

# **The Emergence of Geographic Information Systems as a Core Public Policy Research Tool: Comments on the Paradigm Shift**

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*Presentation to the  
**Friday Lunch Discussion Club  
(FLDC)***

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## **Background and Introductory Remarks**

Two items of context may be useful as a means of establishing my association with the presentation topic, “The Emergence of Geographic Information Systems as a Core Public Policy Research Tool: Comments on the Paradigm Shift”.

First, I went to graduate school at Northwestern University in the 1960s, with support by Canada Mortgage and Housing Corporation, and funding and research support from a number of U.S. federal government agencies and programs, including: NASA; Geological Survey; Housing and Urban Development; Health, Education and Welfare; the National Cooperative Highway Research Program; and the Census Bureau.

During that time, and for the next three years while on faculty at the University of Kansas, I was in the midst of theoretical and applied research involving two of the paradigms central to today’s presentation:

- ◆ The development and use of quantitative methods and techniques for public policy, program, plan, and operations purposes; and
- ◆ The design and application of geographic information systems (GIS) and components of GIS in the executive, management, and operations functions of governments at all levels.

Information about published reports, research projects, etc., regarding the early days of my career formation can be viewed in the C.V. section of my website (<http://wellar.ca/wellarconsulting>).

When I returned to Canada in 1972 to join the federal Ministry of State for Urban Affairs, I carried on those lines of applied research as a senior research officer, urban information coordinator, director of non-metropolitan community development, and senior policy advisor.

For seven years I had first-hand experience with proposing, testing, and using all three paradigms – qualitative, quantitative, visualization – in public policy research that included contributions to OECD and UN panels and committees, to inter-departmental and inter-governmental committees, to Cabinet Documents, and numerous communications “up the ladder” to DGs, ADMs, DMs, and Ministers.

Second, the call from Andrew Sterling to address the *Friday Lunch Discussion Club (FLDC)* came at an opportune time, because I am in the midst of a consulting assignment which ties back to work and activities that marked the onset of my professional career some 50 years ago, as described above.

In brief, based on a retrospective project in 2013 which re-visited papers in proceedings published 30 years earlier (*Proceedings of the Sixth International Symposium on Automated Cartography*), I was retained to organize the colloquium, “Using the Retrospective Approach to Mine for GIS Nuggets”, which was held February 13-14, 2015, at the Environmental Systems Research Institute (Esri) campus in Redlands, California..

And, as a follow-up, I have been retained by Esri to organize an Applied Research Seminar, “Mining U.S. Federal Agency Materials for GIS Nuggets”, which is to be held in February in Washington, DC during the 2016 Esri Federal GIS Conference.

The objectives of the GIS retrospective project are presented in a number of publications, accessible at:

[http://wellar.ca/wellarconsulting/AutoCarto\\_Six\\_Retrospective.pdf](http://wellar.ca/wellarconsulting/AutoCarto_Six_Retrospective.pdf);  
[http://wellar.ca/wellarconsulting/IJAGR\\_AC\\_SixRetroReviewAndImplicationsPaper.pdf](http://wellar.ca/wellarconsulting/IJAGR_AC_SixRetroReviewAndImplicationsPaper.pdf);  
[http://wellar.ca/wellarconsulting/COLLOQUIUM\\_PROCEEDINGS.pdf](http://wellar.ca/wellarconsulting/COLLOQUIUM_PROCEEDINGS.pdf);  
[http://wellar.ca/wellarconsulting/COLLOQUIUM\\_SLIDE\\_PRESENTATIONS.pdf](http://wellar.ca/wellarconsulting/COLLOQUIUM_SLIDE_PRESENTATIONS.pdf);  
[http://wellar.ca/wellarconsulting/Summary\\_GIS\\_Retrospective\\_Research\\_Colloquium\\_FINAL.pdf](http://wellar.ca/wellarconsulting/Summary_GIS_Retrospective_Research_Colloquium_FINAL.pdf);  
<https://www.esri.com/esri-news/arcnews/summer15articles/colloquium-urges-gis-specialists-to-look-to-the-past-to-inform-the-future>

The objectives are outlined as follows for the purposes of this presentation.

