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Frameworks for Systemic and Structural Analysis of Financial Innovations in Infrastructure

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FRAMEWORKS FOR SYSTEMIC AND STRUCTURAL ANALYSIS OF FINANCIAL INNOVATIONS IN INFRASTRUCTURE

Ali Mostafavi[1] and Dulcy M. Abraham[2]

ABSTRACT

Financial innovations have emerged globally to close the gap between the rising global demand for infrastructure and the availability of financing sources offered by traditional financing mechanisms such as fuel taxation, tax-exempt bonds, and federal and state funds. The key to sustainable innovative financing mechanisms is effective policymaking. This paper discusses the theoretical framework of a research study whose objective is to structurally and systemically assess financial innovations in global infrastructure. The research aims to create analysis frameworks, taxonomies and constructs, and simulation models pertaining to the dynamics of the innovation process to be used in policy analysis. Structural assessment of innovative financing focuses on the typologies and loci of innovations and evaluates the performance of different types of innovative financing mechanisms. Systemic analysis of innovative financing explores the determinants of the innovation process using the System of Innovation approach. The final deliverables of the research include propositions pertaining to the constituents of System of Innovation for infrastructure finance which include the players, institutions, activities, and networks. These static constructs can be used to develop a hybrid Agent-Based/System Dynamics simulation model to derive propositions regarding the emergent dynamics of the system. The initial outcomes of the research study are presented in this paper and include: (a) a typology for mapping innovative financing mechanisms, (b) a System of Systems-based analysis framework to identify the dimensions of Systems of Innovation analyses, and (c) initial observations regarding the players, institutions, activities, and networks of the System of Innovation in the context of the U.S. transportation infrastructure financing.

KEYWORDS: Financial Innovation, Infrastructure, System of Innovation, System of Systems.

INTRODUCTION

Infrastructure are drivers of economic development which enhance the economic competitiveness of the nation. Since infrastructure are one of the major drivers of economic development in a country, infrastructure in deteriorating condition can affect the economic performance of the country. The American Society of Civil Engineers (ASCE) gave U.S. infrastructure a grade of "D" in 2009 (ASCE, 2009), which could affect the economic competitive advantage that the U.S. has while countries such as China are expanding their infrastructure investments to enhance their economic competitiveness. To improve the current close-to-failing condition (grade of "D") of U.S. infrastructure to a good functioning condition, an investment of $2.2 trillion is required between 2009 and 2014 (ASCE, 2009).

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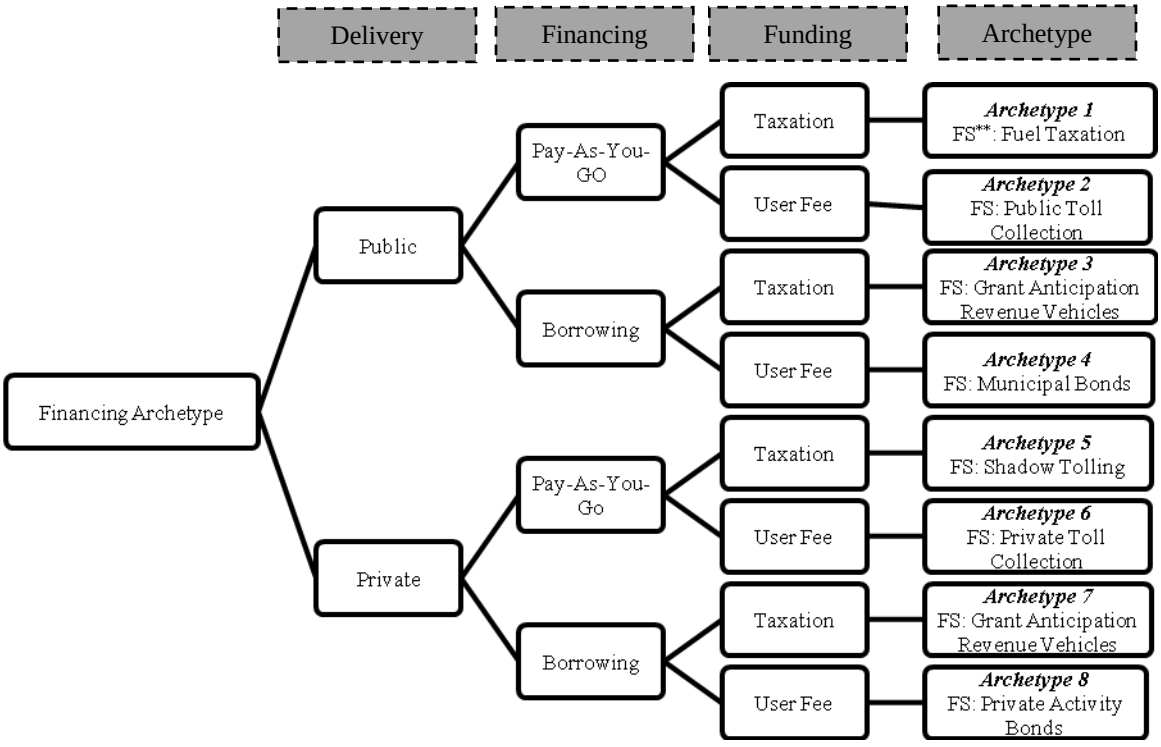
Financing entails providing capital for projects, while funding involves generating that capital through revenue streams, and delivering includes constructing and operating infrastructure. Infrastructure is financed either on pay-as-you-go basis (allocating fund revenues to infrastructure projects) or by borrowing. Taxation and user-pay are the only methods of funding. These serve as the sources of financing in the pay-as-you-go method and the sources of debt principal and interest repayment in the borrowing method and sources of returns on investment in equity investment. Infrastructure is delivered either publicly or privately (Ploeg, 2006). Examples of traditional financing mechanisms include property taxes and reserve funds (pay-as-you-go), pooled vehicles and amortized debentures (borrowing), fuel taxes (taxation), flat rate tolls (user fees), and fully public delivery. The combination of the methods used for financing, funding, and delivery of infrastructure forms the *financing archetype*. Using the two methods of financing (pay-as-you-go and borrowing), the two methods of funding (taxation and user-pay), and the two methods of delivering a infrastructure (public and private), there are eight mutually exclusive and collectively exhaustive infrastructure financing archetypes as shown in Figure 1. While the infrastructure financing archetypes are limited to eight, the *financing mechanisms* for implementing these archetypes are not limited. Financing mechanisms which are called *financing systems* hereafter in this paper are defined as structures that facilitate implementation of each of the financing archetypes. Examples of financing systems for implementation of each of eight financing archetypes are shown in Figure 1.



