortium has a “hot list” of invalid transponders that is updated daily. If an invalid transponder runs past the antenna, it is immediately recognized, and typically a digital image is taken of the vehicle’s license plate. The license plate information is then used to contact the state Department of Motor Vehicles, the registered owner of the vehicle, or both. For “away” transponders that are invalid, the invalid tag list information is passed between agencies just as the billing is handled.

KEY INTEROPERABILITY ISSUES

As described by Barth et al. (4), several SUVs elements will play an important role in future interoperability methods. These elements can be categorized into two main categories:

- Technology elements—issues such as the reservation system, vehicle access, and onboard vehicle electronics, and
- Administrative elements—issues such as billing and insurance.

Each of these elements is described below. The general scenario to consider is that User *a* of SUVs *A* wants to use Vehicle *b* from SUVs *B* with little or no additional paperwork.

Reservation Systems

As described by Barth et al. (4), various reservation mechanisms are used in SUVs, ranging from a manual system in which users call a reservation center to automated systems that can be accessed via the phone or Internet. For any reservation system to be capable of interoperability, it must simply recognize users from other systems and process the reservations normally. The main issue is authorizing away-users at the local SUVs. Many options are possible—for example, having the away-user first perform a short one-time pre-registration with the local system (where the local system performs an authenticity check with the user’s home system) or having the away-user’s authenticity checked for each local reservation.

Methods of authenticity checking are provided in the section on proposed technical solutions. Overall, the impact interoperability places on the reservation systems is relatively small.

Vehicle Access

After the away-user has successfully reserved a vehicle [or the user is simply walking up in an on-demand system (4)] and is ready to obtain a vehicle, several issues are associated with vehicle access. As with other technology components, vehicle access techniques in SUVs vary—from the simple lockbox with shared keys to exclusive user access by sophisticated smart cards (4).

For interoperability to be successful, the SUVs industry should adopt a common technology specification for a smart card or key fob. Several reader systems (for cards and key fobs) already exist for different security applications. Most systems use access control equipment that adheres to the Wiegand standard for electronic interfacing. However, the “tag” data on the cards and fobs are not consistent between systems; therefore, cards and fobs will not work on readers made for other systems. The common technology specification need not be mandated; the market can determine the appropriate specification. Another avenue is to adopt card or fob readers that can interpret multiple protocols. These multiple-protocol readers cost more; however, they are more flexible for interoperability.

Onboard Vehicle Electronics

The operation of onboard vehicle electronics used to facilitate car-sharing has little impact on the user who desires interoperability. From the user’s point of view, the steps taken to activate the vehicle may be slightly different between systems; however, users can adjust to this variability (just as users adjust to different ATM interfaces). As described earlier, some common onboard electronic specifications may evolve so that automakers can produce vehicles that integrate more easily and operate more consistently among various SUVs.

Billing Systems, User’s Cost, and Operator’s Cost

As trips take place in an SUVs, trip logs are created that contain information that contain at least the user’s ID, trip duration, and trip distance; these data are necessary to bill the users for use of the vehicles. For an away-user using a local system, the trip is recorded as for any user; however, the billing system has to later separate the

away-users from the home-users (based on a system ID) and process these charges separately, either through a decentralized reciprocity or a centralized clearinghouse technique (see the section on proposed technical solutions).

Problems can arise when billing structures differ from system to system. For example, SUVS *A* may require that users pay a monthly membership fee in addition to vehicle use fees; SUVS *B* may not require a monthly membership fee but charge slightly higher vehicle use fees. In this situation, a user may sign up for service with SUVS *B* and then use SUVS *A* to minimize the overall cost. Such cost issues are usually discovered by system management, and additional fees are levied or waived to eliminate the discrepancy.

The eventual goal from the operator's perspective is to have sufficient customer demand induced by the increased customer convenience of interoperability. The operator would incur significant initial implementation costs with gradual increases in customer demand that would depend on numerous system and user characteristics. The benefit for an operator to participate within a system must be greater than the cost of system interoperability implementation. To reduce the operator's initial investment, it may be possible to acquire funding from the government to set up the initial interoperability mechanisms as discussed in the subsection on implementation and operational system costs.