First, and consistent with a primary axiom of methodologically designed inquiries, the GIS retrospective research project is organized around a question:

***How can looking back at what has been done, or not been done in the field of geographic information systems (GIS), contribute insights into why and how the field of GIS could and should evolve in the coming years?***

With that question providing an overall sense of purpose, the 2015 colloquium and the 2016 seminar are important events in the process of elaborating what we can learn from the past, and how we can learn from the past, to inform the futures of three core, related missions:

1. Designing, developing, and implementing geographic information systems (GIS) technology;
2. Defining and elaborating the methods, techniques, and operations of geographic information science (GIScience); and
3. Using geographic information systems technology and/or geographic information science in government, academia, business, the media, and other organizations, as well as by individuals, community associations, and other interests.

One of the topics to receive explicit consideration in discussions with U.S. federal agencies about their presentations at the 2016 seminar involves the three paradigms. Drafting my *FLDC* presentation at this time (July) is an opportunity for me to accelerate my thinking in that respect.

Further, the *FLDC* meeting in October is an opportunity for me to obtain insights about the paradigms during the Q&A session, and to raise issues which *FLDC* members may wish to address at a later date.



At a general level, then, my association with the theme of this presentation began about 50 years ago in graduate school, and continued through career stops in academia, government, and business involving education, training, research, applications, and management experiences.

And, at a more particular level, the theme of the presentation falls within the purview of the retrospective research projects that I have been undertaking in recent years with the support of Esri, which itself is a prime mover and shaker in the paradigm shift process.

With regard to framing the presentation for the audience gathered here today, I am informed that attendees at *FLDC* meetings are highly-credentialed, having expertise in a number of disciplines, and a wide range of experience in government, academia, business, and other fields of endeavor.

Consequently, I expect that everyone here is eminently capable of connecting the dots in a talking point presentation such as this one, which allows me to put forth a lot of ideas in a short span of time, and to inject side comments as needed to elaborate the talking points.

My mission today is to outline what I believe to be a significant shift among the paradigms which characterize the public policy research process in federal, provincial, and local governments in Canada, and in numerous other countries.

The long story short is that each of the three core paradigms – qualitative, quantitative, visualization – has its moments as “the big dog” under various circumstances, but I believe the evidence underlying the topic of this presentation is clear and compelling: Namely, a significant shift has occurred in the share of regard allotted to each paradigm in the policy research arena over the past four or five decades on numerous matters of a spatial, i.e., geographic or, more popularly, geospatial nature.

That is, the visualization paradigm, aided and abetted by geographic information system (GIS) technology, is occupying an increasingly pre-eminent and in some jurisdictions a dominant place in policy research initiatives when it comes to dealing with problems, concerns, and issues associated with

entities and conditions which have a spatial dimension. The following are among the hundreds of federal, provincial, and municipal policy research domains which have a spatial or “where” aspect: active transportation (cycling, walking); aggregate extraction; agricultural land reserves; air pollution sources and sinks; airports; building codes/standards; business districts; climate change; community mail boxes; election district/ward boundaries; emergency measures deployment (local, regional, national scales); energy production, distribution, consumption; environmental protection; environmentally sensitive areas; fisheries; forest resources and practices; fossil fuel production, distribution and consumption; “gridlock”; habitat gain/loss; heritage buildings; highway networks; housing; hydro-electric power generation, transmission, and consumption; landfill siting; land use zoning and re-zoning; manufacturing plants; mine tailing pond locations and standards; neighborhood intensification; pesticide spraying regulations; public safety; rail freight and rail passenger services; regional development; siting of public institutions (military bases, schools, hospitals, correctional facilities, arenas, skateboard parks, swimming pools, bridges, docks, wharves, rescue stations, recreation centres, public housing complexes, half-way houses, recycling facilities, etc.); solid waste disposal; toxic waste disposal; traffic congestion; transit infrastructure; urban development; urban sprawl; water bodies and drainage areas; water and wastewater systems; wetlands; and wind turbines.

In this presentation I use a selection of talking points to illustrate why and how the policy research paradigm shift involving the three core paradigms – qualitative, quantitative, visualization – has occurred, is occurring, and will continue to unfold in various ways in the coming decades.

I hasten to add that for reasons of time constraints, and in recognition of the mega-expertise of the audience, the presentation is set at an overview level. This approach allows highlighting the critical points in a general way, and to avoid becoming bogged down in mind-numbing details.

For those who want to give this topic further consideration, I close the Background and Introductory Remarks with references to a selection of websites that provide substantive information about GIS applications associated with the entities and conditions listed above, and recalled in the slides.

