Market Penetration Analysis for VSC-A Safety Benefit Opportunities Estimation

Discussion Document

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1 Market Penetration Introduction

1.1 Background

This market penetration analysis has been developed to support the Vehicle Safety Communications – Applications (VSC-A) Safety Benefit Opportunities estimation effort. The VSC-A project (1), conducted by the Crash Avoidance Metrics Partnership Vehicle Safety Communications 2 (CAMP VSC2) under cooperative agreement with USDOT, involved the development of six prototype safety applications based on vehicle-to-vehicle communications. The safety benefit opportunities estimation, led by the Volpe National Transportation Systems Center, involves modeling the potential opportunities for safety benefits, as measured by reduced crashes, and the associated reductions in fatalities, injuries, property damage, and other crash-related costs, resulting from VSC-A deployment. The primary mechanism of the model involves identifying segments in the crash population that would potentially be addressed by one or more VSC-A applications, and to tabulate the crashes that would likely be successfully avoided, utilizing results from objective testing conducted by CAMP VSC2. In order for the VSC-A applications to be effective in preventing a crash, involved vehicles need to be equipped with an OBE (on-board equipment), so that vehicles can communicate and provide the driver with an alert or advisory for the hazardous situation. If only one vehicle is equipped with VSC-A, the necessary communication between vehicles would not be possible, and no driver alert could be issued. Thus, an important part of estimating crashes prevented by VSC-A is determining the probability, over time, that vehicles involved in a potential crash are all equipped with VSC-A. This analysis is broadly termed market penetration, and is measured by the proportion of the vehicle population exposed to potential crashes that is equipped with VSC-A at a given time in the future.

1.2 Objective

The objective of this analysis is to provide an initial set of supporting information and offer a range of estimates of potential U.S. light-vehicle market penetration of VSC-A OBEs over the anticipated deployment period. These estimates are parameterized when practical so that estimates can be revised as information becomes available or to reflect changes in the anticipated deployment. Where information was limited or unavailable, assumptions were made in order to provide the necessary input to the overall safety benefits opportunities model.

1.3 Scope

Given the significant uncertainties in predicting the future development and consumer acceptance of VSC-A applications, many assumptions are necessary in developing estimates of market penetration. The intent in this analysis is not to provide high-precision estimates, but rather to provide a means to model key contributing factors and enable the adjustment of assumptions as more information becomes available through the research and development process. Assumptions used for the overall VSC-A project are also adopted as assumptions for the market penetration analysis. For example, the

influencing factors relating to supporting infrastructure deployment (e.g., road-side equipment, RSEs) have not been determined at this time and therefore are not explicitly considered in the model and estimation process. However, some non-vehicle elements are assumed to exist since as currently envisioned, certain components of VSC-A, such as security management, may rely on their presence. The level of detail considered for this analysis is a national (USA) level estimate, which is consistent with the safety benefits opportunities approach. While there are variations in regional and urban/suburban/rural vehicle markets, these variations are beyond the scope of this VSC-A market penetration analysis. The specific vehicle market being examined is light vehicles, specifically passenger cars and light trucks, which account for the substantial majority of relevant crashes. Other vehicle markets for which purchasing behavior will likely differ are excluded at this time, as is the consideration of potential countermeasures for crashes involving cyclists or pedestrians.

2 Review of Relevant & Available Prior Research

2.1 Market Penetration Concept

Market research firms often generate proprietary market penetration estimates used for strategic business purposes, such as guiding a company on deciding whether or not to launch a product or service. The model presented here is intended to be non-proprietary, yet specifically targeted to vehicle safety technologies. The baseline level represents a pre-deployment environment, where the safety technology is not yet available in any production vehicle. At a given point in time, the technology is considered to be launched, and is added to selected new vehicle models, either as a standard feature or optional added-cost item. Presuming that the technology has an adequate level of success, additional new vehicle models would begin to include the technology. Government regulation may at some point cause the technology to be required in all or selected subsets of new vehicles. If not, the marketplace may achieve a steady-state equilibrium for proportion of new vehicles covered, or could result in adoption by OEMs in all new vehicles. This analysis provides for alternatives to capture this range of possibilities. However, for the purposes of this analysis, it is assumed that the technology is not superseded by another technology or otherwise made obsolete during the analysis period.

2.2 Automotive Vehicle Fleet Changes

As the OBE-equipped vehicles are introduced into the vehicle fleet, the proportion of equipped vehicles in the overall vehicle population will increase over time. Older vehicles without the technology will gradually be scrapped and removed from the vehicle fleet, thereby increasing the percentage of equipped vehicles. While the overall light vehicle fleet may undergo changes in vehicle type composition (e.g., passenger cars vs. SUV's, gasoline vs. hybrid, etc.), the model used here will not distinguish between these vehicle types. It is assumed that the market penetration will not be significantly affected by these factors, as the operation of the system is expected to be similar within the general class of light vehicles.

2.3 Prior Research – VSC I

As part of the Vehicle Safety Communications (VSC I) project (2), a basic model (3) was developed to estimate the market penetration of each safety application. The model used two parameters, the initial deployment rate in the launch year, and a growth factor to reflect annual growth in market penetration for new vehicles. The first year market penetration was analyzed using values of 0.1%, 0.5%, 1%, 2%, and 100% of new light vehicles. The multiplier values selected for analysis consisted of 1.0, 1.5, and 2.0 reflecting the multiplicative increase in annual (new vehicle) market penetration for subsequent model years. The overall proportion of vehicles in the fleet equipped with the safety application was calculated using the sum of the individual years' market penetration. This assumed that the overall vehicle fleet size did not change, other than new vehicles displacing an equal number of older vehicles, and that the presence of the safety application in the fleet was additive over time.

