HeroX 2016

Infrastructure Vision 2050 Challenge
“Dream” Phase

Monorail 2050: Transit Oriented Development (TOD)

The Hub-and-Spoke Model

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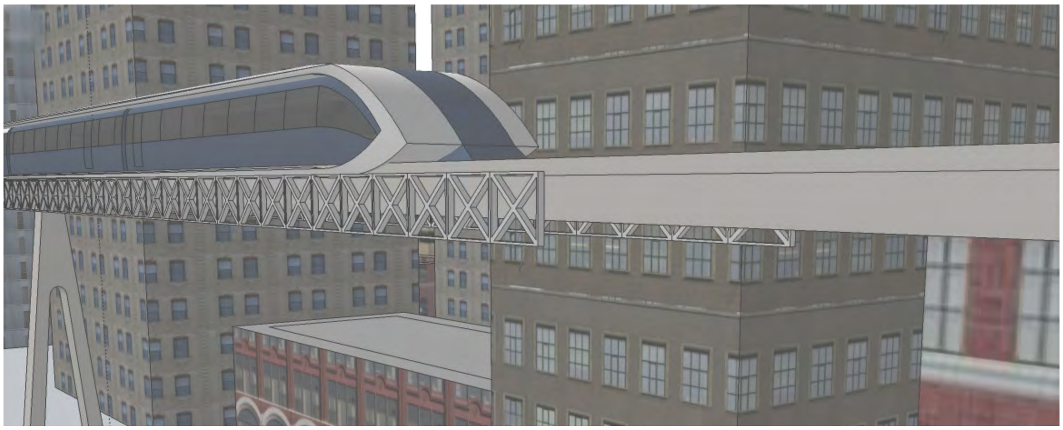
Executive Summary



This proposal addresses the metropolitan needs for housing, retail, public spaces, and efficient transportation. The monorail is an efficient transit source, especially for short distances in cities that are already heavily developed. Only a small footprint is required for monorail track stays. In this proposal, monorail trains connect mixed-use transit hubs hosting retail and residential real estate. These hubs, which also include parks, museums, and art installations, are connected by the spokes of the monorail transit system. In order to fund this large-scale project, retail and residential developers will subsidize the creation of the transit system as part of the cost of ownership of mixed-use transit hubs. This paradigm allows for cost-efficient and rapid development of the project, without needing to impose taxes or extract other public funding. This creates a win-win situation for the developers and the public. In this way, the city gains access to a new transportation system with additional housing and employment, while decreasing vehicular traffic in the city. This proposal also makes suggestions for implementation and explores possible metrics for determining the project's success. Both implementation and evaluation phases are designed to assure political and public support for the project.

Background
The Problem and Past Solutions

In the past, young families opted for the suburbs, as an escape from the grind of city life. The current generation of young Americans has begun a movement back into cities, with a preference for mixed-use developments that afford life necessities in walkable range. While this ability to walk to the nearest store is a tremendous benefit, many continue to drive to work and use their cars to visit other parts of the city. Mixed-use housing has led to increased traffic and parking problems in many cases.

Automobile traffic capacity is also limited. In fact, as more roads are built, the number of cars driving on them increases. Economists Duranton and Turner call this "The Fundamental Law of Road Congestion."[1] As an example, in 2016, Los Angeles was given the dubious distinction of having the worst traffic of any city in the United States.[2] This comes despite significant freeway widening projects in the city funded by the American Recovery and Reinvestment Act of 2009. Traffic engineers call this problem "induced demand," which means more people opt to drive when roadways are enlarged, rather than take public transportation. More roads are clearly a nonproductive solution to the traffic problem.

Traffic congestion contributes to a number of health problems, both for individuals and the planet. Los Angeles Drivers lose over $1,700 in productivity each year,[3] or time that might be spent with friends and family. A 2012 study from the American Journal of Preventative Medicine showed those who drive in traffic weigh *almost 7 pounds more* than those who take public transportation.[4] On the environmental side, Los Angeles traffic produced over 33 million metric tons of carbon dioxide (CO_2) in 2015,[5] a greenhouse gas that contributes to climate change.

There is a need for short-distance transport that does not require the automobile. For the health of Americans and the environment, improving transportation infrastructure has become critical.

Another solution to traffic congestion has been the creation of light rail systems. Light rail is an efficient mode of transportation to shuttle people across cities. In fact, most light rail systems in the United States are limited by *demand* more than *capacity*.[6]

Unfortunately, there are several hindrances to the rapid development of these transportation systems. The first is cost: new light rail construction requires over $70 million per mile.[7] This is expensive compared to freeway construction, which may cost as little as $1 million per lane-mile.[8] Another significant problem for new rail construction is the need for *land*. As seen the attempted expansion of the Purple Line in Los Angeles, lawsuits and NIMBY have halted construction through areas such as Beverly Hills.[9] There is clearly a need for mass transit to accommodate the capacity of commuters, but light rail development has been slow and expensive (sometimes for legal reasons).

An additional concern with rail systems is safety. Accidents related to light rail have recently attracted attention. The U.S. Department of Transportation recently released a report showing light rail fatalities are higher than other forms of transportation (second only to motorcycle travel) with 31.5 fatalities per 100 million miles.[10]

Despite these limitations, light-rail remains an important and efficient part of mass transit. There is a need however, for short-distance mass transit that is safe, inexpensive, and rapidly deployed.

The Monorail as Transportation

Capacity to Meet the Demand

While the monorail is often seen as a Disneyland-type amusement, there are reasons to seriously consider the monorail as a means of public transport.

The largest expense and concern for the development of mass transit in US cities has been the acquisition of land for construction. By utilizing narrow pylon supports, monorail tracks can be suspended with minimal demolition of existing structures. Limiting the demolition required during construction helps avoid legal entanglements and the objections of NIMBYites. In general, public opinion has shown support for monorail projects, including Seattle[11] and past favorable votes in Los Angeles.[12] Why a monorail has not been constructed in Los Angeles is a point of much speculation, perhaps due to political lobbying against the projects.[12] Regardless, a grand opportunity exists to create new infrastructure with short-distance transit to complement existing public transportation.

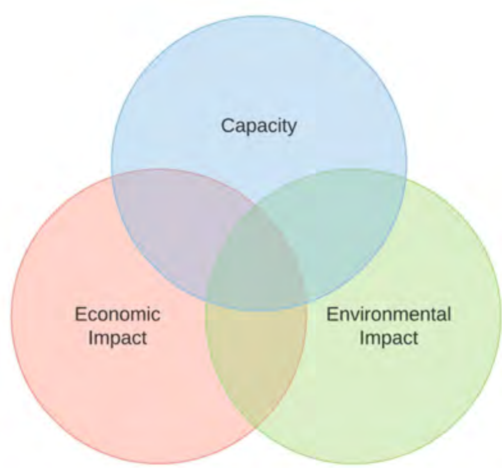


Figure 1. Transportation solutions must consider Capacity, Economic, and Environmental Impact

An additional benefit to monorail transport is capacity. As with light rail, this form of transportation is only limited by *demand*, not by *capacity* (as are roads and freeways). China is home to the largest volume of monorail riders, with Line 3 in Chongqing hosting 682,800 passengers per day, with 32,000 passengers/hour at its peak.[13] The Chongqing Rail Transit (CRT) has also shown that distance can be covered effectively with monorail lines. The CRT has over 125 miles of track to handle its average daily ridership of 1.73 million people.[14]

In regard to safety, modern monorails have a stellar record. Since there are no intersections with people, cars, or bikes, the chance of a collision is almost nil. Today's monorails have the best safety statistics of any mode of transportation, having carried over two billion riders worldwide without a single passenger fatality.[15]

Environmental impact is another benefit of these transit systems. Clean, electric running monorails will decrease carbon emissions from vehicles idling in traffic. The track supports of monorail systems exhibit efficient land-use and limit the environmental impact created by demolition of existing structures.

The cost of monorail projects is similar to light rail at an average of $77 million/mile vs. $78 million/mile. Therefore, cost considerations should not be a hindrance to implementing monorail over light-rail systems.

Light Rail Line	Cost per Mile (millions)
Dallas	$41.38
San Diego-Mission Valley	$73.05
Denver	$46.45
Kansas City	$44.23
Minneapolis	$47.70
New Jersey: Hudson-Bergen II	$182.43
Orange County	$68.57
Orlando	$41.10
San Diego-Mid Coast	$30.76
San Francisco	$79.59
Seattle	$208.33
Average	$78.51

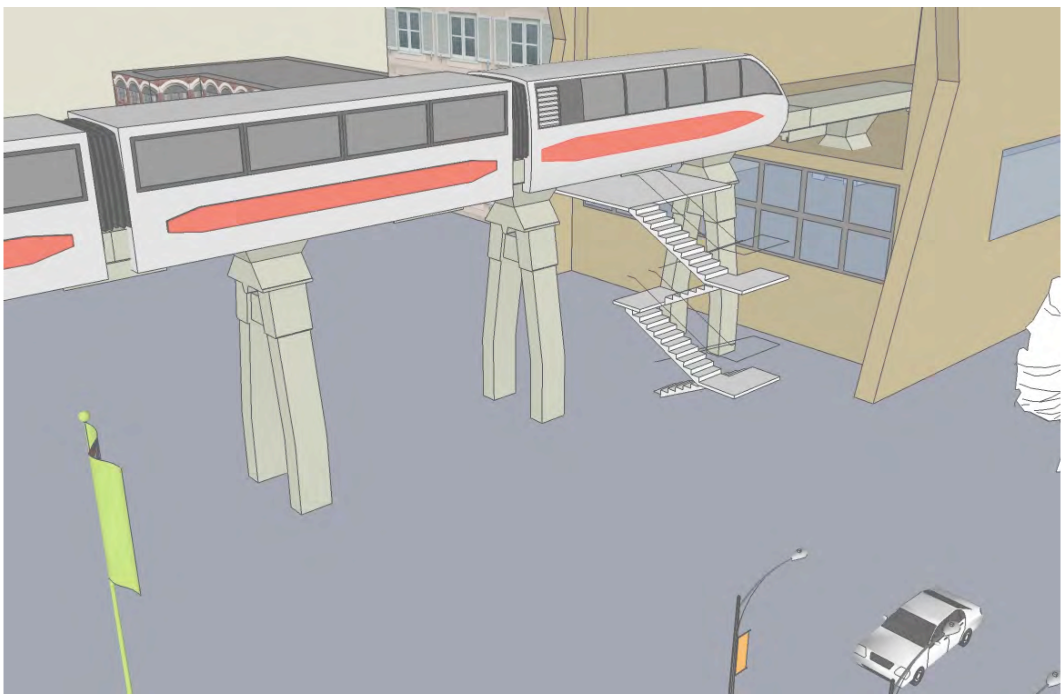
Table 1 - Light Rail Construction Average Cost per Mile[16]

Monorail Line	Cost per Mile (millions)
Okinawa	$44.00
Kuala Lumpur	$57.92
Las Vegas	$88.00
Palm Jumeirah, Dubai	$118.10
Average	$77.01

Table 2 - Monorail Average Construction Costs per Mile[17]

“The Dream”
Transit Oriented Development (TOD): The Hub-and-Spoke Model

The working population is no longer escaping to the suburbs, instead people are moving into cities, where they can live, work, play, and dream. “The Dream” is an evolution of the modern city, using the monorail as a connection to novel live-work structures. This new city has hubs of residential units, retail, and public spaces that are connected by efficient monorail trains. Monorail will not replace existing light-rail, but complement it with short-haul movement of riders between retail/residential hubs.



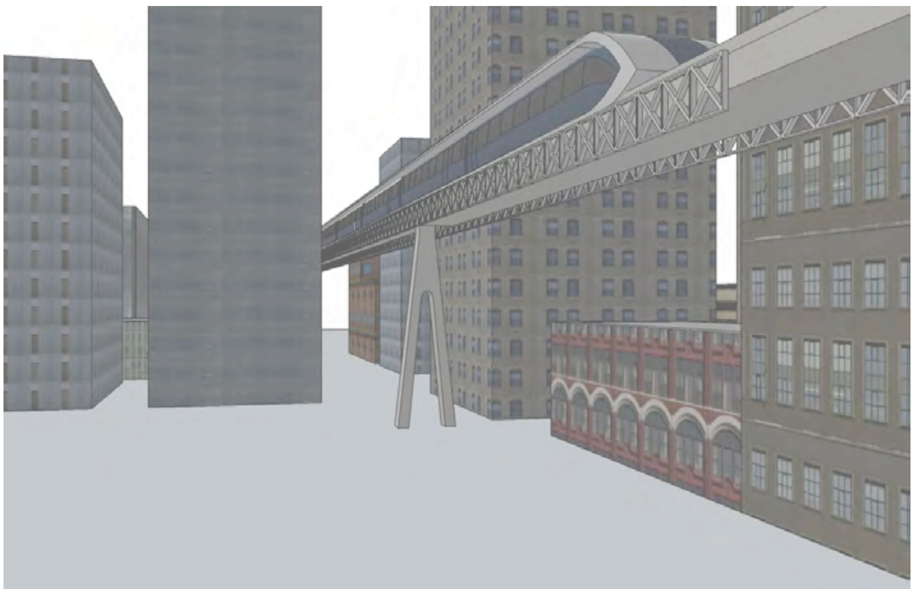
As a response to an influx of individuals from suburbs to cities, there has been movement toward Transit Oriented Development (TOD) or “Transit Proximate Development.” TOD consists of residential or retail centers that act as hubs, with transportation systems as the spokes. This hub-and-spoke model has been successful in many parts of the world. The oldest example is Curribita, Brazil where 85% of its population uses its Bus Rapid Transit System.[18] Another TOD is located in the Bridgeland Community of Calgary, Canada. Here, a system called *The Bridges* interconnects condominium developments, restaurants, retail shops, and parks. As a result, Bridgeland has been called one of the most “livable” cities in Calgary.[19] Not only do residents of Calgary enjoy the “walkable” nature of this community, TOD has produced new jobs and an increase in average household incomes by 22%.[20] In the Unites States, the Bay Area Rapid Transit (BART) connects San Francisco to outlying areas, and has helped create “Transit Villages,” including the development of cities such as Fremont, Union City, and Hayward.[21] This is another example of the positive economic impact of such projects.

Residential/Retail Development: "The Hubs"

In this model, the "Hub" will be a self-contained mixed-use development project. Multi-story residential units will anchor each Hub. Several commercial spaces within the Hub will allow for the addition of retail and services. These Hubs will also provide public spaces such as parks, museums, or art installations. The Hub will be a home for many, and a retail destination for others. Creating such a development allows for the provision of employment alongside housing.

