CUBIC Transportation Systems

UC San Diego

ENVISION 2020

WHITE PAPER | September 2015

Introduction

This white paper provides an overview of the existing environmental and congestion challenges currently experienced at the Southern California San Ysidro and Otay Mesa border crossings. The overall goal of this document is to address current border challenges and to propose long- and short-term solutions to modernize the crossings by leveraging strengths and competencies from the region's innovators. The San Ysidro and Otay Mesa crossings along the U.S.-Mexico border play a key role in the economic, social and political relations between the two countries. The San Ysidro crossing is the busiest land port of entry in the world, with 50,000 northbound vehicles and 25,000 northbound pedestrians processed every day. A successful solution must carefully address complex issues spanning trade and economic growth, national security, immigration and environmental impacts. [1]

The complexity and diversity of the issues faced call for a collaborative bi-national effort, addressed by the U.S. and Mexican local and federal governments, as well as private sector and academic institutions on both sides of the border.

This white paper is a conjoint effort by Cubic and University of California San Diego (UCSD), at the request of the Smart Boarder Coalition. Cubic Corporation, based in San Diego, is a leading technology and services company, providing diversified systems and services in transportation and defense markets worldwide. UCSD is a research-focused, service-oriented public institution, recognized as one of the top 15 universities worldwide. UCSD's culture of collaboration sparks discoveries that advance society and drive economic impact.

Where are we now?

Our region is entering a period of challenge and opportunity with significant trends impacting the border.

We know that the most significant population growth is occurring in urban areas. The expected population growth trends in the border city of Tijuana and neighboring San Diego will inevitably continue to adversely affect our border crossings where we already have major congestion at peak travel periods, and under-utilized capacity at other times of the day.

We also know that we do not have enough real estate to build the requisite infrastructure to cope with this additional peak demand and that we must find ways to make our border more sustainable. Further, the funding source for border crossing infrastructure often hasn't kept in line with bi-national regional growth.

Environmental Issues

Rapid commerce, industry and population growth in the California and Mexico border region is responsible for increasing traffic congestion at borders crossings that in turn affect air quality.

[1] http://www.gsa.gov/portal/content/104872

http://www.gsa.gov/portal/content/227743

The concern about air pollution at U.S.-Mexico border crossings has grown as wait times at San Ysidro and other land ports of entry have risen along with increased security measures following the September 11, 2001 terrorist attacks.

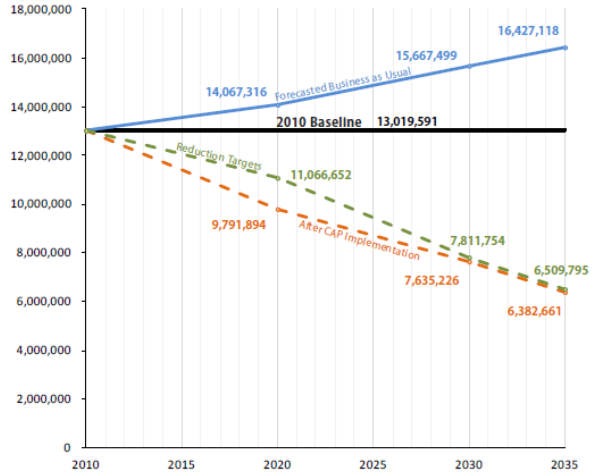
An average 5-litre engine vehicle uses over half a liter (0.132 gallons) of wasted fuel for every 10 minutes of idling. This equates to 0.8 gallons of fuel every hour. The wasted fuel combined with the toxic emissions from idling cars pose a considerable health risk for the population working and living in proximity to the border. [2]

A 2013 report titled “Health Impacts of Crossings at U.S.-Mexico Land Ports of Entry” recommends reducing border wait times as the top measure to decrease exposure to toxic emissions to both pedestrians and drivers at San Ysidro and other ports of entry on the U.S.-Mexico border.[3]

The report cites research showing that pedestrians waiting in line to cross into the U.S. absorb carcinogens found in diesel exhaust at seven times the level of those who live and work in the nearby San Ysidro community but did not wait in line.

Studies show that exposure to traffic emissions can lead to a range of ailments including respiratory problems, cardiovascular effects, cancer, adverse birth outcomes and increased risk for diabetes.

While endeavoring to accommodate a growing population and encourage economic growth of our region, the state of California has at the same time committed to reducing Green House Gas (GHG) emissions. The state’s road map for achieving reductions – the Air Resources Board Scoping Plan – charts future emissions by comparing various policy options to a “business-as-usual” (BAU) scenario.



