



APWA 2020

REUNION TOUR



Entropy-based Resource Management:  
"Smart, Smart Cities with Green Complete Streets"

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# Learning Objectives



Objective 1 - Use the “entropy-based resource management” organizing principle to help your community achieve a sustainable economy and environment



Objective 2 - Develop holistic, multi-resource strategies for sustainability, resiliency (to climate change) and the advent of driverless cars and autonomous vehicles



Objective 3 - Assess how you might collaborate with other disciplines to integrate your current research into a comprehensive and effective sustainability strategy



# Sustainability; *"Life, Liberty and the Pursuit of Negative Entropy"*

Parts I-IV

Public Works Magazine,  
APWA Washington State Chapter



## *Does your community need a....*

- Sustainable land use plan?
- Sustainable roadway grid?
- Strategy for climate change?
- Strategy for driverless cars?



## *Are your.....*

- Commutes miserable?
- Air quality alert days increasing?
- Wetlands drying up?
- Summer stream flows lower and more polluted?
- Wells drying up?

*...we've got an (entropy-based) App for that!*



# Sustainability: *"Mr. Malthus - meet Mr. Smuts"*



<http://centerforsi.org/index.php/2018/05/11/clark/>



# Entropy-based resource management

- Natural processes always minimize energy loss and leave all resources in a *state of minimum entropy* afterwards
- The resource is always maintained in its highest, most ordered state, at the highest energy level possible

Try to create and maintain order, to “*create negative entropy*”, in all things, in all places, at all times



# Natural Examples



## 1. SNOWPACK

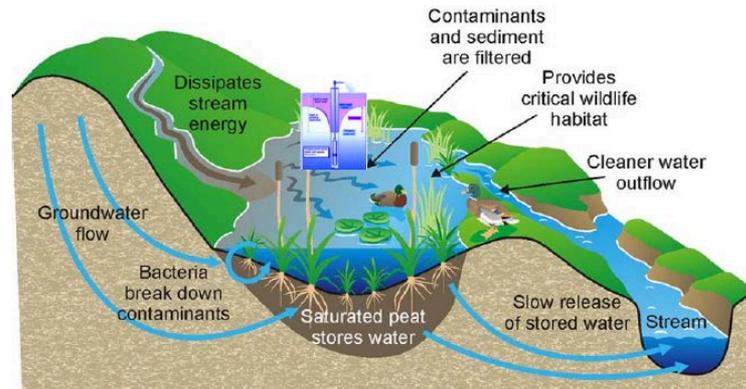
Water in solid phase at the highest potential energy possible.

....next best thing??

## 2. HIGH GROUNDWATER

Water in liquid phase at the highest potential energy possible.

