THE TENSION BETWEEN COORDINATION AND INNOVATION: A CASE STUDY OF IMPLEMENTING ELECTRONIC TOLL COLLECTION TECHNOLOGY

WEDNESDAY, NOVEMBER 11, 2009
E-ZPASS EXECUTIVE SUMMARY

In the 1970s, NY and NJ began examining electronic toll collection (ETC) systems in order to solve specific growing problems, most importantly traffic congestion. It was determined that an ETC system would help alleviate congestion problems, limit ‘free riders’ (drivers who pass through tolls without paying), and decrease toll operating costs. In 1989, seven toll collection agencies from New York, New Jersey and Pennsylvania met to discuss the implementation of a multi state ETC system. From this meeting, an interagency group (IAG) was formed with the goal of developing and implementing E-ZPass. IAG recognized that it faced a number of challenges with the project, but also understood that collaboration was critical for a successful implementation.

E-ZPass utilizes radio frequency identification (RFID) technology. A transceiver at the toll booth activates the in-car E-ZPass unit. The in-car unit sends information to the toll transceiver, including identifying payment information for the car and a computer deducts the toll from the balance that has been prepaid by the owner of the in-car unit.

Immediately, IAG faced both interdependence and initiative risk with E-ZPass. Different agencies had different toll fee structures and therefore required different RFID technologies. Some tolls charge a fixed fee and therefore only required ‘read’ technology, whereas other tolls are based upon distance travelled and therefore need ‘read/write’ technology in order to determine the distance travelled. To overcome this problem, all agencies recognized that interoperability was more important and therefore ‘read/write’ technology was chosen, even though some agencies had to incur higher costs. The agencies understood that customers would not purchase multiple in-car readers for different jurisdictions and ultimately IAG needed to achieve economies of scale and a high adoption rate for success. IAG decided to limit interdependence risk by only mandating that all agencies use E-ZPass’s in-car reader and toll transceiver. Otherwise, IAG permitted individual agencies to handle any additional technological requirements on their own. Overall, through cooperation, IAG was able to successfully implement E-ZPass.

IAG’s E-ZPass has been a huge success. By October 2009, over 18 million active E-ZPass tags on the road and 25 agencies have joined IAG and now use E-ZPass. Adoption decision by new agencies stems from trans-state traffic levels and therefore only adjacent states to an existing E-ZPass area join. Therefore, the decision to join has shifted from implementing new innovation to a network effect.

Even with 14 states using E-ZPass, the future for E-ZPass isn’t certain. There are different ETC systems used in other states like Florida and California, and DOT is calling for a universal ETC system. IAG focused on cooperation and collaboration in order to achieve critical adoption rates.
levels and successfully implement an ETC system. Now, innovation and interoperability has become more important than cooperation for an ETC system. IAG’s E-ZPass has not been updated from its original design and competitors have introduced new innovations that allow agencies greater fee schedule flexibility and Open Road Tolling. In 2010, IAG’s contract on E-ZPass’s vendor expires and it is uncertain whether a new vendor will be chosen.

The IAG’s leadership is now in question. The geographic expansion of E-ZPass was founded on the trade-off between innovation and coordination IAG settled on in the early 1990s. By limiting technology development it was possible to coordinate regional agencies with divergent needs. Now, however, a new, more radical technology settlement is preferred by toll agencies at the national level.
E-ZPASS

Beginning of electronic toll collection

The toll road is not a recent innovation. The first known use of toll roads was by the Mesopotamians more than 2,000 years ago. The first toll road in the United States is believed to have been built in Pennsylvania in the 1700s. By the 1900s toll roads were sprouting all over the United States. Toll roads have become so pervasive in the United States because toll collection on public roads is a boon for governmental agencies that control the roads. Toll roads allow the agencies to generate revenue from roads that are expensive to build and maintain.

In 1993 there was approximately $3B in tolls collected in the United States. More than 30% of the roads built in the past ten years have been supplemented by tolls. In the next decade total toll road mileage is expected to double.

However, tolls can also be a hindrance to commerce since they congest traffic, slowing commuters and deliveries. Electronic toll collecting (ETC) systems improve toll collection in three ways. First, they help limit free riders (those who pass through toll barriers without paying). Secondly, they limit congestion. Drivers can pass through modern ETC systems while driving at 40mph, rather than needing to stop and exchange pleasantries with a toll booth operator. Lastly, they significantly minimize the costs of operating toll booths. In fact, a toll operator in Oklahoma reported $160,000 of savings for each lane that it switched to ETC technology.