**FS: Financing System*

Figure 1- Infrastructure financing archetypes

The challenge facing infrastructure policymakers is that traditional systems of financing infrastructure have not been able to meet the challenges for financing infrastructure. The

challenges include unavailability of required capital, cash flow problems, and unfavorable risk-return profiles of infrastructure for private investors. The challenges are rooted in population growth, aging existing infrastructure, and evolving infrastructure investment risks (from commercial risks to political risks) as a result of rising standards (e.g., more stringent environmental regulations) and competing capital and budgeting priorities.

Innovative financing has emerged globally to offer new financing systems for funding, financing, and delivering infrastructure projects that complement traditional systems to address the existing demand and to enhance sustainable infrastructure financing. For instance, the recent emerging systems which have been adopted by the transportation sector in the U.S. for financing infrastructure include but are not limited to leaseback agreements (e.g., Indiana Toll Road), State Infrastructure Banks (SIBs), Grant Anticipation Revenue Vehicles (GARVEE) Bonds, and Availability Payment Mechanism.

As the U.S. Secretary of Transportation commented in 2009, addressing the nation's transportation (and other infrastructure) issues would require innovative thinking (Reinhardt, 2009). The key to sustainable innovative financing is effective policymaking. The questions to be answered in order to make effective policies include but are not limited to the following: How do innovative financing systems differ from each other? What types of financial innovations are sustainable in specific economical and political conditions? How do the performance of different types of financial innovations differ? What are the organizations engaged in innovative financing? What are the activities and institutional rules affecting the development and the diffusion of innovative financing systems?

This paper presents the framework and initial outcomes of research in-progress by the authors. The research study focuses on the structural and systemic assessment of financial innovations in infrastructure projects. Structural assessment of innovative financing focuses on the typologies and loci of innovations and evaluates the performance of different types of innovative financing systems while systemic analysis of innovative financing explores the determinants of the innovation process.

The first step in research is to "identify a structure to guide the research", which is the so-called *theoretical framework* (Liehr and Smith, 1999). However, there is no priori theory or hypothesis pertaining to financial innovations in infrastructure in the literature that can be used as a theoretical framework. Therefore, creating the guiding structure of the research is necessary in order to proceed with the study. The theoretical framework of the research is created based on the concepts, taxonomies, and approaches found in literature pertaining to the study of innovation.

BACKGROUND

The study of innovation has been a central point of attention in empirical economics literature for more than 30 years and has gained attention in construction and infrastructure engineering research literature during the last decade (e.g., Chinowsky and Taylor (2007), Taylor and Levitt (2007), and Tawiah and Russell (2008)). Studies in innovation can be divided into two broad categories. The first group of innovation studies assess innovation processes at a micro level. These studies focus on the structural analysis of innovation processes to create propositions regarding the typologies of innovations to provide prescriptions for innovators. Innovations can be classified as architectural/generational and sustaining/disruptive. Gatignon et al. (2002) surmised that architectural innovation involves changes in linkages between existing

sub-systems and that changes in sub-systems linked together with existing linking mechanisms result in generational innovation. This dimension of innovation typology describes the information regarding where the innovation occurs in the system. In addition, innovation can be either sustaining or disruptive, which Christensen and Raynor (2003) differentiated as follows: "A sustaining innovation targets demanding, high-end customers with better performance than was previously available. Disruptive innovations, in contrast, do not attempt to bring products to established customers in existing markets. They introduce simpler, more convenient, and less expensive products and services that appeal to new or less-demanding customers." The disruptive characteristic describes innovations that improve a product or service in ways that the market does not expect, either by being lower priced or designed for a different set of consumers" (Anthony et al. 2008). This dimension of innovation typology classifies innovations based on the target market of the innovation.

Innovations also can be characterized as incremental/radical and competence-enhancing/ competence-destroying. According to Gatignon et al. (2002), incremental innovations improve performance at a rate consistent with current technology expectations. Radical innovations provide advanced performance beyond the current rate of progress. Competence-enhancing innovations build upon and reinforces existing competencies, skills, and knowledge, and competence-destroying innovations, as can be guessed by their destructive title, have an opposite effect on competency. The level of performance improvement in the system caused by innovation depends on the incremental/radical characteristic of the innovation. The competence-enhancing/competence-destroying characteristic refers to the competencies upon which the innovators build.

A structural approach for assessing innovation describes the innovation process by determining the: (a) locus of innovation, (b) the types of innovation, and (c) the characteristics of the innovation. For the assessment of innovative financing, identifying the loci of innovation, as well as the type of innovation, are examined to be the first major dimensions to be defined in the structural analysis.

The second group of innovation studies (e.g., (Freeman, 1987), (Lundvall, 1992), (Nelson, 1993), and (Edquist, 1997)) investigated innovation processes at a macro level using a systemic analysis. These studies evaluated the roles and activities of different organizations and the interactions among the organizations and their effect on innovation processes. This group of innovation studies introduced the System of Innovation (SoI) approach to provide propositions for innovation policymaking. According to innovation system approach, innovation and technology developments are the result of the complex set of relationships among the actors in the system, as shown in Figure 2. The innovation process and the interactions involved in this process form the SoI. SoI analyzes and explains important factors shaping and influencing innovation in a system (Edquist, 2001). *"System of innovation includes all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovation"* (Edquist, 2001).

Constituents of SoI include organizations (players) and institutional rules (norms and practices) and the relations among the players. *Organizations* are players or actors, and *institutional rules* are the sets of common habits, norms, routines, established practices, rules, or laws that regulate the relations and interactions between the players and actors. In fact, they are the "rules of the game." The *activities* in SoI are those factors that influence the development, diffusion, and use of innovation and are the drivers and inhibitors of innovation. In order to

assess an innovation process, it is crucial to identify all the important factors affecting development and diffusion of the innovation. In addition to identifying the system components and their relation, it is important to determine what happens in the system. What do the organizations do regarding innovation process? How do institutional rules constrain or stimulate organizations to perform activities related to the innovation process? (Edquist, 2004).