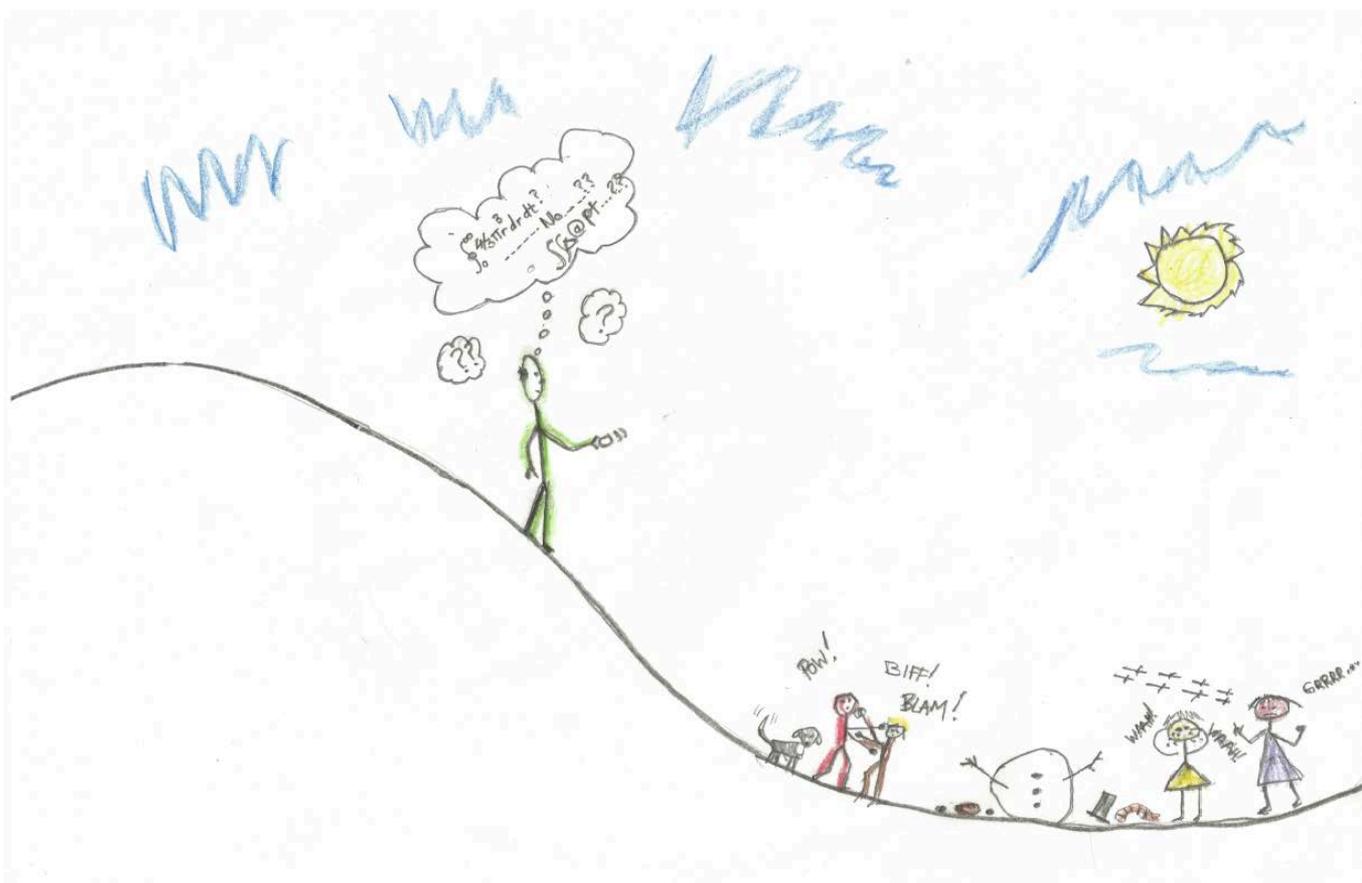
***“Pump up the groundwater as high as possible (then plant everywhere)”***





# Organizing Principle?

*"Just roll the bloomin' snowball down the hill"*





# Literature Review

## Entropy-based Transportation strategies



# Transportation Planning

## *"A Tale of Two Entropies"*

***Minimizing entropy*** in traffic management; ***Reducing energy use.***

"About the analogy between optimal transport and minimal entropy",  
(Gentil et al., 2016)

***Maximizing entropy*** in traffic management; ***Optimizing choice*** in transportation options and routes.

"Maximum Entropy and Utility in a Transportation System", (Mazumber et al., 1999)



# Application to other current issues



# Transportation and Land Use Planning

**“Maximum Entropy and *Utility* in a Transportation System”,  
(Mazumber et al., 1999)**

*“Both entropy and utility\* can be adopted by skilful proponents  
to explain almost any form of transportation problem”.*

\*Utility = benefit from making economic choices such as home and workplace location. *Important in land use planning.*



# Resiliency (to climate change)

Sustainability and Resiliency are really two sides of the same coin. For example:

Electric vehicles:

- use less energy (sustainability)
- produce less greenhouse gases (resiliency)

Low Impact Development techniques:

- recharge groundwater supplies (sustainability)
- reduce flooding (resiliency)

*Plus...emphasis on quick on-the-ground action can help meet urgent resiliency needs.*



# Driverless Cars and Autonomous Vehicles

- Entropy-based transportation strategies can establish energy-efficient *transportation networks*, for all types of vehicles
- *In the vehicle*, entropy-based (energy usage) algorithms can help optimize travel route choices



# Smart Infrastructure and Artificial Intelligence

- Smart infrastructure can be the on-the-ground embodiment of well planned, entropy-based resource management systems
- Artificial Intelligence can make the operation and maintenance of smart, entropy-based public infrastructure easier and more efficient



# Entropy-based resource management

“Back-to-basics sustainability”



# "The Sustainable City"

## Entropy-based Resource Management Plan

*Energy*

*Water*

*Air*



# Energy

*Employ entropy-based transportation strategies to minimize the work needed for home-to-work travel and all other trips.*

*Develop energy-efficient (low pollution) vehicles to perform that work as efficiently as possible.*