Insurance

Probably the largest barrier to interoperability at the present time is vehicle insurance. The predominant method among SUVS organizations is to insure against vehicle damage and liability with a commercial automobile fleet policy. Occasionally, an organization will self-insure up to a maximum amount and have a contingency policy to cover excessive loss. With each organization tailoring insurance to its specifications, many obstacles are created for insurance-related interoperability.

By definition, a commercial fleet automobile policy most frequently insures a specific group of vehicles for an approved group of drivers. The premium incurred by the insured organization depends on vehicle parameters, location, and driver characteristics. This type of policy does not insure a specific individual who is driving a vehicle not listed on the policy. Therefore, individuals belonging to SUVS *A* with a commercial fleet policy are not insured (through SUVS *A*) to drive vehicles that belong to SUVS *B*.

The concept of insurance interoperability would allow an individual that joined SUVS *A* to be automatically insured when authorized to drive a vehicle in a subsequent SUVS *B*. Several potential options have been explored that would facilitate insurance interoperability:

- A national insurance cooperative,
- Driver-specific insurance, and
- A national Electronic Data Interchange (EDI) standard (10).

Each option has the potential to allow users to use vehicles of multiple organizations while being a full member of a single entity.

A national insurance cooperative applicable to the U.S. carsharing industry has been proposed and given considerable attention. This option is attractive for several reasons.

- Unassigned risk. Carsharing and station cars do not have sufficient claims history in the United States to be assigned a risk category; therefore, premiums are elevated to offset the potential risk of

not knowing the loss potential. The national cooperative could be adaptable to the unassigned risk characteristic of the industry.

- Surplus revenue payback. The cooperative would manage the total vehicle risk of all member systems. When enough revenue accrues to cover the estimated potential loss, the premiums for member systems can be reduced.

- National coverage. If each SUVS belonging to the national insurance cooperative has the same driver eligibility criteria (e.g., age, driving experience, driving record), then all users are covered across all participating organizations.

- Economic benefits. This insurance method is potentially the most economical when one considers the industry as a whole. The economic benefits of a national captive policy for carsharing are similar to those of self-insuring (with contingent insurance).

The formation of a national insurance cooperative must overcome several obstacles. First and foremost, a large sum of capital is required to guard against the initial risk. This initial capital is currently being sought through federal appropriations in the reauthorization process of the Transportation Equity Act for the 21st Century (TEA-21). The success of a national cooperative would require a critical mass of participant organizations. Without sufficient participants, the cooperative would not be able to accrue funds rapidly enough to recover founding costs. (This issue is not as critical if an initial subsidy is obtained through a grant.) Finally, the potential member systems would need to determine member criteria guidelines to ensure that any member of a participating SUVS would meet the minimum requirements and therefore would be insured under the national policy.

The potential for driver-specific insurance was also explored. Several types of policies have some flexibility to insure drivers for carsharing.

- Unowned auto. This individual insurance policy is intended to insure drivers who do not own a vehicle. The total premium would be the responsibility of the individual, and costs probably would be excessive.

- Extended commercial policy. Commercial fleet policies can be written to extend coverage to specific drivers. This extension would increase premiums and greatly increase potential liability because it would extend coverage to every vehicle a designated individual would potentially be driving (not only within the SUVS).

- Alternative self-insurance methods. Individuals who have private auto policies often have coverage that would apply to unowned automobiles; furthermore, some credit cards offer liability coverage in addition to property damage coverage when the card is used for payment. These methods of self-insurance only apply to a small portion of SUVS participants and lack flexibility for broad interoperability.