The following sections of the paper discuss the theoretical framework and initial outcomes of the research, which include: (a) a typology for structural assessment of innovative financing, (b) an analysis framework for exploring the dimensions of systemic analysis, and (c) initial observations pertaining to innovative financing implementation in the U.S. transportation infrastructure sector.

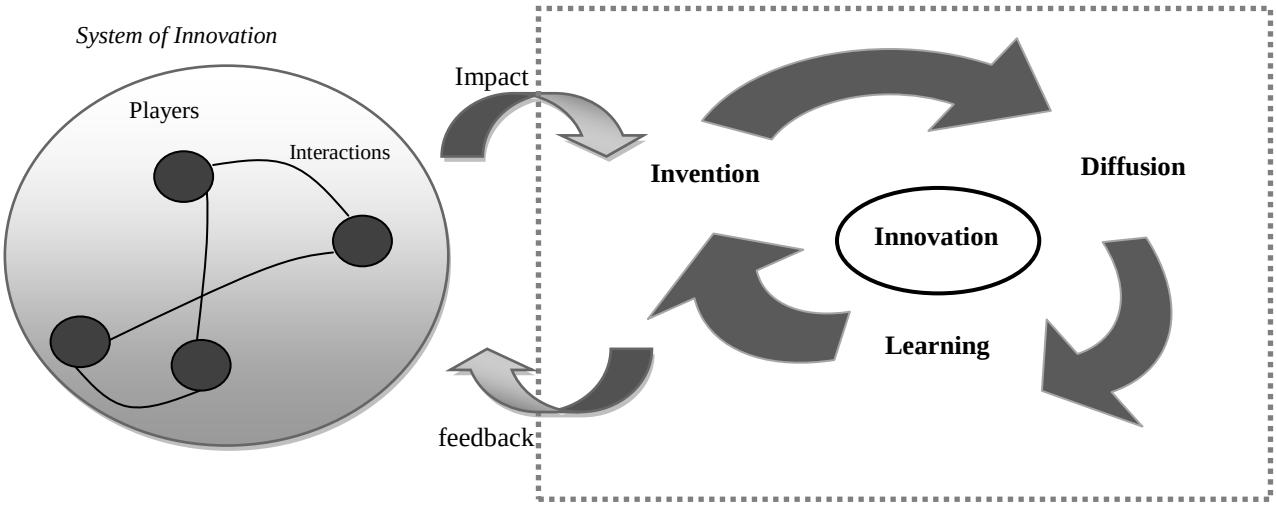


Figure 2- Concept of System of Innovation

TYPOLOGY OF FINANCIAL INNOVATION

The first step in the structural analysis of financial innovations is to distinguish between different types of financial innovations. Unless financial innovations are distinguished on the basis of a consistent taxonomy, development of propositions pertaining to their performance and, thus, creation of prescriptions for innovation, is unlikely. Since there is no single right way to distinguish between them, there is a need for a typology to map different types of financial innovations. In developing the typology, the criteria proposed by Scott (1981) for developing organizational typologies were used:

- The typology should be "intuitively sensible." It should capture the common intuitive sense of what an infrastructure financial innovation is by grouping together innovations that seem similar and disentangling innovative systems that seem different.
- The typology should be "mutually exclusive and collectively exhaustive" (i.e., it should provide a systematic way of classifying all innovative financing).
- The typology should have "construct validity," indicating that the typology should be sufficiently different from related typologies. In addition, while some amount of subjective judgment is always needed in classifying innovative systems, the innovative systems should be classified in the same way, if given the same information.

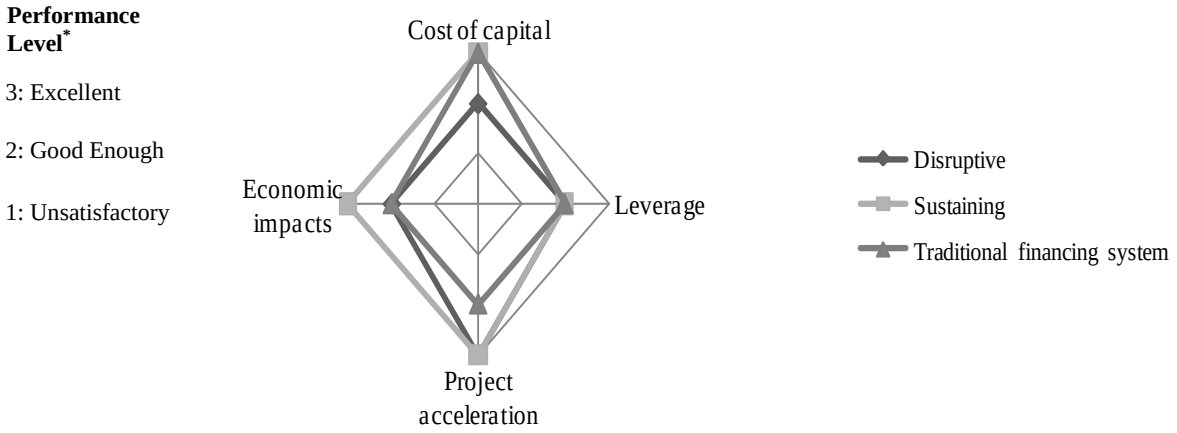
- The typology should be "conceptually elegant." Conceptual elegance is somewhat subjective, but in essence it is desirable to use as few concepts as possible in the typology (Malone et al. 2006).

