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Sreedharan, Jayashree and Franklin, Dr. CG, "Location Intelligent IS: GIS Decision-making and GISc Innovations" (2022). *AMCIS 2022 Proceedings*. 19.
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Location Intelligent IS: GIS Decision-making and GISc Innovations

Completed Research

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Abstract

Enhancing an IS (Information System) with GIS (Geographic Information System) decision-making software creates, manipulates, compares, and analyzes high resolution, spatial-temporal data-events like sales and census data on digital maps that improve the customer value chain. When this robust GIS insight (i.e., WHO is involved, WHAT the consequences are, WHEN events occur, WHERE events occur, and perhaps WHY events occur) is fused with a rigorous theoretical foundation in GISc (Geospatial Information Sciences) and other disciplinary theory and knowledge, the IS becomes a powerful predictor of demand chain management challenges and opportunities related to Marketing, Sales and Service. The paper demonstrates these linkages for the benefit of IS practitioners interested in understanding the effects of such an IS enhancement.

Keywords

Bass, Bayes, Location Intelligence, Innovation Diffusion Theory, 3rd Order Green IS, Supply Chain Management, Demand Chain Management

Introduction

The goal of this paper is to demonstrate how acquiring location intelligence in a corporate IS enhances the customer value proposition by delivering powerful management insights into how to improve the demand chain management (DCM) functions of Marketing, Sales and Services (Madhani, 2013). The adoption of robust GIS (Geographic Information System) software tools in addition to the rigorous implementation of Geospatial Information Sciences (GISc) methods, theories and procedures including other disciplines such as economics, behavioral psychology and so on, create a Gestalt-like combination that provides unique marketing insights to support sustainable profitable growth (SPG) in the face of multiple and rapidly changing globalization conditions (e.g., economic, energy, health and political). These ideas lead to a demonstration of a location intelligent model.

Research question

With the wide application and success of GIS implementations supporting IS supply chain management (SCM) applications e.g., the pulp and paper industry in New Brunswick, Canada (Killham & Morrison 2018), this paper seeks to investigate the following question:

- What benefits can GIS decision-making and GISc innovations create with a location intelligent IS demand chain management (DCM) approach?

Other questions for future research might include: If subtle changes are detected through the GIS decision-making and GISc innovations for the DCM, do those create timely opportunities for pivots or corrections in the SCM management functions (see Figure 2) i.e., Purchasing, Manufacturing and Distribution?

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Conceptual Model

A physical/geographic analog (i.e., a topographical hill - Figure 1) is used to visualize the concepts. The conceptual model views the IS "hill" (ISH) as a stratified hierarchy structure in the "landscape" of supply and demand. The back-side (left) of the ISH represents all of the supply chain management functions – Purchasing, Manufacturing and Distribution. The front-side (right) of the ISH (the focus of this investigation), represents all the demand chain management functions of Marketing, Sales and Service (Figure 2).

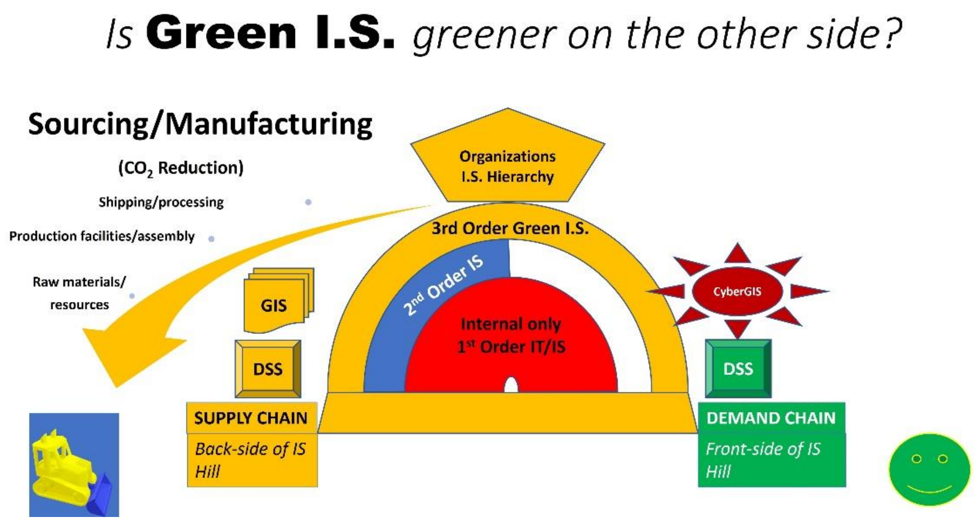

Figure 1. Conceptual 3rd Order Green IS/DSS with CyberGIS Forward-Looking customer location intelligence (Franklin & Sreedharan, 2021)