The final option for industrywide interoperability addresses the insurance obstacles as well as some of the back-office issues (described in the section on proposed technical solutions). An EDI standard would provide a means for every SUVS to exchange necessary user information for insurance requirements and other membership qualifications. After an EDI standard has been accepted by the majority of systems, member(s) of a single SUVS could authorize pertinent member information to be made available for other participating systems. When a member chooses to use a participating SUVS vehicle, that organization would request the user's information, and vehicle use would be evaluated on the basis of available

data. Therefore, an SUVS with self-secured insurance could authorize a member from a different system if that individual's criteria (available through EDI) met their standards. Because large operators have an economic advantage to independently secure insurance, this may prove the most viable means for interoperability relative to insurance.

In the event a national insurance cooperative develops, the EDI would provide a means to validate membership within a specific SUVS. Assuming each SUVS still operates with independent insurance policies, the EDI would serve the purpose of providing the necessary data to evaluate driver eligibility within the potential organization. The most frequent data required for membership driver approval include age (years of driving experience), driving record (accidents and citations), license status (valid, expired, or suspended), and credit rating (used by some insurance groups). These parameters would be made available through the EDI. Therefore, a prospective organization could obtain relevant user information without burdening the parent organization. This type of data exchange has widespread use within the healthcare, goods movement, and insurance industries (11). The technology and software are readily available, and costs are not prohibitive. The EDI could also serve as the means to resolve billing between primary and secondary systems.

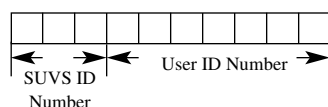
In recent years, the insurance industry has incurred extreme cost increases that have resulted in increased premiums for customers. The SUVs industry has been subjected to additional price increases because of the assigned risk category. Excessive insurance costs are promoting the exploration of alternatives and more economical solutions. A national insurance cooperative is a good alternative but requires heavy capital investment at the outset. Self-insurance methods lack reliability and consistency across the industry. EDI methods provide a means for transferring needed data between systems but leave the inherent insurance risks to the organization that provides the vehicle. There are few obstacles to implementation of an EDI standard, but the current benefits to each individual SUVs are small. For the current structure of SUVs operating in the United States, the most feasible method of accomplishing insurance interoperability is through data transfer using standardized EDI.

PROPOSED TECHNICAL SOLUTIONS

As described in the section on key interoperability issues, two primary technical questions are common for interoperability:

- How does an SUVS distinguish users from different systems?
- How is user information shared and authenticated between different systems?

To address the first issue, a unique ID can be used as a general technique to identify each subscriber in all SUVSSs. A simple scheme may be a 10-digit number in which the first 3 digits identify the SUVSS and the last 7 digits specify the user:



Within an SUVS consortium, the first three digits can be assigned to different members.

Regarding the second issue, three methods or topologies can be used to share information and authenticate users when an away-

user is accessing a local system: distributed, centralized, and relay control.

Distributed Management

The distributed management architecture (Figure 2) is based on the principle of reciprocity (discussed in the section on interoperability in other similar systems). In this topology, there is no central point of information; each entity holds its own information and requests information and settles billing through simple communication links that exist between all system combinations.

This kind of communication is easily achieved via the Internet. Access and billing protocols would be devised, and additional software would be added to the management of each system. Protocols and transaction sets have already been devised through several institutions, for example, the American National Standards Institute [ANSI (12)], EDI (10), and the Accredited Standards Committee X12 [ASC-X12 (13)].

An SUVS consortium does not appear directly in this topology; however, it still plays an important role in unifying data formats and setting up appropriate protocols for data exchange among the systems. For this topology, we provide two examples of how data exchange can occur between two systems. Figure 3 illustrates how a reservation can be made between User a (belonging to SUVS A) and SUVS B , consisting of the following four steps:

1. User a logs on to SUVS B 's reservation website and enters an ID number and a PIN.
2. SUVS B extracts the first three digits of the user ID and determines that the user is an away-user from SUVS A . SUVS B sends a query to SUVS A to authenticate the user's ID and PIN.
3. SUVS A authenticates or rejects User a , then generates and sends a reply message to SUVS B .
4. On the basis of SUVS A 's reply, SUVS B accepts or rejects User a . If User a is approved, a regular reservation can be made, recording the appropriate information.