The typology proposed in this study classifies innovative systems based on the *loci of innovation* and the *type of innovation* (as shown in Figure 4). The loci of an innovation is the sub-system in which an innovation takes place and can include each of the sub-systems of an infrastructure financing system: capital, risk mitigation, regulatory, contract, cash flow, and organizational. These sub-systems can be identified through an investigation of infrastructure financing literature (e.g., Vives et al. (2006), Finnerty (2007), Griffith-Jones and De Lima (2004), Settel et al. (2009), Bertolini (2006), Ploeg (2006), and Grigg (2010)). The type of innovation is either disruptive or sustaining. A disruptive innovation refers to the application of financing systems that have traditionally been used in other sectors (e.g., investment of pension funds in hedge funds) to finance infrastructure projects (a sector in which they have not been previously applied) by lowering one of the performance dimensions of the investment. Performance measures differ for private and public entities. Performance measures for public entities include cost of capital, project acceleration, leverage, and economic impacts while for private entities the performance measures include return on investment, liquidity, and risk avoidance. Figure 3 demonstrates how disruptive innovations differ from sustaining ones using an illustration. In Figure 3, performance levels are illustrated in a subjective way for the purpose of exemplifying the difference between sustaining and disruptive innovations while comparing alternative financing solutions. The disruptive innovation in this illustration has lowered the performance measure of cost of capital while improved performance measure of project acceleration. In the case of sustaining innovation, performance measures are either maintained or improved. Pension funds have been a well recognized source of capital in different investment opportunities (e.g. hedge funds) before they found their way to infrastructure financing. If public or private pension funds are utilized for infrastructure investment through an innovative system while a performance measure is lowered (e.g., increase of cost of capital) and other performance measure is improved (e.g., increase of availability of capital), it can be considered as an example of disruptive innovation. Grant Anticipation Revenue Vehicle (GARVEE) is an example of a sustaining innovation since it improves traditional infrastructure bonds by making them repayable by future federal funds which facilitates project acceleration.

Furthermore, sustaining financial innovations are either incremental or radical. Innovation is defined to be incremental in infrastructure financing system if it improves performance (decrease cost of capital, accelerate projects, increase leverage ratio, increase funds availability, or increase rate of return) at a rate consistent with the country's infrastructure finance trend. An innovation is defined to be radical if it advances performance at a rate higher than the country's infrastructure finance trend.

In addition, financial innovations are either modular or integrated. Infrastructure financial innovations take place at any sub-system (i.e., at the component level and at the linkages). New tools in each sub-system represent a modular innovation. Since the sub-systems are interrelated, a change in a sub-system may bring about changes in other sub-systems which represents integrated innovation. As a case in point, introduction of a new organizational structure may require integrated changes to the regulatory framework or adopting a new capital source may require emerging risk mitigation tools. An example of an integrated innovation is earmarking property taxes for capital purposes. Earmarking property taxes for capital investment purposes is

a different usage of this traditional source through an integrated change in regulation and capital sub-systems. New types of bonds (e.g., build America bonds) are examples of modular innovation since they include modular changes in the capital sub-system. Figure 4 shows the structure of the proposed typology. The typology was validated by evaluating different innovative financing systems. The validation of the typology reveals that the innovation loci and type dimensions satisfy the typology criteria introduced by Scott (1981). The typology is used in structural assessment of financial innovations in infrastructure. Initial outcomes pertaining to structural analysis of innovative financing is discussed in the subsequent sections.



*the values on the axes starting at 1 - unsatisfactory and going towards 3 – excellent

Figure 3- Sustaining vs. disruptive financial innovations

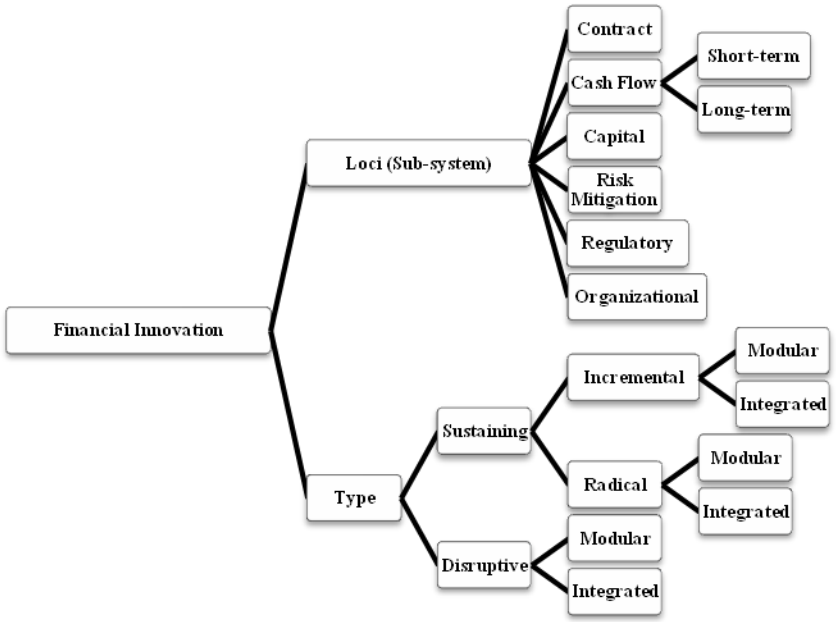


Figure 4- Typology for assessment of innovative financing systems

SYSTEMIC ANALYSIS FRAMEWORK

SoI has yet to become a theoretical framework partly due to some methodological challenges that have not been addressed thus far (Chang and Chen, 2004). Generally, there are five methodological challenges impacting SoI analysis: the lack of a consistent methodological lexicon, the need to address the impact of the interrelationships between different SoIs, the need to identify the appropriate level of analysis, the need to make ex-ante predictions, and the dynamics of systemic boundaries (Chang and Chen, 2004). A comprehensive analytical framework for SoI analysis should address the existing methodological challenges (Chang and Chen, 2004), in order to pave the way for case studies. Comparative case studies are needed to evaluate innovation systems and develop theories pertaining to the determinants of innovation processes" (Edquist, 2004).

The primary reason for the above-mentioned challenges appears to be that SoIs have been analyzed as monolithic systems when, in reality, SoIs are Systems of Systems (SoSs), which have different features compared to monolithic systems. A SoS is "*an assemblage of components which individually may be regarded as systems, and which possesses two additional properties: operational independence of components...and managerial independence of the components*" (Maier, 1998). SoIs possess all the distinguishing traits of SoSs introduced by Maier (1996) (which includes geographical distribution, emergent behavior, evolutionary development, operational independence, and managerial independence). Thus, assessing SoIs using a SoS-based framework would facilitate elimination of existing methodological challenges in the analysis of SoIs. To emphasize the advantages of using SoS lexicons and principles for enhancing the SoI framework, Table 1 lists the SoI challenges cited by Chang and Chen (2004) alongside the corresponding robustness of SoS analysis. An examination of Table 1 reveals that the SoS approach is a good match for designing SoI studies, thereby providing the foundation for a theoretical framework.