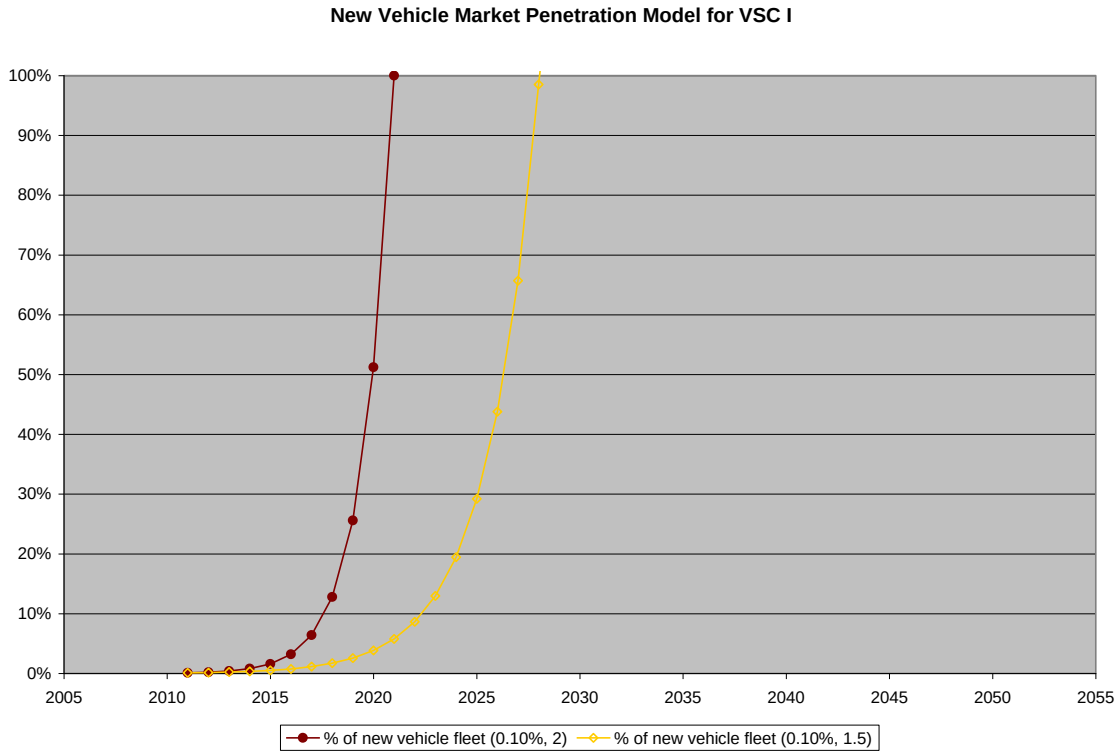

Figure 1: Projected New Vehicle Market Penetration from VSC Project

2.4 Prior Research – VII / IntelliDrive℠

The Vehicle Infrastructure Integration (VII) effort involved the potential deployment of infrastructure-based communications equipment and applications that could operate in conjunction with OBEs providing VSC-A applications. Infrastructure-based applications could significantly affect the market and user demand for vehicle OBEs and result in different market penetration over time for VSC-A applications operating without infrastructure. Since the predicted deployment plan for VII included various assumptions that may not coincide with future deployment of VSC-A, it is difficult to directly link the

penetration of the two application sets. However, the estimated deployment schedule for OBEs that was used for benefit-cost analysis (4) is included here for comparison purposes with the VSC-A analysis. The VII market penetration curve for equipped vehicle-miles traveled estimated approximately 2% market penetration in 2012 and approximately 50% in 2019, after 8 years, based on the assumption of a phased, mandatory deployment in new vehicles. The IntelliDrive[SM] project (www.intellidriveusa.org) has taken on many of the components originally envisioned by VII but aims for a broader look at communications technologies and capabilities, including those being developed under the VSC-A project.