The monorail will enter these transit hubs aboveground, improving safety for pedestrians, by avoiding vehicular traffic. Retail will be opened at rail-level, making purchases convenient for both residents and visitors. Residential units will occupy the highest floors of the buildings, with office spaces residing in the mid-to-lower levels. These office spaces will host professional services or smaller companies like tech "start-ups." At the street level, additional retail spaces are made available, which are easily accessed by the general public.

The budgeting for these developments will include open and public spaces. These might be parks, outdoor athletic facilities, or sculpture gardens. There will be a requirement for the planting of green foliage in these open spaces, contributing to a pleasant park-like atmosphere. One example of an existing transportation hub in a TOD development can be seen here: The Milton Residences - Brisbane, Australia.



The Monorail as "Spokes"

There are a number of features that differentiate this project from existing transit options. One is the focus on short-distance travel between pre-designed transit hubs. This proposal creates new microcosms within the existing infrastructure of the city. The monorail trains provide lightweight, safe, and efficient travel between destinations.

Again, monorail does not replace light-rail trains, but complements them, intersecting these lines in key areas, providing alternative transportation to alternative living and working hubs. Light-rail and commuter trains will shuttle passengers longer distances, including inter-city travel. The monorail trains provide passage in approximately 1-mile increments within the urban environment. When we look at ridership from similar established TOD projects, residents and employees from the surrounding community show an increase in public transit use.[20] It could be predicted that about 37% of residents within ½ mile of the hub will begin using the rapid transit system.[22] These hubs have been shown to effectively produce ridership when located within a ½ mile of the rider's residence; similarly, highest levels of ridership for commuters is seen when the hub is located within ¼ mile.[22] These figures highlight the need for short-distance transportation to attract passengers.

Implementation of "The Dream"

Enlisting Developer Support

The implementation of this project is unique in that it enlists the funding of developers to cover the costs associated with the project. This includes the costs of building the monorail system, property purchases, and the physical development of mixed-use hubs. The initial project will start with 8 transit hubs, with interconnected trains. A single developer who commits to the development of one transit hub also shares 1/8 of the costs involved in building the monorail system. In this way, the investors will benefit from ownership of concentrated retail and residential property, while the public benefits from the development of an efficient transit system, also providing additional jobs and housing.

A key consideration for implementation is developing key relationships not only with developers, but also with local government officials. The design and planning process will include input from multiple stakeholders during the implementation phase. Designs will be completed and finalized with the input of the city planning office, board of supervisors, and other city or county officials. This will aid in the efficient processing of environmental impact reports, permits, etc. Developers will be heavily involved in the design process and will be tasked with property purchases and leases. For this reason, developers will need to agree on the path of monorail tracks and the location of mixed-use developments.

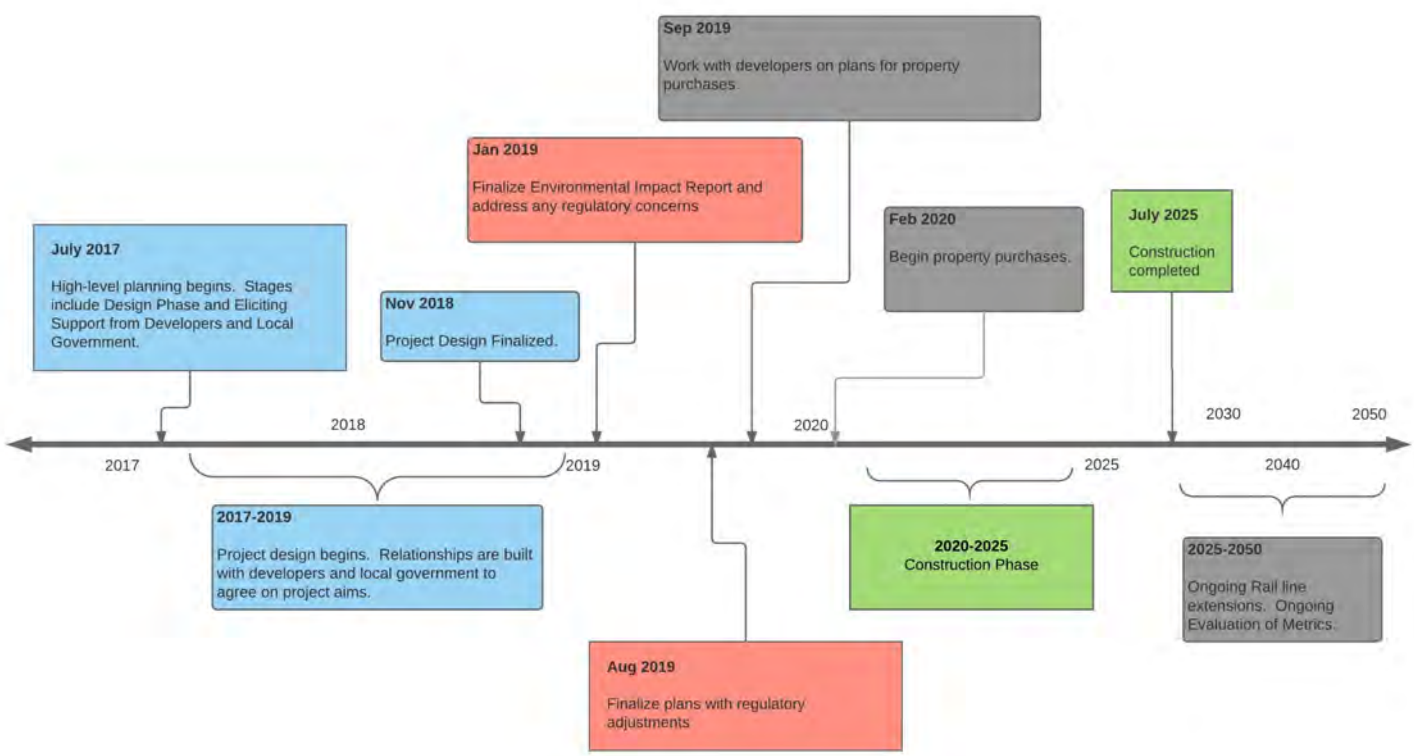


Figure 2 - Sample Project Timeline

To build environmentally friendly and efficient trains, requests for proposals (RFPs) will be elicited from major firms. These will be overseen by the creation of a transit board comprised of developers and local officials. This board will have the ultimate decision-making authority for the design and construction of the entire development.

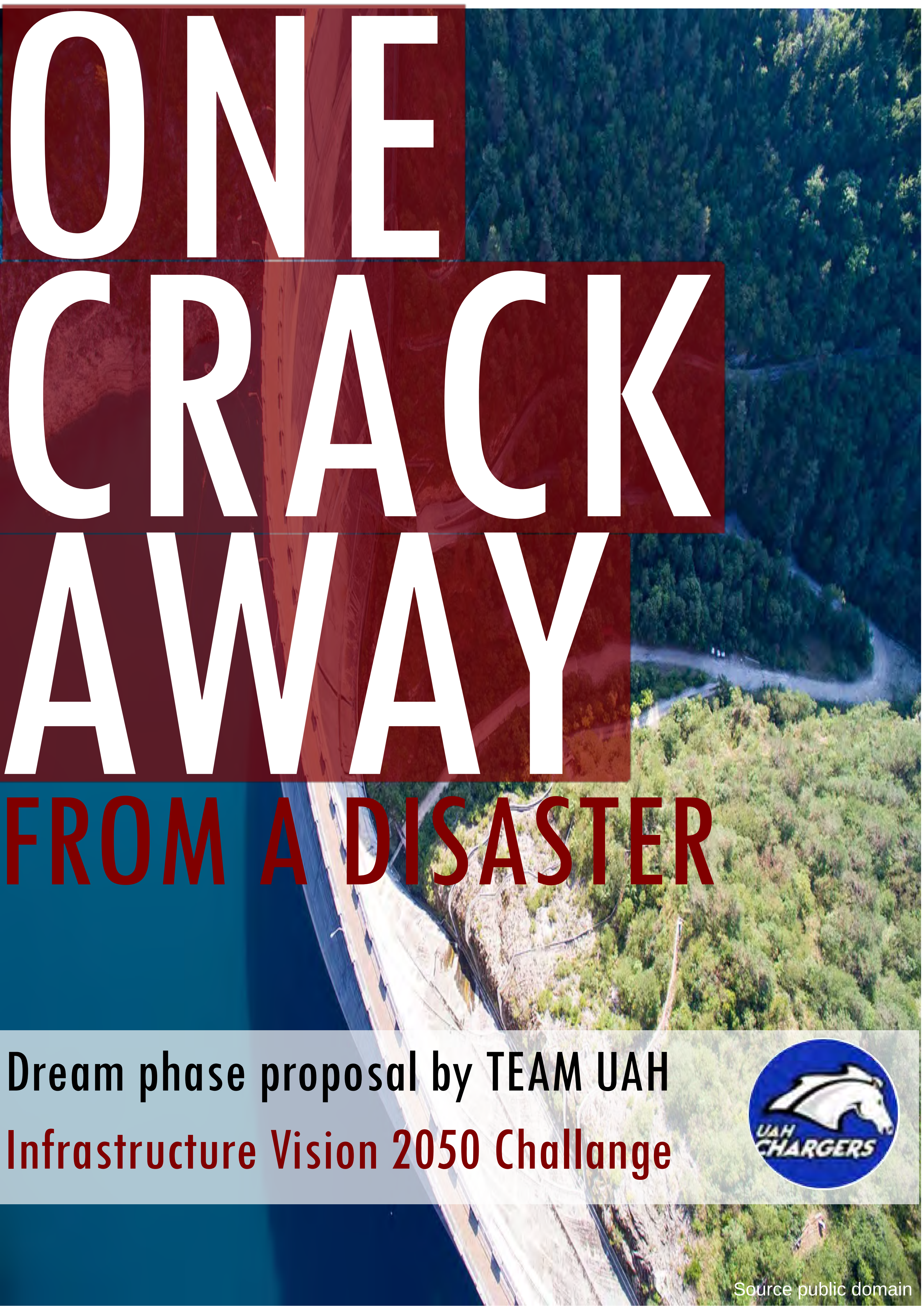
Evaluation Metrics

Broad Success Measures

A wide array of metrics will be investigated to evaluate the success of the project. The first is ridership, with calculated Equivalent of Vehicle Miles Traveled. Housing capacity and traffic impact will be measured as well. Metrics will also be designated for Transit Quality and Rider Satisfaction. The cost effectiveness of the project can be evaluated from a number of angles. In addition to Fare Collection, Operating Expense Per Passenger Mile will be calculated. This metric is exemplified by U.S. buses, which cost an average of $1.00 per passenger mile, compared to $0.60 per passenger mile for rail operations.[22] Economic Impact can also be measured; this may include average household income within a 0.1 mi, 0.25 mi, 0.5 mi, and 1 mi radius of the transit hub. From an environmental standpoint, reduction in energy use and carbon emissions may also be tracked. Detailed and varied metrics provide holistic measures of success for the project, assuring public and political support for the development.

References

[1] Gilles Duranton & Matthew A. Turner, 2011. "The Fundamental Law of Road Congestion: Evidence from US Cities," American Economic Review,
[2] http://inrix.com/los-angeles-traffic-is-the-worst-in-the-united-states/
[3] http://www.latimes.com/local/lanow/la-me-ln-is-los-angeles-traffic-the-worst-20150826-story.html
[4] http://www.cnn.com/2015/04/06/health/commute-bad-for-you/
[5] Sorensen, Paul, Martin Wachs, Endy M. Daehner, Aaron Kofner, Liisa Ecola, Mark Hanson, Allison Yoh, Thomas Light and James Griffin. Reducing Traffic Congestion in Los Angeles. Santa Monica, CA: RAND Corporation, 2008. http://www.rand.org/pubs/research_briefs/RB9385.html.
[6] Hanson, Susan; Giuliano, Genevieve (2004). *The geography of urban transportation*. Guilford Press.
[7] "US Light Rail Costs Near $70 Million per Mile" http://www.publicpurpose.com/ut-lrt00capcost.htm
[8] Highway Construction Cost Comparison Survey Final Report" (PDF). Washington State Department of Transportation. April 2002. p. 3. https://web.archive.org/web/20090905215838/http://www.wsdot.wa.gov/biz/construction/pdf/I-C_Const_Cost.pdf
[9] Smith, S.J. "L.A. Transit: Breaking Down the Enemies, the Lawsuits and the Future" https://nextcity.org/daily/entry/ethan-elkind-book-railtown-losangeles-rail-lawsuits
[10] "National Transportation Statistics 2013" (PDF). U.S. Department of Transportation. http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/NTS_Entire_13Q4.pdf
[11] https://books.google.com/books?id=0nwbDqaxSToC&lpg=PA206&ots=9ZiHf-W7wN&dq=public%20opinion%20monorail&pg=PA206#v=onepage&q=public%20opinion%20monorail&f=false
[12] "Why Monorail?" http://www.monorails.org/tMspages/Why.html
[13] "重庆轨道 3 号线成世界上最繁忙的单轨线" http://cq.cri.cn/115/2014/11/21/5s720.htm
[14] http://www.cq.xinhuanet.com/2013-05/02/c_115606517.htm
[15] "Monorail-Safety/Hazards" http://www.theamericanmonorailproject.com/comparative-matrix/monorail-safety-hazards
[16] http://www.publicpurpose.com/ut-lrt00capcost.htm
[17] http://www.monorails.org/tMspages/HowMuch.html
[18] https://trans4m.org/2014/11/25/brazil-curitibas-rapid-growth-through-rapid-transit/
[19] Calgary FFWD Weekly (2013). "Best of Calgary Winners"
[20] "Community Social Statistics: Bridgeland/Riverside" (PDF).
[21] Michael Bernick, Robert Cervero (1996). *Transit Villages in the 21st Century*. University of California, Berkeley: McGraw Hill.
[22] https://jackimurdock.files.wordpress.com/2013/03/public-transit-performance.pdf



ONE CRACK AWAY

FROM A DISASTER

Dream phase proposal by TEAM UAH

Infrastructure Vision 2050 Challange

Source public domain

Dams and Water Infrastructures for 2050

Credit Pixabay, public domain

Credit Pixabay, public domain

Alabama is the only state that doesn't have a dam safety program, and only two percent of Alabama's dams are inspected. The number of deficient dams in the U.S. is estimated at more than 4,000 and req- -uire an investment of $21 billion to repair [1].

An Alabama Power engineer inspecting a crack using conventional techniques [2].

Dams are often out of sight, but play a critical role in our daily lives in addition to drinking water facilities. Also, hydropower is the biggest source of green energy in the United States and farms that are the main food supply in the market also rely on dams for irrigation in many regions. Industries such as food processing, chemical manufacturing and power plants were built near dams or nearby. Drinking-water systems in many states collect source water from dams, besides rivers and lakes. But like most infrastructure, dams go largely unnoticed until something goes wrong.