## Supporting strategies:

- *Multi-modal transportation systems*
- *Replace fossil fuels with renewable energy*

## Implementation measures:

- *Sustainable land use plan (“Smart Growth” plan)*
- *AI-enhanced “Smart City” infrastructure/operations*

## Other compatible strategies:

- *Complete Streets, driverless cars, First Mile travel options, 20-minute Neighbourhoods, roundabouts, entropy-based limits on sprawl, etc.*
- *Solar energy, wind energy plus pumped storage, better batteries, artificial photosynthesis for fuel, etc.*



# Water

*Establish and maintain high groundwater elevations in all places at all times.*

(Maximize retention of the annual rainfall supply/maximize the availability of water throughout the watershed)



Water: Low entropy > high groundwater 😊





# Water: High entropy > low groundwater ☹️





## Supporting strategies:

- Infiltration-retention-detention hierarchy for stormwater
- Flood flow capture and aquifer replenishment
- Headwater wetland restoration projects
- Trench dams in pipeline and utility trenches
- Runoff flow control

## Implementing measures:

- Sustainable land use plan (incorporating “envirometric overlay”)
- “Pump up the groundwater then plant everywhere”

## Other compatible strategies:

- “One-Water” strategies, Low Impact Development BMPs, “Green Streets”, “Smart City” infrastructure, Beavers



# Air

*Increase photosynthesis*

*Reduce greenhouse gas emissions*



## Supporting strategies:

- Entropy-based watershed management strategies
- Entropy-based transportation strategies

## Implementing measures:

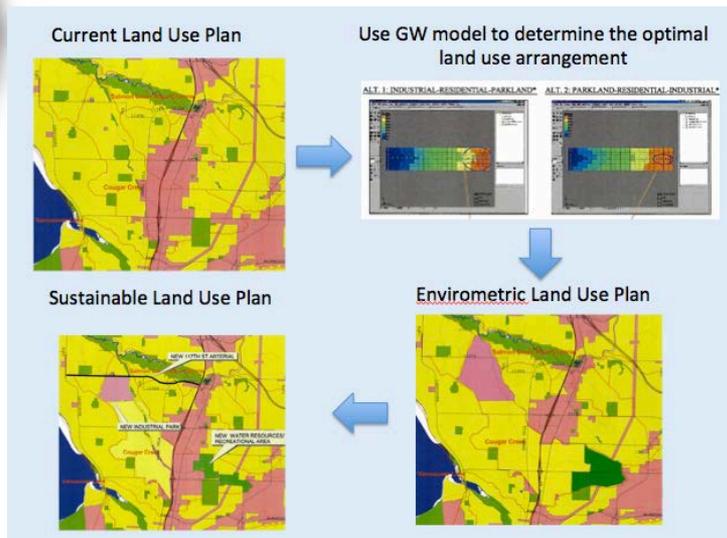
- Sustainable land use plan (incorporating an “envirometric overlay”)
- “Pump up the groundwater then plant everywhere”

## Other compatible strategies:

- Electric vehicles, Reforestation



# Smart "Smart Cities"....



"Smart Growth"  
Comprehensive Plan



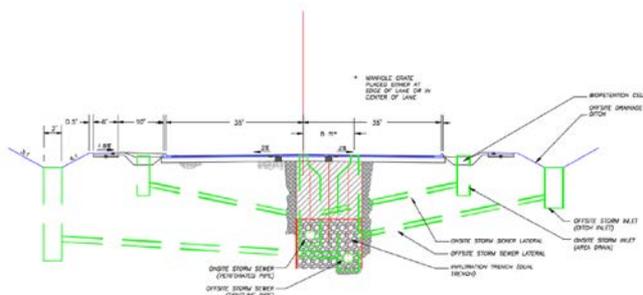
"Smart City" Infrastructure



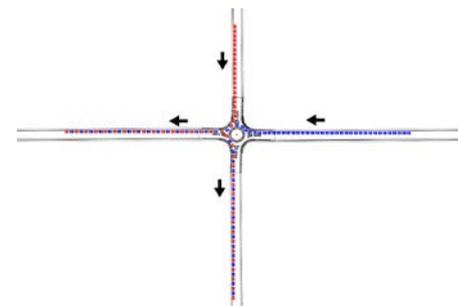
# ...with Green "Complete Streets"



## Complete Street...



Green Street



...including roundabout corridors



# Sustainability and Resiliency: *Are things bad enough yet?*

- In some places, maybe.
- In any case, there's no harm in being effective and cost-efficient, at any time...

