Commission Briefing Paper 4G-02

Evaluation of the Potential Impacts of Operational Vehicle Infrastructure Integration Technologies

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Introduction

This paper is part of a series of briefing papers to be prepared for the National Surface Transportation Policy and Revenue Study Commission authorized in Section 1909 of SAFETEA-LU. The papers are intended to synthesize the state-of-the-practice consensus on the issues that are relevant to the Commission's charge outlined in Section 1909, and will serve as background material in developing the analyses to be presented in the final report of the Commission.

This paper presents information on Vehicle Infrastructure Integration (VII). The VII initiative seeks to deploy a communications infrastructure on roadways nationwide and in all production vehicles that will significantly improve safety, mobility and commerce. Near instantaneous communication between vehicles and infrastructure could enable an array of mobility and safety functions that alert drivers, traffic control, and traffic management systems, thereby enhancing traffic flow and reducing fatalities and injuries on our roads and highways. The U.S. Department of Transportation website states that "the VII concept offers the opportunity to make major advances in preventing crashes and to truly manage our transportation system based on real time information about the actual conditions on virtually all major roads."

Key Findings

- VII could significantly enhance safety, mobility, and commerce within the nationwide transportation system.
- When VII is fully deployed, society is expected to observe measurable improvements in highway safety through crash prevention.
- Through VII applications, roadway network operators are expected to experience more effective operation of the state and local transportation systems through collection of valuable information about the real-time status of the roadways.
- The auto industry is expected to see significant safety benefits to its customers and a cost effective way of communicating with its customers and their vehicles.
- The potential for VII to include other value-added information services will further broaden its utility and further justify the cost for the deployment.
- Public-and-private partnerships led by federal, state and local governments and automobile manufacturers are key to the success of the VII.

Commission Staff Comments

The staff wants to highlight one of the challenges and issues presented in section 4 of this paper. The deployment of integrated roadway infrastructure and vehicles presents a challenge to the owners of the roadways to find widely accepted business models and value equations, as noted in section 4.3. While the costs to instrument the infrastructure are envisioned as relatively modest compared to roadway construction, the timeliness for deployment of such instrumentation to justify the equipping of vehicles may force a different approach for implementation than that typically used by public agencies. Relying upon equipment replacement schedules and budgets based on attrition and life cycles will not produce the national "footprint" of infrastructure necessary to provide adequate services and benefits to equipped vehicles. A significant, early investment is likely. Public-private partnerships, revising budgets or increasing revenues are among the possible approaches by public agencies to address the challenge of timely deployment of roadway instrumentation. A timely nationwide deployment may also require a more centralized, national approach, in conjunction with the local owners of the roadways, instead of relying upon the implementation practices of multiple public jurisdictions.

The schedule discussed in section 1.2 provides a sense of staging that is needed for deployment of VII. While this schedule has been discussed, has not been formally adopted by the VII partners identified in section 1.2. The dedicated short-range communications discussed in section 2 as authorized by the FCC refers to spectrum allocated in the 5.9 gigahertz band for these purposes, and as such is differentiated from other widely available communications techniques. In addition to the safety applications discussed in section 3.1, the vehicle-to-vehicle communications, as well as the vehicle-roadside communications presented throughout this paper, may likely provide opportunities in the future for partial control of vehicles, for example to stop one vehicle from hitting another.

Executive Summary

Over the past several decades, enhancement of communications technology has advanced many aspects of modern life and transportation systems are no exception. In particular, significant research has been devoted to the study and application of communications technologies, which would support wireless data integration of vehicles with the national transportation infrastructure. These Vehicle Infrastructure Integration (VII) technologies support a wide array of VII concepts and applications which can enhance commerce, mobility, and, most importantly, safety.

The current vision of VII technologies within the United States is embodied in the U.S. Department of Transportation (USDOT) VII System. The VII System will be a nationwide data network that wirelessly links vehicles with the transportation infrastructure and with value-added services. The VII System will support applications related to safety, mobility and commerce, and will support applications sponsored by both public and private sectors. Vehicles and network users will process data and present relevant safety, mobility and commerce data to drivers on a prioritized basis. Real time display of "Amber Alerts" within vehicles in a particular geographic region is a simple contemporary example of public sector applications possible via the VII System.