As may be expected given my role here today, I have produced a number of reports on geographic information systems technology and its applications, geoscience methodology, the retrospective research project, and on many of the topics mentioned above. They are posted on my website (<http://wellar.ca/wellarconsulting/>), as well as on other websites including:

<http://www.transport-action.ca/en/wellar.html>;  
<https://www.google.ca/#q=urisa+wellar&nfpr=1>;  
<http://www.slideshare.net/wellarb/presentations/2>

Finally, to broaden the literature search and review opportunities for anyone seeking a wide-ranging discussion of geographic information systems (GIS) technology and applications, I recommend a visit to several of the following websites:

<http://www.esri.com/>; <http://www.esri.com/esri-news/arcnews>; <http://www.esri.ca/en>;  
<http://www.urisa.org/>; <http://www.urisa.org/resources/the-gis-professional/>;  
<http://www.urisa.org/resources/books-and-resources/#foundationsURISA>;  
[http://www.cag-acg.ca/en/GIS\\_day.html](http://www.cag-acg.ca/en/GIS_day.html);  
<http://www.cartogis.org/about.php>;  
<http://canadiangis.com/geo-listings/gogeomatics-canada>;  
<http://www.cihr-irsc.gc.ca/e/48922.html>;  
<http://www.ducks.ca/what-we-do/gis/>

Prior to discussing the slides it is recalled that the immediate audience for this presentation is highly sophisticated in matters of governance, so slides are designed accordingly.

Viewers seeking more details could use terms in the slides as the basis of keyword searches.

And now, to the slides.

# **Background and Introductory Remarks**

## **Spatial Policy Research Domains (1)**

Presentation focus is on policy research problems, concerns, and issues associated with entities and conditions which have a spatial component, such as: aggregate extraction; agricultural land reserves; air pollution sources and sinks; airports; climate change; earthquakes; election district/ward boundaries; energy production, distribution, consumption; environmental protection; “gridlock”; fisheries; forest resources and practices; fossil fuel production, distribution, and consumption; habitat gain/loss; and highway networks.



# **Background and Introductory Remarks**

## **Spatial Policy Research Domains (2)**

Presentation focus is on policy research problems, concerns, and issues associated with entities and conditions which have a spatial component, such as: hydro-electric power generation, transmission, and consumption; landfill siting; land use zoning and re-zoning; mine tailing pond locations and standards; neighborhood intensification; pesticide spraying regulations; public safety and emergency measures deployment; rail freight and rail passenger services; regional development; and retail shopping complexes.