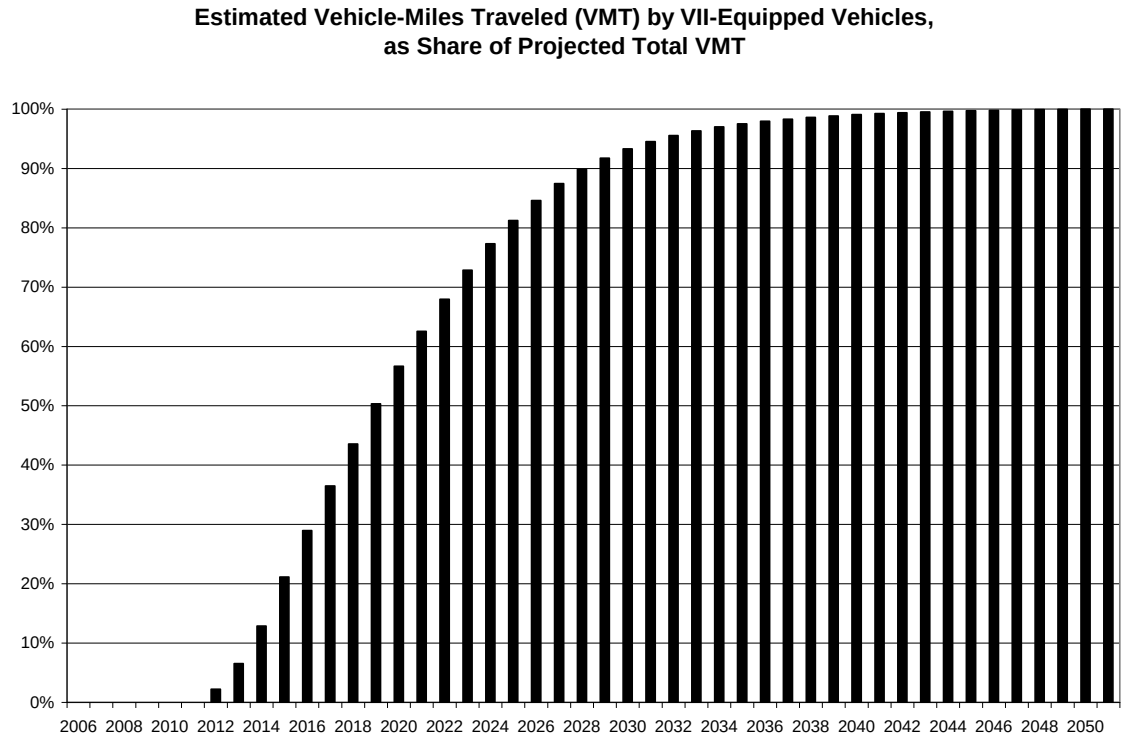

Figure 2: OBE Deployment Projection from VII Benefit-Cost Analysis (4)

2.5 Other ITS-relevant Prior Research

2.5.1 Hall

A 1996 analysis by Hall (5) of Automated Highway Systems potential market penetration rates included estimates based on historical data for driver airbags, ABS, and cruise control to provide high, medium, and low benchmarks, respectively. The model used was a Gompertz double-exponential relating market penetration to number of years since introduction. Using a launch year of 2000, the chart shows approximately the following:

IntelliDrive is a service mark of the U.S. Department of Transportation

Table 1: Automated Highway System Project Vehicle Sales Projections

Year	Low Sales		Medium Sales		High Sales		Total Sales
	equipped-vehicles	% of total	equipped-vehicles	% of total	equipped-vehicles	% of total	vehicles
2000	0	0%	0	0%	0	0%	19,000,000
2004	1,000,000	5%	2,500,000	13%	7,500,000	38%	20,000,000
2008	2,500,000	11%	10,000,000	45%	19,000,000	86%	22,000,000
2012	6,000,000	26%	17,000,000	74%	22,000,000	96%	23,000,000

After 12 years, the low growth rate corresponds to approximately 26% of the new vehicle fleet, while the high rate predicts coverage of more than 95% of sales. The middle rate estimates that 74% of new vehicles will be equipped after 12 years.

2.5.2 Matheus

Another analysis uses a simple set of market penetration options. Matheus et al (6) provide market penetration curves over time based on four categories. At the extreme, all new cars are equipped. Other curves are presented representing 50%, 25%, and 8% of all new vehicles being equipped. These are noted descriptively to reflect all middle class cars and above, all vehicles with navigation units, and upper and upper middle class cars, respectively. The prognosis of the authors is that the market penetration will be similar to the 25% value. Over 10 years, the market penetration over time for all four curves is essentially linear since most vehicles survive for at least 10 years.

3 Market Penetration Model Background

3.1 Requirements from Safety Benefits Opportunities Estimation Analysis

The Safety Benefits Opportunities Estimation analysis uses the projected VSC-A OBE market penetration over time to assist in estimating the opportunities for preventing crashes with VSC-A applications. The proportion of targeted crashes by scenario that could be prevented includes a market penetration factor that reflects whether the drivers of the vehicles involved would have received a warning. In the two-vehicle case, if both vehicles were equipped, the warning would be possible. However, if one or both of the vehicles did not have the OBE installed, the necessary communication to effect the warning would not be possible, and therefore the crash would not have been directly prevented by VSC-A. Therefore, the fleet penetration figure for any given year must be squared to generate an estimate of the probability that *both* vehicles are OBE-equipped. For example, if 10 percent of the vehicle fleet exposure is equipped with the VSC-A technology, the chance of both crash-involved vehicles being equipped is 1 percent.

The safety benefits opportunities estimation currently considers an analysis timeframe of 2012 to 2052, and estimated benefits opportunities will be presented for this period only, without regard to any benefits opportunities beyond 2052. The number of new and registered vehicles will be modeled over this time period, and estimates will be generated for the predicted market penetration as a percentage for the study years.

3.1.1 Market Penetration/Safety Benefits Opportunities Interface

This section describes in more detail the output of market penetration analyses to be used for safety benefits opportunities estimation. It also presents a few key issues that involve coordination in inputs.

The market penetration analysis has been implemented using a Microsoft Excel spreadsheet workbook. The workbook contains input assumptions, fixed model data and formulas, and output tables and charts. The output tables may be exported in native Excel format or in a variety of flexibly structured formats (e.g., comma delimited files, etc.). Since there is more than one alternative to consider, each output table may be exported separately, or as a combined table.

Since newer vehicles are generally driven more miles as compared to older vehicles (7), the model also includes consideration of VMT per vehicle by age, to more accurately reflect crash exposure. For ease of input, a "squaring factor" is also included, whereby the VMT-adjusted market penetration output is squared to yield the probability that both involved vehicles are equipped.