Successful deployment of the VII System not only requires significant development and deployment of a new nationwide network, it also requires collaboration of federal, state and local government and a wide range of business interests within the vehicle community. Security and privacy of personal data as it traverses between vehicle occupants, vehicles and the nationwide network is also an important aspect of VII System design. The USDOT is currently collaborating with a large and diverse group of interested parties towards conducting a VII System Proof of Concept demonstration scheduled for the Detroit area in 2007. Safety, mobility and commerce applications will be demonstrated and evaluated, and the results will be included as part of a 2008 funding decision for VII nationwide deployment.

The remainder of this document is organized as follows. Section 1 provides an overview of the VII program, including its relationship to earlier related USDOT initiatives. Section 2 provides a description of the VII system as currently envisioned. VII applications, benefits and impacts are discussed in Section 3. Section 4 provides a discussion of challenges and issues associated with continued development and deployment of the VII system.

1. Background

1.1 Goals and Objectives of VII Technologies

Approximately half of the 43,000 deaths annually on America's highways are caused by roadway departure and intersection related incidents. Near instantaneous communication between vehicles and infrastructure could enable an array of functions to alert drivers, traffic control, and traffic management systems in order to reduce fatalities and injuries on our roads and highways. The USDOT website states that "the VII concept offers the opportunity to make major advances in preventing crashes and to truly manage our transportation system based on real time information about the actual conditions on virtually all major roads."[1]

The VII initiative seeks to deploy a communications infrastructure on roadways nationwide and in all production vehicles that will significantly improve safety, mobility and commerce. Establishing a direct data link between vehicles and the transportation infrastructure in an integrated, nationwide system has long been a vision of the USDOT. The USDOT Intelligent Transportation System (ITS) program is "based on the fundamental principle of intelligent vehicles and intelligent infrastructure and the creation of an intelligent transportation system through integration with and between these two components."[2]

1.2 Overview of US VII Program

The current vision of deployed VII technologies within the United States is the VII System, which is being developed under the USDOT's VII Program. The VII Program is a cooperative effort involving federal and state Departments of Transportation (DOTs) through the American Association of State Highway and Transportation Officials (AASHTO), local government agencies, vehicle manufacturers and suppliers, and the USDOT with participation of research

[1] http://www.its.dot.gov/vii
[2] http://www.its.dot.gov/about.htm

agencies, universities, and a variety of associations. The Federal Government has taken a leading role in supporting the VII Program directly and by sponsoring research in related programs.

The current schedule calls for a VII System definition and Proof of Concept demonstration by the end of 2007. Phase 1 VII System infrastructure deployment would be expected to begin after the deployment decision is made in 2008. The Phase 1 deployment will provide a core level of infrastructure to cover half of all signalized intersections, freeways and Interstate highways in the nation's fifty largest metropolitan areas. Vehicle manufacturers would be expected to begin to roll-out of VII-equipped vehicles in 2012. By 2014, it is anticipated that all new vehicles would come off the assembly line equipped with VII functions.

1.3 International VII Programs

An initiative known as the Cooperative Vehicle-Infrastructure Systems (CVIS) is in progress in Europe to develop a program similar to the VII. While VII sets its priority on safety, mobility, and commerce through data communications, the European system intends to incorporate multiple wireless communications to provide vehicle-based multi-media services and functions. Coordination exists in the development of the US and the European systems, which serves the common interest of drivers as well as the automobile manufacturers who will be selling VII or CVIS-equipped vehicles in both continents.

1.4 Relationship with Other USDOT Initiatives

VII capitalizes on concepts and technologies previously developed under the USDOT's Intelligent Transportation System (ITS) initiatives since early 1990's and provide a foundation for computer- and communications-based technology developments in the future. The Inter-modal Surface Transportation Efficiency Act (ISTEA) of 1991[3] called for a test of an Automated Highway System (AHS) – a goal that was accomplished through a cooperative effort involving both the public and private sectors. The Transportation Equity Act for the 21st Century (TEA-21) established the Intelligent Vehicle Initiative (IVI) in 1997. The IVI Program focused on improving the safety of surface transportation by "accelerating the development and commercialization of vehicle-based and infrastructure-cooperative driver assistance products."[4] The research and development fostered by these and other related programs provided many of the building blocks for the current VII System. The VII System in turn will be a building block for the future.