Table 1 - SoI challenges and SoS strengths

Challenges in assessing SoI	Strengths of an SoS analysis
Lack of consistent SoI definitions	Facilitates clarity using consistent lexicon
Need for a bottom-up orientation	Facilitates identification of appropriate level of analysis
Establishment of interdependencies between SoIs	Facilitates determining the within- and cross-level interactions
Need for quantitative models (understanding the dynamics of SoI)	Facilitates consistent modeling techniques

A SoS-based analysis framework is proposed (shown in Figure 5) to illustrate the dimensions and elements of analysis in the study of SoIs (Mostafavi et al. 2010). The framework is called *Innovation System of Systems (I-SoS)*. The three dimensions of analysis in *I-SoS* framework (*definition*, *abstraction*, and *implementation*) will be addressed in the research study to investigate the determinants of financial innovations in infrastructure. The initial outcomes and observations pertaining to the definition and abstraction dimensions for systemic analysis of infrastructure innovative financing are discussed in the subsequent sections.

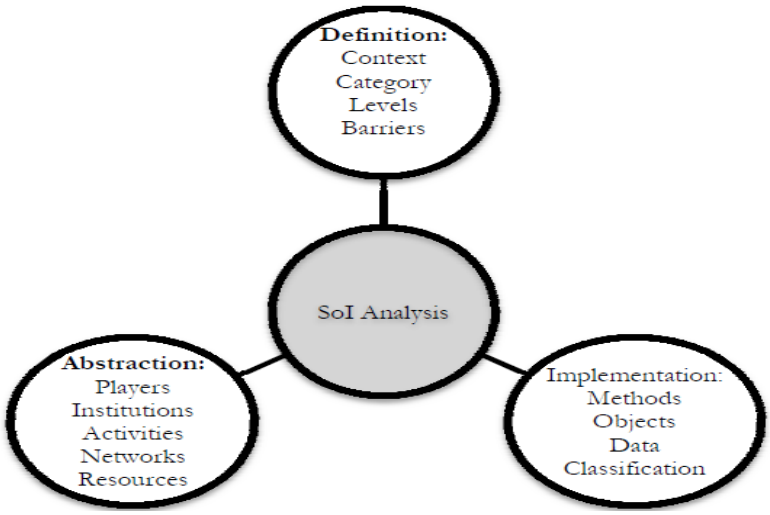


Figure 5- Dimensions and elements of I-SoS framework

STRUCTURAL ANALYSIS OF INNOVATIVE FINANCING: EVALUATION OF CASE STUDIES

The proposed typology is used to identify the type and loci of financial innovations. The initial assessment includes evaluation of innovative financing systems in four transportation infrastructure case studies of in the U.S. The cases were selected to illustrate the diverse innovative financing systems available in order to evaluate the capability of the proposed typology to map loci and types of innovation. The case studies include the Indiana Toll Road, the North Tarrant Expressway (Dallas, TX), the Port of Miami Tunnel, and the Illinois State Toll Highway Authority.

1. Indiana Toll Road (FHWA, 2010)

The state of Indiana's transportation funding shortfalls hindered its ability to complete new projects and maintain existing transportation infrastructure in 2004. The shortfall along with Indiana Governor Mitch Daniels' vision to turn Indiana into the "transportation logistics capital" of the U.S. led to the state leasing the Indiana Toll Road to a private consortium through an innovative leaseback system to provide capital for the unfunded $2.8 billion estimated capital plan while there was an inability to raise fuel tax as the traditional system. A leaseback agreement is a system whereby an infrastructure asset is sold by the owner and leased back for a long-term. Thus, the state continues to use the infrastructure asset but no longer owns it. The system was the first long-term lease by a state of an existing public toll road (this was a brownfield project) in the U.S. The concession agreement establishes toll rates and possible increases and places limits on the return on investment for the concessionaire. The leaseback agreement cost was $3.8 billion with an agreement period of 75 years starting in 2006. Leasing agreements and private investments in infrastructure have been in existence as financing systems. However, they have not been used in the context of the U.S. brownfield transportation projects.

The innovation has been in contract and capital sub-system and is integrated in nature. The innovation is disruptive since it targeted institutional equity investors (in this case,

Macquarie Group from Australia and Cintra from Spain) to invest in brownfield projects to raise funds for infrastructure projects rather than relying on fuel taxes or issuing bonds for funding infrastructure. Institutional equity investors have been traditionally targeted to directly finance greenfield infrastructure projects. Disruptive innovation targets their investment towards brownfield projects. The innovation is disruptive since the cost of capital is higher (lowered performance measure) comparing with alternative borrowing tools while other performance measures such as availability of capital and project acceleration are improved. The funds raised through the leaseback agreement are used by the state of Indiana for financing greenfield infrastructure projects. The innovation has led to Archetype 6 of infrastructure financing.

2. North Tarrant Express (Dallas-Fort Worth Metroplex, Texas) (FHWA, 2010)

Phase 1 of the North Tarrant Express project includes the design, development, construction, finance, maintenance, and operation of 13 miles along Interstate Highway (IH) 820 and State Highway (SH) 121/SH 183 from IH 35W to SH 121, from north of Fort Worth to just southwest of Dallas-Fort Worth International Airport. The innovation utilized in this project included an innovative financing package consisting of Private Activity Bonds (PABs) and *Transportation Infrastructure Finance and Innovation Act (*TIFIA) loan credit assistance that is subordinated to PABs (FHWA, 2010). TIFIA credit assistance was used because of the market collapse of monoliners due to the economic recession at the time of project planning (early 2009) to enhance the credit worthiness of the project. Monoliners are entities who guarantee the timely repayment of bond principal and interest in case of issuer default. The TIFIA credit assistance facilitated self-sustaining PABs in the absence of monoliners. The project was only the second PABs issuance ever under the $15 billion of authority provided to a Department of Transportation (DOT). It was also the first transportation infrastructure project in the U.S. to reach financial closure with direct investment by a pension fund. The innovation (using TIFIA credit assistance) includes a sustaining-incremental innovation at the risk mitigation and capital sub-system that enhances the performance measures through risk mitigation. Thus, the innovation is integrated. The innovation has resulted in an Archetype 8 of infrastructure financing. The financial close of the project was reached in December 2009. The project construction starts in late 2010 and will be completed in 2015.