Notice that if User a makes the reservation via telephone, the only differences are in Step 1 and Step 4, where the connection between SUVS B and the user is established via the telephone line instead of the Internet.

Figure 4 illustrates an on-demand checkout process. In this scenario, the system may not have reservations and simply provides

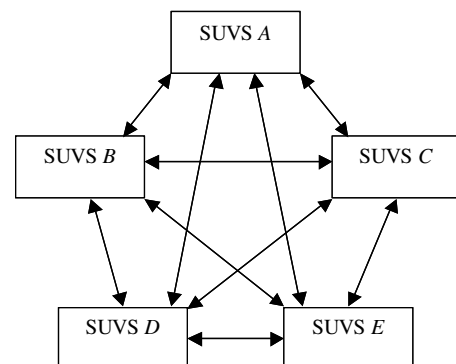


FIGURE 2 Distributed management topology.

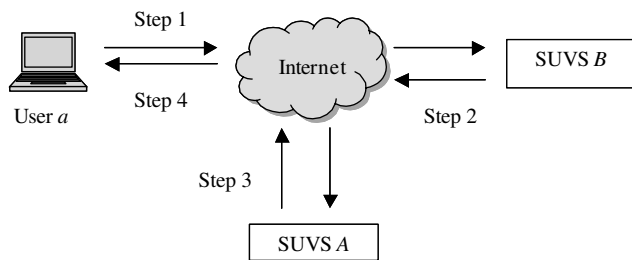


FIGURE 3 Example reservation transaction in distributed topology.

on-demand access to the vehicles via a kiosk located at the vehicle site (4). The following six steps take place:

1. User *a* of SUVs A wants to use Vehicle *b* of SUVs B. User *a* walks up to the Kiosk *b* and uses an ID card to gain access to SUVs B's checkout system.
2. The Kiosk *b* computer sends an authentication request that includes the user ID and PIN to SUVs B.
3. SUVs B extracts the first three digits of the user ID and determines that the user is an away-user from SUVs A. SUVs B sends a query to SUVs A to authenticate the user's ID and PIN.
4. SUVs A either authenticates or rejects User *a*, then generates and sends a reply message to SUVs B.
5. If User *a* is valid, then SUVs B assigns Vehicle *b* to User *a*.
6. SUVs B sends User *a* checkout information for Vehicle *b*.

A distributed topology such as this one is advantageous when the group of members is relatively small. It is also very secure from a data point of view, because user databases remain at each agency. However, as more and more agencies join the consortium, this distributed mechanism becomes increasingly cumbersome. When a new carsharing company wants to join, interfaces must be established with all the other agencies, thus increasing the administrative burden.

Centralized Management

A centralized management architecture for SUVs (Figure 5) is premised on having a centralized clearinghouse that processes infor-

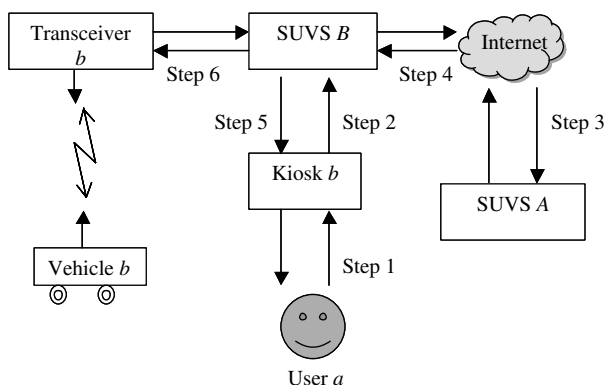


FIGURE 4 Example on-demand checkout transaction in distributed topology.

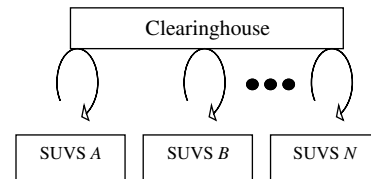


FIGURE 5 Centralized management or clearinghouse topology.

mation requests and billing. The clearinghouse would maintain up-to-date user membership data from the participating agencies. All cross-system service queries are sent to the clearinghouse directly, and authentication would be approved or denied at this centralized point. Billing would also be handled by the clearinghouse.