2. Description of VII

The VII System is a nationwide system that integrates vehicles, and users within those vehicles, with the transportation infrastructure. Public and private entities involved in providing VII services are also connected to and interact with the VII network. The national VII System is comprised of three main components:

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[3] Intermodal Surface Transportation Efficiency Act of 1991

[4] Intelligent Vehicle Initiative, Final Report, Saving Lives through Advanced Vehicle Safety Technology, September 2005, http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_PR/14153_files/ivi.pdf

- Onboard equipment (OBE) - a processing and communications platform, resident on VII-equipped vehicles, that provides an interface with driver, interfaces with vehicle systems, position sensing using Global Positioning System (GPS), and radio communications using a portion of the spectrum (dedicated short-range communications, DSRC) specifically authorized by the FCC for VII purposes
- Roadside equipment (RSE) - equipment positioned along highways, at traffic intersections and other locations, which includes DSRC communications functions, optional connection to a local safety system (including the traffic signal controller), and a connection to the VII network.
- VII network – consists of the national network that connects to all RSEs and to computers that host VII applications.

VII System network users include a variety of organizations that support vehicle operations. These will include state and local DOTs concerned with roadway maintenance, surface street operation, freeway operation, and commercial vehicle regulation. Vehicle Original Equipment Manufacturers (OEMs) and vehicle fleet owners will likely be interested in monitoring the operational condition of the vehicle via their connection to the VII network. Other potential network users include response agencies gaining information about incidents requiring response, traveling to the scene, and responding on the scene as well as planning organizations interested in monitoring traffic and roadway conditions. Finally, it is expected that vendors could use in-vehicle messages to advertise nearby services such as restaurant meals and gasoline in a vehicle-based version of the highway exit services signs currently on the roadway.

Figure 1 portrays the concept and example applications of the VII System. In some ways the VII System is analogous to the internet in that it provides a mechanism for users to obtain services and to communicate relevant data to service providers. In the case of the VII System however, access to the network will be carefully controlled, the services will be focused on enhancing safety, mobility and commerce, and the users of course, will be mobile.

3. Potential VII System Applications and Impacts

3.1 Safety Applications

Collision at an intersection is the most common type of vehicle accident. VII collision avoidance at intersections will be achieved by providing in-vehicle warnings that notify drivers if they appear likely to violate a traffic signal or stop sign. Other intersection collision warning applications include providing a warning if a driver at an intersection has his/her turn signal on when gaps in oncoming traffic are too small to allow for a safe turn. In this case the application may utilize additional equipment at the intersection to perform gap detection in support of the warning issuance.

Safety applications can also provide warnings related to excessive speed on a curve, on a freeway interchange, or in a work zone. The in-vehicle warnings are coordinated with data from the roadside equipment that has information regarding advised speed for specific geographic boundaries.

The VII also envisions low bridge warnings for commercial vehicles, warnings for ice on pavement/bridges, wrong way driver warnings, and lane departure warnings (run off road, radical lane change).