Figure 2. Internal DCM (Value Chain) functions:

SCM [Purchasing, Manufacturing, Distribution]; DCM [Marketing, Sales, Service]

Source: https://upload.wikimedia.org/wikipedia/commons/0/0b/Value_Demand_v_small2.png

Literature Review

Diffusion of Innovation Theory (Rogers, 2004)

The diffusion of innovation theory *"…has been widely used to study the adoption of IT. The theory simply says that an innovation can be an idea or something that is unknown to the one perceiving the innovation. The flow of information in a social system from one person to the next (i.e., word of mouth) is the process for diffusion. 'There are four main determinants of success of an IT [IS] innovation: communication channels, the attributes of the innovation, the characteristics of the adopters, and the social system.'* (Zhang et al., 2015)". Figure 3 shows potential adopters of an innovation divided into five groups (Rogers, 1962) under the assumption of a normal Gaussian distribution with likelihood probabilities estimates of proportion, occurrence, and timing.

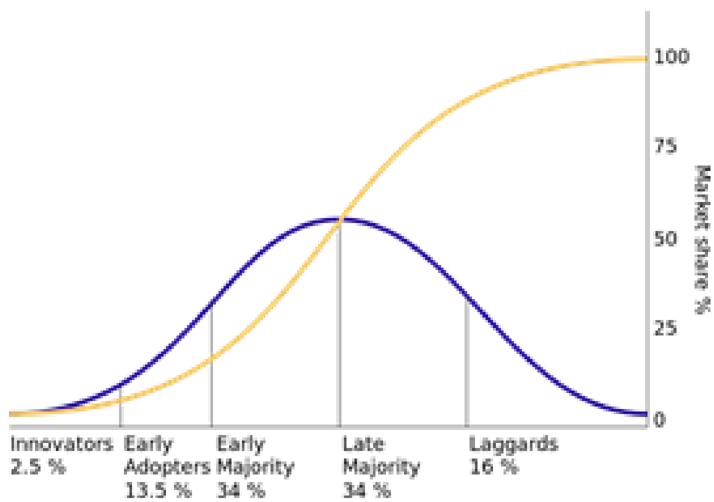

Figure 3. Diffusion of Innovation – Everett Rogers

Innovators form the first and most influential and important early buyers e.g., retail customers camping out on the sidewalk of an Apple store before the release of a new product the next morning is a typical image of these enthusiastic adopters.

The Bass-Bayes Spatial Extension (BBSE)

The Bass diffusion model (Bass, 1969). The Bass diffusion model is a mathematical Riccati equation of constant coefficients. First introduced in 1963 after discussion with Sociologist Everett Rogers and his diffusion of innovation theory itself derivative of previous work in the agricultural sector (Bass, 1969). The Bass diffusion model however specifically lacks any explicit spatial context. To spatialize the Bass diffusion model we re-conceptualize the Three-Machine/Defect problem (Kalbfleisch 2012). See Figure 4. Utilizing this simple analog overcomes the "aspatial" Bass delimitation and allows Bass to function within the context of the increasing availability of spatial-temporal data and information components.

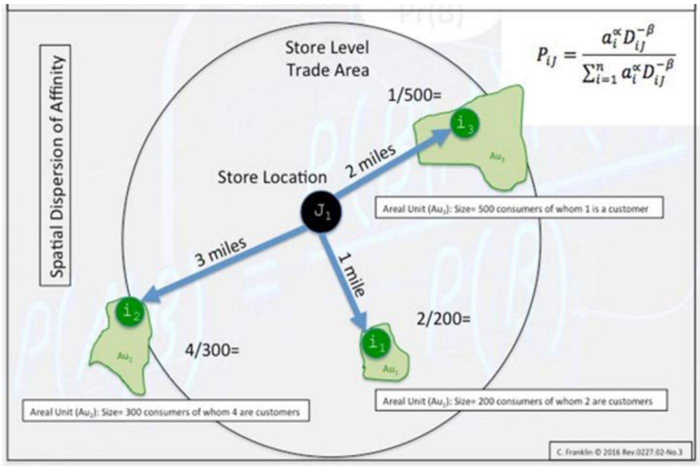

Figure 4. Bayesian 3 machine factory defect example. Source: Authors

The Bass-Bayes Spatial Extension (BBSE) approach operates parsimoniously based on the following assumptions.