[2] http://www.nrcan.gc.ca/energy/efficiency/communities-infrastructure/transportation/idling/4463

http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=11

[3] http://www.sandiegouniontribune.com/news/2013/may/16/san-ysidros-long-border-waits-pose-health-risks/

Accounting for future population and economic growth to achieve its proportional share of the state reduction targets for 2020, 2030 and 2050, the City of San Diego will need to reduce emissions below the 2010 baseline by 15% in 2020, 40% by 2030 and 50% by 2035.[4]

These state-mandated reductions must be taken into careful consideration when addressing the border traffic congestion and resulting GHG emissions from the current and projected numbers of idling traffic.

Economic Issues

Traffic flow across Southern California's borders plays a key role in the economic growth of the bi-national region. U.S. goods and private services trade with Mexico totaled an estimated $536 billion in 2012. Exports totaled $243 billion in 2012; imports totaled $293 billion.

Foreign trade is a vital component of California's $2.2 trillion economy. Mexico has been California's main trading partner since 1999 and is the largest market for exports of California-made goods. California is the third largest importer of Mexican goods, accounting for 10.2% of all Mexican imports in 2014.

Export-supported jobs account for an estimated 4.9% of California's total private-sector employment in 2011. Nearly one quarter (25.2%) of all California manufacturing workers are dependent on exports for their employment.

Approximately 177,000 California jobs (17% of all export-supported jobs in California) are related to the commercial relationship with Mexico.

Commerce, tourism, and foreign direct investment from Mexico support more than 200,000 jobs in California (1.5% of total payroll jobs in California).[5]

It is therefore vital that California's borders with Mexico continue to support the existing commercial relationship between the two nations, and provide viable infrastructure that will support the economic growth and exchange between the two nations.

Security Issues

More than 116 million vehicles cross the land borders with Canada and Mexico each year, creating a challenge to screen all vehicles for illegal activity. The U.S.-Mexico border, in particular, is believed to be the primary point of entry for cocaine (65%) being smuggled into the United States. [6]

Disruptive Technologies for the Envision 2020 Border

People's expectations of border services are being elevated by disruptive technologies, which will be a large part of the solution. The strategy to realize an Envision 2020 border is by retaining and extending the border's core

[4] http://www.sandiego.gov/planning/genplan/cap/pdf/draft_cap_july_2015.pdf
[5] https://ustr.gov/countries-regions/americas/mexico
[6] http://transborder.bts.gov/programs/international/transborder/TBDR_BC/TBDR_BCQ.html

capabilities, expanding on the use of state-of-the art technologies, and researching the latest technical solutions that are aligned with the expected economic growth, security and environmental sustainability goals for the region.

The next wave of disruption will begin to solve some of these issues: There will be a more coordinated road-space as vehicles talk to infrastructure (V2I) and each other (V2V), further ride-pooling and smarter bikes. Vehicles won't be charged based on how much gas they use, but for which roads they use and at what time of day. Increasingly sophisticated vision analytics, biometric markers and sensor technology will replace the current paper-based identification documents. Drug-sniffing dogs and human intelligence will be augmented and, in time, exceeded by sophisticated sensor technologies mounted on drones or autonomous robots providing narcotic and explosive detection capabilities.

Then there is the expectation of the autonomous wave. Our cars will drive themselves. There will be driverless taxis and cars that are shared as a service. Buses and trucks can become driverless, and while some may have fixed routes, others will optimize based on demand. We will be charged according to how efficiently we utilize capacity and contribute to sustainability.

These waves of disruption will fundamentally change the way that we operate and plan transportation in cities and across our borders. At the moment we plan and schedule, and then control and respond, in the future the technology will allow us to be demand-led with our traffic and borders optimized for most efficient throughput.

How humans interface with border agents will also change. We will augment interfacing with border agents and equipment such as biometric kiosks with mobile and location-based services, to ultimately digitized personal assistants that will provide predictive services based on a very rich understanding of our habits and preferences. The infrastructure will be smart enough to detect us entering and exiting a border region – a concept referred to as "Be In, Be Out."

All of the above will cause the strategic border crossing and competitive economic landscape to become more complex than ever before.

These changes will drive growth in the border crossing solutions. There is going to be a greater need for management services. Operators of mobility infrastructure are progressively deploying Intelligent Transport Systems (ITS) to provide them with greater levels of information on the performance of their part of the mobility network. To date, these systems are relatively distributed and not integrated, neither with revenue management systems nor the ITS technology of other operators. It is now recognized that this technology will become significantly more powerful if it is completely integrated, resulting in advanced "systems of systems."