In this topology, only a single connection is required between each SUV and the clearinghouse. The SUV consortium would set up or select an existing clearinghouse organization that every member agency could trust. Database formats and protocols would then be devised so that the interoperable functions could take place seamlessly. As with the distributed topology, several institutions offer generic transaction sets that could be adapted for carsharing purposes.

For completeness, consider the same example illustrated in Figures 3 and 4: User *a* wants to use a vehicle from SUVs B. In this scenario, however, the clearinghouse is substituted for SUVs A. In other words, instead of sending an authentication query to the customer's host system, it is sent to the clearinghouse, which maintains a real-time updated database on SUVs A members.

This type of topology is well suited when the consortium includes many member agencies. It is less prone to network failure, and adding new agencies is relatively simple. Only one new interface must be established with the clearinghouse rather than with all members, as is the case in the distributed topology. The complexity of the overall system does not grow significantly when new members are added.

However, one annoying issue in this scheme is that when a membership database changes at any agency, this information must be updated (in real time) to the clearinghouse. An even more important issue is nontechnical: The member agencies must trust that their databases will not be abused and shared for other purposes. Many agencies will be reluctant to place these databases where they are out of their direct control, not only for membership privacy reasons but also for protecting business secrets.

Relay Management

Relay control management (Figure 6) is very similar to how ATM networks work today. In the ATM analogy, banks do not store their

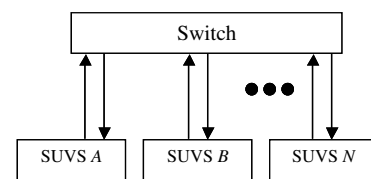


FIGURE 6 Relay control management topology.

customer databases at the switch; instead, information is forwarded from one bank to another through the switch. In this topology, the central node that was the clearinghouse in the centralized topology becomes a “switch” where information is simply routed for authentication and billing. The switch is also commonly referred to as a value-added network (VAN). The VAN provides secure access, data integrity, and a single interfacing point for new participating organizations. In this new topology, many of the good attributes of the distributed and centralized topologies are maintained.

A relay management transaction has six steps (Figure 7):

1. User *a* of SUVs *A* wants to use a vehicle in SUVs *B* and enters an ID and PIN.
2. SUVs *B* extracts the system code from the ID, determines it is SUVs *A*, and sends an authentication query to the switch.
3. The switch relays the message to SUVs *A*, which authenticates the request.
4. SUVs *A* sends a reply to the switch.
5. The switch relays the message back to SUVs *B*.
6. SUVs *B* informs User *a* to proceed.

In this case, databases are kept at the respective agencies, and the centralized switch simply passes messages. As in the distributed topology, message and billing protocols must be determined by the consortium.

Implementation and Operational System Costs

The most significant cost associated with the interoperability methods discussed thus far is initial system development costs. Regardless of the consortium, clearinghouse, VAN, relay, or distributed methods—the standard protocols must be fully developed, marketed, disseminated, and managed. Assuming that this cost is not incurred directly by the individual operators (e.g., government funding may be acquired to set up the initial mechanisms), each operator would be left with the smaller costs of system integration, maintenance, and management.

The systems discussed thus far would operate on an Internet-connected server. Because most advanced systems use a similar computer for system management (e.g., reservations and accounting), the additional hardware cost is negligible. The operator also would require the appropriate software and training, the cost of

which would potentially include the indirect costs of initial system development. This expense could be the greatest, reaching tens of thousands of dollars. The remaining costs would consist of individual system maintenance and management costs—incremental and proportional to usage—which would be similar to the cost of maintaining and managing current reservation systems. Therefore, the greatest economic hurdle is associated with system development costs being passed on to operators, directly or indirectly.