# **Background and Introductory Remarks**

## **Spatial Policy Research Domains (3)**

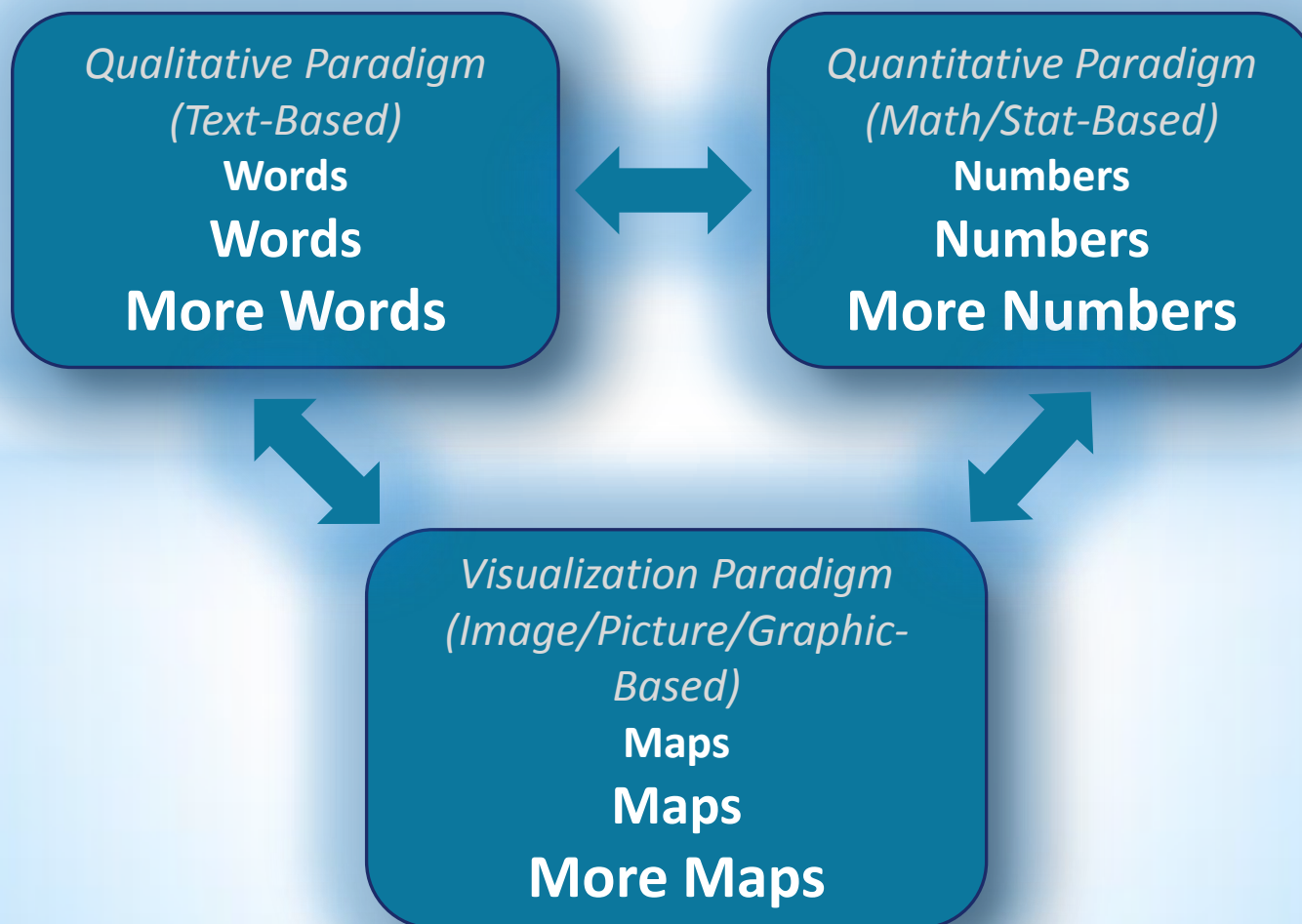
Presentation focus is on policy research problems, concerns, and issues associated with entities and conditions which have a spatial component, such as: siting of public properties; (schools, hospitals, arenas, correctional facilities, docks, wharves, libraries, rescue stations, fire stations, police stations, recreation centres, public housing, half-way houses, etc.); solid waste disposal; toxic waste disposal; traffic congestion; transit infrastructure; urban development; urban sprawl; water bodies and drainage areas; and water and wastewater distribution and treatment systems.

# **Background and Introductory Remarks**

## **Two Research Paradigm Shift Drivers**

- The development and use of quantitative methods and techniques for public policy, program, plan, and operations purposes; and
- The design and application of geographic information systems (GIS) and components of GIS in the executive, management, and operations functions of governments at all levels.

## Three Policy Research Paradigms





## **Push-Pull Forces Behind the Qualitative Paradigm Shift**

**When Language Succeeds** as a means of effectively and efficiently describing, explaining, or predicting policy inputs, outputs, situations, processes, relationships, outcomes, etc., the qualitative paradigm prevails.

## **Push-Pull Forces Behind the Qualitative Paradigm Shift**

*Qualitative Paradigm  
(Text-Based)*

**Words**

**Words**

**More Words**

## **Push-Pull Forces Behind the Qualitative Paradigm Shift**

**When Language Fails** as a means of effectively and efficiently describing, explaining, or predicting policy inputs, outputs, situations, processes, relationships, outcomes, etc., the qualitative paradigm wavers.

## **Push-Pull Forces Behind the Qualitative Paradigm Shift**

**When Language Fails** as a means of effectively and efficiently describing policy impact assessment, policy evaluation, and related performance measurement procedures the qualitative paradigm wavers.



## **Push-Pull Forces Behind the Qualitative Paradigm Shift**

**When Language Fails** as a means of effectively and efficiently disseminating and communicating information about policy-related challenges, opportunities, situations, processes, relationships, outcomes, etc., the qualitative paradigm wavers.