- Assumption 1: The Bass Diffusion Model is both a necessary and sufficient condition for forecasting and predictive formulation, correctly estimating the timing and quantity of first-time Adopters (Imitators and/or Innovators) of an innovative product or service, throughout a store level trade area (SLTA) as defined by the Bass diffusion model.
- Assumption 2: There exists ongoing, geo-coded empirical, sales transaction data or "evidence" which provides the likelihood of the hypotheses being true. These initial random empirical adoptions of the innovation thus "qualify" certain census blocks in the store level trade area as "QCBs" for receipt of Bass predicted Adopters, after the innovation begins to diffuse throughout a SLTA.
- Assumption 3: We assume all Bass adopters are initially located in the store's census block (Note: this is an initializing placeholder condition only) until there is intervening evidence (i.e., empirical innovator sales transactions), in a Bass period to allow additional new QCB(s) into the innovation diffusion trade area shape. Gelman (2008b) points out that utilizing a "placeholder" for initializing Bayesian iterations is valid and has little or no distinguishing effects on evolving equilibria.

There are many micro-pathways of generating processes and many customer states in equilibria during an evolving retail trade area for an innovation. The well-defined phases of distance and time related consumer behavior activities can be studied and micro-analyzed during the presence of an innovation diffusion in a store level trade area.

The retail industry analysis, forecasting and market area revenue and profit projections however tend to predict results on a firm-wide basis.

Seeking the basics for a microscale (store level perspective versus the firm level) understanding of innovation diffusion generating processes, we hypothesize the "affinity" behavior between buyers and sellers has a strong influence on the buying behavior of adopters of innovation diffusion. This is based on widely known information that, for example, Apple products have an affinity with certain early adopters that is well explained by the diffusion of innovation theory and affinity marketing principles.

To study this question, we adopt a logical approach in the search for factored scalars (vectors or variables) like time and distance for understanding the marketing microscale processes and/or high spatial and temporal resolution interactions occurring in the SLTA (Mason, 1975.)

Methodology and Data

In the simplest of practitioners terms, (1) we focus on a geography (using GIS) of Adopter and potential Adopters (2) using GISc theory and methodologies we determine the potential number of customers (using the Bass Diffusion Model) and (3) their specific census areal units (Census block, block groups or tracts) location (Bayes Theorem) (4) then we apply census demographic information to the understanding of Adopters (Innovation Adopters in this example) and predict and forecast the spatial location intelligent data back to an IS on how the organization can best prepare for delivery of the value proposition and to meet predicted demand.

The paper posits that under innovation diffusion conditions (Hägerstrand 1952,1968; Allaway et al. 1994) the "affinity/supply" retail marketing strategy has certain advantages over the typical "loud" marketing stance of "attraction/demand" retail merchandising & marketing.

Affinity is defined as "a feeling of closeness and understanding that someone has for another person, because of their similar qualities, ideas, or interests" (Merriam-Webster, 2018). Creating "affinity" by recognizing and appealing to certain social group and/or individual attributes is not new. It is typically practiced and implemented by marketers who use only demographic variable profiling by census division (Sweitzer, 1975).

An empirical private dataset is utilized to help visualize and demonstrate the outcomes of this approach. The longitudinal spatial-temporal empirical data was collected under the author's guidance for the introduction of an innovative home improvement product/service under the conditions of innovation diffusion.

The Location Intelligent Model

A Census block becomes "qualified" based on one or more ongoing geo-coded, empirically derived sales of an innovation (i.e., an Adoption) occurring in that particular census block.

In the classic Bayesian three machine/defect problem (Kalbfleisch 2012), the census blocks can be crudely thought of as "machines"; the census block population being analogous to the items produced by the "machines". Conceptually, the Adopters can be allocated to the census block based on the proportion of ongoing geo-coded, empirically derived sales of the innovation in that census block, and considered as "defects" for predictive prior and posterior Bayesian modeling purposes.