Despite dams being so vital, there are more than 87,000 dams in the United States and at least 14,000 dams are in need of repairs, deficient, or stressed [1].

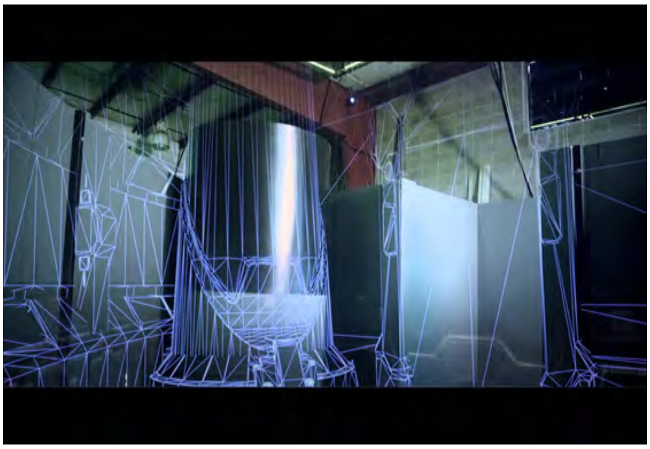
The problem with dams is not confined to the reported and inspected ones because thousands more are not inspected.

In the Complain phase of the Infrastructure Vision 2050 Challenge, we proposed to tackle the issue of water resources and dams because they directly impact the quality of life of people and communities in the U.S., and because they have a deep impact on the economy. In the Dream phase, a novel technology is proposed for inspection and maintenance of existing structures that can even revolutionize the planned ones. If the capacity and safety of existing infrastructures are achieved, more resources can be dedicated to building new ones. For example, it is estimated that dams will require an investment of $21 billion to be repaired [1]. This figure will increase by 2020 when 70% of the total dams in the United States will be over 50 years old, which is more than the maximum service time these dams were designed for. If we were able to lower the figure of the required investment in 30%, and increase the efficiency of inspection and maintenance by up to 70%, newer project could be funded to boost the economy and people's quality of life will be considrably improved .

SUMMARY OF THE SOLUTION

Inspecting the vast number of dams requires allocating a greater portion of resources for mobilizing the inspection engineers and their tools. This is not a cost efficient model and a limits any further growth of the magnitude and scale of the infrastructure of tomorrow. What if we are able to bring the dam, the bridge, and any structure to the engineers to inspect them. What if we had a centralized center to reconstruct the infrastructures in virtual reality and let the engineers walk and fly around the structure and inspect thousands of dams in the same spot where they work.

Example, virsual reality in gaming [7]



Example, virtual reality used in gaming [3]

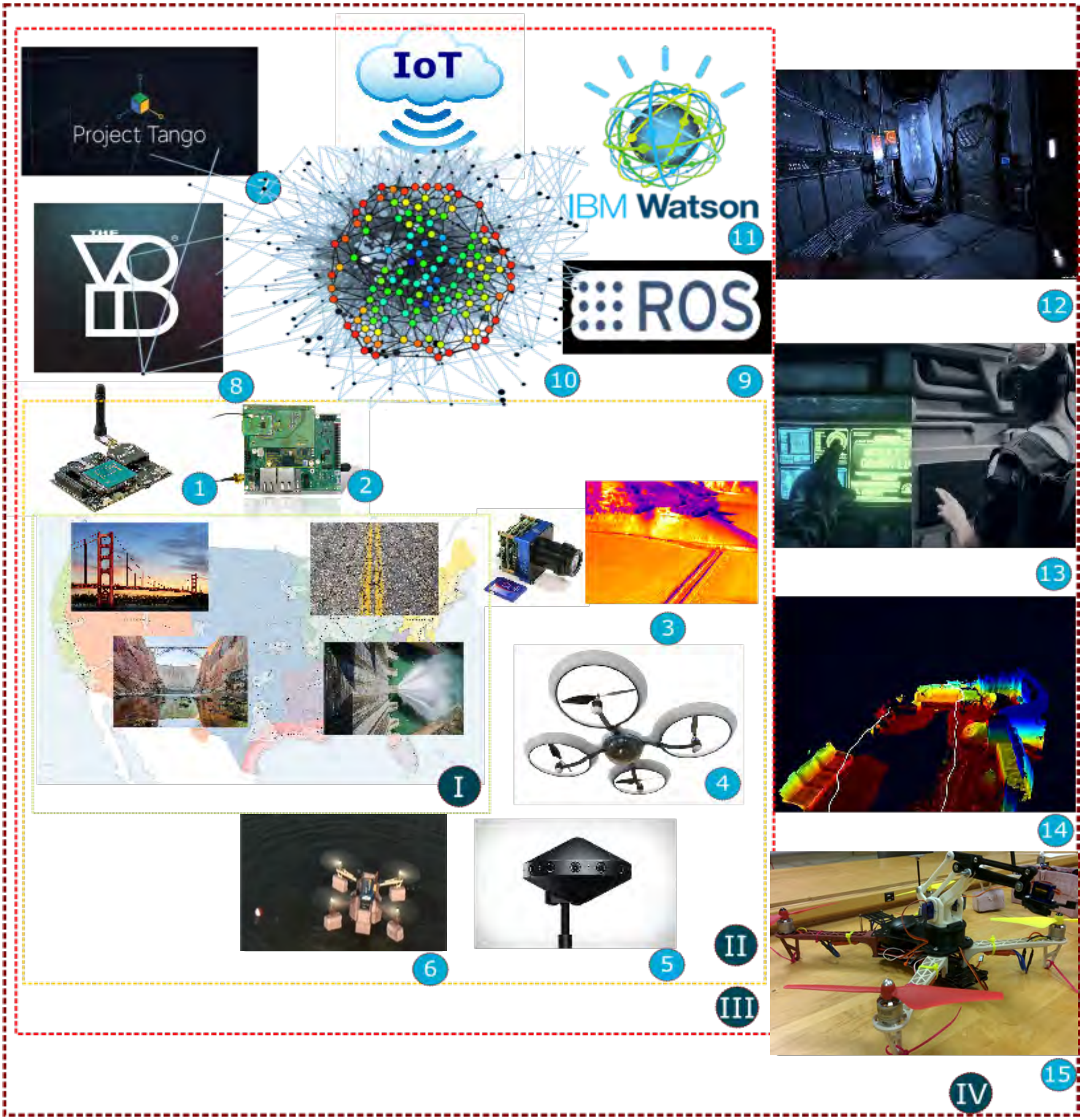
In our vision for a solution for America's dams and water resources problem in general, and for the state of Alabama in particular, we are proposing an architecture for inspecting, repairing and improving the overall safety of the dams. The objective is to revolutio- -nize the water infrastructure and reduce the cost of inspect- -ion by 70% after the second year of implementing the solution, and to lower the cost of the repairing and maintenance by 40%. We also aim to lower the time required for acquiring the data for disaster response to a real-time acquisition. We will be able to achieve theses goals by creating a centralized virtual reality center, where the engineers could inspect every single dam in the nation from a centralized location. Also, the augmented reality can be used on-site the structure to enable the engineers and workers to see the output from the embedded sensors in real time. The proposed architecture consists of 4 tiers and they are, Implementation, Data acquisition, Data processing, and Execution.

Imagine that every dam and bridge in America have a virtual reality replica and it's aided by data from sensors and with a system for a machine learning based prediction. The inspection engineers could have an avatar that enables them to fly around and inspect, in real time, these structures from a centralized location.

Example, virsual reality can also be used onsite the actual structure to help engineers read the data streamed from the sensors to the cloud [3].

Image credit imgur.com

Overall Architecture



I Implementation

The solution is tailored for revolutionizing how dams and water delivery system are inspected and maintai--ned, and that's the infrastructure where it can be implemented. However, we are inheriting a very agile approach in developing our futuristic module which enables it to be implemented in other critical infrastr--uctures such as bridges.

II Data Acquisition

Embedded sensor, thermal and radiometric camera on--board drones, 360 degree HD cameras, and water robots are all part of the main technologies that will be used for acquiring the data. These data will consist of images, and signals that will be used for reconstructing the virtual and augmented realities.

In the overall architecture figure, tier II has the following data acquisition tools,

Taking Actions
Technology of Tmowrrow, Now

credit collider.com

1. Strain sensors that are used for monitoring stress on girders.
2. Tilt sensors that are used for monitoring bearings tilt, pier movements and settling, and displacement sensors for monitoring expansion in the infrastructures
3. Thermal and radiometric cameras used for capturing the heat signature and other abnormalities in the structure, including cracks, leaks, and deterioration [15].
4. Waterproof drones used for carrying sensors and taking thermal/radio--metric images [13].(This is our proprietary robot)
5. 360 degree HD cameras used for creating the images required for reconstructing a virtual reality structure [16].
6. Underwater working robots equipped with cameras and sensors for inspecting the submerged parts of the structure [13].(This is our proprietary robot)

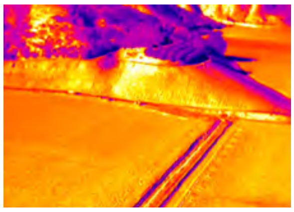


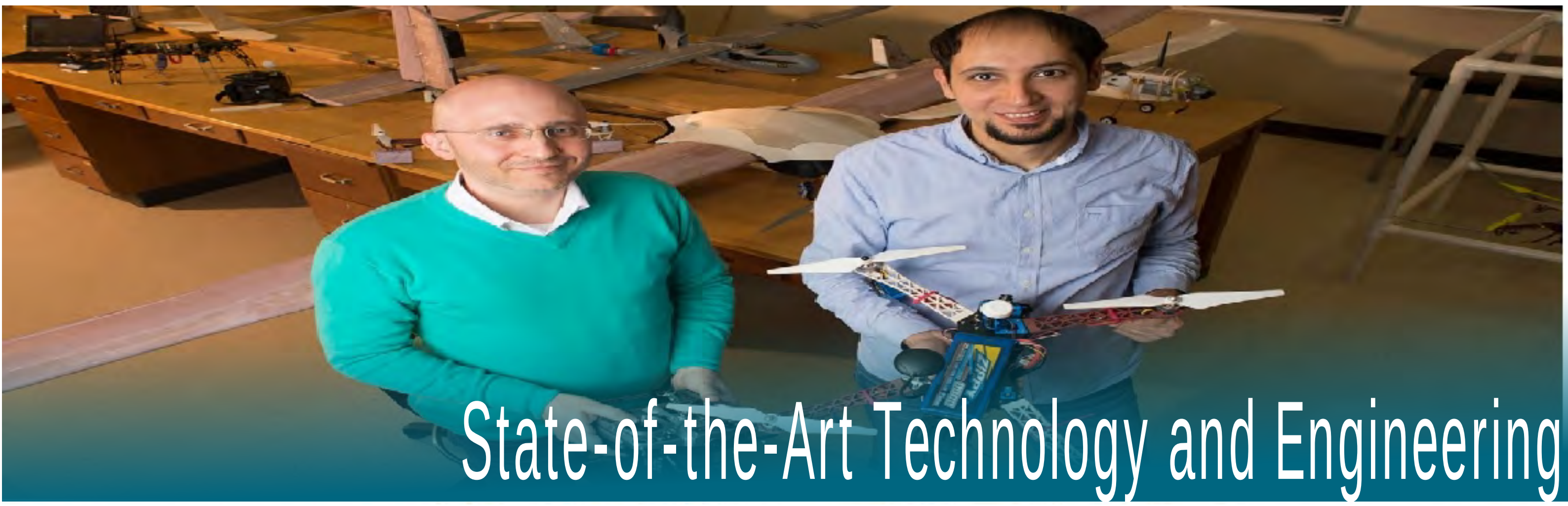
Image credit [15]

III Data Processing

In the data processing Tier III, there is a cloud that runs several services that are required for processing, storing, and reconstructing the data and information. This layer includes more sophisticated techniques for event prediction and classification. It uses data-fusion and a variety of machine learning algorithms to enable classification of the processed data from Tier II into discrete actions in real-time and with high accuracy. This information can be used to make predictions for dam failure and other potential risks. Therefore, the cost of mitigating structural abnormalities will be substantially reduced. The cloud services also processes and stores the captured HD images for creating virtual reality replicas for the centralized inspection center. The cloud in this tier runs four services,

Image credit [16]

7. Project Tango [5] is used to bring augmented reality to the mobile devices that the engineers will use for inspection. The virtual structure is constructed by using Motion Tracking, Depth Perception, and Area Learning. The inspection engineers can point their mobile devices at any structure within the dam and get an accurate reading of the embedded sensors in real time. By using machine learning, discussed in 10, a prediction of the future state of the inspected area will also be displayed.



State-of-the-Art Technology and Engineering

Credit [5]

8 By enabling a virtual reality engine on the cloud, the HD images that are captured using (5) will be reconstructed. The VOID [3] is one example of many virtual realities that are currently under-development and it could be used for this task. The mapping of the infrastructure can be so precise and accurate because it's aided with sensor readings and machine learning predictions that can reveal issues otherwise won't be observable to the naked eyes.


Credit [3]

9 Components from the Robot Operating System (ROS) [6] will run on the cloud in order to control the robots used for scanning and fixing the dams. These robots are programmed to autonomously accomplish their tasks and charge themselves when they run out of power.

10 The machine learning engines will be responsible for classifying events and making predictions. When important readings from the sensors are missing or when a problem arises the machine learning can help prioritize actions and aid in preparing a response plan. The machine learning agent is interconnected with 7, 8, and 9 and it can drive the robots that are used for scanning or fixing the infrastructure and ROS as the main OS

Credit [6]

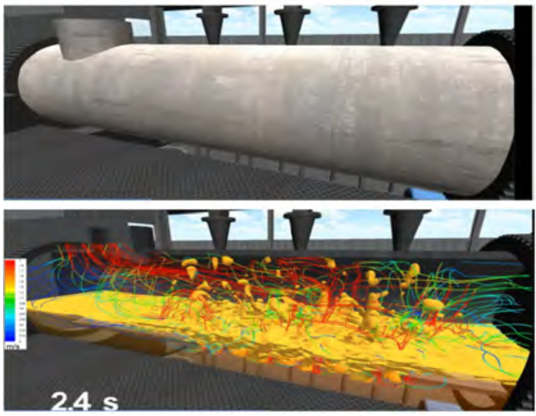
11 The IBM Watson API [10] will bring deep learning, natural language processing, and machine learning to the proposed system. It will also bring new knowledge, expert knowledge, and make machine intelligence available for the infrastructure engineers in both the augmented and virtual realities. Recently, the IBM Watson was successfully embodied in robots [11],[12].