Outputs:

PE_i = probability that a vehicle involved in a crash is equipped with VSC-A equipment for alternative i
CY = calendar year for which the PE is provided

Considerations:

Base Year – this value represents the initial year in which VSC-A benefits opportunities will be tabulated (2012)

End Year – this value represents the final year for which the market penetration values are needed for purposes of safety benefits estimation (2052)

Number of alternatives – this value represents the number of market penetration alternatives that can be accommodated by the safety benefits estimation (4)

Output format – this specifies the format in which the market penetration outputs will be transferred to the safety benefits estimation (Excel tables)

3.2 Potential Models

3.2.1 VII model

As discussed previously, the presence of infrastructure-based applications, such as traveler information, etc., is expected to have a significant influence on the consumer demand for OBE units. Therefore, the VII market penetration estimates cannot be applied directly to VSC-A applications. However, the curves serve as a useful benchmark for comparison purposes with other market penetration estimates.

3.2.2 VSC I model

The market penetration analysis in the original VSC project provides a useful starting point for this effort. It offered several parameter options for initial market penetration, representing the percentage of new vehicles equipped with OBE's in the first launch year, and the multiplier rate, representing the growth in new vehicle market penetration. However, for most parameter choices, it relies upon a basic assumption of natural (geometric) growth in the availability and selection within the new vehicle market over time.

3.2.3 Modified VSC I model

It is possible to expand the basic VSC I model by virtue of relaxing some of the model constraints, such as the geometric growth criterion, to more accurately reflect the expected nature of deployment or explore potential variations. In addition, elements of the model could be blended with other market penetration models to create a hybrid approach that balances simplicity and ease of understanding with the ability to model significant aspects of the expected market deployment mechanism. The primary model combination explored here involves the addition of a Bass model.

3.2.4 Bass model

The Bass market penetration model (8) fundamentally revolves around two phenomena. The first is the natural innovator adoption of new technologies. This factor represents the adoption of a technology by individuals who learn about the system's capabilities or benefits through salespersons, promotion, advertising, or other information available in the press or media channels. These individuals make the decision to adopt the technology based on their own understanding and/or belief in its benefit, without reliance on others with experience with the technology. The second factor is the imitation effect,

representing the adoption of a technology by individuals who hear about the technology from previous adopters or choose to adopt the technology because others have done so. Bass Model Equation:

$$n(t) = [m - N(t)][p + (q/m)N(t)] \qquad (9)$$

n(t)=sales at time t

N(t)=previous adopters

m=total market potential

p=coefficient of innovation

q=coefficient of imitation

The imitation factor is expected to be significant for individuals exposed to stories from other drivers who experience a prevented crash or near-crash where a warning was provided by the VSC-A application. Experiences where warnings were given and where drivers considered the warning to be helpful are also likely to provide support for potential adopters. Since the frequency of actual crashes is much lower than near-crashes or conflicted driving states, the incidence of positive application warnings are expected to provide significant support for the imitative factor. Such situations are likely to result in anecdotes told to friends and acquaintances, and with the prevalence of word-of-mouth advice requested and given on automobile purchase decisions, such exposures can lead to influence on decision on selecting an equipped vehicle.

4 Proposed Primary Model

The primary model proposed in this analysis involves the use of the Bass model as the core, representing the innovator and imitator factors, but adjusting the market potential and parameters over time. The original Bass model involves a fixed market potential, while the size of the vehicle fleet changes over time. This will be addressed by using a growth factor for the size of the vehicle fleet. Also, the proposed model provides for adjustment of the Bass coefficients over time. It is likely that VSC-A will evolve over the analysis period such that a more mature version would have enhanced consumer acceptance. For the initial period (launch year), the initial market penetration values (0.1% of new vehicles) from the VSC I project are used to approximate parameters for the initial launch year. Finally, the scrappage factor is added to the model. Since vehicles are replaced over time as they become too old, cost ineffective to repair, or totaled by crash, the removal of vehicles from the fleet is an important attribute to model at higher market penetration values. In this analysis, data from NHTSA's Survivability Analysis (7) is used to reflect scrappage rates that vary by vehicle age. In order to

accommodate varying ages of vehicles, EPA estimates (10) are used to provide an initial distribution of vehicle ages across the fleet.

4.1 Parameters

The following parameters represent a reasonable set of assumptions that may be adjusted to determine their influence on market penetration over time.

Vehicle Fleet Growth – Annual growth rate of the total light-vehicle fleet, assumed to follow projected population growth

VMT per vehicle Growth – Annual rate of change in the miles traveled by each vehicle

New Car Sales – Number of new vehicles sold on an annual basis

Scrappage – Annual percentage of vehicles removed from fleet, by age of vehicle

Innovator Factor (p) – Bass model parameter reflecting effect of adopters based on innovation

Imitator Factor (q) – Bass model parameter reflecting effect of adopters based on influence of other adopters

Initial Market Penetration – Percentage of new vehicles equipped in introduction year, based on VSC I

5 Analysis / Results

5.1 High & Low Consumer Scenarios

The high Bass market penetration model was established to target a relatively high acceptance and deployment scenario, while the low Bass model was designed to examine the opposite. The curve representing penetration in the new vehicle market was compared to that of a rapid deployment like Electronic Stability Control for the high scenario and a slower deployment like ABS and side airbags (12). Bass parameters were selected accordingly based on a graphical comparison and matching the VSC I initial market penetration. A multi-year phase-in period was also selected for the Bass coefficient of innovation to reflect a period when the nascent technology would become more refined.