*Let's "walk-through" sustainability and resiliency, from an entropy-based resource management viewpoint...*



# Need:

## *Sustainability and Resiliency*

1. Lots for Public Works to do (without much money)...
2. We need to be very effective (and cost-efficient)...
3. A holistic strategy would consider all resources when making our management decisions...
4. Holistic, coordinated strategies can also achieve “whole is more than the sum of its parts” levels of effectiveness...

*So, let's try to find a “holistic” strategy....*



## Purpose: *Entropy-based resource management; a holistic strategy*

5. A physical expression of “holism”, and a *“holistic strategy”*....
6. Purpose is the frugal use and effective storage of all our natural resources *i.e. sustainability*....
7. The fundamental focus on entropy *opens up many physical, chemical and biological ways* to achieve that....
8. The physical concepts are *well supported by mathematical analysis procedures targeted at systems-optimization*, our primary objective ....
9. Being based on natural systems, you can have confidence in achieving good outcomes, and so be free to have a *strong bias in favor of action*....
10. ... this, in turn, *allows fast responses to urgent resiliency needs*...



# *Entropy-based Transportation strategies can...*

11. Make very effective use of energy resources, and so are important when *developing optimal transportation systems...*
12. An optimized transportation system *maximizes utility* and so *is an essential element of any sustainable land use plan...*
13. Are good at (first maximizing then) *optimizing choice in travel routes*, and so *can contribute to software for autonomous vehicles and driverless cars...*
14. By reducing energy use, entropy-based transportation strategies also *reduce emissions, a key resiliency need...*



# *“Smart City” infrastructure and Artificial Intelligence software can then...*

15. Operate and maintain that sustainable, resilient public transportation and infrastructure system even more cost-effectively...



# A holistic strategy: *Design for Liberty...*

## ENERGY BOOSTING FOODS



EGGS



NUTS



PEANUT



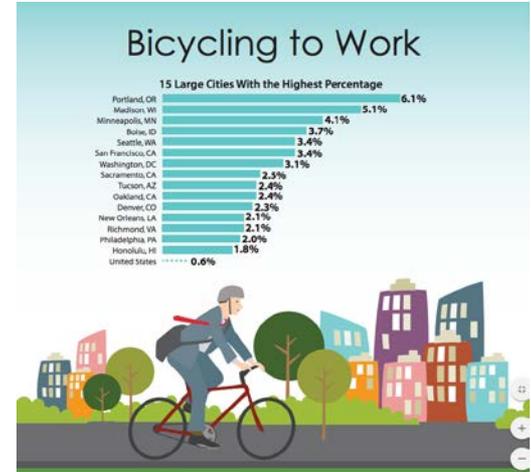
BROWN RICE



BANANAS



DARK CHOCOLATE



Multi-modal transport options – *use food energy first...*



*... you get Life too!*

HEALTHY HEART

LESSEN EFFECT OF ASTHMA

OVERALL MENTAL HEARTH

STRENGTHEN IMMUNE SYSTEM

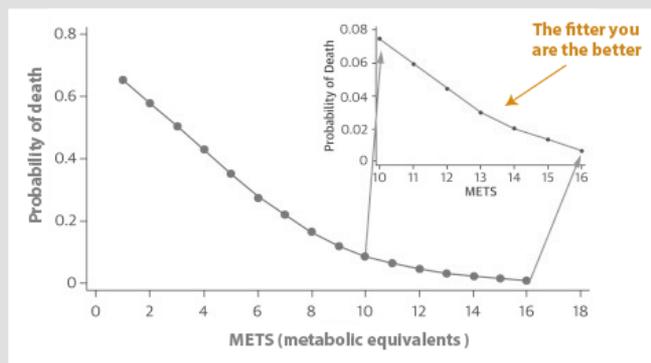
PHYSICAL STAENGTH

STAENGTHENING JOINTS AND STABILITY

HEALTH CHECK

### The Fitter You Are The Longer You Are Likely To Live

Age and risk factor adjusted mortality as a function of cardiovascular fitness (METS)



**Result: "we observed no evidence of an upper threshold for mortality benefit with increasing fitness, even in the most highly fit subjects"**

Source: Feldman, D.L, Al-Mallah, M.H., Keteyian, S.J. et al, No evidence of an upper threshold for mortality benefit at high levels of cardiorespiratory fitness. J Am Coll Cardiol. 2015;65:629-630.