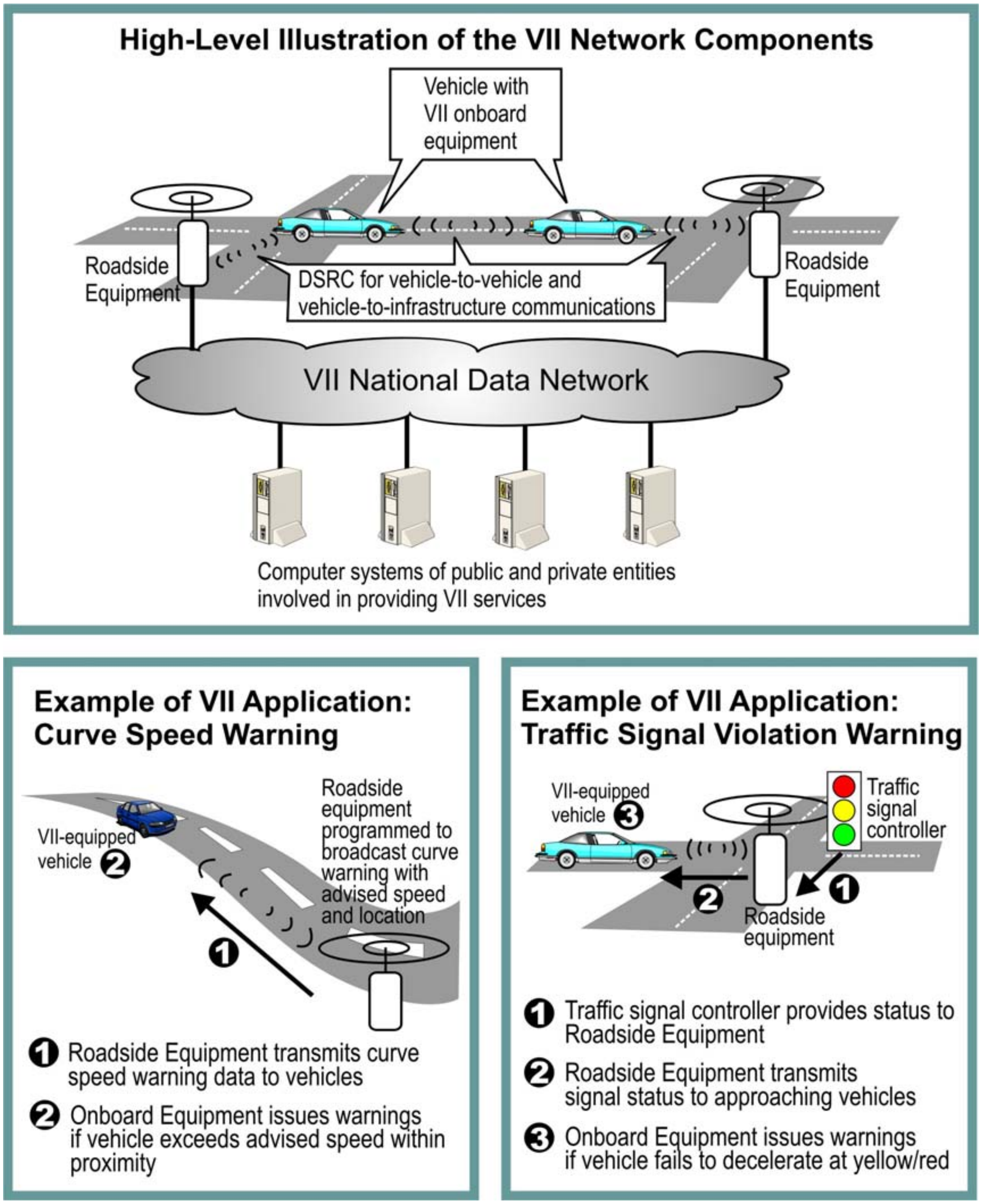

Figure 1: VII System Concepts and Application Examples

In-vehicle signing applications enhance safety by augmenting fixed roadway signs with in-vehicle messages. These applications are expected to be effective in rural settings where changing road conditions may not be effectively communicated due to limited signage. The in-vehicle messages are cognizant of the geographic boundaries in which the advisory applies. The

VII-equipped vehicle will therefore only display the message while traveling nearby and within the hazardous area.

3.2 Mobility Applications

The potential beneficiaries of VII mobility applications include traffic management and planning agencies, public transit and emergency vehicles that demand special treatment, and occupants of VII-enhanced vehicles.

Traffic management agencies may use the VII data to achieve better intersection control. With VII, instrumented intersections can “read” the movements of nearby VII-equipped vehicles and derive useful information that facilitates the optimization of traffic signal timing. That is, signal timing will be dynamically adjusted to real-time traffic patterns as opposed to a pre-determined configuration based on historical observations. While dynamic optimization is currently possible with conventional methods (cameras, in-pavement traffic detectors), VII can achieve the same functions with substantially less capital, installation, and maintenance investment than is required for conventional hardware.