Vision for California's State-of-the-Art BorderThe objectives for the Envision 2020 border include:

- A flowing and secure border
- Reduction in Green House Gas emissions lined up with City of San Diego goals
- A connected, IoT region-wide border solution
- An open, expandable software gateway, accommodating new technologies as they become available

- Secure and automated sensor-based prescreening that profiles pedestrians, drivers, trucks, and related contents of interest
- Automated traffic flow diagnostics, and automated traffic equalizations, across local borders and border lanes
- Trusted Worker Program for Mexico residents commuting daily for employment in the U.S.
- Simplified, automated and secure commercial trade passage and crossings, with lower reliance on agent inspections
- Reduction in border operations cost
- Increased social and cultural exchange in the border region
- Fairness for all citizens

Immediate Opportunities

Today, congestion occurs primarily in the northbound direction at the Mexico-to-U.S. points of entry due to inspection on the U.S. side of the border. It is predicted that congestion and the resulting environmental impact will also become problematic on the U.S. side of the border due to increasing enforcement of southbound inspections into Mexico.

While the modernization and expansion border project resulted in the opening of additional inspection booths and faster crossings, the temporary drops in wait times have been increasing as the number of crossings continues to climb.

Using the existing civil infrastructure, a number of immediate opportunities to improve the border operation for pedestrians, cars and cargo are currently available from Cubic and its partner companies. These include:

1. Improved Tijuana surface street signage guiding traffic in real time to the appropriate Standard Lanes, Readylane and SENTRI Lanes at the San Ysidro crossing
2. Clear, live signage to the Otay and Tecate crossings
3. Traffic equalization across local borders using live data from video analytics
    - for real-time border traffic management
    - accurate reporting of crossing times
    - active lane management
    - staffing management

    (Current methods of using human-estimated wait times results in inaccurate data, incorrect choice of border for crossing and ineffective lane adjustments.)

4. Clearly visible displays showing current crossing times by lanes for the different crossings
5. License plate recognition for cargo trucks
6. A cell phone app with exact crossing times and navigation by lanes for the different crossings
7. Appointment-based crossings for non-perishable cargo
8. 24-hour border operation across all points of entry
9. Public education campaign on the SENTRI Program to increase enrollment by reporting correct immigration status

These recommendations can be easily implemented through the active advocacy of the Mexican and U.S. governments, and the advocacy of the Smart Border Coalition (SBC).

The effect of these technologies on the border traffic wait times can be initially modeled and then measured in a fairly straightforward way by conducting isolated pilot studies.

Phase 1 - Baseline and Evaluation

Following on the immediate opportunities above, a longer two-phased approach is proposed.

Traffic Flow Study

A comprehensive car, cargo and pedestrian traffic flow study will be needed to establish a baseline understanding of movement across existing civil infrastructure and how it currently utilizes and is affected by existing technologies.

Environmental Impact Study

In parallel, a regional border environmental study will be needed to establish current emission levels and economic impacts associated with current elevated pollutants.

It is expected that both studies will utilize the expertise of U.S. Customs and Border Protection (CBP) and external subject matter experts to harness a comprehensive data set. The extracted data set will be run through system wide analysis, harnessing the power of big data tools and deep analytics to succinctly explore points of failure and opportunities for improvement.