After weighing the costs of implementing an ETC system against these benefits the system would offer, in 1989 toll collectors from four states representing seven toll collecting agencies led to a meeting to discuss the implementation of an ETC system. This meeting would lead to the formation of the interagency group (IAG) in order to design and implement E-ZPass.

How ETC Works

The first toll collectors were human beings. Even today many toll booths are still manned by an individual working an hourly wage. However, a series of advancements in microwave and radio frequency identification (RFID) technology permitted the invention of the Electronic Toll Collection System.

1 http://www.discovery.org/a/10581
2 Gifford, Yermack, 11
3 http://www.discovery.org/a/10581
4 Spasovic, 6
In its basic form, ETC consists of two main pieces - an in-car unit and a roadside unit (above left and above right). The roadside unit is always sending out a signal. The roadside transceiver activates the in-car unit when a car drives near the roadside transceiver. The in-car unit sends information to the roadside unit, including identifying payment information for the car and a computer deducts the toll from the balance that has been prepaid by the owner of the in-car unit.

IAG's E-ZPass

The E-ZPass was designed to explore the use of a common ETC among IAG member agencies respective jurisdictions. IAG was an early innovator in ETC technology, but they were not the first mover. In 1993, when IAG was still researching ETC technology, ETC systems already existed in seven jurisdictions, four in the United States and three in Europe. Dallas North Tollway released the first system in the United States in 1989. Furthermore, IAG was also not the first to coordinate among different agencies. By 1993 Spain, Italy and France had already agreed to a common set of specifications.

However, even though IAG was not the first to use ETC, or even the first to cooperate in its use, IAG’s work was still a unique and overwhelming task. When formed, the members of IAG

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5 http://en.wikipedia.org/wiki/Toll_road#Early_toll_roads
6 Spasovic, 7
accounted for 37% of all US toll transactions. The scope of responsibility for the IAG toll agencies was massive. IAG members ran 200 toll plazas, 1500 miles of road, 4 tunnels and 14 bridges. Each toll plaza also saw a mindboggling number of cars pass through its gates each day. “The lowest-volume toll plaza within the Triborough Bridge and Tunnel Authority system handles just over 5.6 million vehicles per year; the highest volume plaza must handle more than 63.6 million vehicles a year.” That’s more than 170,000 cars on average per day. Cooperation among so many different bureaucratic agencies representing so many transactions was certainly a Herculean task requiring extensive cooperation.

During the initial meeting of seven toll collector agencies, it was clear that while all agencies were interested in creating and implementing an ETC, not all agencies were ready to commit to a coordinated process to develop and implement unproven technology. As a result, the participants at the meeting decided that only agencies willing to officially sign-on could be voting members in the Interagency Group (IAG). Those agencies were the Port Authority, South Jersey Transportation, Metropolitan Transit Authority for Bridges and Tunnels, New Jersey Turnpike Authority, New Jersey Highway Authority, New York State Thruway, and the Pennsylvania Turnpike Authority. These agencies were already familiar with each other through previous cooperative projects like coordinating on highway construction initiatives and emergency response protocols. This familiarity and history of cooperation clearly helped IAG implement E-ZPass.

From the beginning, it was clear how difficult it would be to complete this undertaking across a multi-jurisdictional region with a voluntary, loosely defined charter. Creating an interoperable ETC that would accommodate the varying technological and infrastructure needs, allow for the different procurement procedures, and accommodate the mission and standards of all agencies would require an unparalleled joint effort for a loosely defined organization of agencies and a long-term approach to implement (see timeline below).