The Adopters are allocated based on the proportional probability ratio of ongoing geo-coded, empirically derived sales of the innovation (i.e., the numerator) in specific Qualified Census Blocks (QCB) and divided by the "census population" in the denominator. Posteriors are updated using Bayes theorem. In addition, the census block "population" value may be weighted with demographic attributes for hierarchical ranking purposes with other census blocks as desired.

This alternative ecological modeling and geographic analysis appears to provide dynamic capability. By simulating the developing trade area formation, under an assumption of monopolistic conditions, high spatial-temporal resolution delimits the eventual market equilibrium to Bass time periods. These aggregating equilibria, forming longitudinally over Bass time periods, result in the "Huff gravity model's eventual market equilibrium". This approach provides a means of analysis of high-resolution, spatial-temporal innovation diffusion adoption behavior across the retail trade area (RTA) i.e., District, Regional or National. There have been several attempts (e.g., Haynes 1977, Shinohara 2012) but few, if any, parsimonious in supporting retail practitioners interested in studying microanalytic innovation diffusion effects at the store level trade area.

The Bass-Bayes Spatial Extension (BBSE) is a method by which a "temporal-only" Bass innovation diffusion model forecast, or prediction of potential Adopters can be located "spatially" within a SLTA and then actually be predicted and allocated to specific areal units (Huff Gravity Model) (i.e., census blocks, the units-of-areal/spatial analysis). Only census blocks (i.e., qualified) that contain at least one geo-coded Random Empirical Adoption are included in the SLTA "shape" (Mason, 1975) of the innovation diffused store level trade area. These census blocks are referred to as "qualified census blocks" or QCBs and can accept the Bass diffusion model's predicted or forecasted Adopters according to proportional formulations.

Finally, by linking the "aspatial/temporal" Bass diffusion model's predictions of quantity to the "spatial/atemporal" Huff gravity model projections provide a novel solution to predicting quantity and location of potential adopters, and has many potential applications (e.g., proactive intervention with ongoing innovation diffusion processes). In addition, utilizing the census blocks as the units-of-spatial analysis provides demographic statistics and attributes that can assist the retail practitioner.

Thus, a store level trade area (SLTA) could be disaggregated into its smallest units-of-temporal-analysis (i.e., Bass time periods) and its smallest units-of-spatial-analysis (i.e., Huff Euclidean distances) from the store location, for detailed study and analysis.

Bayes' theorem and the Law of Total Probability provide the probabilistic likelihood values for each census block containing Bass Innovators and Bass Imitators (derived originally Roger's concept (Figure 3), based on the proportions of adoptions made to each census block. REAs (Random Empirical Adoptions, i.e., sales) can signal potential spatial auto-correlation and Tobler's first law of Geography, among Adopters and adoptions, indicating potential new neighborhood market potential and opportunities for the retailer.