3. Port of Miami Tunnel (FHWA, 2010)

The Port of Miami Tunnel project is a public-private partnership with Miami Access Tunnel, LLC (MAT). Approximately 50 percent of the capital costs (design and construction) and all operations and maintenance costs are being paid by the state of Florida, while the remaining 50 percent of the capital costs will be provided by the local governments. The Florida DOT will pay MAT milestone payments at various stages of project development and construction in varying amounts totaling $100 million, followed by a $350 million final acceptance payment after construction is completed. In addition, the Florida DOT will provide availability payments to the concessionaire that begin at the completion of construction and that will occur annually for 30 years (FHWA, 2010). An availability payment is a payment for performance irrespective of demand. The commercial close of the project was reached in mid 2009. The project construction started in early 2010 and will be completed in 2014. The project innovation includes adoption of availability payments in the project. The innovation is an integrated innovation in contract and risk mitigation sub-system. The state will set and retain all

tolls and will pay the availability payments to the concessionaire. The innovation also mitigates the risks that the investor faces if there are fluctuations in the demand. The innovation improves performance measures (e.g., cost of capital) and, thus, is a sustaining-incremental innovation that has resulted in Archetype 6 of infrastructure financing. The availability payment system facilitates implementing the user-fee method (the fees are controlled by a public entity, and are not part of the concession).

4. Illinois State Toll Highway Authority (FHWA, 2010)

The Illinois State Toll Highway Authority (the Tollway) issued $500 million in early 2009 in toll highway senior priority revenue bonds as taxable Build America Bonds (BABs). BABs are taxable municipal bonds (fixed-income securities) that carry special tax credits and federal subsidies for either the bond issuer or the bondholder. The offering for the Tollway comprised two tranches: a $400 million 25-year term bond subject to a make-whole call and $100 million 15-year term bond subject to a 10-year par call. The Tollway decided to issue the 15-year tranche as taxable BABs but maintained its flexibility by including a 10-year par call. BABs are issued to reduce the cost of borrowing for state and federal agencies and to increase the capital availability for financing infrastructure in addition to traditional municipal bonds which are tax-exempt bonds. In this project, the cost of interest of the 15-year taxable BAB's was3.44% compared to the 3.97% of cost of interest for the traditional callable tax-exempt bond alternative. This innovative structure was accepted by taxable investors familiar to non-callable or market-whole callable bullet maturities. The innovation is sustaining-incremental. It includes an independent change at the capital sub-system and, hence, is a modular innovation. The innovation is sustaining since it enhances performance measures (e.g., availability of capital and cost of capital). The innovation has led to Archetype 4 of infrastructure finance. Table 2 summarizes the innovative systems illustrated in the case studies.

Table 2 - Summary of typology of innovative financing systems in the case studies

Case Study	Traditional Alternative System	Innovative System	Locus/Loci of Innovation	Innovation Type	Infrastructure Finance Archetype
Indiana Toll Roads	Fuel-taxation + Bonds	Leaseback Agreement	Contract + Capital	Disruptive/Integrated	Archetype 6
North Tarrant Express	Tax-exempt bond+ Monoliners' Insurance	Private Activity Bonds + TIFIA Loan	Risk Mitigation + Capital	Sustaining-Incremental/Integrated	Archetype 8
Port of Miami Tunnel	Toll Collection by Concessionaire	Availability Payment	Contract+ Risk Mitigation	Sustaining-Incremental/Integrated	Archetype 6
Illinois State Toll Highway	Tax-exempt Bonds	Build America Bonds	Capital	Sustaining-Incremental/Modular	Archetype 4

SYSTEMIC ANALYSIS OF INNOVATIVE FINANCING: INITIAL OBSERVATIONS

For systemic analysis, the U.S. transportation infrastructure was studied using I-SoS framework to identify the constituents of the system. The initial assessments include implementing the definition and abstraction phases of the analysis. The analysis begins with the definition phase. The *context* of the analysis includes assessment of innovative financing systems for transportation infrastructure in the U.S. All *categories* of financial innovation are considered in the analysis as discussed earlier in the structural analysis section. The *barriers* of the analysis include the heterogeneity of the players and their activities within and across different levels of analysis, which adds to the complexity of the analysis.

The abstraction phase includes identification of the *players*, *institutions (norms and practices)*, *activities*, *networks*, and *resources* within and across the different levels of analysis (sub-national, national, and global). These elements are identified using a case-based research approach. The initial assessment includes interviewing fourteen (14) experts from organizations engaged in innovative financing of transportation infrastructure who had significant knowledge and years of experience to capture detailed information pertaining to the players, institutions, and activities in the system. Table 3 shows the organizations represented by the different interviewees. The interviews were conducted between March and July 2010, and were taped for consequent transcription and review. The interviews were analyzed through transcription and coding for our use in hypotheses induction. Coding refers to deciphering the transcribed interviews and labeling the pieces of information pertaining to the players, institutions, and activities. The codes are refined through pattern analysis to summarize groups of codes into constructs. The initial observations pertaining to the constituents of infrastructure finance SoI are presented in the subsequent sections.

Table 3- Informants interviewed for data collection

Organization	Number of experts interviewed
Federal Agencies	2
State Departments of Transportation	2
Global Institutional Investors	2
National Institutional Investors	2
National Financial Consulting Firms	2
Universities (Academia)	4

Players

The first element of the abstraction phase is identification of the players. Players are the organizations that are operationally and managerially independent, and the emergence of innovative financing is the result of their activities and the interactions among them. The major groups of players in the infrastructure financing process were identified as follows: federal and state agencies, global and national institutional investors, consulting companies, and the general public.