Table 2: Phased-in Coefficients of Innovation (p) and Imitation (q) for Consumer Scenarios

Year	p (High)	q (High)	p (Low)	q (Low)
2017	0.00007	0.5	0.00007	0.25
2018	0.00021	0.5	0.00021	0.25
2019	0.0005	0.5	0.00063	0.25
2020	0.001	0.5	0.002	0.25
2021	0.002	0.5	0.002	0.25
2022 & later	0.002	0.5	0.002	0.25

5.2 Mandated Scenario

In addition to the consumer-based model, a mandated scenario was developed to reflect the potential if a government mandate was established for new vehicles, without any requirement for retrofitting older vehicles. Assuming that a final regulatory rule was issued in 2015, three years after the base year, a timeline for compliance was developed loosely based on the one adopted for Electronic Stability Control (11). This involved a two-year period for the rule to become effective, followed by a phase-in period. The assumed percentage of new vehicles equipped with VSC-A is as follows:

Table 3: Assumed New Vehicle Phase-in Schedule for Mandated Deployment

Year	% of new vehicles equipped
2015	0%
2016	0%
2017	30%
2018	60%
2019	90%
2020 and later	100%

5.3 Combined Mandate & Consumer Retrofit Scenario

The final alternative selected for modeling is one that combines the government mandate for new vehicles, as specified in the mandated scenario, with a consumer-based model for all other (existing) vehicles. In order to accommodate existing vehicles, this alternative assumes that appropriate development activity will take place which enables a full-functioning retrofit of any light vehicle in the modeled fleet. Since this alternative is intended to reflect a high-adoption scenario, the high-acceptance Bass model parameters from the High Consumer scenario were used to model retrofit adoption for vehicles other than those covered by mandate (new vehicles starting in 2017). Estimates of retrofit units adopted were distributed across the existing vehicle fleet in proportion to non-equipped vehicles and average VMT by vehicle age. Thus, a relatively new non-equipped vehicle driven more miles on average would be more likely to result in a retrofit adoption as compared to an older vehicle driven fewer miles.

5.4 Summary Tables/Charts

The results of the analyses for each of the four alternatives are presented here. Both the percentage of new vehicles for each year and the percentage of vehicle travel (VMT) equipped with VSC-A is presented. By observing the percentage of new vehicles being equipped, a better understanding of the alternative concept over time can be gained. The results for the alternatives illustrate the range of possibilities, from a strict mandated deployment with fast deployment and retrofits to a low-consumer acceptance model where 100% deployment is not reached during the analysis period. These ranges can assist in exploring the impact of varying market penetration levels on potential safety benefit opportunities resulting from VSC-A deployment.

Table 4: Summary of New Vehicle and VMT Market Penetration over time

	Consumer (High)		Consumer (Low)		Mandated		Mandate & Retrofit	
CY	new equipped	%VMT equipped	new equipped	%VMT equipped	new equipped	%VMT equipped	new equipped	%VMT equipped
2012	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
2013	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
2014	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
2015	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
2016	0%	0.0%	0%	0.0%	0%	0.0%	0%	0.0%
2017	0%	0.0%	0%	0.0%	30%	2.6%	30%	2.7%
2018	0%	0.0%	0%	0.0%	60%	7.9%	60%	7.9%
2019	1%	0.1%	1%	0.1%	90%	15.8%	90%	16.9%
2020	2%	0.3%	3%	0.4%	100%	24.3%	100%	28.1%
2021	4%	0.7%	4%	0.7%	100%	32.5%	100%	41.1%
2022	6%	1.2%	5%	1.1%	100%	40.4%	100%	54.9%
2023	9%	2.0%	6%	1.6%	100%	47.8%	100%	68.2%
2024	13%	3.1%	7%	2.1%	100%	54.7%	100%	79.5%
2025	19%	4.8%	8%	2.8%	100%	61.2%	100%	88.1%
2026	28%	7.2%	10%	3.6%	100%	67.0%	100%	93.6%
2027	40%	10.5%	12%	4.6%	100%	72.4%	100%	96.8%
2028	56%	15.1%	15%	5.7%	100%	77.2%	100%	98.5%
2029	77%	21.4%	18%	7.1%	100%	81.4%	100%	99.3%
2030	100%	29.5%	22%	8.7%	100%	85.0%	100%	99.7%
2031	100%	37.2%	26%	10.6%	100%	88.0%	100%	99.8%
2032	100%	44.6%	30%	12.8%	100%	90.5%	100%	99.9%
2033	100%	51.5%	35%	15.3%	100%	92.5%	100%	100.0%
2034	100%	57.9%	41%	18.1%	100%	94.1%	100%	100.0%
2035	100%	63.9%	47%	21.4%	100%	95.4%	100%	100.0%
2036	100%	69.3%	53%	25.0%	100%	96.4%	100%	100.0%
2037	100%	74.2%	59%	28.9%	100%	97.2%	100%	100.0%
2038	100%	78.6%	66%	33.1%	100%	97.8%	100%	100.0%
2039	100%	82.4%	71%	37.6%	100%	98.2%	100%	100.0%
2040	100%	85.8%	76%	42.2%	100%	98.6%	100%	100.0%
2041	100%	88.6%	80%	46.9%	100%	98.9%	100%	100.0%
2042	100%	90.9%	83%	51.4%	100%	99.2%	100%	100.0%
2043	100%	92.7%	84%	55.8%	100%	99.4%	100%	100.0%
2044	100%	94.3%	84%	59.7%	100%	99.6%	100%	100.0%
2045	100%	95.5%	84%	63.3%	100%	99.7%	100%	100.0%
2046	100%	96.4%	84%	66.6%	100%	99.8%	100%	100.0%
2047	100%	97.2%	84%	69.5%	100%	99.9%	100%	100.0%
2048	100%	97.8%	84%	72.0%	100%	100.0%	100%	100.0%
2049	100%	98.3%	84%	74.2%	100%	100.0%	100%	100.0%
2050	100%	98.7%	84%	76.1%	100%	100.0%	100%	100.0%
2051	100%	99.0%	84%	77.7%	100%	100.0%	100%	100.0%
2052	100%	99.2%	84%	79.0%	100%	100.0%	100%	100.0%