Credit [10]

IV Execution

In the execution Tier IV, we propose an approach that has four main components. These components are designed to revolutionize infrastructure inspection, servicing, repair, emergency response and planning.

12 The first component is a centralized virtual reality center that is used to reconstruct the scanned infrastructure and display the sensors' data in a visual format in both the virtual and augmented realities. This method is expected to lower the cost of inspection by 70%, and will also provide major improvements in emergency response and other areas that will emerge after implementing this component.

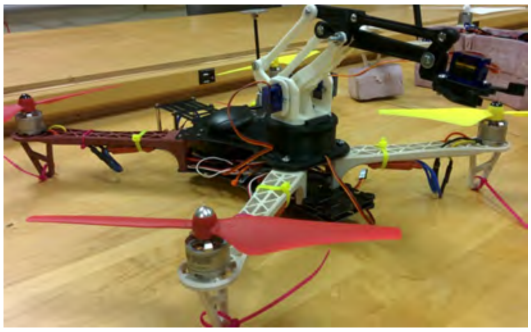


VR is bringing a new era for engineering [17].

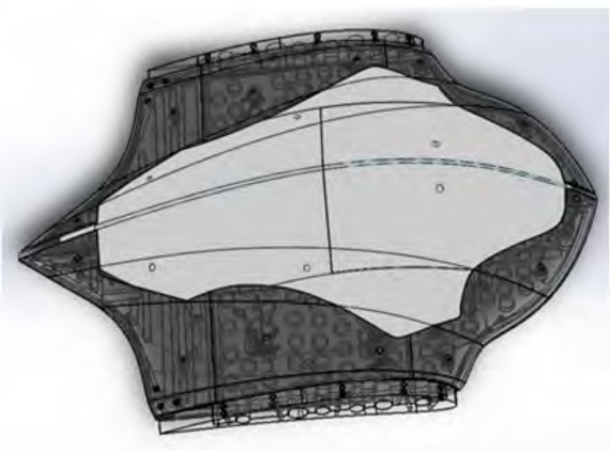
13 Augmented reality on the other hand can be implemented on the inspection site. This component will enable the engineers to see visible cues from the reconstructed graphics on their personal devices. It will change how the on-site inspection is managed and will also reduce both the time required for inspection and the human errors in reading and collecting data.


A prototype of a multirotor drone designed by Team UAH [14].

14 The sensors data and the thermal/radiometric images can be reconstructed as a 3D model using the project Tango agent. This model can be used to give the robots the data that they need to navigate inside the infrastructure even in a GPS deprived area. Also, it gives the inspection engineers a third eye into what is hidden inside the walls and could be detected by the sensors. This component is vital for the infrastructure repair and maintenance for the deployed robots and it has been implemented recently by Boston Dynamics [8].


A 3D printable robotic arm drone prototyped by Team UAH .

15 The submarine robotic drones that we are developing are designed for two main tasks, to scan the dam and to report issues found in areas that are hard to reach for humans.It also executes tasks such as remote fixing and service. We designed the robot to enable it to live on the sea floor, and carryout cleaning and keeping check on undersea equipment.
Also, it can float on the surface of the water and autonomously scans the dam and the water pipes and drop sensors in hard to reach areas [13].


A 3D printable submarine robot drone designed by Team UAH .

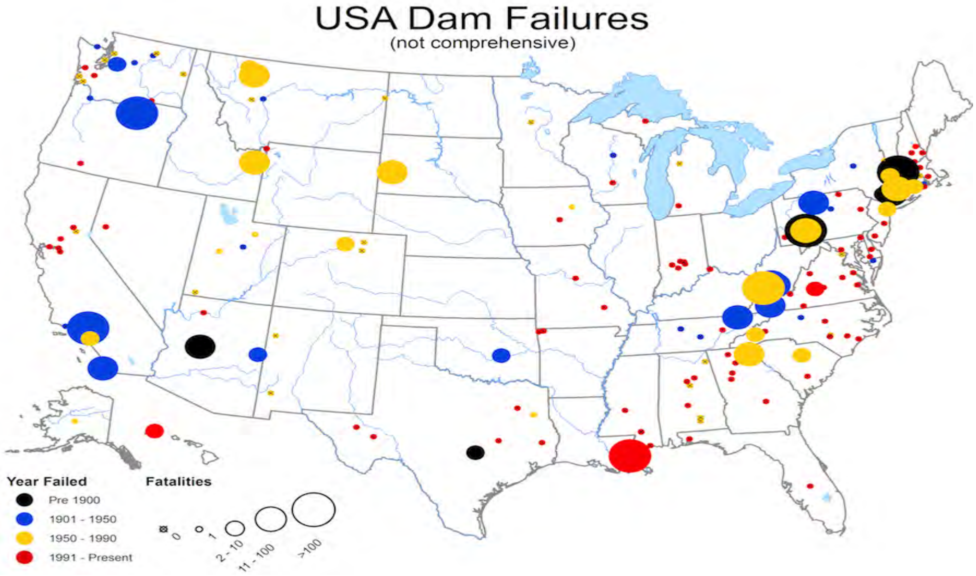
Overall Metrics

Safety

Cost

Reliability

Environmental sustainability



Map prepared by James S. Halgren, Office of Hydrologic Development, National Weather Service, National Oceanic and Atmospheric Administration, based on data complied by the Association of Dam Safety Officials.

Credit cbc.ca

Our proposed solution is technology focused and forward-looking and It must meet four over-arching goals: Safety, reliability, cost and environ--mental sustainability. It must be measurable and accountable.
We will have succeeded, when we meet and exceed these goals,

Safety, increase the safety of the U.S. infrastructures and reduce the fatalities and eliminate failure or collapse due to lack of maintenance and structural flaws.

Reliability, the system must be reliable in reporting data and in providing the engineers with a robust tool. The machine learning, predicting and the autonomous robots involved in maintaining the infrastructure must have zero error otherwise human lives will be lost.

Cost, we determined our goal of reducing the inspection cost by 70% and the maintenance cost by %30 after the second year of implementing the system.

Environmental Safety, the infrastructure of the future must coexist with nature instead of working against it. Furthermore, the U.S. has 900 [18] mining dams that were built to block hazardous materials from mining and human activity. The collapse of these dams could have catastrophic impact on the environment. Our goal will be achieved if we were able to prevent the collapse of these dams.

Credit Pixabay, public domain

The Public Library (center right) Ground Transportation Center, (left) and the Cedar Rapids Science Station (bottom left) in downtown Cedar Rapids (Perry Walton/P&N Air)

In Alabama

Provide the required inspection data for Alabama's dams to make the state eligible for federal funding. Lack of data is blocking Alabama from receiving these funds.

Have all High Hazard dams, including privately owned ones, in Alabama equipped with the technology that we are proposing to address potential collapse and protect people living in the dam break inundation zone. Alabama lacks statistics on the numbers of people who live in dam failure inundation zones, but those people are completely unaware of the potential hazard lurking upstream.

Enable the engineers to inspect and fix the vulnerable dams remotely without allocating huge resources for logistics that the state may not be able to afford.

In the U.S.

The solution that we are proposing is expected to have the highest impact on these four areas

Population, in the U.S. millions live downstream from dam failures. An advanced inspection and warning system is vital for this population, especially to minorities, elderly people, and depressed communities that are incapable of escaping the area within the needed time frame.

State facilities, all state facilities in the dam failure inundation zone are vulnerable to damage

Critical facilities, all critical facilities, Utilities such as overhead power lines, cable and phone lines, and transportation infrastructures in the dam failure inundation zone are vulnerable to damage.

Economy, Damage to buildings, farms, properties can impact a community's economy and tax base, water and food supply, and affect all aspects of life.

Impact

Population

State Facilities

Critical Facilities

Economy

The Team that Can Build the Technology of the Future For America's Infrastructue

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http://www.waaytv.com/videos?autoStart=true&topVideoCatNo=default&clipId=12401274

http://www.waaytv.com/tech_alabama/uah-students-look-to-address-alabama-s-lack-of-dam/article_07411e8a-0e37-11e6-a045-0ff67bd4e60c.html

https://www.uah.edu/news/campus/team-uah-eyes-next-phase-of-infrastructure-challenge

https://www.uab.edu/mix/stories/in-the-lab-these-drones-are-made-for-fishing-dam-patrols-and-globe-trotting-rescue-missions

References

[1] Grade Sheet: America's Infrastructure Investment Needs, http://www.infrastructurereportcard.org/a/#p/grade-sheet/americas-infrastructure-investment-needs., 2016. Web. 13 Feb. 2016.

[2] "Robust Inspection Program Keeps Focus On Safety At Alabama Power, Hydroelectric Dams - Alabama News Center". Alabama News Center. N.p., 2016. Web. 15 May 2016.

[3] "The Vision Of Infinite Dimensions | THE VOID". Thevoid.com. N.p., 2016. Web. 1 3 May 2016.

[4] "Eelume Looks Like An Alien Killer Robot, But It Actually Helps Humans Maintain Undersea Equipment". Tech Times. N.p., 2016. Web. 13 May 2016.

[5] "Google's Project Tango". Google. N.p., 2016. Web. 20 May 2016.

[6] "ROS.Org | Powering The World's Robots". Ros.org. N.p., 2016. Web. 22 May 2016.

[7] "Voice Of America Features: Project Blueshark". Projects.ict.usc.edu. N.p., 2016. Web. 20 May 2016.

[8] "Boston Dynamics: Dedicated To The Science And Art Of How Things Move.". Bostondynamics.com. N.p., 2016. Web. 23 May 2016.

[9] "Workswell WIRIS - Product - Thermal Camera For Drones". Workswell WIRIS - thermal imaging camera for drones. N.p., 2016. Web. 24 May 2016.

[10] "IBM Watson Developer Cloud". Ibm.com. N.p., 2016. Web. 28 May 2016.

[11] J. G. Wolff, "The SP Theory of Intelligence: Distinctive Features and Advantages," in IEEE Access, vol. 4, no. , pp. 216-246, 2016.

[12] Statt, Nick. "Hilton And IBM Built A Watson-Powered Concierge Robot". The Verge. N.p., 2016. Web. 28 May 2016.

[13] Leder, Travis. "UAH Students Look To Address Alabama's Lack Of Dam Inspections". Huntsville News | WAAYTV.com and ABC 31. N.p., 2016. Web. 28 May 2016.

[14] Windsor, Matt. "The UAB Mix - In The Lab: These Drones Are Made For Fishing, Dam Patrols And Globe-Trotting Rescue Missions". Uab.edu. N.p., 2016. Web. 28 May 2016.

[15] M. Aghaei, A. Gandelli, F. Grimaccia, S. Leva and R. E. Zich, "IR real-time analyses for PV system monitoring by digital image processing techniques," Event-based Control, Commun--ication, and Signal Processing (EBCCSP), 2015 International Conference on, Krakow, 2015, pp. 1-6.

[16] "Facebook Surround 360". Facebook360.fb.com. N.p., 2016. Web. 29 May 2016.

[17] Supporters, Parents et al. "Research - Center For Innovation Through Visualization And Stimulation". Centers.pnw.edu. N.p., 2016. Web. 29 May 2016.

[18] M.P. Davies, ”Tailings Impoundment Failures: Are Geotechnical Engineers Listening?” Geotechnical News, September, p. 31-36, 2002

Disclosure

In the proposed solution, there are components that rely on third party development kits and software, which is either, 1) open source, e.g., ROS, or 2) offered for integration and development with an SDK or an API, e.g., IBM Watson and project Tango, and 3) proprietary e.g., The VOID. The latter is presented as an example and the authors were given credits and cited in the references.

InfinitPipe®

A Breakthrough for the Pipeline Infrastructure Construction and Repair Industry

Mo Ehsani, PhD, PE, SE

Bahira Abdulsalam PhD EIT

Patent Pending Application by Prof Mo Ehsani

Moving the worlds infrastructure forward

Abstract

InfinitPipe ® is a great unique composite pipeline product. The product road map will be focused on a simple powerful idea based on InfinitPipe ® a patent pending application. The simple nice model of onsite manufacturing of composite joint less InfinitPipe®.

InfinitPipe® is the latest revolutionary product developed by Professor Ehsani that allows construction of a pipeline of virtually any size and shape on-site! Most pipes manufactured to date require extensive heavy equipment that necessitates manufacturing in a plant. The pipe sections are typically made in pieces and shipped to the job-site for assembly in the field. This adds significant transportation and installation costs. Worst of all, joints are the weakest link in the pipe where water, gas or oil can leak and cause environmental damage. For sewer pipes, these joints become a source of penetration of roots and a constant maintenance expense. This pipe is corrosion resistant, stronger than steel and light weight. Manufactured onsite with no joints.

Our technology is mainly concerned about environmental protection, high efficiency, green industry and lower carbon foot print. Our team of engineers and professional is extremely excited about the strategy of the company. Innovation is our key aspect and we are focusing on what the customer needs. *InfinitPipe*® will be custom designed and fabricated to satisfy the pressure and loading requirements of each project on a case by case basis. This will not only allow catching up the Industry, it is rather breaking a new ground in pipeline Industry which is planned to happen in the coming few months. InfinitPipe® is a great innovation that needs investment and caring. Our target is not to provide only a new innovative solution to overcome pipeline problems for Pipeline construction and rehabilitation. However we need to clarify the point that through this invention we honor environmental protection efforts and green industry. Our core value to move forward with this innovation from dream to reality is that we believe that people with passion can change

the world forever. “Those people who are crazy enough to change the world are the people who actually do”. We honor those people who are working hard to change the world and move it forward. To transfer this dream into reality **InfinitPipe®** Company will be established. Figure 1 shows the first prototype of the mobile manufacturing unit of **InfinitPipe®**.