Furthermore, a series of traffic signals can be coordinated to provide better progression (fewer vehicles stopped by a traffic signal) in favored commute directions. With VII, the effectiveness of traffic signal coordination can be verified and dynamically adjusted using data from vehicles actually traversing through the corridor – an option not available with the conventional methods. VII-enabled traffic signal coordination would achieve higher efficiencies in terms of improved corridor throughput and travel time, and these efficiencies could be continually monitored and improved from remote locations.

Other traffic management functions can benefit from the use of real-time onboard vehicle data collected by the VII System. With a large number of VII-equipped vehicles on the road, congestion or suspected incidents can be brought to the attention of traffic management personnel by automatic examination of travel speed data reported by individual vehicles. In this case, each VII-equipped vehicle essentially serves as a probe in reporting traffic conditions – a highly effective alternative or supplement to the more expensive and limited infrastructure-based traffic surveillance using cameras and traffic sensors.

Metropolitan Planning Organizations (MPOs) and state and local DOTs will use VII data for infrastructure planning purposes. With VII, data such as anonymous origin and destination[5], speed, travel time, and delay will be readily available from all instrumented vehicles. The quantity and quality of VII data would be significantly better than those collected using the expensive, yet limited conventional methods (license plate readers, traffic sensors). The benefit is that planning agencies would greatly improve the accuracy in things such as air quality models and regional transportation demand forecasts. Consequently, better decisions can be made on infrastructure investment to improve the regional mobility.

[5] Origin and destination data, if included, will be anonymous to protect the privacy of individual users. The decision of retrieval and use of anonymous travel path data from individual VII-equipped vehicles is the subject of continued discussion.

Public transit and emergency response vehicles may benefit from traffic signal priority or traffic signal pre-emption that use VII as the communication medium. Once programmed, these vehicles will be automatically recognized by the instrumented intersection to provide priority (extended green time) or pre-emption (all red) without the proprietary hardware that is required by current practice.

Personal mobility will benefit from improved traveler information services enabled by VII. The improvements are expected to come both from the information contents and the method of delivery. With vehicle position information, the VII-equipped vehicles can acquire traveler information that is pertinent to their current location and destination. The provision of location-specific content simplifies the task of information acquisition while on the move. The users will also benefit from improved traffic condition information collected and disseminated through the VII. With further integration, the in-vehicle navigation device in support of route planning may use the real-time traffic condition data.

3.3 Commercial Applications

The commercial application of VII arises from the ability to communicate with a specific individual or a group of vehicles and drivers and the opportunities for improved convenience and services related to the use of automobile. The auto companies will use the data generated by onboard sensors for quality control, improving vehicle designs, maintenance, and remote diagnostics.

Businesses would benefit from the wireless electronic payment applications of VII (gas stations and other pay-and-go services). Though not in the near-term scope, value-added information content providers may use the communications medium to provide a host of services to vehicle occupants, from location-specific infotainment to customized navigation to electronic payments.

Other commercial applications relate to the commerce of transportation such as electronic tolling (toll road) and fee payment (parking, entrance fees) that can be facilitated by VII communications. Because the VII short-range wireless communication is similar to those used by today’s electronic tolling, it is logical to predict that VII could serve as a platform for universal electronic tolling across the nation. Since future vehicles will be equipped with VII, electronic tolling will be automatically available to all vehicles without the need for proprietary hardware (toll tags and transceivers). This could easily facilitate applications such as congestion-based pricing, if a region chooses to deploy.

4. Challenges and Issues

4.1 Technical Challenges

A key challenge lies in the development and nationwide deployment of a highly reliable and responsive safety-critical communications network. As discussed earlier, the network includes widespread use of the dedicated short-range communication (DSRC) service between vehicles and infrastructure, and a nationwide network of regional and national data servers and roadside units. In terms of technical complexity, comparisons with a cellular telephone network (mobile networking) and the internet itself (ubiquitous access) are not unreasonable.