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7 Spasovic, 5
8 Gifford, Yermack, 10
9 Gifford, Yermack, 11
In 1990, the seven members created an executive committee, and having acquired the appropriate funds to create this regional plan, they created a policy committee later that year. While IAG received financial support and commitments from the seven agencies involved, IAG managed to function by operating on an informal basis without a defined policy or formal contractual relationships. The IAG created specialized committees in an as needed basis. The committees all reported to the Policy Committee and included procurement, marketing/public relations, operations, finance, legal and technical committees. One of the primary reasons IAG was able to work so quickly and effectively, was the loose operating nature of the IAG. Without formal contractual obligations, the Policy and Executive Committees were able to grant exceptions, resolve disputes and change objectives more fluidly and thereby reduced the time it took to implement the E-ZPass.
The IAG’s primary goal was to develop a standardized ETC for the areas where its representative members collected tolls. To accomplish this policy objective, the IAG only focused on seeking to standardize the most essential infrastructure elements necessary to make ETC possible. As a result, the IAG’s left considerable autonomy to each member agency in terms of how each agency chose to implement the non-standardized parts of the ETC. The IAG played a more critical role in the higher level decisions such as the choice of underlying technology. Accordingly, the IAG controlled the relationships with technology vendors and regulatory issues such as obtaining approval from the FCC for the radio frequency transmitter used in the car unit. The IAG had to balance the contrasting need for rapid implementation with the need for state of the art technology.

Value Creation through Cooperation

From the beginning, the members of IAG saw significantly greater value in a coordinated system than in individual initiatives. They could certainly have each built their own systems, but they realized that few consumers would want to buy a separate transponder for the roads controlled by each separate agency. In these smaller northeastern states, commuters frequently not only travelled on toll roads managed by different toll collecting agencies, but they also travelled in between states. For example, if IAG had not chosen to coordinate their efforts, a commuter coming from New Jersey to New York City to work might need three separate transponders in her car – one for the Garden State Parkway, one for the New Jersey Turnpike and one for the bridge or tunnel to New York. Thus, it made sense for the relevant toll operators to work together, since the product they could create together would be significantly more valuable than the one they would have built separately.
Furthermore, if the agencies worked separately and developed their own technologies, each agency could certainly have found users for its own distinct passes. However, these would be the “early adopters” and “innovators”, those who have very specific needs. Maybe these commuters only cross one bridge, or use one tunnel for their commute, and otherwise they use public transportation. Such commuters would be happy to simply buy a transponder from the one agency that is responsible for that specific road that they use. However, in order to “cross the chasm” to widespread acceptance of the technology, the agencies needed to work together so that they were creating a “standardized solution for [a] mainstream problem”. Lastly, when IAG eventually purchased its equipment for the technology, they would have significantly more buying power by approaching a vendor together. Therefore, coordinating on technology permitted IAG to negotiate more favorable terms with their contractor.

1990 IAG Policy Statement

Realizing the benefits of cooperation, a senior management level committee of IAG members created a policy statement that described broadly the benefits of a communal ETC system with a single device for drivers to purchase that could be used in all IAG jurisdictions. This policy

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10 Class Notes
11 Gifford, Yermack, 12
statement served as the informal agreement for IAG for the entire process of the development of the E-ZPass system. Only in 1996 did the IAG members finally begin the process of creating a formal agreement between the members of IAG.\(^{12}\)

**Minimizing Interdependence Risk**

As the development of the E-ZPass system progressed, IAG formed numerous committees each staffed with committee members representing multiple agencies. One of the first acts of these committees was to limit technological coordination to only the specific pieces of technology that absolutely had to be coordinated. IAG deftly realized that in order to limit their interdependence they should only share technology for the in-car RFID tags and the complimentary RFID readers. These two pieces of equipment were the only parts of the ETC system that had to be compatible to ensure that drivers could move seamlessly between the systems.

IAG certainly could have decided to coordinate on all other pieces of the ETC system as well. They could have designed identical toll booths and ordered identical hardware and software systems in order to process transactions. However, IAG deliberately chose not to coordinate these efforts, realizing that the minimum coordination necessary was a large enough task. Consequently, in the first iteration of the E-ZPass system, customers would still have to maintain multiple debit accounts for their E-ZPass tags (although some cooperation existed on this front through earlier systems integration).

By limiting coordination to only the base components, IAG adeptly minimized their interdependence risk. Each agency was confident that their own proprietary system would work efficiently on their own if this partnership ever fell apart.

**Minimizing Initiative Risk**

IAG had to make multiple technology decisions that could have either increased or decreased their initiative risk. First, they needed to choose between using “read / write” technology for their ETC system or simply the more proven “read” only technology. “Write” technology was desirable for those members who had systems that required distance travelled in order to calculate the correct toll (for example, a car that travels 2 exits is charged $.50 while a car that travels 10 should pay $5.00.) However, other agencies (those responsible for bridges and tunnels for example) only needed “read” technology, because everyone travels the same distance on their roads and therefore pays one fixed fee.