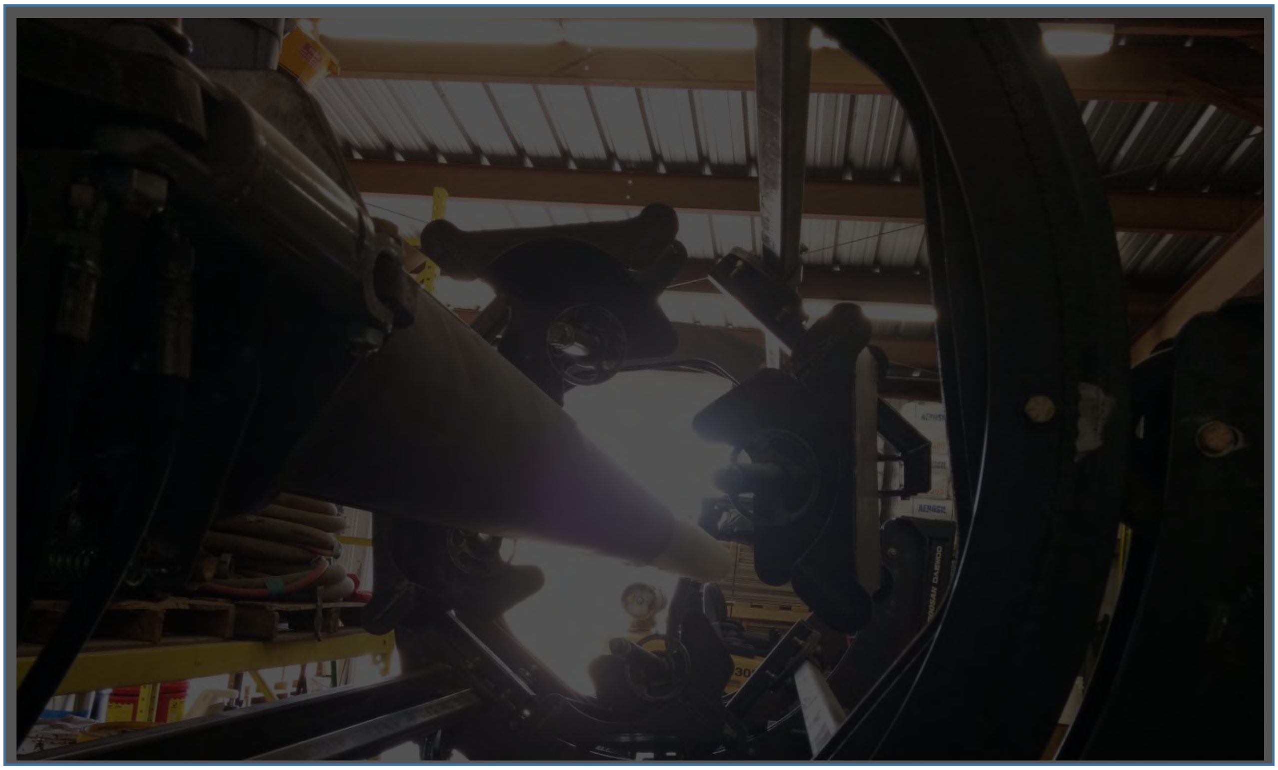

Figure 1 First Prototype of the MMU (Mobile Manufacturing Unit) InfinitPipe®

InfinitPipe® Company Description

InfinitPipe®, Inc. is a leading designer, supplier, and installer of Infinite Pipes Fiber Reinforced Polymer (FRP) for pressure and non-pressure and repair applications. The company is also a pioneer research and development firm committed to providing economical solutions and unparalleled pipeline services to engineering projects and pipeline agencies. The company is based in Tucson Arizona USA. Our staff includes structural, geotechnical, pipeline and mechanical engineers and composite material specialists who team with each client to develop customized solutions to complex pipeline challenges. We have the experience, knowledge and tools to take on your toughest technical challenges and deliver the right answer. InfinitPipe® will be serving various markets all related problem solving related to technology is what we do and what we deliver. It is our commitment to provide the most comprehensive design, analysis, and manufacture a custom made pipeline product with an unsurpassed level of engineering integrity innovation and skill. This devotion to quality stems from the two basic principles on which the company was founded - technical excellence and a passion to serve.

The nature of this business is composite manufacturing of InfinitPipe® which is manufactured onsite. InfinitPipe® is an innovative patent pending technology that introduces a new concept in pipeline manufacturing industry, which attracts attention from various industries. It provides all the well-known advantages of composite materials and adds to it constructing a joint-less composite pipe onsite. The prototype machine for manufacturing InfinitPipe® machine can provide multiple advantages and can help overcome multiple challenges.

InfinitPipe® business is composed of two main aspects. Mobile Manufacturing Unit used to manufacture the pipe (MMU), the pipe design and construction, tests required to verify the effectiveness of the design and constructed pipe to make sure that the pipe meets the required structural and physical properties. Those tests should be perform according to the Standard specifications accepted by the sector that the pipe will be used and the zone were the project will be constructed. There are many aspects were this type of pipe can satisfy the needs of various construction sectors and applications. The pipe can be used either for the slip lining applications to restore the original capacity or even exceed the original capacity of a deteriorated pipes. Or to construct a new pipe that is designed to withstand various loading and environmental conditions. The fact that the pipe is joint-less will reduce the construction time significantly as well as reducing the risk of leakage through pipe joints that usually happens for traditional pipe construction techniques.

InfinitPipe® Business Plan Outlines

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Key infrastructure metric

In a global scenario of rapid urban growth and climate change, **energy supply** (i.e. generation, storage, distribution of energy) becomes an highly sensible matter from which will depend the quality and efficiency of future dense urban settlements. On one side, the current global environmental awareness roused the necessity to change radically the energy supply system, abandoning the non-renewable sources as main power sources. On the other side, the growth and densification of the contemporary cities will require in the future an increased resiliency. Among different aspects to be considered, this reflects in the necessity to provide a more stable power supply, that currently can't be guaranteed relying exclusively on renewable power sources. In a global scenario for 2050, where 70 % of the 7.1 billion people in the world will live in urban environments[1], a reduced capacity in providing a stable power supply will reflect in an higher fault risk for services and infrastructures, with increased economic losses in case of temporary blackouts, and possible catastrophic situations for the cities in case of prolonged blackouts.

Approach to the problem

Why a change in the energy supply system is needed?

Energy supply, from the industrial revolution to date, has been mainly based on fossil fuels exploitation. Fossil fuel combustion accounted in 2010 for 76 % of the total anthropogenic Green House Gasses (GHG) emissions, which have been recognised as the main cause of Global Warming (GW) in the last 250 years[2].

Urbanization is the major driving force of the contemporary scenario, in fact, as per 2006 data, energy demand in urban areas was around **71 % of the Global energy demand**, and CO2 emissions from these areas were around 73% of the Global energy-related emissions[3].

The actual global consciousness of the problems and risks related to GW, with the subsequent intake of responsibility for the consequences of anthropic GHG emissions, is leading stakeholders at all levels, from policymakers till final users, toward an epochal change of the energy supply system, from fossil-fuel based, to renewable-sources based. The COP21 agreement, signed by 195 countries in 2015, is just the last striking proof of the consolidation of this trajectory in the global policies. The increasing stock quotes value of private companies as Tesla Motors® [4], and similar, could be interpreted as a further evidence of the current growing confidence of the market toward the development of tangible alternatives to fossil-fuel based systems.

Is urbanization an obstacle or an opportunity to enhance the change?

Accounting for **positive scenarios of economic and demographic growth**, i.e. excluding catastrophic scenarios for the world's population, urbanization is unlikely a problem that could be excluded from the equation[5]. If urbanization can't be avoided in a positive scenario, then a **smart densification of the cities is a most desirable urbanization trend**, in order to mitigate its effects on GW. Smart densification means:

- an optimization of the land use to not compromise food-productive grounds and water sources

[1] IPCC, Fifth Assessment Report (AR5), 2014
[2] ibidem
[3] "In 2006, urban areas accounted for 67 – 76 % of energy use and 71 – 76 % of energy-related CO2 emissions" cit. IPCC AR5, Mitigation Measures: Summary of Policymakers, 2014, p.25
[4] Tesla Motors Inc (TSLA:US) stock quotes raised from around 25-35$ in 2012-2013, to 200-250$ in 2015-2016 (http://www.bloomberg.com/quote/TSLA:US)
[5] For global scenarios of urban growth and climate change see IPCC AR5 Mitigation Measures Summary of Policymakers, 2014

- an improvement of efficiency of transport systems, particularly of mass transport systems, in order to reduce the energy use while increasing people's mobility in the most dense environments
- an improvement of energy efficiency of buildings through all their life cycle (e.g. through passive design, re-use or improvement of existing buildings, improvement of construction technologies and construction processes, etc.)

While these mitigation measures are main objects of discussion in the current debates of urban policymakers, the possibility to use **urbanization as a catalyst of positive effects** toward the change of energy supply systems is a minor object of debate, and still fairly unexplored as realistic possibility of development. Cities and energy supply systems are usually considered as physically separate systems, where the seconds can be considered an extension of the firsts, but not vice versa. In fact, is it possible think a city as an extension of an energy infrastructure? Is it possible to inhabit a power plant?

To date, projects to implement a large scale renewable-energy generation capacity inside the cities has been discussed worldwide mainly as theoretical scenarios[6], with few isolated examples of practical applications, still at an early stage of development (e.g. Masdar City, Sonnenschiff and Solarsiedlung, Dongtan City, etc.). The impact of those projects in a global scenario is still minor and not comparable with the impact of big power plants harvesting the renewable-energies of sun and wind, installed in the countryside or in the deserts, or offshore, promoted in the last years by regional planning policies worldwide.

Power-plant city

In 10 years, in the United States, the construction of big solar and wind harvesting plants, plus hydroelectric, geothermal and biomass plants, allowed an increasing of renewable electricity capacity from 9,4% (2004) to 15,5% (2014) of the total electricity capacity, with a generation, in 2014, of 554,040 GWh[7].

Are these efforts still enough?

The IRENA REmap study[8] enlighten how, to achieve significant results in terms of GW prevention and economic benefits in terms of reduced energy costs and employment, the worldwide **renewable energy share should double the current 18%, reaching the 36% of the total global power capacity in 2030**. However, the same authority, analysing the single countries involved, showed how US current policies will only achieve, by 2030, a generation capacity from renewables "far below the 27%" over the total, which is the optimal US goal, to r identified in the study[9].

As known, today **US are one of the most urbanized countries in the world**, with 81.6% of its total population living in urban areas[10]. Then the question is, if were possible to implement a similar electric capacity per square meter of a renewable energy power plant in US urban areas, wouldn't be possible to meet or to go beyond the goal stated by REmap?

The NREL recently published a study [11] that shows how, **in the USA, rooftop photovoltaic (PV) could generate 39% of the current annual electric energy demand**. This is considering an installed PV technology with 16% efficiency. Taking into account more efficient PV technologies and not just the rooftops as suitable surface for the installation of PV technologies but also building facades[12], urban canopies, or even the paved

[6] Jeremy Rifkin, The Third Industrial Revolution, 2011
[7] NREL, Renewable Energy Data Book, 2014
[8] IRENA, Remap: global report, 2016
[9] IRENA, REmap: United States of America - Executive Summary, 2015
[10] US Central Intelligence Agency, The World Factbook, 2015 https://www.cia.gov/library/publications/the-world-factbook/fields/2212.html
[11] NREL, Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment, 2016 http://www.nrel.gov/news/press/2016/24662
[12] International Energy Agency, Photovoltaics in Buildings, Paris (FR), 1999

surfaces, U.S. cities could generate a consistent surplus compared to the objective suggested by the REmap study.

Following these observations, then the answer is yes, power-plant cities would be more than a concrete possibility of making the change to the renewables effective in the USA.

Energy supply stabilization problem

The "power-plant city" hypothesis is still far from a possible application nationwide. At the state of the art, there are many limitations in this idea. First of all, as discussed, the hypothesis relies mainly on the harvesting of solar energy through PV technologies, but solar energy is a discontinuous source and the production patterns don't match the patterns of the electric demand. Therefore, a backup energy production from other sources would be needed, to cover completely the electric demand (e.g. during the nights, when solar energy production is null, or during the winters and the overcast days, when production is reduced). But, if on one side the solar potential of US cities could cover more than 40% of the national electric demand, on the other side this limitation implies that would be more effective not to rely as much as possible on solar. In that case, would make more sense to have a reduced investment on PV installations, to be able to invest on other sources, to have a balanced national energy production.

There is another possibility, that is invest enough to take the maximum advantage of the solar resource from the cities, to **provide a large scale energy generation capacity and at the same time an adequate energy storage capacity**, to distribute better over time the energy generated. Now, the storage of electric power requires processes of transformation that not only cause an additional cost to the implementation of PV in the cities, but also imply a certain amount of energy losses, in fact, none of the current storage technologies is 100% efficient[13].

Therefore the question remains: even if the renewable energy potential of the cities is acknowledged, is it worth to transform radically the urban environment to try to make the most of it despite the current state of the technology?

Win-win strategy

The city works as an hyper-connected system of anthropic processes where different human ideas and actions influence each other as in an ecosystem. Differently from the development of a power plant on the desert, the development of a power-plant city would affect not just the national energy generation but also the qualities of the urban environment. If we **take advantage of the diversity and the interconnection of the urban environment**, then there would be the possibility to balance the current technological inefficiencies of the renewable-energy supply system with the indirect benefits that the city could gain, in the long-term, from the transformation into power-plant.

Because the technology efficiency is constantly increasing (with different growing rates over time though) becomes a secondary objective in a long-term perspective, whereas the main objective should be to **amplify the benefits of the change** and create new "ecological niches" in the urban ecosystem.

Therefore the research question is: Acknowledging the renewable-energy potential of the cities, how to provide a base for the transformation of the city into a power-plant city, which would allow to make the most of these resources, without being limited by the inefficiency of the current technologies and enhancing instead the evolution of the renewable energy supply system?

[13] I. Hadjipaschalis et al., Overview of current and future energy storage technologies for electric power applications, 2008

Proposal

Here a schematic urban model that, leveraging the transformation of industrial/commercial areas and the improvement of the mass transport systems in the city, aims to provide a basic infrastructure for the production, storage and distribution of renewable energy inside the city.

Urban transformation and generation of energy

Cities' industrial/commercial areas are typically planned as mono-functional zones, occupying extensively portions of land with low rise buildings, large asphalt surfaces dedicated to the mobility on wheels and to open air storage of goods, scarce presence of vegetation, scarce walkability. These characteristics makes them hardly embeddable in a dense urban environment and the city usually grows around them as a discontinuous structure.

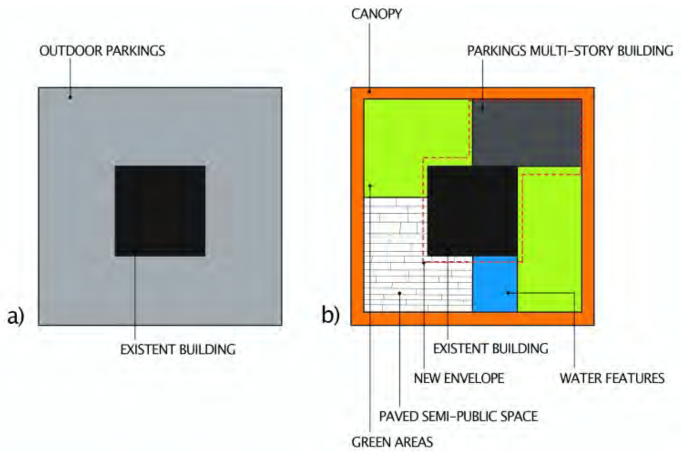

Fig.1 Clear distinction between industrial/commercial (I/C) areas and residential (R) areas in San Francisco
Fig.2 Typical configuration of industrial/commercial urban block (a) and proposed scheme of urban reform (b)

When the pressure of the city around these areas increases, and the values of the land rise, the industrial activities starts to be dislocated and replaced by mixed-use medium to high rise buildings. The willingness to improve the quality of the existing industrial/commercial environment to fit the standards of the mixed use urban fabric and to enhance the value of the new buildings causes an additional cost of urban structure reform.