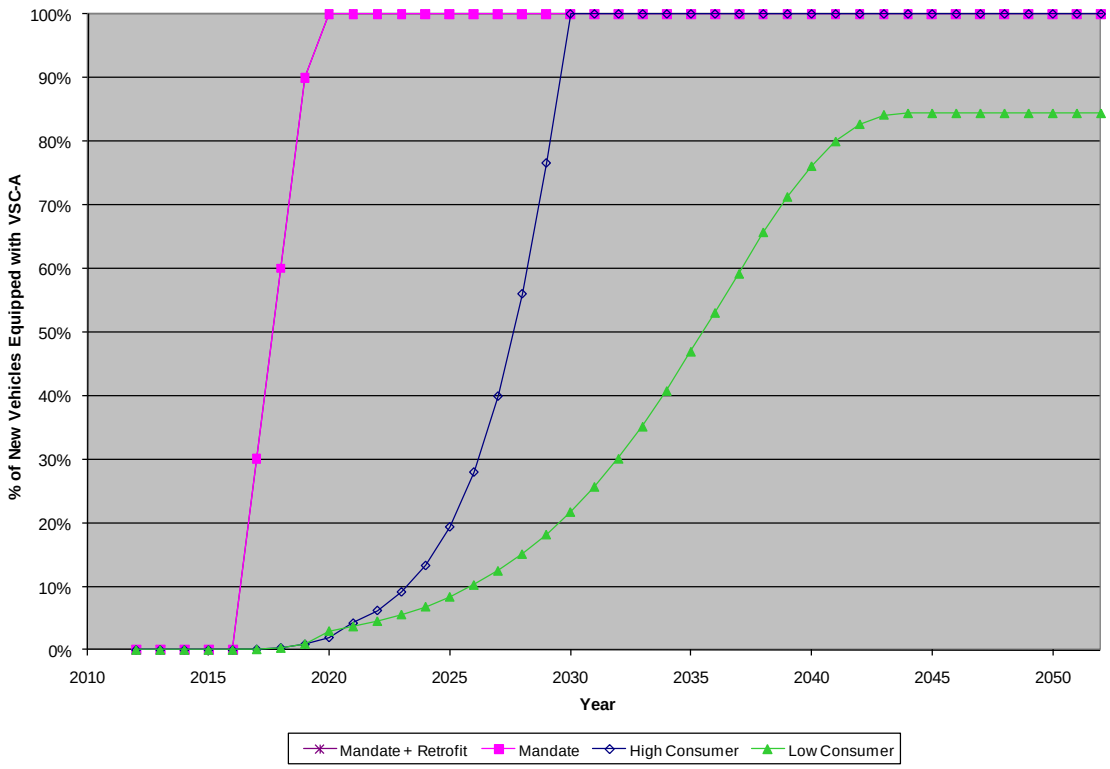

Figure 3: Projected New Vehicle Market Penetration

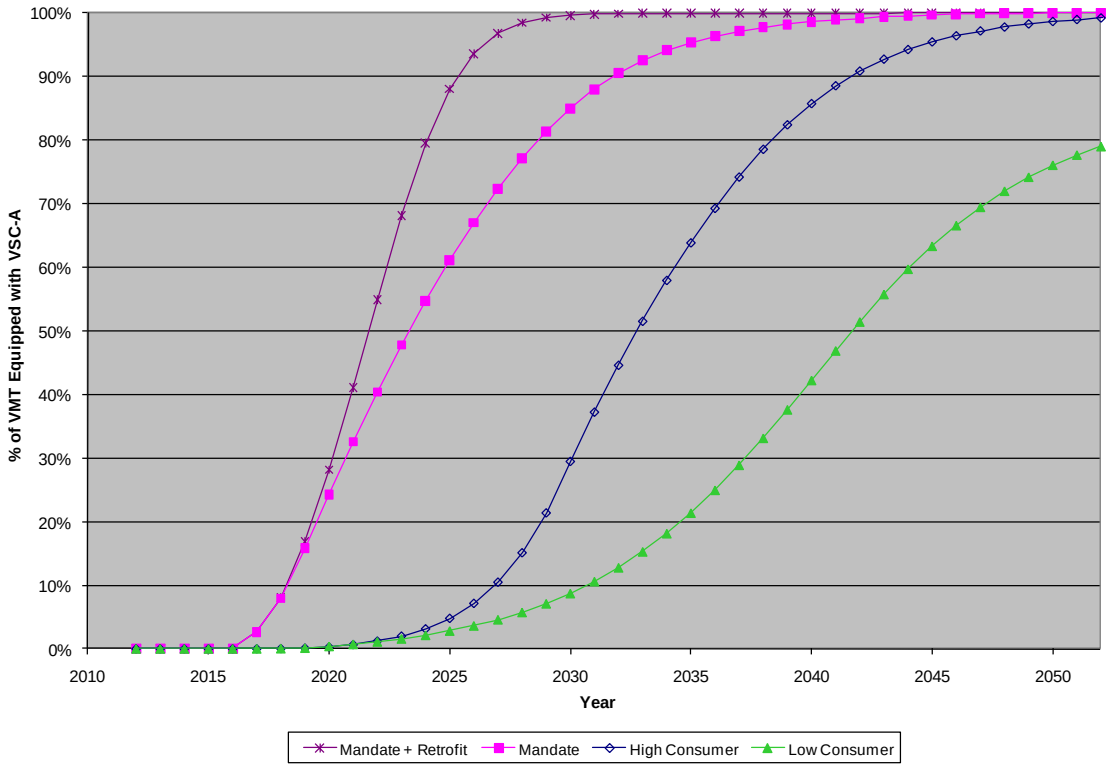

Figure 4: Projected Market Penetration – Single Vehicle Exposure

6 Input tables provided for Safety Benefits Opportunities Analysis

As previously discussed, the output of the market penetration analysis serves as input to the safety benefits opportunities estimation for VSC-A. For each calendar year during the analysis period, 2012 through 2052, the estimated proportion of vehicle travel (VMT) generated by VSC-A equipped vehicles is presented. The following table represents the input provided to the safety benefits opportunities estimation, listed as percentages by year, for each of the four modeled alternative scenarios. The granularity of this input is consistent with the safety benefits opportunities methodology which uses projected annual crash impacts. The subsequent table and figure includes the squaring of market penetration values to account for interactions required between the host vehicle and principal other vehicle to support the crash avoidance applications. This squaring offers a first-order approximation of two-vehicle OBE coverage associated with the four scenarios, but does not consider other factors such as application functionality or geographic variability.

Table 5: Projected Market Penetration by Vehicle Travel

	% of VMT equipped			
CY	**Consumer (High)**	**Consumer (Low)**	**Mandated**	**Mandate & Retrofit**
2012	0.0%	0.0%	0.0%	0.0%
2013	0.0%	0.0%	0.0%	0.0%
2014	0.0%	0.0%	0.0%	0.0%
2015	0.0%	0.0%	0.0%	0.0%
2016	0.0%	0.0%	0.0%	0.0%
2017	0.0%	0.0%	2.6%	2.7%
2018	0.0%	0.0%	7.9%	7.9%
2019	0.1%	0.1%	15.8%	16.9%
2020	0.3%	0.4%	24.3%	28.1%
2021	0.7%	0.7%	32.5%	41.1%
2022	1.2%	1.1%	40.4%	54.9%
2023	2.0%	1.6%	47.8%	68.2%
2024	3.1%	2.1%	54.7%	79.5%
2025	4.8%	2.8%	61.2%	88.1%
2026	7.2%	3.6%	67.0%	93.6%
2027	10.5%	4.6%	72.4%	96.8%
2028	15.1%	5.7%	77.2%	98.5%
2029	21.4%	7.1%	81.4%	99.3%
2030	29.5%	8.7%	85.0%	99.7%