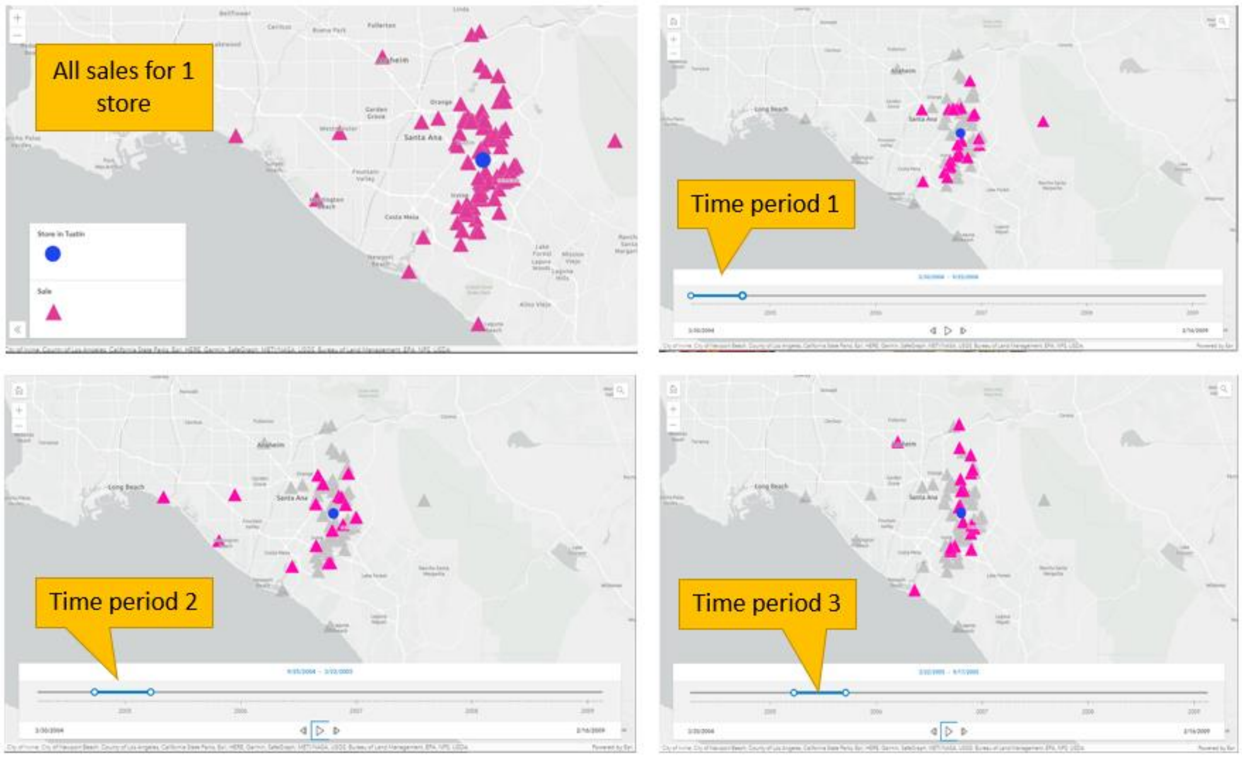

Figure 5. All sales for 1 store as a reference map followed by sales in individual time periods 1 to 3 using Esri ArcGIS Online Time Slider app

In the time series of GIS maps in Figure 5 (and continued in Figure 6), we see the development of a SLTA (store level trade area). The bright colored triangles represent period Adoptions or Random Empirical Adoptions (REA) of an innovation (in this case certain types of innovative architectural fenestrations) in Orange County, California. Those REA's are associated with specific Census block groups (Figure 7.)

Once a Census block group is known, a plethora of demographic and derived attribute data (available from census data and other sources such as Esri in Figures 8 and 9) can be applied to understand and create knowledge and insight into the buying behaviors of those consumers. This is referred to as location intelligence (or more specifically Location Awareness and Proximity Intelligence). Once the location is identified, Esri's Business Analyst can provide multiple dynamic infographics, one of which is shown in Figure 8, the Demographic Profile, including aggregate data on education, income, employment, population, median age, and more.

This then creates the basis for an informed DSS in the DCM and within the marketing, sales and customer service processes found in the conceptual customer-facing side of the IS hill.