# Push-Pull Forces Behind the Quantitative Paradigm Shift

## Examples of Math/Stat Equations behind the Numbers

*Linear regression*

$$Y = a + bX + e$$

*Multiple regression*

$$Y = \beta_0 + \beta_1 X_1 + \beta_4 X_4 + \varepsilon$$

*Exponential growth/decay function*

$$y(t) = a \times e^{kt}$$

*Linear programming objective function*

$$\text{maximize or minimize } Z = \sum_{i=1}^n c_i X_i$$

*Logistic growth model or the Verhulst model*

$$\frac{dP}{dt} = rP \left( 1 - \frac{P}{K} \right),$$

*Chi-square*

$$\chi^2 = [ (n - 1) * s^2 ] / \sigma^2$$

*Intersection and Volume Design Index (IVDI)*

$$IVDI = V_1 \bullet V_2 \bullet V_3 \bullet V_4 \bullet \\ V_5 \bullet V_6 \bullet V_7 \bullet V_8$$

*Driver Behaviour Index (DBI)*

$$DBI = \frac{ALI + RLI + FTYI}{P}$$

## **Push-Pull Forces Behind the Quantitative Paradigm Shift**

**When Numbers Succeed** in replacing words, complementing words, or supplementing words as the preferred means to describe, explain or predict policy-related challenges, opportunities, situations, processes, relationships, outcomes, etc., the quantitative paradigm ascends.

## **Push-Pull Forces Behind the Quantitative Paradigm Shift**

**When Numbers Succeed** in achieving the perception, creating the impression, attaining acceptance, etc., that relative to words they bring accuracy, precision, clarity, definitiveness, certainty, etc., to the policy research process, the quantitative paradigm ascends.



## **Push-Pull Forces Behind the Quantitative Paradigm Shift**

**When Numbers Succeed** in achieving the perception, creating the impression, attaining acceptance etc., that relative to words they represent hard versus soft science, firm versus mushy edges, sharp versus fuzzy thinking, etc., the quantitative paradigm ascends.

## **Push-Pull Forces Behind the Quantitative Paradigm Shift**

**When Numbers Succeed** in enabling the creation of classes and categories, separating entities by degrees, discriminating by rank order, defining hierarchies in terms of size, value, cost, etc., the quantitative paradigm ascends.

## **Push-Pull Forces Behind the Quantitative Paradigm Shift**

**When Numbers Succeed** in serving and promoting the use of variables to express relationships underlying policy research activities (scanning, scoping, filtering, forecasting, analysis, synthesis, etc.), the quantitative paradigm ascends.

## **Push-Pull Forces Behind the Quantitative Paradigm Shift**

*Quantitative Paradigm  
(Math/Stat-Based)*

**Numbers**

**Numbers**

**More Numbers**



## **Push-Pull Forces Behind the Quantitative Paradigm Shift**

**When Tables of Numbers Fail** as a means of effectively and efficiently describing, explaining, or predicting policy inputs, outputs, situations, processes, relationships, outcomes, etc., the quantitative paradigm wavers.

## **Push-Pull Forces Behind the Quantitative Paradigm Shift**

**When Optimization Techniques Fail** as a means of describing, explaining, or predicting resource allocation inputs or outputs as a result of policy alternative choices the quantitative paradigm wavers.

## **Push-Pull Forces Behind the Quantitative Paradigm Shift**

**When Population Parameters and Sample Statistics Fail** as a means of effectively and efficiently describing, explaining, or predicting policy inputs, outputs, situations, processes, relationships, outcomes, etc., the quantitative paradigm wavers.

## **Push-Pull Forces Behind the Quantitative Paradigm Shift**

**When Differential Calculus Fails** as a means of effectively and efficiently disseminating and communicating rates-of-change information about policy-related challenges, opportunities, situations, processes, relationships, outcomes, etc., the quantitative paradigm wavers.

## **Push-Pull Forces Behind the Quantitative Paradigm Shift**

**When Indexes Fail** as a means of effectively and efficiently describing, explaining, or predicting policy inputs, outputs, situations, processes, relationships, outcomes, etc., the quantitative paradigm wavers.



## **Push-Pull Forces Behind the Quantitative Paradigm Shift**

**When Sensitivity Analysis Fails** as a means of effectively and efficiently describing, explaining, or predicting policy inputs, outputs, situations, processes, relationships, outcomes, etc., the quantitative paradigm wavers.