For example, data exchange between vehicles and roadside units is confined to the 1,000 feet range of the DSRC wireless communication, and it must be reliable and effective for vehicles moving at different speeds. Furthermore, the VII data network must achieve security and service levels at least as good as the internet, otherwise consumer expectations of the network will not be met. DSRC, the VII network architecture, and related communication standards are among the focus of the VII proof of concept activities to be demonstrated by end of 2007.

4.2 Operational Challenges

A non-profit VII Operating Entity is envisioned to be responsible for management of the design, implementation, expansion, operations and maintenance of the VII network. An oversight group consisting of representatives from the USDOT, the various States, local government representatives, and the vehicle manufacturers will manage this entity. Establishment and ongoing operation of the entity is likely to face both funding and political challenges.

Another important operational consideration is balancing security and privacy needs. The challenges of transaction security (e.g. for fuel payment or tolling applications) are likely to be solved using solutions similar to those secured financial services widely proven via the internet. At the same time however, collection and monitoring of vehicle data (position, speed, etc.) for many other VII purposes must be done in an anonymous fashion that protects personal privacy and vehicle anonymity. The VII System dichotomy of secure personalized transactions and simultaneous anonymous data collection is a challenge that may be technical as well as operational.

4.3 Policy Implications

Security and privacy concerns may spill over into the policy arena. VII has the potential to generate a large amount of data by the instrumented vehicles, including travel patterns (positioning), driving characteristics (travel speed, acceleration), and vehicle system data (engine and system parameters). While DOTs may use those data for traffic management and planning (e.g., re-timing of traffic signal, origin-destination study), automobile manufacturers may also use the onboard data for customer service and quality improvements. Debates over ownership and protection of this information are possible. The basic technical approach of VII is to maintain data anonymity in order to protect the privacy of the users. The data privacy is expected to be enforced by the central Operating Entity which maintains the infrastructure and data network, but its ability to do so in domains outside of the VII System may require the establishment of policies which have statutory underpinnings.

Liability is a concern for VII as it is for any system that includes safety-related capabilities. It is inconceivable that lawsuits can be entirely avoided. For automobile manufacturers, the key is to reduce their likelihood as part of the a larger strategy of reducing business risk, at the same time trading that off against sales gains and profits as customers are attracted to cars with the latest technology, according to an industry expert.

It is clear that the automobile manufacturers will not equip their vehicles with VII functionality without a clear commitment from the government for deployment of the VII infrastructure, and the government will not deploy the necessary infrastructure without a commitment from the automobile industry. Furthermore, both sides must find widely accepted business models and value equations because VII is clearly a long-term endeavor. USDOT's leadership and commitments in the VII program will play an important role in breaking this chicken-and-egg cycle. High level congressional support will be needed as the VII moves beyond the proof of concept stage and demonstrates the benefits to the decision makers.

5. Conclusions

VII is one of the most ambitious and significant developments in transportation ever seen. It could significantly enhance safety, mobility, and commerce within the nationwide transportation system. Public-and-private partnerships led by federal, state and local governments and automobile manufacturers are key to the success of the VII.

When it is fully deployed, society will observe measurable improvements in highway safety through crash prevention. Through VII applications, roadway network operators will experience more effective operation of the state and local transportation systems through collection of valuable information about the real-time status of the roadways. The auto industry will see significant safety benefits to its customers and a cost effective way of communicating with its customers and their vehicles. The potential for VII to include other value-added information services will further broaden its utility and further justify the cost for the deployment. While many applications are possible, the focus on safety, mobility, and commerce enhancement will ultimately differentiate VII from its international counterpart and other future vehicle-based wireless data services.

It is important to note that, as a national data network system, VII is an enabling technology that many applications may be built upon. The benefits of VII will grow as more innovative applications are developed in the years to come.

In light of the complexity of VII, "visionary champions must come onto the scene – within Congress, within government, and within the auto industry". The full impact of VII can only be appreciated when high level of market penetration is achieved both on the infrastructure and vehicle sides.