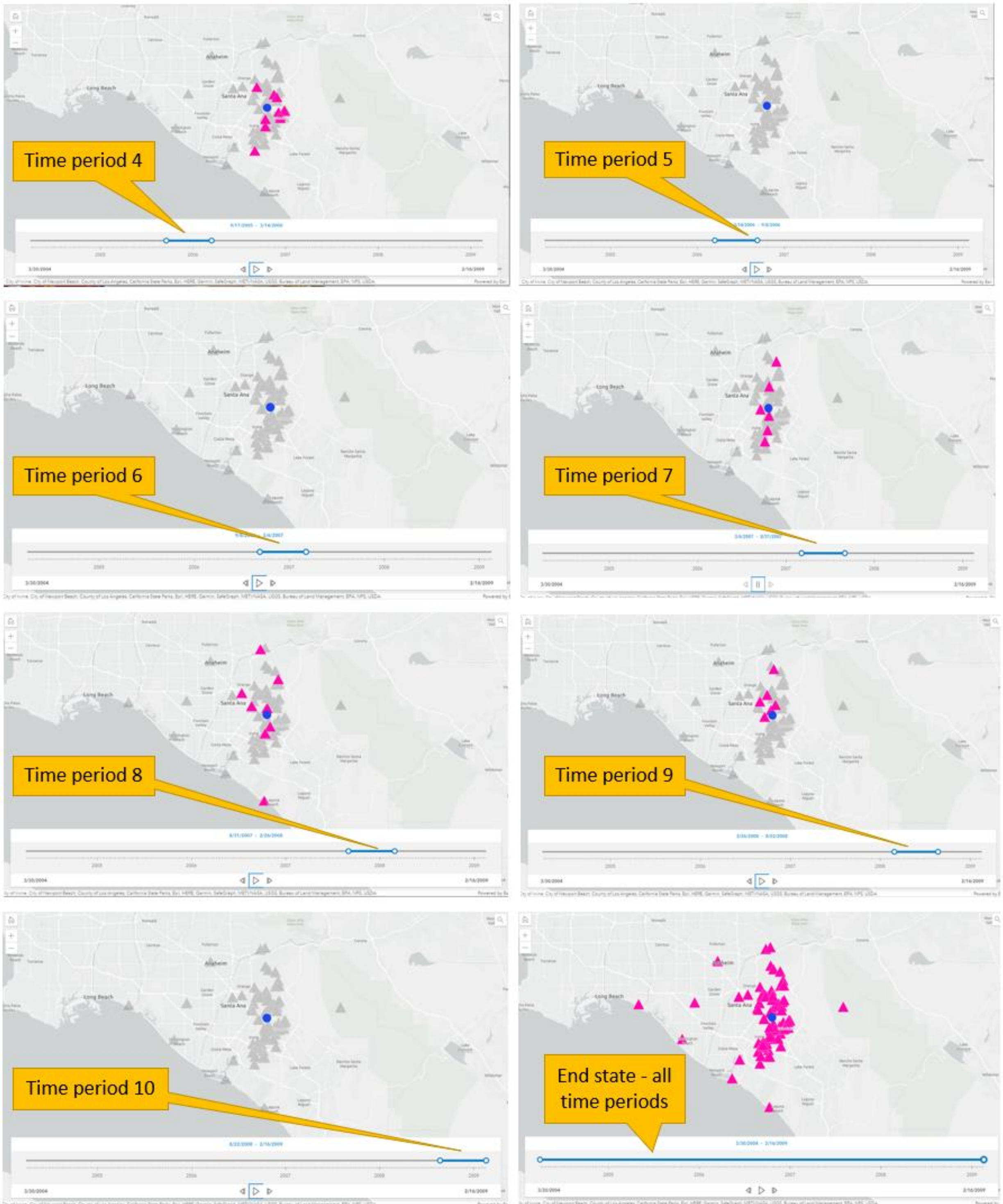

Figure 6. Innovation Diffusion for a single store mapping time periods 4 to 10 and end state equilibrium using Esri ArcGIS Online