Phase 2 - System-Wide Modernization

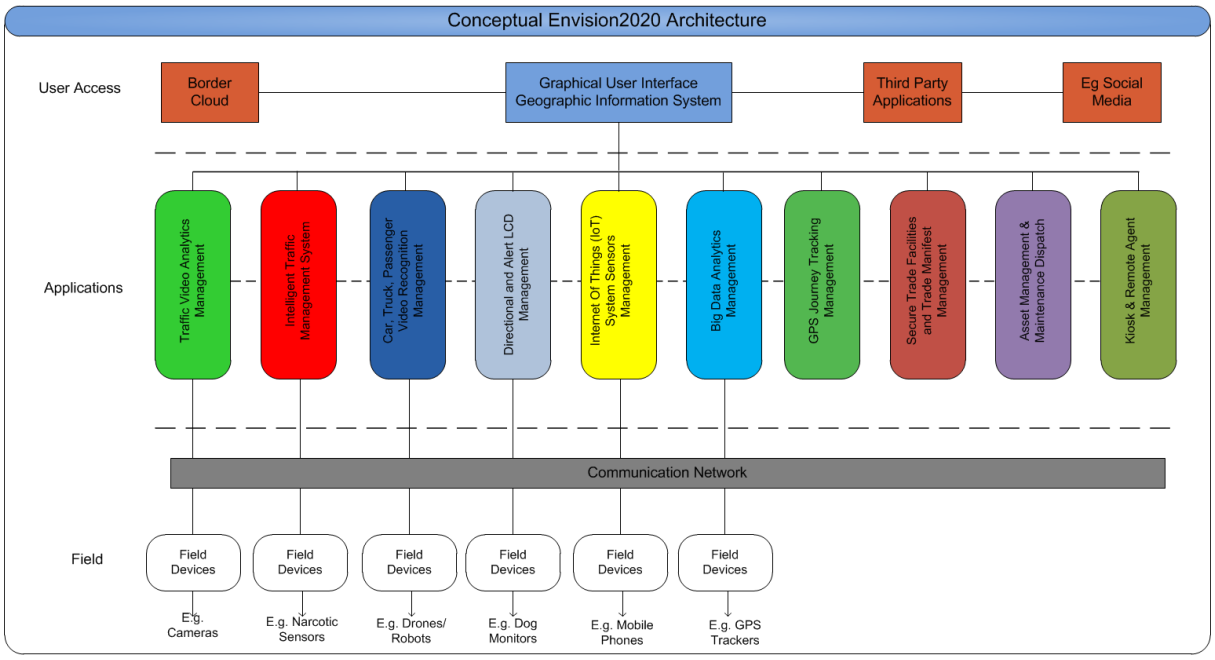
Backend and Gateway

The initial step in creating an integrated border crossing system is to put in place a state-of-the-art, secure and scalable Central Management Software Subsystem (CMSS) for processing system-wide data across pertinent border operations.

The CMSS will provide the processing, storage, monitoring and management capabilities, with an integral scalable gateway architecture accepting inputs from internal and third-party applications, servers, network devices, as well as inputs from system-wide Internet of Things (IoT) sensors such as field devices, cameras, lane capacity sensors, traffic lights, scales, biometric devices, chemical sensors, mobile phone sensors, GPS tracking devices, dog performance tags or any new sensors or technologies as they become available. The gateway inputs can include asset management and maintenance tracking to automate and reduce border operation costs.

The access to the system will be through an intuitive and easy-to-use Graphical User Interface (GUI) access that automates and facilitates system monitoring, management, maintenance, and performance monitoring. The interface will be configurable using standard mouse and keyboard, touch, gesturing, voice and any other pertinent and biometric command interfaces suitable to the usage environment.

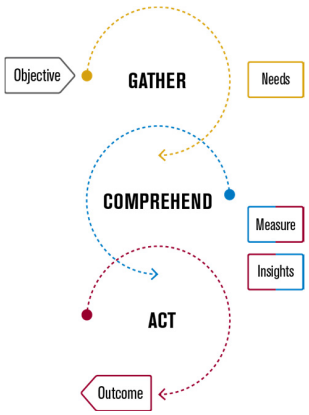
The system will provide a private cloud or browser-based equivalent cloud-based system and in the future allow the provision of **Software-in-the-Cloud Service**s, enabling additional entities/agencies to the service.



Data Analytics

Improvement of border throughput and maximization of overall border operation can be achieved through utilization of data science techniques and data integration against multiple complex datasets known as Big Data Analytics.

The focus of the analytics is to enable the CBP to make data-driven decisions through the application of innovative data science techniques to solve complex problems and provide a superior outcome with much less investment than traditional approaches. The proposed approach incorporates an agile analytics process complemented by data collected from practically any reliable system that can generate it.



This iterative approach supports the introduction of data-driven cultures into the planning and provisioning of border services by further informing the decision-making process. The outcomes of this process are the delivery of high-value information to the CBP that will help drive throughput, environmental, and other pertinent operations improvements, and suggest incremental changes to operations.

Phase 3 – Next-generation technologies.

Collaboration between the private sector and the region's universities offers the opportunity to develop the next generation of inspection technologies that will enhance the currently available solutions.