2031	37.2%	10.6%	88.0%	99.8%
2032	44.6%	12.8%	90.5%	99.9%
2033	51.5%	15.3%	92.5%	100.0%
2034	57.9%	18.1%	94.1%	100.0%
2035	63.9%	21.4%	95.4%	100.0%
2036	69.3%	25.0%	96.4%	100.0%
2037	74.2%	28.9%	97.2%	100.0%
2038	78.6%	33.1%	97.8%	100.0%
2039	82.4%	37.6%	98.2%	100.0%
2040	85.8%	42.2%	98.6%	100.0%
2041	88.6%	46.9%	98.9%	100.0%
2042	90.9%	51.4%	99.2%	100.0%
2043	92.7%	55.8%	99.4%	100.0%
2044	94.3%	59.7%	99.6%	100.0%
2045	95.5%	63.3%	99.7%	100.0%
2046	96.4%	66.6%	99.8%	100.0%
2047	97.2%	69.5%	99.9%	100.0%
2048	97.8%	72.0%	100.0%	100.0%
2049	98.3%	74.2%	100.0%	100.0%
2050	98.7%	76.1%	100.0%	100.0%
2051	99.0%	77.7%	100.0%	100.0%
2052	99.2%	79.0%	100.0%	100.0%

Table 6: Input for Safety Benefits Opportunities Estimation – both vehicles equipped with VSC-A Squared - two vehicles equipped

CY	Consumer (High)	Consumer (Low)	Mandated	Mandate & Retrofit
2012	0.0%	0.0%	0.0%	0.0%
2013	0.0%	0.0%	0.0%	0.0%
2014	0.0%	0.0%	0.0%	0.0%
2015	0.0%	0.0%	0.0%	0.0%
2016	0.0%	0.0%	0.0%	0.0%
2017	0.0%	0.0%	0.1%	0.1%
2018	0.0%	0.0%	0.6%	0.6%
2019	0.0%	0.0%	2.5%	2.9%
2020	0.0%	0.0%	5.9%	7.9%
2021	0.0%	0.0%	10.6%	16.9%
2022	0.0%	0.0%	16.3%	30.1%
2023	0.0%	0.0%	22.8%	46.4%
2024	0.1%	0.0%	30.0%	63.3%
2025	0.2%	0.1%	37.4%	77.5%
2026	0.5%	0.1%	45.0%	87.6%
2027	1.1%	0.2%	52.4%	93.7%
2028	2.3%	0.3%	59.6%	97.0%
2029	4.6%	0.5%	66.3%	98.6%
2030	8.7%	0.8%	72.3%	99.3%
2031	13.9%	1.1%	77.5%	99.7%
2032	19.9%	1.6%	81.9%	99.8%
2033	26.5%	2.3%	85.6%	99.9%
2034	33.6%	3.3%	88.6%	100.0%
2035	40.8%	4.6%	91.0%	100.0%
2036	48.0%	6.2%	92.9%	100.0%
2037	55.1%	8.3%	94.4%	100.0%
2038	61.7%	11.0%	95.6%	100.0%
2039	67.9%	14.1%	96.5%	100.0%
2040	73.5%	17.8%	97.3%	100.0%
2041	78.4%	22.0%	97.9%	100.0%
2042	82.6%	26.5%	98.4%	100.0%
2043	86.0%	31.1%	98.8%	100.0%
2044	88.8%	35.7%	99.1%	100.0%
2045	91.1%	40.1%	99.4%	100.0%
2046	93.0%	44.3%	99.6%	100.0%
2047	94.5%	48.3%	99.8%	100.0%
2048	95.6%	51.9%	99.9%	100.0%
2049	96.6%	55.1%	100.0%	100.0%
2050	97.4%	57.9%	100.0%	100.0%
2051	98.0%	60.4%	100.0%	100.0%
2052	98.5%	62.4%	100.0%	100.0%