The group of federal players includes the federal government (legislative representatives), the Federal Highway Administration (FHWA) and the American Association of

State Highway and Transportation (AASHTO) within the U.S. Department of Transportation (USDOT). State agencies include state governments, state Departments of Transportation (DOTs), regional district offices, and toll road authorities. Institutional investors include investment banks, venture capitalists, wealth firms, and pension funds. Examples of global institutional investors include Macquarie Group, Cintra, and Brisa; and examples of national institutional investors include firms such as Goldman Sachs. Consulting and advising firms as well as law firms are another group of players, and include the Parkers Company, Goldman Sachs, and the P3 Development Company. Finally, the general public is an important player at either the sub-national or the national level.

Initial Observations Regarding Institutions and Activities of the Players

Federal and State Agencies

The federal government facilitates invention and diffusion of innovative financing systems through policies. An example of such policies is the Transportation Infrastructure Finance and Innovative Act (TIFIA). The TIFIA program provides federal credit assistance in the form of direct loans, loan guarantees, and standby lines of credit to finance surface transportation projects of national and regional significance.

The FHWA developed the Innovative Finance Program to enhance innovative financing of transportation infrastructure through "learning" the best financing practices in other sectors and in other countries and creating guidelines to be used by states DOTs (FHWA, 2010). Similarly, AASHTO's Center of Excellence in Project Finance was developed to provide policy guidance pertaining to innovative financing. This center partners closely with FHWA's Innovative Finance Program for policy implementation. All categories of financial innovation (architectural, generational, and disruptive), as defined in the definition phase, are of interest to AASHTO's Center of Excellence in Project Finance and the FHWA Innovative Finance Program.

The innovative financing policies and best practices guidelines developed by federal agencies are provided to state governments and state DOTs to be adapted for financing projects. State governments practice innovative financing based on their transportation infrastructure development plans and needs. For instance, the capital shortfall in the State of Indiana early in the Indiana Governor's administration (2004) along with his vision to turn Indiana into the "transportation logistics capital" of the U.S. led to the state leasing the Indiana Toll Road to a private consortium in 2006. A leaseback innovative system was used to provide capital for the unfunded $2.8 billion estimated capital plan while there was an inability to raise fuel tax as the traditional funding system.

State DOTs adapt policies and best practices provided by federal agencies based on their needs and based on the characteristics of projects (e.g., project risks, possibility of tolling in the project, and project priority) and economic conditions such as a recession. Thus far, states such as Florida, Virginia, and Texas with a significant need for financing sources have implemented innovative systems such as availability payments and shadow tolls. As the states pursue innovative financing, they learn in the process to adapt more innovative systems. For instance, the state of Texas started using shadow tolls as an innovative funding system for projects financed to facilitate private investments. As Texas DOT learned through adaptation of the mechanism, a Pass-through Financing program was developed in 2008 within Texas DOT that

led them to consider the possibility of tolling for each project whether it is financed by private investors or it is financed using federal or state money.

Once a state succeeds in meeting its infrastructure demand by implementing innovative financing, other states are prompted to adapt the mechanism. The interviewees from the Texas and Florida DOTs mentioned that they have been contacted by other states DOTs (e.g., Georgia) asking about their experiences and lessons learned using innovative financing systems.

Institutional Investors

Institutional investors invest in infrastructure either through infrastructure funds or through concession agreements. These investors seek long-term stable return (inflation-indexed return) that matches their investment portfolios. Global institutional investors who have invested in mature markets like Australia, Spain, and England since the early 1990s have started to participate in financing of U.S. transportation infrastructure. For instance, the Macquarie Group (from Australia) and Cintra (from Spain) who invested in infrastructure in Australia and Spain, respectively, for over ten years have invested in U.S. highway projects such as the Chicago Skyway Bridge and the Indiana Toll Road. The inclusion of global investors using innovative Public-Private-Partnership (PPP) structures is an innovative way of financing U.S. transportation infrastructure.

In addition to investment, institutional investors (both global and domestic) can educate public agencies at either the national or state level about the process and the benefits of the innovative systems that they initiate. In fact, private institutional investors (e.g., Macquarie, Cintra, and Brisa) are pushing the frontiers of innovative financing by using their long-established expertise based on experiences in financing infrastructure projects in different countries. Greater involvement of the private sector in infrastructure development, financing, and management leads to greater potential for innovation (Garvin, 2007). Institutional investors (like all the investors) are looking for profitable infrastructure investment opportunities. Thus, they are motivated to innovate and create systems that make an infrastructure investment opportunity desirable for their investment portfolios. Their motivation and activities are different from what public agencies implement regarding innovative financing, which is either an adaptation or issuance of different types bonds (so-called "Plain Vanilla"). Institutional investors may use the tools provided by public agencies to develop a mechanism which is appropriate for the project of their interest. For instance, in the case of the North Tarrant Express project in Dallas, Texas, institutional investors (Cintra, Meridiam Infrastructure, and Dallas Police and Fire Pension System) took advantage of TIFIA loans to enhance the credit worthiness of the project to be able to issue private activity bonds. TIFIA enhanced the credit worthiness of the private activity bonds in the absence of monoliners.

Institutional investors need to receive signals from federal and state agencies to invest in the country's infrastructure, which will occur when federal and state agencies set established policies and programs for private investment in infrastructure. As a case in point, the TXDOT's Pass-through Financing program sent a signal to private institutional investors prompting them to participate in transportation infrastructure investments in the state of Texas.

Since investors tend to invest in the markets that they know, as the leading institutional investors start to experience successful investments, other investors are encouraged to enter infrastructure markets. An example of this case is the participation by pension funds in infrastructure investments. For instance, in 2009, Texas Police and Fire Pension System invested

in the North Tarrant Express project in Dallas. It was the first investment of pension funds in transportation infrastructure in the U.S. The Texas Police and Fire Pension System considered infrastructure market for investment after observing successful infrastructure investments made by other pension funds such as Australian pension funds and the Ontario Municipal Employees Retirement System which made investments in infrastructure markets in Australia and Canada, respectively.

Consulting Agencies

Consulting firms provide advice to both public and private agencies regarding the benefits and processes related to innovative financing systems. These agencies also facilitate innovative financing through research on what is being practiced in other countries and other sectors, such as water, energy, and communication. Their activity complements the programs of entities such as FHWA's innovative financing program and AASHTO's Center of Excellence in Project Finance that work more closely with state agencies to facilitate adaptation of the innovative guidelines provided by public agencies.