\(^{12}\) Gifford, Yermack, 13
IAG chose to send out a RFP in 1992 asking for either type of system. The two respondents to the proposal both offered “read / write” technology. Since the technology was not fully proven in the market, IAG worried that it might produce too many errors and toll revenue would not be charged. Since they were dealing with more than 4 million toll charges a day, they worried that even a small error rate could result in a customer service nightmare as well. IAG tested the technology in two separate rounds of tests and found that both systems met the guidelines of 99.95% accuracy.

IAG eventually chose Mark IV industries to provide the “read /write” tags and readers for their ETC system. They had successfully minimized risk by thorough testing, and furthermore by choosing a more advanced technology they minimized the risk that the system would become obsolete in the short-term. ETC was and still is a rapidly changing technology. There were other approaches that could have, given further development and investment, met the 99.5% error rate threshold. When IAG chose to use Mark IV’s tags they used state of the art RFID technology. However, IAG knew that day by day as they distributed the tags to more and more commuters the technology supporting the tags would slowly be going out of date.

**Bringing more states into the fold**

One measure of the success of the E-ZPass ecosystem constructed by the IAG is the number of new toll agencies that have joined the IAG. In October 2009, the Ohio Turnpike Commission was the 25th agency to join the IAG. As a result the E-ZPass system now covers 14 states in the northeast and mid-west. It is possible to drive all the way from Maine to Illinois or from upstate New York to Virginia using the same E-ZPass tag for any tolls encountered. (See map of the E-ZPass IAG group below). In 2008 the IAG reported that there are over 18 million active E-ZPass tags and 11 million user accounts.

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13 Gifford, Yermack, 12
The successful introduction of the E-ZPass system in New York, New Jersey, and Pennsylvania reduced technological uncertainty for the next wave of toll agencies implementing ETC. User acceptance of E-ZPass was also very strong proving that drivers valued ETC. For example, the New Jersey Turnpike issued a million E-ZPass tags between 1998 and 2000 achieving an average penetration of 45% of all toll transactions\textsuperscript{14}.

**Basis for evaluating ETC technology**

It is important to recognize that there is actually significant variety between different highway agencies in the US in terms of the rationale for tolls and therefore the basis of evaluation for ETC. In some states such as California, transport policy encouraged high occupancy vehicle journeys (car pooling). In some other states the introduction of a toll was directly linked to financing highway construction so revenue generation would have been weighted more. Safety at toll plazas is another important consideration. In fact, tolls in Connecticut were removed after a series of accidents. In

\textsuperscript{14} E-ZPass Transponder Issuance Reaches Milestone (January 2001) 
www.state.nj.us/turnpike/01news08.htm
London, discounts on the congestion charge are available for drivers of approved low-emission vehicles.

The diagram below summarizes the different dimensions which are relevant to ETC procurement\textsuperscript{15}. It must be emphasized that the interactions between toll agencies and drivers are actually part and parcel of state-level politics. Drivers in many states navigate toll plazas several times each day and many people view tolls as a tax just like state and federal gas taxes. There is literature on whether fuel taxes are more efficient than tolls in reducing congestion. Although highway agencies are special purpose vehicles and operate with some independence they are subject to significant scrutiny by state governments.

\begin{itemize}
  \item Price of tolls
  \item Cost of tag: deposit, annual fee
  \item Number of (dedicated) electronic toll lanes
  \item Inter-operability with other states
  \item Ease of setting up account and billing
  \item Customer service
  \item Error rate
  \item Transferability to other vehicles
  \item Other uses of tags
\end{itemize}

\begin{itemize}
  \item Impact on congestion, emissions, safety
  \item Revenue generated
  \item Cost of implementation
  \item Error rate
  \item Cost of IT systems & customer service
  \item Inter-operability: (volume of inter-state traffic)
  \item Type of toll: hours of operation, fixed, variable, high occupancy
  \item Toll plaza design
\end{itemize}

**Technology choice set in second wave influenced by E-ZPass**

This section of the report examines the incentives for toll agencies implementing ETC for the first time or upgrading an existing system to select E-ZPass technology. For the second wave of toll agencies the technology landscape looked very different than it did for the IAG’s founding members. As the earlier section described, by necessity, the founding agencies focused on innovation and technology development. Although the E-ZPass technology and membership rules of the IAG reflected the requirements of these agencies, it represented a proven technology option that drivers had readily accepted.