# **Push-Pull Forces Behind the Visualization Paradigm Shift**

## **Examples of Using GIS to Produce Maps (1)**

**Highway Performance Monitoring System**

**Areas of Critical Environmental Concern**

**Wetland Inventory**

**DevelopmentTracker**

**Global Forest Watch**

***Source:***

**<http://www.arcgis.com/home/search.html?q=Government%20policy&t=content&focus=maps&start=121>**

# **Push-Pull Forces Behind the Visualization Paradigm Shift**

## **Examples of Using GIS to Produce Maps (2)**

**Evidence Based Policy-Making in Addressing Wildlife Crime**

**EPI 2010 Biodiversity and Habitat**

**EPI 2010 Air Pollution Effects on Human Health**

**EPI 2010 Fisheries**

**EPI 2010 Air Pollution Effects on Ecosystems**

**USA Soil Farmland Class**

**Source:**

<http://www.arcgis.com/home/search.html?q=Government%20policy&t=content&focus=maps&start=11>

**Lac-Mégantic Train Derailment 2013 Before and After**

<http://esri.ca/en/content/lac-m%C3%A9gantic-train-derailment-2013-and-after#sthash.JubeZvGX.dpufaps.arcgis.com/apps/StorytellingSwipe/index.html?appid=ff8d9e175be642ac941b681d7e5dc61c&webmap>

## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When Storage Devices Succeed** in being able to handle the massive amounts of spatial data which may be required to support geographic information systems (GIS) technology, the visualization paradigm ascends.

## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When GIS Technology Succeeds** in integrating satellite data with ground-truth data to provide near-time information for climate change policy research, the visualization paradigm ascends.



## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When GIS Technology Succeeds** in integrating satellite data with ground-truth data to provide near real-time information for emergency measures policy research, the visualization paradigm ascends.

## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When GIS Technology Succeeds** in compiling spatial data from multiple sources to enable policy research about forest canopy cover from the local to the global scales, the visualization paradigm ascends.

## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When GIS Technology Succeeds** in compiling spatial data from multiple sources to enable near-time policy research about the distribution of fresh water resources from the local to the global scales, the visualization paradigm ascends.

## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When GIS Technology Succeeds** in integrating satellite data with ground-truth data to provide near-time information for environmental degradation policy research initiatives, the visualization paradigm ascends.

## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When GIS Software Designers Succeed** in creating applications which effectively and efficiently provide policy research geo-information about the spatial relationships connecting interdependent infrastructures, the visualization paradigm ascends.

## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When GIS Software Designers Succeed** in creating applications which effectively and efficiently provide policy research geo-information about the cascading effects of disruptions to interdependent infrastructures, the visualization paradigm ascends.



## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When GIS Software Designers Succeed** in creating applications which effectively and efficiently provide policy research geo-information about public safety and security vulnerability, the visualization paradigm ascends.

## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When GIS Software Designers Succeed** in creating applications which reveal land use development patterns which are not discernible by other means, the visualization paradigm ascends.

## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When GIS Software Designers Succeed** in creating decision support applications which are a comfort to elected and senior appointed officials, the visualization paradigm ascends.

## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When Educators Succeed** in building GIS courses into university and college curricula in a variety of disciplines (e.g., geography, engineering, surveying, landscape design, regional planning), and graduates occupy policy research positions in line, oversight, central, and other agencies of federal, provincial, and local governments, the visualization paradigm ascends.

## **Push-Pull Forces Behind the Visualization Paradigm Shift**

**When Organizations Succeed** in creating the Geographic Information Systems (GIS) Certification Institute, and accrediting the Geographic Information System Professional (GISP) at all levels of government, in business, and in academia the visualization paradigm ascends.