The banking and health care industries have successfully completed these steps and found significant savings associated with developing interoperability (14, 15). Both of these industries required significant maturation to allow interoperability to become advantageous to the industry. Carsharing will also require significant maturation before the implementation of interoperability procedures becomes economically beneficial for the SUVs industry as a whole.

INTEROPERABILITY WITH OTHER TRANSPORTATION MODES

Thus far, this paper has focused on interoperability between SUVs. Another important aspect is to achieve interoperability (e.g., in transportation access and billing) with other transportation modes. For example, an SUVs can serve well for the first and last mile part of a commute. User convenience would be greatly enhanced if a commuter could use the same smart card for all transportation modes and get a single bill for the entire trip.

The transit industry has already started to embrace interoperability so that transit customers can use a single smart card for travel across large regions. In several areas (e.g., Chicago, Illinois; Washington, D.C.; and San Diego, California), a single smart card-based automatic fare collection system is being implemented for the area's buses, trolleys, and commuter or light rail systems (16). It would be relatively straightforward for transit managers to include SUVs as part of their systems, greatly enhancing mobility at trip ends. It would be critical for the transit operators to strongly advertise this feature for the interoperability to work.

Many of the issues described in previous sections would also apply to interoperability between transportation modes, such as implementing common billing systems and handling operator costs.

SUMMARY AND CONCLUSIONS

At this point, the SUVs industry is not totally embracing the interoperability concept. Many companies are still in the growth and refinement stage, and addressing interoperability is seen as an extra burden. Nevertheless, the future need for interoperability is evident as long as this transportation niche continues to grow. Large metropolitan regions possess a multitude of mobility options that require customers to obtain authorization for use. More extensive authorization is needed for systems that require the user to operate a vehicle. This paper has evaluated the interoperability issues associated with user interfaces, system operations, and vehicles in shared-use vehicle applications.

Relative to customers, an individual desires consistency between systems for the greatest user friendliness. This aspect has been previously demonstrated in the ATM and ETC industries. The greatest obstacle in this area is the access to systems and vehicles. Most current technology-based systems use a proximity card or key fob. These

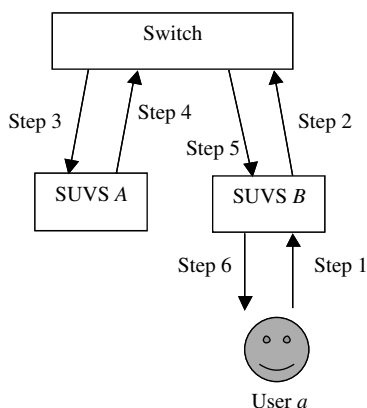


FIGURE 7 Example transaction in relay control management topology.

devices are not currently interoperable. They never will be, unless a single manufacture or format is chosen for all systems. The reservation and vehicle checkout or interface methods are primarily software driven and can be easily modified for improved interoperability.

Interoperability of vehicle electronics and vehicle interfacing has also been addressed. Integrating vehicles into a SUVS is often a cumbersome task. Automobile manufacturers are currently developing methods to improve interfacing methods that will allow future technology to be more “plug and play” and minimize the custom installation currently required.

System operations currently have great diversity across SUVSS. It is inconceivable to expect companies to modify their overall operations to accommodate a small percentage of users from other systems. Therefore, solutions for system operation interoperability must be easily added to any business structure. The area of electronic commerce currently best suited for this type of application is EDI, which provides the methodology to establish a data format and exchange standard. Initially, cooperating organizations can directly exchange user data as in the distributed method. As volume and participants increase, it may be desirable to incorporate a VAN or switch to monitor and manage data transfers.

When each SUVS operator becomes sufficiently motivated to share its customer database, EDI probably will be the best method to exchange customer information. This same method can also transmit pertinent driver information for insurance concerns. Regardless of the state of a national insurance cooperative, the participating organizations will require driver information to authorize a driver. The final deciding factor will be whether the participating organizations can increase revenue through the cooperative sharing of their customer base.

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