General Public

The general public plays an important role in the development and/or the adaptation of innovative financing systems. When user-pay or taxation methods are used for funding of infrastructure, public perception is an important factor to be considered in evaluating innovative financing. Innovative systems are not easily understandable by the public, and implementation of innovative financing might be perceived as disadvantageous especially when it conflicts with public interests. For instance, systems which include user-fee funding and long-term concession agreements raise public concerns and may lead to the perception of conflict of interest by the general public. An example of public and political objections include leasing of the Pennsylvania Turnpike. In 2007, the Pennsylvania Governor announced his intention to lease the Pennsylvania Turnpike and implement tolls on I-80. When the Turnpike commission applied to FHWA for an expression of interest to implement tolls on I-80, there was an objection among community and business groups, who complained about the increased costs to travel as a result of leasing the Turnpike. Subsequently, political oppositions formed as a state senator requested the U.S. Secretary of Transportation to turn down the application for leasing the Turnpike. Finally, the application was rejected by the state house (Levy, 2008). Therefore, it is important to educate the public regarding the existing condition of the nation's infrastructure, the growing demand for financing sources, and the advantages and impacts of implementation of innovative financing. Educating the public would reduce the likelihood of public objections which could arise as a result of the implementation of innovative financing. In fact, education is required to improve the institutional capacity of all the players to implement innovative financing (Garvin, 2010).

Networks

Three networks (set of players interconnected through communication and knowledge transfer) exist in the infrastructure financing SoI, which include: networks of institutional investors, networks of public agencies, and networks among the general public (e.g., social networks). So, there are links among the public agencies, among the institutional investors, and among the social networks within general public. Some institutional investors form coalitions (networks) to communicate and find solutions to tackle existing obstacles for their investment in

infrastructure. An example of such coalitions at the national level is the Sustainable Public Finance Coalition, a special working group dedicated to developing the core body of knowledge and leadership for the development finance industry (Council of Development Finance Agencies, 2010). Similarly, networks of public agencies have emerged, mainly the Innovative Finance Initiative of FHWA, AASHTO's Center of Excellence in Project Finance, and States DOTs, to communicate and share knowledge with one other regarding the best practices and solutions for problems. Networks within the general public play an important role in the implementation of innovative financing. The existence of general public networks facilitates education of the public and, thus, enhances implementation of innovative financing by addressing public objections. Despite the existence of these three networks within the U.S. transportation infrastructure financing SoI, these networks are mostly isolated and do not interact (in terms of learning and knowledge transfer) with each other. The insufficiency of communication and knowledge transfer between the networks has been referred to by the interviewees as one of the inhibiting factors in implementing innovative financing.

Implications of the Initial Observations Regarding the Drivers of Innovation

Drivers and inhibitors of innovative financing are the factors that expedite and decelerate, respectively, the development and diffusion of innovative financing implementation. The main driver for innovative financing for public agencies is the need for capital. On the other hand, for private institutional investors, the opportunity for a stable investment is the main driver. As the need for capital investments increase, the willingness of public agencies to implement innovative financing increases. Other drivers of innovative financing include the political attitude and public perception of innovative financing. Political attitude and public perception change with expansion of the need for capital. The greater the need, the more open the people and politicians are to innovation. Need was cited by the interviewees as the major driver of innovative financing. For instance, the main reason why states like Texas, Florida, and Virginia stand at the forefront of implementing innovative financing among all the states is that these states were in a greater need for infrastructure financing sources. For private institutional investors, the driving factor of investment opportunity leads to innovations to reduce risks and obtain favorable returns on the investment. Global and national economic conditions, such as an economic recession, are other drivers of innovative financing. Global and national economic conditions do not eliminate the need for innovative financing but change the objectives of the players to innovate. For instance, private institutional investors implement innovative financing during economic booms to make themselves competitive. During a recession, on the other hand, innovative financing is implemented to enable private investors to close deals. An example of innovation during a recession is the case of the North Tarrant Express in Dallas, Texas as discussed earlier in the paper.

Future Steps

The future steps in the systemic analysis of financial innovations in infrastructure include implementing more case studies to create propositions regarding the determinants of innovation in infrastructure financing. Case studies will be implemented on successful and unsuccessful projects which adopted innovative financing to see which policies encourage innovative financing to be diffused through the networks of projects. Then, the implementation phase of the systemic analysis is conducted. The themes and constructs pertaining to players, activities, and

institutions in infrastructure financing system will be integrated using a hybrid Agent-Based (ABM)/System Dynamics (SD) model to simulate the emergent effect of different policies on the innovative financing process. The model can be used for ex-ante analysis to be used for policymaking purposes. Agent-based modeling is capable of modeling the emergent behavior of a system that consists of managerially and operationally independent organizations. Furthermore, SD is used for understanding the behavior of complex systems and the effects of causal factors over time. Concurrent use of ABM and SD facilitates taking advantage of the capabilities of both modeling tools to simulate players' activities and institutional rules in conjunction with the important driving and inhibiting factors in the infrastructure financing system.

CONCLUSION

The theoretical framework and taxonomies presented in this paper serve as the first building block for the structural and systemic assessment of financial innovations in global infrastructure projects as there are no priori propositions/frameworks in the area. The proposed innovation typology will be used in the future steps of the research study for structural analysis of innovative financing. More in-depth analysis of case studies will be conducted and propositions related to the performance of different innovative financing systems will be created. Similarly, the proposed *Innovation System of Systems* framework will be used to guide the systemic analysis. Based on the initial observations, the infrastructure finance System of Innovation in the U.S. transportation sector is in the learning process. Education, standardization of financing processes, and alignment of players' objectives were identified as important activities enhancing innovative financing. In the future steps of systemic analysis, constructs pertaining to the determinants of Innovation in infrastructure financing will be created. These constructs, when eventually integrated in a simulation model, could enhance understanding of the dynamics of innovative financing through assessment of probabilities and possibilities (ex-ante analysis). Such analysis could potentially be used in innovative financing policymaking.

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