This changed the basis of evaluation. A review\textsuperscript{16} of tolls in the US suggests that successful schemes had effective advertising and PR emphasizing the benefits to drivers. While unsuccessful schemes created concern about the technological practicality of implementing the pricing system and that the promised benefits were unlikely to be obtained. E-ZPass addressed all these concerns. As a result, the technology choice set for the second wave of toll agencies was strongly influenced by the success of E-ZPass. In their procurement of ETC systems toll agencies confronted a choice between:

\begin{itemize}
  \item Predetermined, interoperable technology package
  \item Other solutions more closely tailored to an agency’s particular requirements and mission
\end{itemize}

**Incentives for joining E-ZPass**

\textit{E-ZPass storming south, nor’est and west – ‘tag imperialism’}\textsuperscript{17}

As described above, the new basis of evaluation gave E-ZPass a significant advantage in ETC procurements. There were extremely strong incentives for the second wave of toll agencies to select E-ZPass particularly if adjacent states had already done so. Procuring agencies carefully assessed the volume of interstate traffic on their toll highways for two reasons. First, adoption of ETC tags would be higher if there was a high volume of traffic using tolls with E-ZPass in adjacent states. Second, if there was large number of ‘foreign’ E-ZPass tags coming into the state then a higher penetration of toll transactions was likely. Strong network effects could be achieved so long as agencies allocated enough dedicated lanes to E-ZPass. Thus the sequence of E-ZPass implementations was important (see table below).


\bibliography{references}
\begin{footnotesize}
\begin{itemize}
  \item \textsuperscript{17} www.tollroadsnews.com/node/854
\end{itemize}
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### Geographic Expansion of E-ZPass Technology

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>1999</td>
<td>Massachusetts FastLane system becomes inter-operable with E-ZPass</td>
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<tr>
<td>2000</td>
<td>West Virginia introduces E-ZPass</td>
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<tr>
<td>2001</td>
<td>Maryland’s M-Tag system becomes inter-operable and is rebranded as E-ZPass</td>
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<tr>
<td>2004</td>
<td>Virginia (SmartTag) becomes inter-operable but with dual branding</td>
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</table>
| 2005 | Buffalo and Fort Erie Public Bridge Authority introduce E-ZPass on Peace Bridge (US:Canada border)  
New Hampshire and Maine join E-ZPass  
Illinois joins IAG and becomes interoperable E-Zpass |
| 2007 | Virginia (SmartTag) rebranded as E-ZPass  
Indiana joins E-ZPass system |
| 2008 | Rhode Island introduces E-ZPass |
| 2009 | Ohio Turnpike introduces E-ZPass |

Reviewing the procurement process of a few agencies highlights the importance of inter-state traffic in decision making. The Maine Turnpike introduced its own system (Transpass) in 1997 but when it decided to upgrade it 2005 it was chose to use E-ZPass technology because so many drivers from Massachusetts and New York with E-ZPass tags were driving through the tolls on I-95. Transpass was also infamous for having a high error rate and the Maine Turnpike decided the lost revenue and cost of recovering tolls were unsatisfactory. West Virginia, another E-ZPass state, has ‘double-digit’ percentage of out of state E-ZPass traffic as I-77/64 is a major trucking route.\(^\text{18}\)

Though a member of the E-ZPass IAG, Maryland dragged its heels in implementing inter-operability on its toll roads. The Maryland Transport Authority felt that many of its tolls roads carried local commuter traffic rather than interstate traffic. However, with Maryland finally honoring its obligations in October 2001 there were suddenly more E-ZPass drivers heading to northern Virginia adding to weight of traffic from Pennsylvania, New York, and New Jersey. Virginia subsequently joined E-ZPass in 2004.

\(^{18}\) [www.tollroadsnews.com/node/2909](http://www.tollroadsnews.com/node/2909)
Trade-offs made when joining E-ZPass IAG

‘Someone described it as paying a lot of money to be told what you can’t do’

There are trade-offs to be made in joining E-ZPass. The chart below illustrates some of the different factors.