# **Push-Pull Forces Behind the Visualization Paradigm Shift**

*Visualization Paradigm  
(Image/Picture/Graphic-Based)*

**Maps**

**Maps**

**More Maps**

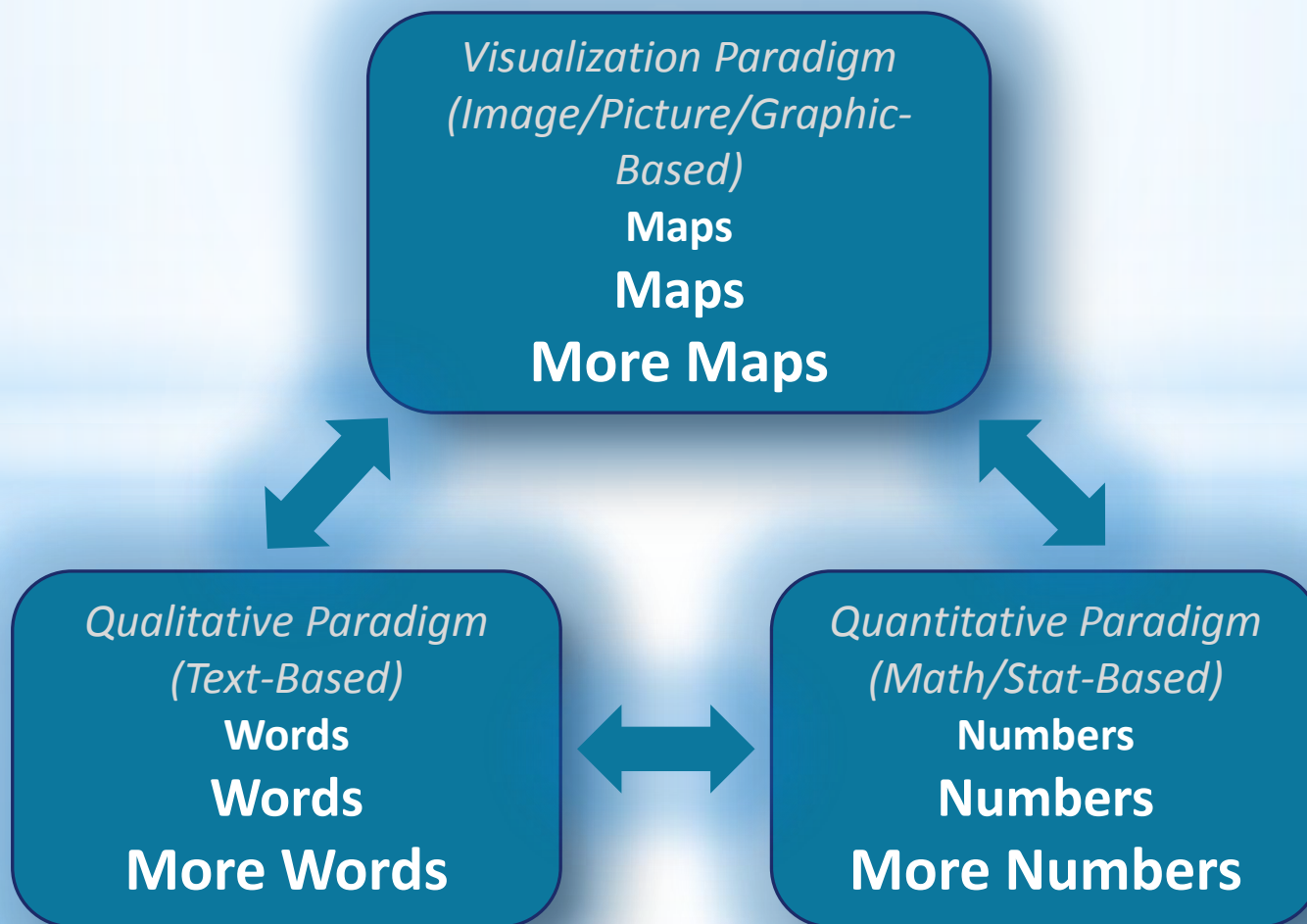


## **Core Message from Examining Push-Pull Forces behind Policy Research Paradigm Shifts**

Each paradigm – **qualitative, quantitative, visualization** – has its place in policy research. As a result, institutions which can honestly lay claim to policy research best practices for matters dealing with entities, relationships, and processes of a geographic nature are those which make the best use of each paradigm, which means making the best use of each research means, namely

**WORDS and NUMBERS and MAPS.**

## Three Policy Research Paradigms



## **Thank you for your attention!**

This report and the slide deck prepared for the FLDC presentation are part of the background work undertaken for the GIS Retrospective Applied Research Seminar, ***Mining U.S. Federal Agency Materials for GIS Nuggets***, which is to be held as part of the Esri Federal GIS Conference, February 24-25, 2016 Washington, DC. Support provided by the Environmental Systems Research Institute (Esri) for the Applied Research Seminar is gratefully acknowledged. In addition, I wish to acknowledge the strategic advice provided by Gordon Plunkett, Director, Spatial Data Infrastructure, Esri Canada, the proof-reading assistance of Marjorie Wellar, and the report preparation assistance of Sam Herold, Technical Advisor, Information Research Board Inc.