Moreover, the current typical characteristics of these areas, plus the residual anthropogenic heat of industrial and commercial buildings increases the overall Heat Island effect of the city (UHI), affecting the cooling loads for the buildings surrounding the industrial areas[14].

Nevertheless the large roofs and walls of the industrial/commercial buildings (usually concrete or steel opaque structures) are optimal surfaces for the installation of PV mono-crystalline Si panels, which currently is one of the most affordable and efficient solar cell technologies[15]. The opacity of the cells, which is a weakness for some building integrated PV applications, in these buildings would reduce the exposed surfaces with high thermal inertia, therefore would help to counteract the UHI effects discussed before.

[14] S. Kato, Y. Yamaguchi, Analysis of urban heat-island effect using ASTER and ETM+ Data: separation of anthropogenic heat dischargeand natural heat radiation from sensible heat flux, 2005
[15] M.A. Green et al., Solar cell efficiency tables (version 45), 2014

In a recent study, developed by the author in collaboration with the University of Auckland[16], is analysed a possible implementation of this technology within a scenario of urban reform of the industrial areas of Christchurch (New Zealand), which are very close to the structure and form of the industrial/commercial areas of the American cities. The study proposes and tests the energy output of an hypothetic future urban scenario informed by a series of **planning measures to improve the quality of the urban environment** (Fig.2).

The measures aim at a more articulated strategy of mitigation of UHI effects, which would have immediate impacts on the city. On the long term, in a future perspective of city growth, the measures would allow a densification of these areas with a reduced cost for urban reconversion from industrial/commercial to mixed use.

These planning measures include:

-the reconversion of the paved areas for parking to green areas

-the relocation of the existing parking spaces in multi-storey structures that could be reconverted to other functions (e.g. small commercial or residential) with minimal efforts

-the implementation of energy-generating skins in the existing buildings and in the proposed multi-storey parking buildings

-the development of energy-generating canopies as urban visual features, able to optimize the direct sun radiation over the outdoor paved surfaces while increasing the walkability of the area through sheltering from wind and rain.

The following tables describe with few parameters the formal impact of these planning measures over an industrial/commercial **test area**, of around 4.8 hectares (ha), in the city of Christchurch (New Zealand) [17]:

TABLE 1: urban transformation

	Existing	Proposal
Floor/Area ratio	0.46	0.99
Outdoor paved surfaces	2.77 ha	0.57 ha
Green areas	0.33 ha	1.98 ha
Building Envelopes (roof+walls)	2.76 ha	3.88 ha
Canopies	-	1.14 ha

TABLE 2: resources for new urban niches

Electricity harvested in a year (calculated through a computer analysis of the annual solar radiation in the area, and considering a PV technology 20% efficient, covering 90% of the roof surfaces and 40% of the facades surfaces)	70.26 GWh (total) 14.64 GWh/ha
Water harvested in a year (considering an annual total precipitation of 648 mm/m^2)	216,000 m^3 (total) 45,000 m^3/ha

[16] A. Melis, A. Figg, E. Lisci, T. Auer, Urban strategies for achieving positive development in Christchurch (New Zealand) through a new infrastructure system for a region of the inner city, 2015

[17] The data are extrapolated from the dataset of the Christchurch model; see Melis et. al. for a detailed explanation of the calculations methodologies.

How to make the most of the harvested resources?

Looking at the data of the test area, 10 ha of a similar intervention would be able to generate as much as a 17MW coal power plant running 24h/day all year and emitting 49 Gt of CO_2 in the atmosphere[18].

This is just considering the installation of a PV layer, i.e. without considering the possibility to harvest other types of renewable sources e.g. the wind energy, through a technology as Windbelt™ or similar, or the piezoelectric energy, through a technology as Pavgen™ or similar. But the question is how to stabilize this amount of energy generated to evenly distribute it during the year.

The idea is to take advantage of electricity and water harvested from the roofs at the same time, to store the energy. Water is a perfect renewable medium for storage on a medium-large scale.

The first possibility would be to pump, with the produced energy, the harvested water on large dams and generate energy when needed through hydroelectric plants. However this option would imply to dislocate large amounts of water outside the cities, in places suitable to such hydroelectric dams, which are difficult to find everywhere, e.g. in regions which are almost flat. And also not from all the cities is possible to harvest large amounts of water.

The second possibility would be to split, with the PV electricity, the water molecules through water-electrolysis, producing Hydrogen. At the state of the art of the technology **water electrolysis systems can reach an efficiency of 45-50 % in the production of the hydrogen**[19], which means that around 66 kWh are required to produce 1kgH[20]. However, in all the cities can be harvested even little amounts of water (theoretically, around 9 litres of H_2O are required to produce 1 kg of H), and all the places are suitable to store hydrogen, even the flatlands.

Hydrogen as energy storage medium

There are **limitations** in the use of Hydrogen as an energy storage medium, in fact the technologies to reconvert H to electricity add a further energy loss. **Hydrogen fuel cells have today an average efficiency of that ranges between 50% and 85%**[21]. This means that after the water electrolysis, the compression and stocking, and the reconversion to electricity through fuel cells, we can get just approx. ¼ of the electricity that we have tried to store[22]. This makes it not competitive in small applications, because batteries are much more efficient. But on medium-scale applications, **where batteries can't be used**, because they don't have enough electric capacity, or because they recharge too slowly, H produced through water electrolysis becomes the most sustainable alternative to fossil fuels.

Medium-scale applications are e.g. on-site distributed generation, for buildings and industrial plants, fuelling for space, aviation and naval industry, on ground transportation with heavy vehicles. Power capacity and reliability makes Hydrogen an interesting opportunity to develop a **public mass transport system for dense cities**, where medium-large vehicles are required to run sometimes uninterruptedly 24h/day. Having "clean" public transport fleets in the cities would be a double goal toward the GW problem discussed initially. In fact not only the overall energy needing on the city for the mobility will be diminished, using few common vehicles instead of an infinity of individual vehicles, but also the GHGs emissions and the air pollution in the urban environment, both caused by fossil fuel alimented engines, would be reduced dramatically.

[18] Based on U.S. data, the carbon intensity coal combustion is 334.5 kg/MWh (https://www.eia.gov)
[19] Houcheng Zhang et al. , Configuration design and performance optimum analysis of a solar-driven high temperature steam electrolysis system for hydrogen production, 2012
[20] A theoretical electrolytic transformation, 100% efficient, would require 2.94 kWh to produce $1m^2H_2$ at a temp of 273 K and 1bar pressure, which would be 0.08988 kg H_2. This means 32.71 kWh/ kg H_2 are required in an electrolytic process 100% efficient.
[21] US Department of Energy, Hydrogen Fuel Cells factsheet, October 2006 https://www.hydrogen.energy.gov/pdfs/doe_fuelcell_factsheet.pdf
[22] Hydrogen have an energy density of 33.3 kWh/kg (Zittel, Werner & Wurster, Reinhold & Bolkow, Ludwig. Advantages and Disadvantages of Hydrogen. Hydrogen in the Energy Sector. Systemtechnik Gmbitt. 1996.). A fuel cell which is 50% efficient could generate 16.65 kWh/kgH, which is only the 25% of the previously discussed energy to generate 1kg of H (66 kWh/kgH).

Hypothesis of implementation in San Francisco

U.S. government is already financing research programs and projects of implementation of FCV for the mass transport in the cities. The ZEBA bus project, in San Francisco is one of these projects[23].

The following table summarizes with few data how would that be if the energy generated through an urban intervention in San Francisco's industrial areas, with characteristics similar to the test area previously discussed, was used to aliment a bus fleet in the city.

TABLE 3: hydrogen generation and use

If electricity and water harvested in the test area were converted in hydrogen and stored (considering the inefficiencies previously discussed):	hydrogen: 221,800 kgH / ha water surplus: 43,000 m^3/ha
If the hydrogen produced were used only to aliment the ZEBA busses (considering a current average annual consumption of 5040 kgH/bus):	44 bus/ha
If the entire bus fleet of San Francisco (800 busses) were FCV, could be possible to aliment them with:	18.2 hectar of intervention
If the hydrogen produced were reconverted to electricity for on-site distributed generation, with a system 50% efficient, would be possible to generate:	16.65 kWh / kgH 3.73 GWh / ha 17.9 GWh (over the 4.8 ha model)
If the hydrogen produced were reconverted to electricity for on-site distributed generation, with a system 85% efficient, would be possible to generate:	28.30 kWh / kgH 6.28 GWh / ha 30.14 GWh (over the 4.8 ha model)

A new building typology

Following the considerations on the use of hydrogen as an energy storage medium for medium-scale applications, the proposal concludes with the idea of include in the urban transformation of industrial areas structures to generate hydrogen in loco from the harvested resources. **These structures will work as building-batteries**, with the possibility either to redistribute H as fuel for a clean fleet of mass transport vehicles, or to provide back-up energy to the city through the reconversion of H in electricity.

The structures will be distributed inside the urban industrial/commercial areas according to the amount of resources produced by the surrounding resource-harvesting installation capacity. The energy generating skins and the urban canopies, will be connected to these structures to transfer the resources in the "urban batteries" with the shortest possible distance, in order to minimize the dispersion due to the grid inefficiencies.

Varies examples of hydrogen filling stations or medium-large scale fuel cells, sized to fit an urban scale, could be mentioned, e.g the 1.1 MW Fuel Cell System at Toyota's Sales and Marketing Headquarters, in California, or the hydrogen generating/filling station built in Nevada by Proton Energy Systems® [24]. However is still unexplored the possibility to integrate these types of structures within a wider urban intervention which aims to improve the quality of the urban environment, as the urban model discussed before. Also is unexplored the possibility to integrate the technology of projects similar to the cited examples, within buildings which could host other functions, and would be experienced as city landmarks or collective places. The possibility to integrate a new building typology that mixes the functionality of a medium-scale battery with architectural qualities not only would stabilize an energy supply system of a power plant city, but would also enhance the effects of a large scale urban intervention on industrial areas, facilitating the reintegration of those areas within a dense city. This idea is part of the urban win-win strategy previously discussed.

[23] NREL, Zero Emission Bay Area (ZEBA) Fuel Cell Bus Demonstration: First Results Report, 2011
[24] Mark R. Campbell et al., A Solar Powered Hydrogen Generation and Filling Station, 2008