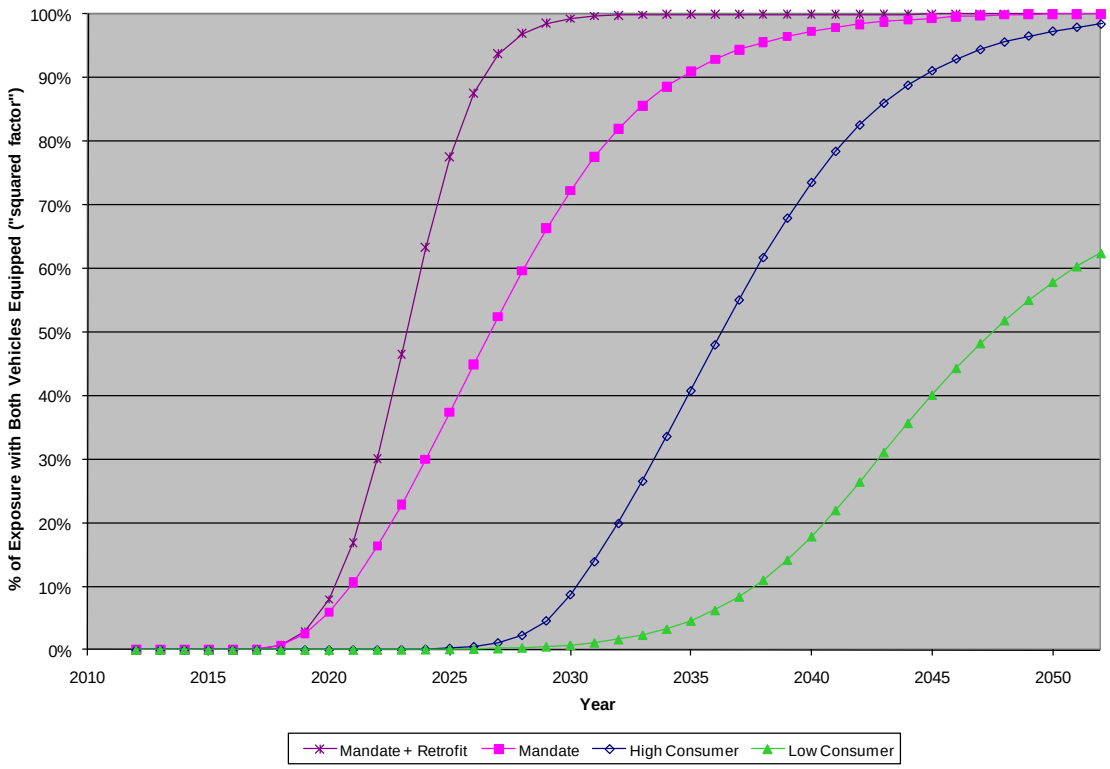

Figure 5: Potential Coverage of VSC-A Exposure (Both Vehicles Equipped)

7 Summary / Conclusions

Using both consumer-based and mandate models, four broad alternative scenarios were modeled to examine the potential market penetration for VSC-A. These scenarios can assist in understanding a range of possibilities for market penetration over a long term horizon. As the figures help to illustrate, the long time horizon is necessary to capture changes over time, especially for slower adoption rates.

The penetration of VSC-A into the vehicle fleet is a key factor in vehicle-to-vehicle cooperative safety. In order to enable the functionality of these safety applications, vehicles involved in a pre-crash situation need to be equipped with VSC-A communications. This has been modeled as a "squared effect" – the squaring of the market penetration values approximates the probability that both vehicles would be equipped, a necessary step in enabling vehicle-to-vehicle warning applications.

These market penetration results are intended to provide input to the larger process estimating safety benefits opportunities associated with VSC-A. As such, this market penetration analysis does not evaluate application functionality or effectiveness and relies upon various assumptions in modeling future OBE deployment. Results should be viewed with due consideration for the uncertainties in early stage development.

7.1 Potential Extensions

There are potential extensions to the market penetration analysis that may be pursued based on expectations of future research and development activities. Among these include the following:

- consideration of vehicles that incorporate both autonomous and communications-based crash avoidance capabilities
- refinement to include combinations of equipped and non-equipped vehicles for crashes caused by several (more than two) vehicles
- estimation of additional models reflecting variations on aftermarket/retrofit equipment installation and other vehicle platforms
- modeling to reflect potential variations in growth forecasts in vehicle-miles traveled per vehicle, overall vehicle fleet size, and annual new vehicle sales

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