Learn more: <http://fitfolk.com/fat-loss-framework/>

**fitfolk**

*...folk are healthier and live longer!*



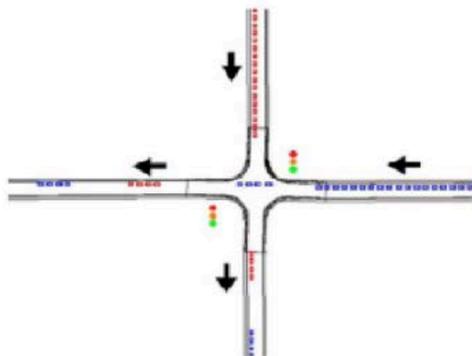
# A holistic strategy: *Design for Liberty...*

## SUSTAINABLE ROADWAY GRID

### B. Mimic a natural system

#### Regular Intersection

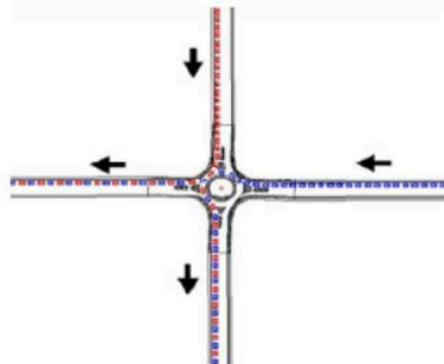
Platooning



Gaps...disorderly...random  
- like a gas

#### Roundabout

Smooth flow and no gaps



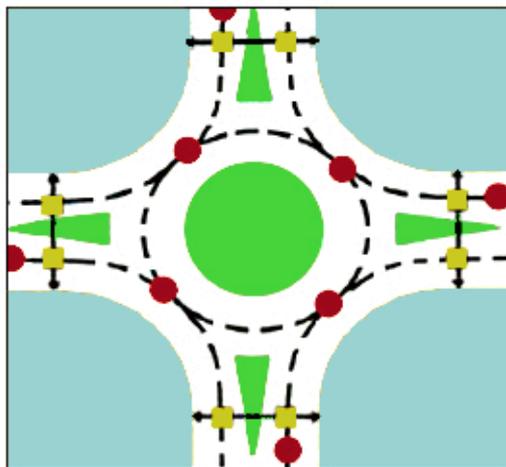
No gaps...orderly...continuous  
- like a liquid

Add in *choice* – one more degree of freedom....



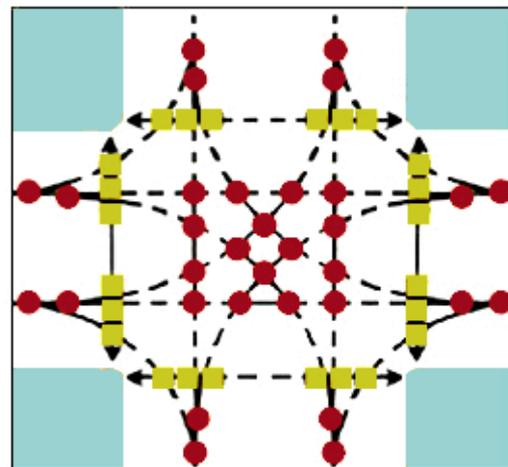
*... you get Life too!*

## Roundabout



- 8 Vehicle conflicts
- 8 Pedestrian conflicts

## Intersection

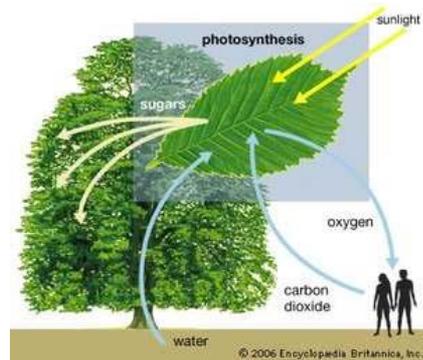


- 32 Vehicle conflicts
- 24 Pedestrian conflicts



# *Sustainability for America!*

"Life"



"Liberty"



*... and the pursuit of...*



"Negative Entropy"



# *John's "entropy-based resource management" mix tape*

"Multi-modal transportation"; The Cycle Jerks

"Roundabouts"; Yes

"Green complete streets"; Traffic

"Trench dams rock"; Bob and Marlee

"Headwater wetland restoration projects"; Wet, Wet, Wet

"Leave it to beavers"; The Dammed

"Streamflow restoration grants"; DOE

"Offsite stormwater mitigation credits"; DOE