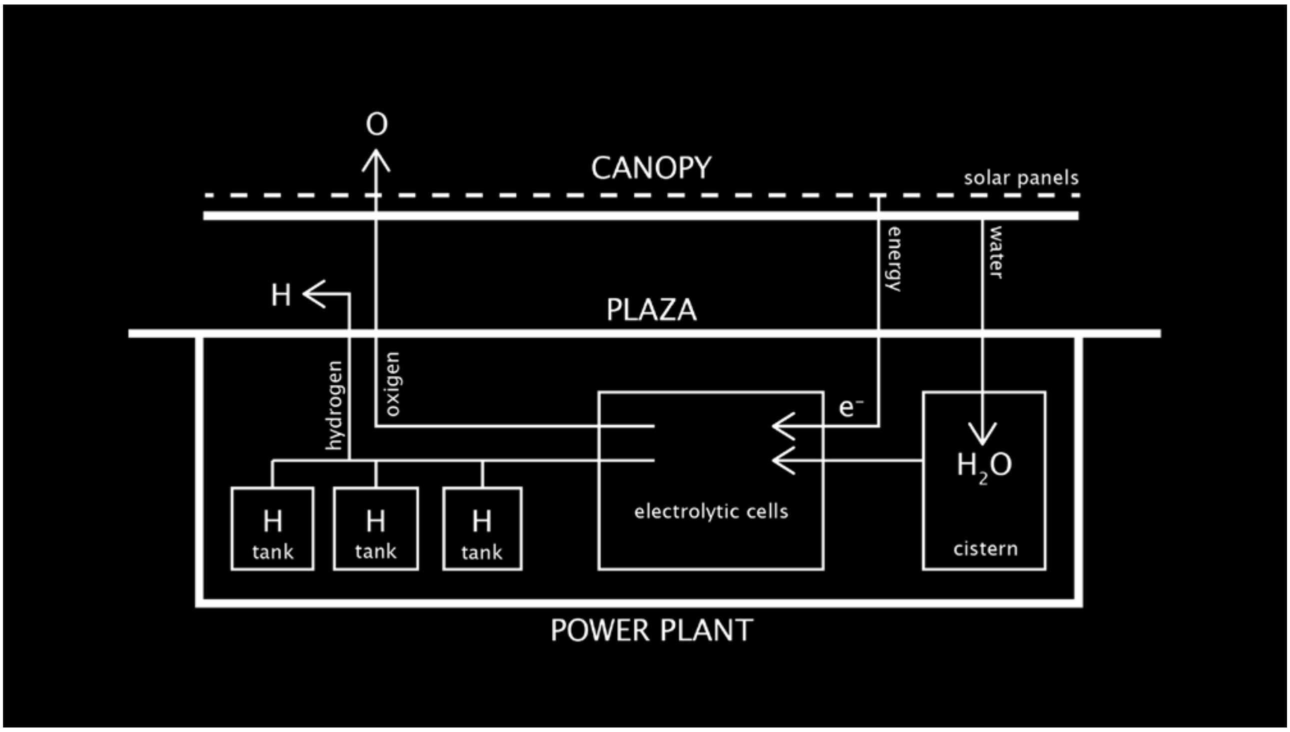

Fig.3 Scheme of building-battery

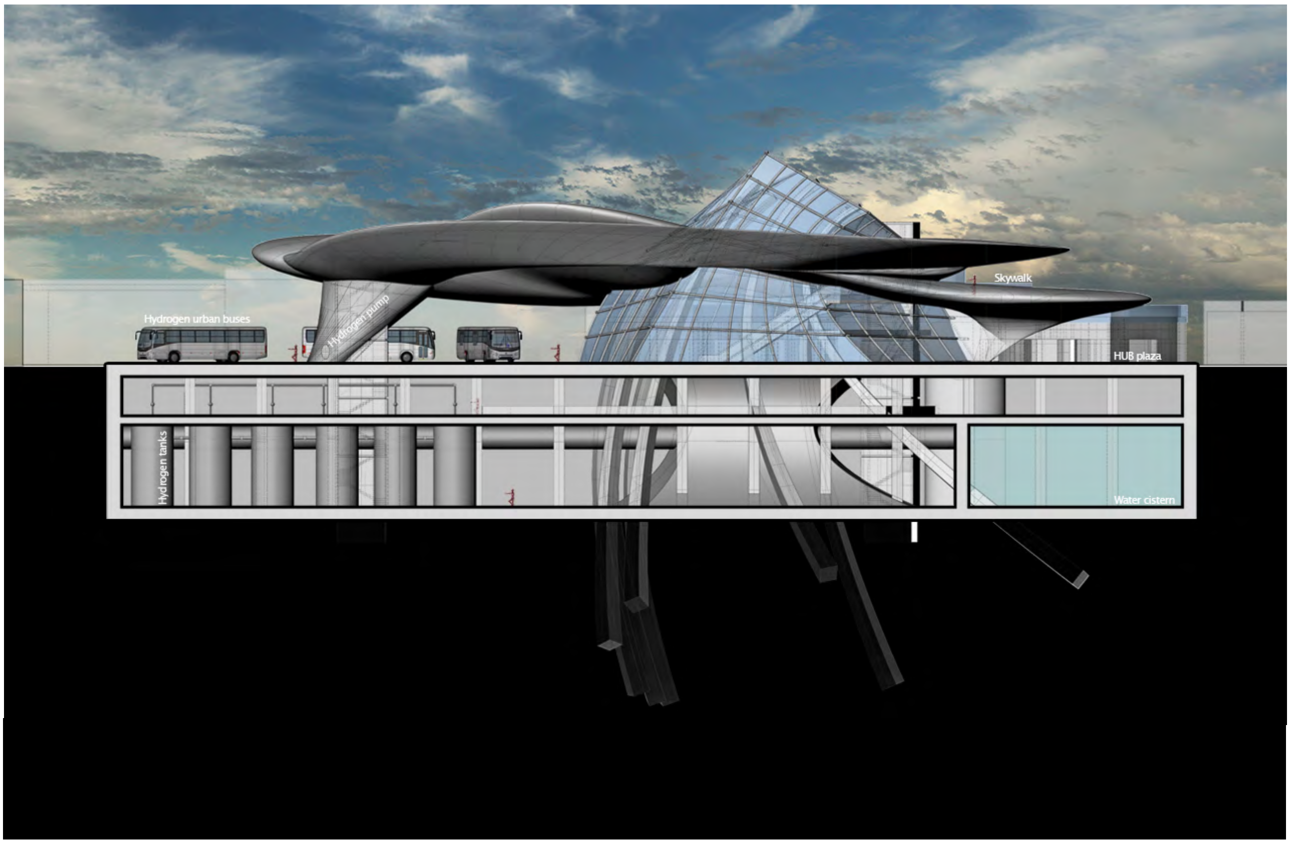

Fig.4 Functional scheme of the building-battery within an architectural form (artist impression)

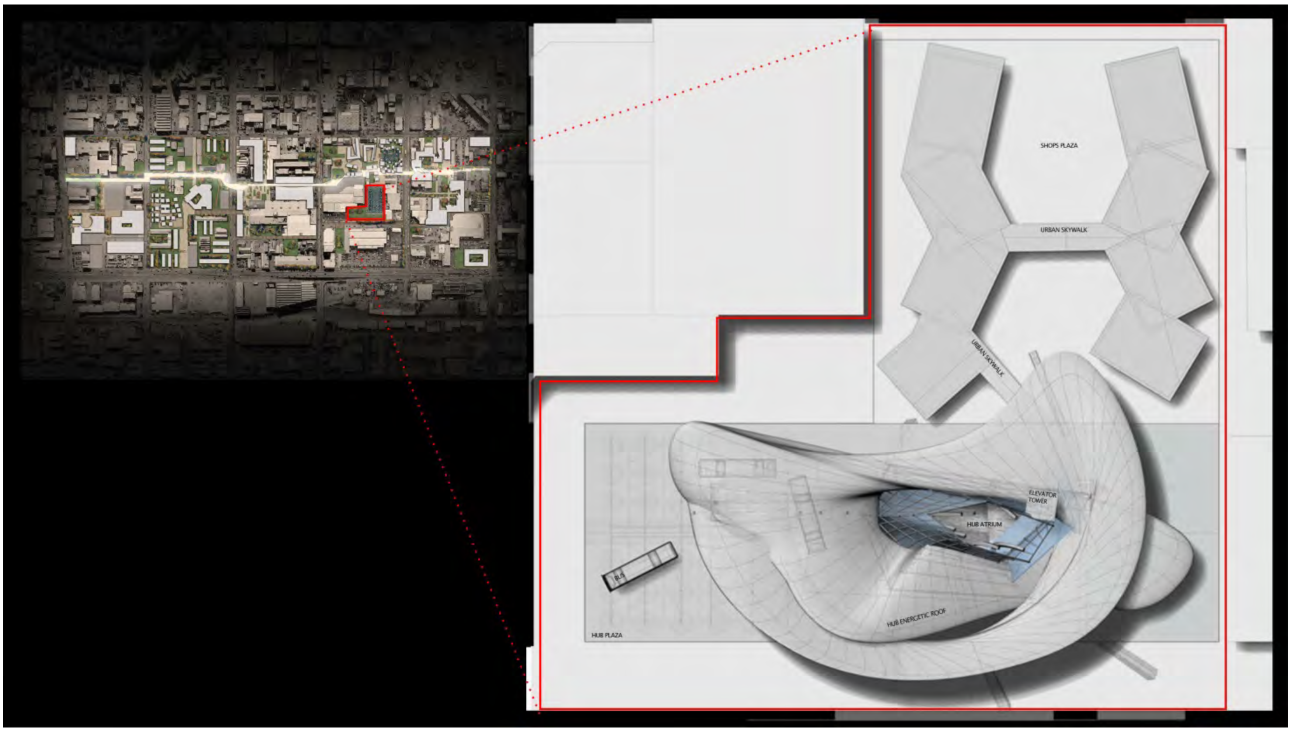

Fig.5 Integration of the proposed building typology within a commercial/industrial urban scenario (artist impression)

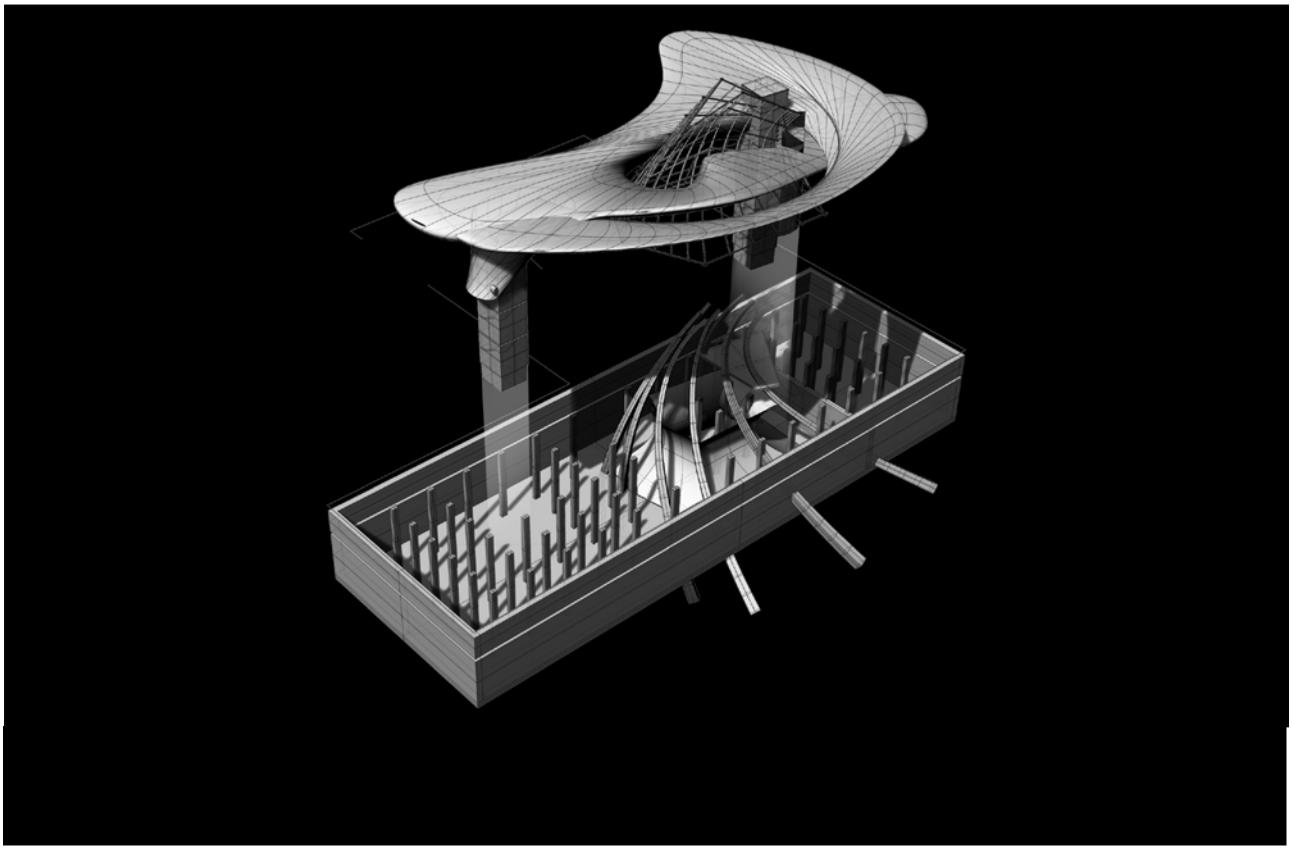

Fig.6 3D structural concept of the proposed building typology (artist impression)

Limitation of the current study and further development

The idea here proposed and the related discussion is presented in general terms which would require a further investigation in relation to real case studies.

This general proposal has the potential to be actuated in different U.S. cities, particularly those cities where the densification of the urban environment is already demanding for a reform of old industrial/commercial areas and for the improvement of a mass transport system, as well as for measures to contrast air pollution and the Urban Heat Island effects.

Once the opportunity for the development of this proposal has been found (San Francisco could be a good first case study, where an urban intervention could be developed in conjunction with the institutions and stakeholders already involved in the ZEBA bus project) the scheme of planning measures here discussed has to be expanded and adapted to meet the existing planning standards of the city.

Because this is a proposal to be developed with a long-term planning action, and because the energy harvesting technologies, as well as the hydrogen-based technologies, are being improved with an increasingly speed, the systems to be implemented as “urban batteries” needs to be discussed with specialized consultants once the project has reached an operative phase, for an overall costing and for an estimate of the energy supply scenario, expanding the data here presented as indicative only.

To conclude, the design of the buildings that will work as urban batteries will need to be discussed and adapted to the related urban context. The spatial configurations of the typology may vary to the necessities of public or private developers. If projects compatible with the idea of the building typology here proposed are already programmed, a possible integration of the “urban battery” scheme should be considered, as a strategy to amplify the benefits of the change while reducing its impacts, e.g. in terms of realization costs, land use, etc.

Air Travel Is the Future. It Needs to Be Not Miserable.

Hyper-connected cities and the art of easy travel – year 2050

HeroX Infrastructure 2050 Challenge
Anthony Barrs
Baiyu Chen
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Air travel is the future. More people are taking more flights as the world grows increasingly interconnected. The internet, which was originally anticipated to reduce the need for physical travel, has actually done quite the opposite – it has allowed people to enter a digital, globally connected world with limited barriers. This has, paradoxically, driven our desire to connect in the physical space rather than decrease it. Both people and products are crossing vast distances and borders like never before – and much of that is happening via air. In fact, since 2000, air travel has doubled[1] – and it shows no signs of abating. Air cargo has, likewise, experienced a jump in volume over the same time – almost 60%[2]; growth that occurred despite a global financial crisis and contraction in emerging economies. Air is here to stay – and it will only grow to be a bigger part of our world in the future.

But while the world has taken to the miracle of flight, the tremendous volumes of people and products passing through the world's airports have made air travel miserable, inconsistent and unreliable.

This is a problem. And it is a significant problem.

On your way to the airport, wouldn't you dread seeing this?

To understand how much wealth creation is generated by airports, one must simply look at landlocked cities like Dallas and Atlanta whose fortunes have been transformed by their enormously hyper-connected airports. In the master-planned suburb directly abutting Dallas/Fort Worth International Airport (DFW), Las Colinas, over 2,000 corporations and 400 corporate headquarters have made their homes. Proximity to the airport is a key reason why companies choose Las Colinas over downtown Dallas – a point that was reinforced when the suburb added a light rail providing service directly into the airport[3].

Over the past 50 years, cities like Chicago, London, Atlanta, Dallas and Amsterdam have made airports a central part of their city economies. Rolling into the 21st century, new emerging power cities like Dubai, Beijing and Zhengzhou, are building massive airport complexes that will hyper-connect their cities to the world, too. This creates incredible opportunities for these cities, as exemplified in the case of Zhengzhou, China. Their airport has landed them large manufacturing sites like Foxconn which can produce Apple products and immediately transfer them to the airport where they can be air shipped around the world in a rapid and seamless manner[4]. In a digital world of immediate gratification – speed matters – and airport cities have speed.

Moving into the future, towards 2050, airports will no longer serve as differentiators for some cities that want to capitalize on the airport economy. Instead, cities that are not plugged into a hyper-connected airport will be overlooked for business, tourism and growth opportunities. Robust airports will be an imperative.

To move forward, cities will need to radically expand their airports and reduce the friction that exists between the starting point and the end point of a journey. By increasing the size of their airports, cities create growth and interconnectivity – simply put, larger airports have more flights, greater network effects and more global touchpoints with fewer transfers. And by decreasing friction and increasing seamlessness, cities can enmesh airports into the overall fabric of their mass transit systems and make flight a natural commuting option.

How do cities achieve this growth and seamlessness? Especially in an environment of land scarcity and increasing travel and security barriers?

The answer is to deconstruct the airport and turn the area where planes take-off and land, whether with people or cargo, into dedicated airfields. Then place the front doors of the airport – the portals in which people enter and engage with the airport – around the city. These front doors are then linked with high speed pods to the airfield.

Imagine, for example, San Francisco. Today, one of the most heavily trafficked airports in the United States, San Francisco International Airport (SFO) sits about 15 miles south of downtown. On a typical day, one can expect to spend either 30 minutes on the subway or 30-90 minutes in traffic to reach the front doors of the terminal. And that's just the beginning. The airport user must take air train, and then check their bags and pass through security – which can take anywhere from 30-70 minutes. Finally, inside the secure area, the traveler makes their way to the gate. In this scenario, the airport is a centralized destination with over 25 tasks a person must complete in their airplane journey – everything from sitting in traffic to removing shoes at security. It's not efficient, and well, let's be honest, the whole transaction is just miserable.