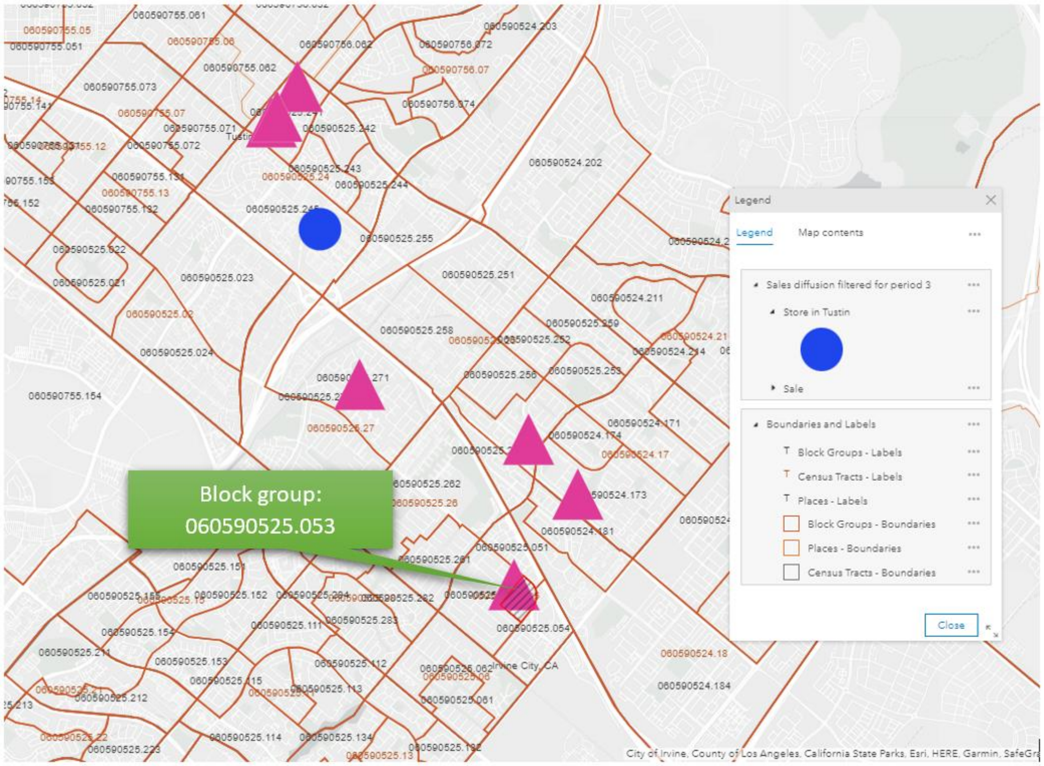

Figure 7. Census Block Group boundaries using Esri Business Analyst; highlighting a qualified QCB group. Triangles represent sales