Biometric Data

An electronic "pre-check" procedure can be implemented to improve the inspection and processing of pedestrians and cars passengers. This procedure will require every person crossing the border to provide"

- scanned copy of their passport
- voice sample stating their name
- car passengers: the license plate of the car they are traveling in.
- car drivers: extensive information about the car, such as license plate, make, model and year of the car

Smart Phone Apps with Backend Support

Smart phone apps as well as back-end algorithms can be developed to collect and analyze the provided biometric information as follows:

- Extraction of relevant information from passport scan to automatically preprocess verifications that are traditionally run after manually inspecting the passport
- Storing the voice sample; if the person has provided a voice sample during a previous border crossing, then verify against stored record
- For cars: linking passenger and driver information through the license plate
- For cars: predict the expected weight of the car based on car parameters (make, model, year) and passenger parameters (as extracted from the passport: gender, date of birth); the expected weight can then be verified against the actual weight, if available

All of the above will be run in real time, so the results are available by the time a pedestrian or car reaches the border officer. A "green light" result (no red flags) would allow the officer to let the pedestrian or car proceed without additional, time-consuming interaction. This will improve the flow of both pedestrians and cars crossing the border.

Advanced Vehicle Forensics

A strong opportunity to integrate innovative ideas, in particular in the areas of vehicle and cargo movement across the border, includes the use of advanced vehicle forensic technology.

Technological forensics may include the inspection of vehicle tires to automatically determine the tire age, as well as the type of roads the vehicle has been driven on, by analysis of the dirt sediments and consistencies on tires.

These can be cross-checked against a statement of the car/truck activities between border crossings, which would be provided as part of the "pre-check" activity.

Advanced Video Analytics

Advanced video analytics technologies can be used to extract information about passengers in the vehicles. This requires the analysis of "pre-check" video of the driver and each passenger. For example, person re-identification based on face recognition can be used to verify for passport forgeries or to track how many times a person crosses the border and whether they have a "single identity." Eulerian video magnification analysis of a 30-second video of each vehicle occupant can be used to determine the pulse and potentially the "emotional state" (calm, nervous, etc.) of each person.

Electronic Sensors

The primary narcotic detection method today utilizes calculated risk score and trained dogs. However, these dogs are a finite, precious resource and cannot be used to screen every vehicle or cargo truck crossing the border. The estimated coverage today is believed to be less than 20%. Technology is needed to augment the dogs and provide a first-level screening with much higher coverage. This technology will complement current screening technology to expedite process, reduce pollution, and increase screening coverage.

Screening of vehicles at the border can be complemented by a combination of advanced electronic noses and robotic systems. UCSD has the expertise to develop an electronic method of detecting cocaine and other illegal drugs to expedite this process and increase the screening coverage. The proposed nanotechnology-based electronic nose (e-nose) leverages several unique capabilities available at UCSD, in particular the nano3 clean room for fabrication of the nanosensor arrays, core expertise in circuit design for the readout electronics, and big data signal processing and analytics for pattern recognition. The resulting sensors could be used in several different form factors such as handheld e-nose sensor arrays for border agents, robotic articulating arms that could be snaked inside of cargo trucks minimizing the number of offloads and screening time, or attached to autonomous vehicles (such as drones).

Robotic Systems

Robotic systems, such as a dexterous snake robot, can be developed and utilized for the inspection of the visible and non-visible parts of cars/trucks, namely the space under the car/truck.

Combined with electronic noses, these systems can assist K-9 units in detection of narcotics and other illegal drugs.

The use of a snake robot is of significant value for performing inspections in order to reach locations that would otherwise be very difficult for a border officer to access. The robotic snake will be dexterous enough to maneuver its way through obstacles and tight constraints. The snake will have a head-mounted camera and be controlled in first-person view by the operator through simple joystick control. The robot can therefore be commanded to reach quickly and efficiently into the bowels of the vehicles and their cargo, with embedded sensors (chemical, gas sensors, heat-vision) at the head of the robot to provide feedback of concealed items or persons in-situ.

To accomplish these goals, new designs of the robotic snake, the vision system and the user-interface need to be fully investigated and developed. Novel algorithms for efficient control of the snake body need to be developed to maximize its dexterity and locomotion through a constrained environment such as a vehicle's chassis.

Such next-generation software detectors can be designed to analyze x-ray imagery to find concealed packages or people in cars/trucks. Machine-learning algorithms can be developed to fuse the information collected from cameras, x-rays, artificial nose and infrared sensors.

Conclusion

As populations continue to expand in the San Ysidro and Tijuana border region, existing Points of Entry will be faced with ongoing environmental, throughput, economic and social challenges. To proactively solve the complex interplay of these parameters, a border solution must take advantage of the myriad of current and emerging technologies. The Envision2020 border will need to be a well-structured but expandable “system of systems” that is connected, efficient and secure.

CBP, UCSD, CETYS Universidad and Cubic Corporation, as individual entities and members of the Smart Border Coalition, are strongly vested in the technological and political success of our region. This partnership is well positioned to be the driving force behind a cutting-edge, and optimally modernized, border crossing of the future.