But imagine for a moment that SFO was built differently: stations all over the city – perhaps one on Market Street in the heart of downtown, one at Moscone Center, one of the largest convention centers in the world, multiple in the suburbs around the city like Palo Alto (home to Stanford University) and Berkeley (home to, well, University of California, Berkeley). At these stations you load your luggage into a self-driving pod that travels through tunnels and dedicated lanes around the city to the airfield at SFO. While in the pod en route to the airport, all security measures are completed: bags are

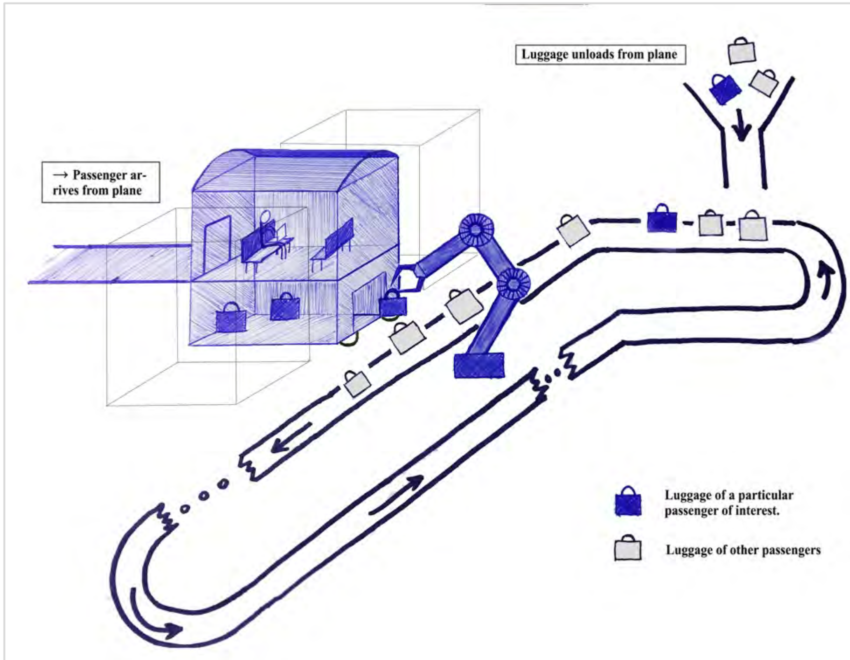
The Airport Transit Pod

- Self-driving
- Holds up to six people. Americans with Disabilities Act compliant
- Travels at speeds up 80 miles per hour through dedicated tunnels, pathways and lanes

Experiencing the Pod

- Pod scans travel information from your personal electronic device
- The pod also scans for dangerous substances while onboard; if there's anything suspicious, the pod diverts to a designated area in the airport
- Luggage is stored in a compartment under the passenger level (like storing things under a bed); luggage will be handled automatically with an electric tracker that points to the location of traveler
- The pod travels directly to boarding gate, while luggage is automatically shuttled to plane loading area
- The pod then waits near boarding area to pick up the newly arriving passengers from the plane.
- As passengers disembark, luggage will be dropped onto a lower level conveyor belt, that is similar to current luggage conveyor belts in airports today. As passengers scan into pods, a mechanical arm will slot luggage into the lower level storage area of the pod.

scanned and explosives "sniffed out." If necessary, you will be alerted and diverted to a secure area for additional screening. Once you arrive to the airfield, the pod takes you directly to your plane's gate. Your bags are deposited automatically in the cargo loading area for your flight and all you do is board once the plane is ready. Leaving the airport is essentially a reversed process. After disembarking from the plane, you simply walk to one of the pods waiting at the gate. The pod would detect your identity and your luggage would be automatically inserted into the luggage compartment of your pod.



This is an example of a pod preparing to leave the airport. The passenger waits as their luggage is automatically loaded from the plane.

It's as easy as changing trains in a subway stations. And more importantly, it fundamentally alters the way we interact with air travel.

At first blush, this might sound like an elaborate taxi scheme – or worse yet, a luxury that will be rendered obsolete by the autonomous driving car. But we believe this approach runs deeper than just providing a ride to the airport lobby – it's about excising friction from the air travel process so that boarding a plane is almost akin to changing subway trains at Times Square Station. The idea is to make air travel as ubiquitous and seamless as other modes of transportation. *See Appendix A for maps that demonstrates current and envisioned airport situation, as well as a map of possible portal locations in San Francisco.*

Pods, unlike cars, operate on a separate set of paths, tunnels and dedicated lanes that ensure that arrival times to the airport are consistent and not delayed by traffic – this reduces friction. And in fact, pods render the airfield component less critical. Today, airfields are home to parking garages, shopping areas, hotels, security, etc. In a pod oriented, decentralized airport, all of those functions would occur in the city – where they belong. Thus, from any point in the city, an individual can pod-travel directly to their plane, check in and be ready for take-off. The airfield is no longer the one-stop-shop destination. Even more, the pod converts the commute into value-add time by checking and completing security protocols while in-transit, therefore reducing a significant bottleneck associated with air travel.

Using this hub-and-spoke pod network creates the following benefits for travelers:

1. **Creates consistency in user experience:** elements like traffic and security checks, which are unpredictable, are made more consistent.
2. **The process is automated:** the passenger has one access point close to home or work, and once ensconced in their pod, automated systems complete all other tasks like security, gate finding and luggage transfer.
3. **Promotes air travel and interconnectivity:** visitors to the city can quickly and easily access major points of attraction, like convention centers, universities and key tourist areas without having to think about logistics.
4. **Provides airfield flexibility:** where the airfield is located is of less consequence. Individuals and businesses interface with the portals, distributed across the city, and the pods transport people from those portals automatically at high and consistent speeds to the airfields. So if an airport needs to expand, but find themselves hemmed in by urban growth (Chicago, London, Los Angeles), this deconstructed and distributed model can provide a path to growth – simply move the airfield and link it to the pod network. Additionally, multiple airfields can be linked together with a rapid pod network allowing passengers to land at one airport, like Heathrow, but quickly depart from another airport, like Gatwick – all without having to engage with traffic and security protocols which hamper seamlessness.

The technology that drives this vision is already in place, or very close to development. Self-driving pods have been tested in multiple markets traveling along slender lanes – akin to a bike trail – that could be easily constructed in easements along interstates. Security features that "sniff" explosives and x-ray luggage are also available. The technology is on the cutting edge, but it is not the key element. Rather, it is reinventing the process by which we engage with airports that is fundamentally different.

> Cities like London, with multiple airports, can now link those airports together with pod-lanes – which essentially means that one can land at Heathrow International Airport in London, but take off on a connecting flight from Gatwick Airport. Today, that journey will take you 1-2 hours and is highly dependent on traffic on the M3 motorway. Pods would reduce this journey to 20 minutes and would create consistency in timing. This in essence provides airports like Heathrow the opportunity to tacitly expand their capacity without adding friction for passengers.

Cities that make air travel easy and accessible will be rewarded with more travelers and more flights. This only further increases the value of the airport as a hub of global interconnectivity and economic growth. Not only is this true in terms of moving people, but also goods – in this model, physical goods can be directly channeled quickly through the airport conduit and to its destination. For the most hyper connected airport cities, it is possible that products will no longer need to be filtered through sorting facilities, but will instead travel on cargo air shuttles that run directly between cities on a reoccurring basis. This fundamentally changes how people and goods move through air – and by making the process faster, easier and more seamless, cities can expect to see increased passenger and cargo activity.

Today, airports process over 208 billion revenue ton kilometers (RTK)[5] of cargo a year, a number that has been increasing by an average of 3.2%[2] a year for the past decade – and it will only increase. Self-driving pods can be designed to move high value goods and mail directly to downtown areas and key business districts.

For example, 25 miles (but often times 60-90 minutes) from San Francisco International Airport sits Berkeley, a suburb that is home to University of California, Berkeley – not only would a portal connecting the university town benefit students, faculty and visitors to the world-renowned school, but also vital lab equipment, biological samples and other important materials could be quickly and easily shuttled from the airport to the research school's labs. It would be as though Berkeley were right next to the airport, rather than an hour away on the opposite side of the San Francisco Bay.

A majority of the cost to implement a decentralized, pod-oriented airport strategy would be pod-development and creating the networked infrastructure across a region to tie portals (those front doors) back to the airport. Some cities might choose to exercise more traditional measures to fund these transformations – for example bonds or private/public partnerships. But our favorite is a model that can be borrowed from the construction of the Japanese high speed rail lines in the 1970s. Office parks, convention centers, hotels and other entities that benefit most from global interconnectivity can pay an excise tax that funds an airport portal close to their offices, factories, convention sites and hotels. Additionally, stations built in the suburbs can sell land parcels to high density developers close to the station entrance and use this revenue stream to offset costs. This has the double benefit of ensuring stations are built in areas with significant demand and density, and providing a revenue source to cover development costs.

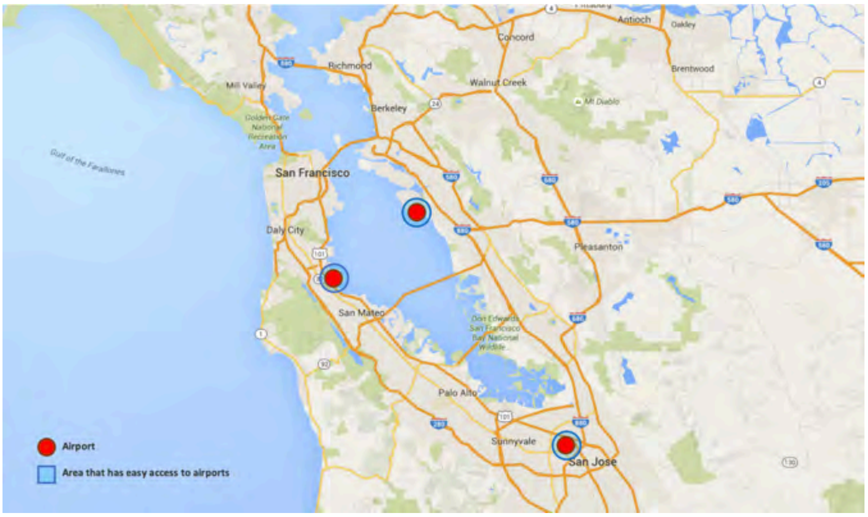
But ultimately, the cost of building hyper-connected airports that are enmeshed into their cities will be recovered in economic growth and increased flight activity; especially for cities that capture first mover advantage. There are simply endless possibilities once airports are expanded and deeply connected to the regions they serve.

Today, air travel has fundamentally transformed our world – and it continuing to do so. People love the ability to move across borders and regions with ease – but while the magic of flight has changed how we interpret space and distance, the process of engaging with flight at our airports has never been worse.

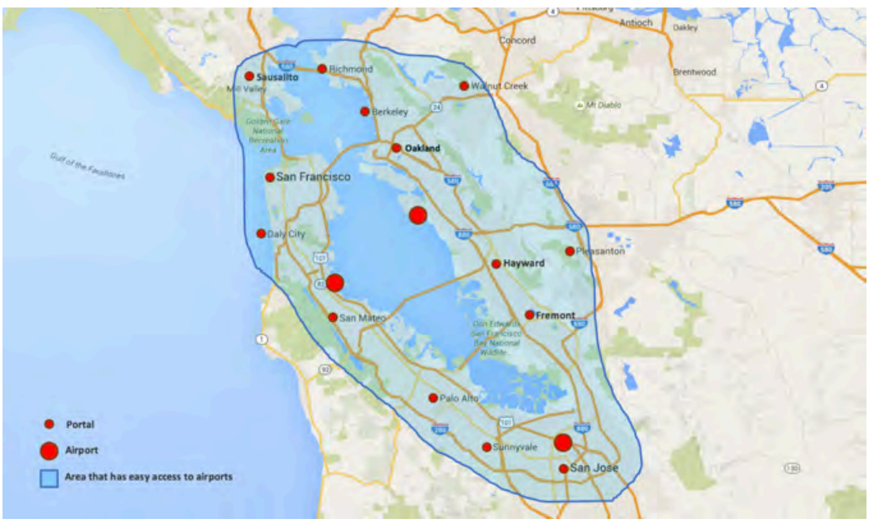
The best cities in the future will seamlessly connect their hyper-connected airports into the fabric of their transportation systems. And in doing so, they will link the businesses and people of their city to the world.

Sources:
1. http://data.worldbank.org/indicator/IS.AIR.PSGR
2. http://data.worldbank.org/indicator/IS.AIR.GOOD.MT.K1
3. Kasarda, J. D., & Lindsay, G. (2011). Aerotropolis: The way we'll live next. New York: Farrar, Straus and Giroux.
4. http://www.citylab.com/design/2016/05/aerotropolis-zhengzhou-china-airport-economy/481842/?utm_source=nl__link2_050916
5. http://www.boeing.com/resources/boeingdotcom/commercial/about-our-market/cargo-market-detail-wacf/download-report/assets/pdfs/wacf.pdf

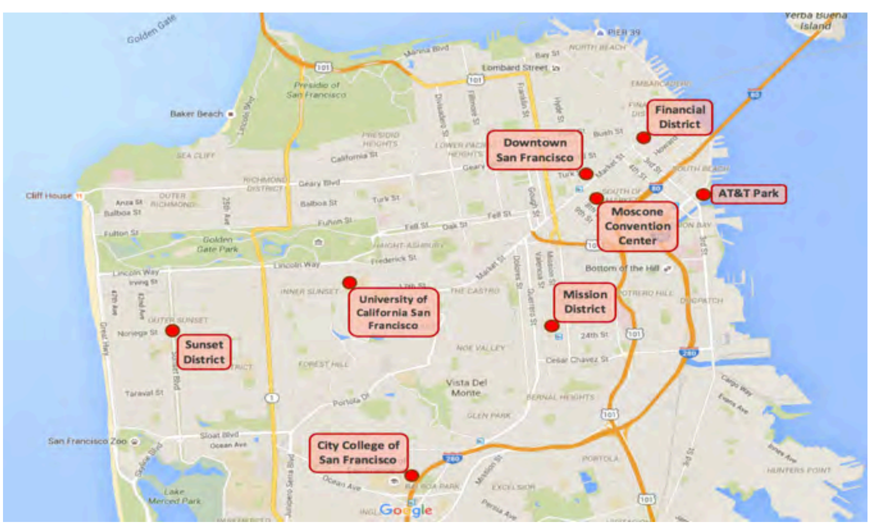
Appendix A:



Current airport locations in Bay Area



Decentralized portals all over the region serve as front doors to San Francisco's three main airfields



Examples of portal locations in San Francisco