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
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<tr>
<td>• Buying power of consortium</td>
<td>• One size fits all technology</td>
</tr>
<tr>
<td>• Inter-operability</td>
<td>• Fee to join IAG and annual membership dues</td>
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<tr>
<td></td>
<td>• Additional costs and complexity for IT systems</td>
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<tr>
<td></td>
<td>• Rules and regulations of IAG membership</td>
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In the absence of a large flow of interstate drivers with E-ZPass tags other agencies pursued other technology options. Agencies in California, Texas, and Florida have taken different approaches to road pricing and traffic management. As a result they have developed different ETC packages. For example, on SR91 in California the toll varies in 17 steps from $1 during the night to $4.75 during the evening rush hour\(^{20}\). Segmented toll prices, such as High Occupancy Tolls, are mostly seen beyond the E-ZPass territory. On I-10, part of the QuickRide ETC system in Texas, cars with 3 or more passengers do not pay tolls.

Next generation? Technology options for the future

‘Mark IV hasn’t updated its technology in a meaningful way since it got the original contract 15 years ago, and rival shops have cropped up with offerings that could render Mark IV’s technology obsolete’

Although the IAG has been contractually free to seek alternatives to Mark IV’s technology since 2006, it did not issue an RFP until 2008 and has delayed making a decision on the contract until 2010. Thus far the stability of the E-ZPass technology has been the key reason that many agencies

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\(^{19}\) Quote attributed to spokesperson for the Maryland Transport Authority

www.tollroadsnews.com/node/2909


\(^{21}\) New York Post (July 13, 2009) Mark IV may lose east coast deal

http://www.nypost.com/p/news/business/mark_iv_may_lose_east_coast_deal_vsSga23F2W2aChBjVN6YzL
have been able to collaborate. Indeed, when the Ohio Turnpike Commission implemented E-ZPass in 2008 one commentator noted that ‘imitation rather than innovation will serve their interests\(^{22}\). Meanwhile both North and South Carolina have opened procurement processes for ETC systems. They face a different and more uncertain set of technology options.

The IAG is likely to receive several proposals from several vendors: the incumbent Mark IV; TransCore who has developed a sticker tag and reader which can detect all major tags used in the US; and Sirit the main vendor in California. Proposals are likely to include a mixture of tags and readers supported by cameras with license plate recognition software. Interoperability will still be the key principle and may even be mandated by the federal government. This summer the chairman of the US House Transport Committee introduced the Surface Transportation Authorization Act which included a requirement for a national standard of ETC interoperability.

**Will the E-ZPass IAG be as important in the third wave of ETC?**

It is clear that the one-size fits all model has stifled innovation for E-ZPass members. Outside of the E-ZPass system, Sirit and TransCore have developed innovative products which enable agencies to pursue Open Road Tolling and more complicated real time and segmented pricing. In the future, E-ZPass IAG will not be able to rely upon inter-operability to trump all other considerations especially on the national scale. The diagram below illustrates the trend in ETC technology. E-ZPass needs to offer a menu of innovative options for members while maintaining inter-operability.

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Many commentators believe that the IAG is not equipped to handle this task. One of the leading technology vendors (perhaps the federal government or a national highway agency association) may well provide leadership and coordination in the future. Indeed, agencies from Texas and North Carolina have founded the Alliance for Toll Interoperability (ATI), a new forum to coordination the next generation of ETC. Inter-operability is still a basic requirement but the ATI, focused on North Carolina’s ETC procurement, has become a lightning rod for those interested in innovative ETC technology. The membership includes E-ZPass IAG members as well as major toll agencies such as Texas, Florida, and Oklahoma.

The next generation of ETC could be radically different from what has come before. The future standard is likely to be All Electronic Tolls (AET) and Open Road Tolling (ORT). RFID tags will continue to be important but many states are pushing for tags to be incorporated into vehicle number plates rather than standalone tags. More agencies are using camera recognition technology to supplement or replace tag and toll systems. If the E-ZPass IAG continues to emphasize coordination over innovation it is likely to be supplanted by a more radical leader that can provide more than ossified leadership.
**References Used**

3. Terry G. Vavra, Paul E. Green, and Abba M. Krieger; “Using Conjoint Analysis to Assess Consumer Response to a New Tollway Technology”. Summer 1999
5. Jonathan L. Gifford; “Standards for Intelligent Vehicle-Highway System technologies”. Transportation Research Record 1358