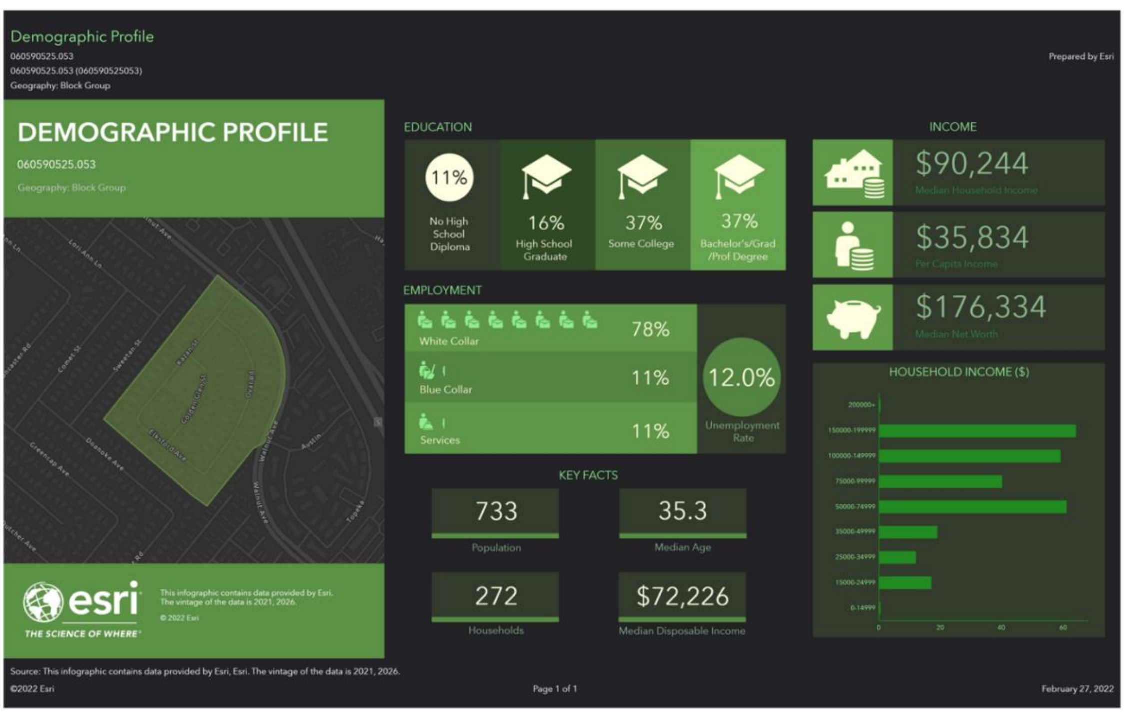

Figure 8. Demographic profile of the QCB group using Esri Business Analyst

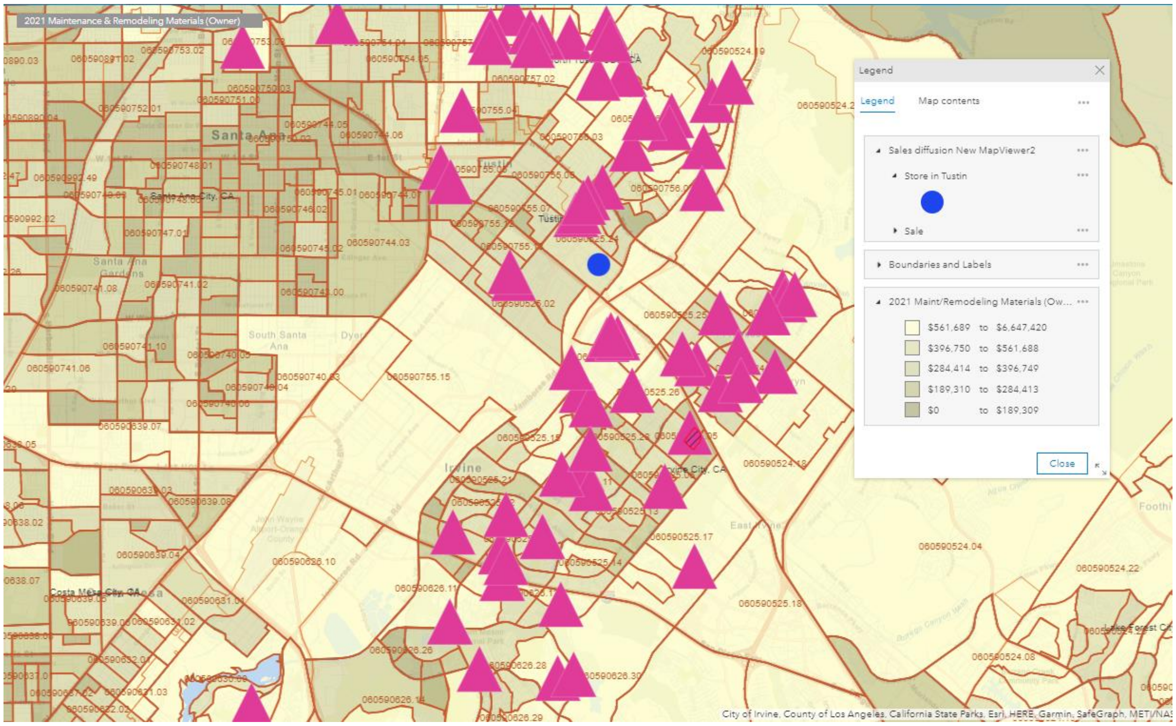

Figure 9. Homeowner Spending for Maintenance and Remodeling in 2021 using Esri Business Analyst. Darker shades represent higher spending areas

Conclusion

Although the diffusion of innovation today is thought of as delimited to only innovative products, a generalized model of innovation diffusion has existed in the rich literature of economics for over a century. Innovation diffusion or the "creative-destructive" process and nature of capitalism was well developed by Joseph Schumpeter after the second world war and up to his death in 1950. His students who include John Kenneth Galbraith and Alan Greenspan of the Federal reserve incorporated his ideas within their own work. A detail examination of Schumpeter's ideas on economic generalized innovation diffusion theories or "Schumpeter's Gale" as his work is referred is beyond the scale and scope of this paper but receives clear support for a generalized version of diffusion of innovation theory (Hardy, 1945).

In response to the research question: *What benefits can GIS decision-making and GISc innovations create with a location intelligent IS demand chain management (DCM) approach?* 1. Preemptive prediction can husband resources and signal changes and pivots that may be required. The DCM can assist the SCM side of the IS hill in a feedback loop that enhances sustainable profitable growth 2. Knowing the current and potential shape and structure (Mason, 1975) of a geographic retail trade area saves time and reduces the friction of cost of distance in optimizing resource investment. A clear example in retail would be geography-based ad-campaigns. The ability to quickly evolve from a "Location Ignorant IS" to a "Location Intelligent IS" allows the practitioner to focus on the most lucrative innovators and early adopters first, thus increasing the likelihood of a success during the overall innovation diffusion word-of-mouth process.

Kennan and Miscione summarized the IS/GIS challenge well as *"…atypical research drawing from different disciplines presents problems of finding reviewers and assessing the quality of the work…In relation to GIS and IS this fragmentation poses two dangers; that IS will not learn from GIS and that GIS will not learn from IS…If the IS field is largely divorced from GIS, then these similarities may not be identified and a danger of reinventing the wheel arises. Spatial technologies are now widespread and significant and the IS academic field must address their importance. IS academics with awareness of GIS must link the fields so that IS academics in other areas can fully take account of spatial systems without becoming specialists" (*Keenan and Miscione, 2015).

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