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Developing a Marketplace for Smart Cities Foundational Services with Policy and Trust

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ABSTRACT
This paper examines the issues of policy and trust in the context of IT infrastructures for Smart Cities. This paper proposes that trusted Smart city policies can lead to the development of a set of ***trusted foundational services underlying all smart city solutions. Such services are critical*** to ensure that the architectural choices used to drive efficient integration among data and service consumers and providers to use within smart city domains, and ***will lead to the development of a marketplace where service providers and consumers engage in a free and fully informed exchange to choose worthy and reliable experiences addressing everything from reporting street light outages to identifying economic advantages during city planning***. It argues that two usually mutually exclusive architectural meta-models; Centralization and Federation, are both required to achieve a robust set of trusted foundational services. It reviews a scale of options for implementing the marketplace component of the foundational services to support a matrix of consuming scenarios from fully isolated well known analytics to the anonymous access that allows potential users to browse for services without any controls before requesting access. It concludes that Trusted Policies are highly important as successful ingredients in the development of foundational services during the developmental stage and in the operations and maintenance stages for integrated Smart city systems. It is critical that Smart cities systems implement city-wide policies and similarly policy driven marketplaces that improve and sustain trust and in turn help Smart cities manage the multitude of systems that are continuously both developmental and operational, and will be so for many decades to come.

KEYWORDS
Policy — Trust — Foundational Services — Integrated Solutions — IT Infrastructures — Marketplace.

1. Introduction

The market places of current software services are predominantly focused on the sale of software and services to customers that may research, buy, and quickly apply the technology purchased to business and operational problems. Examples of this market place phenomena include AWS Marketplace which offers services in the EC2 cloud [1]; CompuCom's Application Marketplace Services which employs Application Management System (AMS) from a cloud base to manage applications[2]; Hubspot Service Marketplace that connects marketing service providers and users seeking marketing services[3]; Microsoft's Azure services catalog which provides an array of platform and software services; [4] and SAP which uses the SAP Service Marketplace to implement Cloud Integration for 20 end-to-end hybrid integration business scenarios[5]. These marketplaces have offered the industry an evolving operational model of how systems can either manually or automatically acquire services required to select, configure, test, and deploy new applications.

A similar model of evolving services may prove to be a critical element contributing to the solution of one of the most important issues today in terms of Smart cities project selection, implementation and effectiveness. The model illustrates in a basic fashion how architectural choices for integration and use may be established to support the ongoing development of dynamically evolving norms, policies, and standards within smart city domains. It is a situation where cities are awash in integration problems driven by potentially acute numbers of city data sources, data flows from social networks, sensors, and public sources (such as utilities); and the integration of these flows with both known an d unknown Service and data (proprietary and open). The complexity of the problems related to the continuing and supporting integration is made acute as social network dynamics introduce change in the objectives and purposes of data. ***The need is for policies that drive and support procedures to provide controls on data distribution, establish trustworthy data source ratings to enable consumers of information (public decision makers and/or private consumers of data) to choose sources based on an established scale of trust.*** It is posited that providing a high degree of trust adds great value to such a systems of systems with interconnected data sources in the smart city domain. Key questions addressed in this paper are:

- what is trust for a smart city,
- how can smart cities develop trust in developing systems,
- how important are the technical concerns (e.g., data and data connections),
- how can one introduce new data sources with a very high degree of trust and reliability, and
- how can a marketplace model effectively support the acknowledgement, acceptance, and use of policies and support procedures.

The policies that can aid in establishing trust are beneficial because they foster, enable, and support an environment of active, real time negotiations between participating parties in a smart city ecosystem. Smart city systems must respect the control choices of service providers and provide meaningful understanding to service consumers by supporting the service providers' ability to expose all, some, a partial set in a marketplace based on consumer, an index of available responses, or none of their service. By providing a more diverse set of sharing options the service owner has the opportunity to consider who is requesting the service. Are they well known and do they have a history of interacting with the system? Similarly the requesting consumer can, as part of agent based negotiations, choose to evaluate the service prior to consumption from the marketplace by reading reviews or monitoring the services' rating, and perhaps even the ability to reject the service if the results appear to be outside of the consumers policy defined conditions.

Policies evaluated through continuous machine learning are critical for the complex web of systems and stakeholders involved in a smart city. It is impractical for data and sources to be reassessed every time a new source, consumer, or process is introduced. Instead systems must become active participants with each other so that they can efficiently and rapidly establish trust and learn to respond to change.

Done well, the marketplace benefits are robust, including increased confidence and reduced time to make decisions, as well as vetting and automated comparisons of analytics for fit with previously accepted data and results. Further benefits stem from supporting individual choices and decisions based on social networks combined with the additive and "morphing" data a smart city provides to further deepen the engagement and transparency between citizen and city. This can be achieved when ***a trusted foundational service underlying all smart city solutions provides a marketplace where service providers and consumers engage in a free and fully informed exchange to choose worthy and reliable experiences that address everything from reporting street light outage to identifying economic advantages during city planning.***

Large scale service and data marketplaces are realistic and achievable particularly when the idea of such marketplaces is compared to the huge and growing number of e-marketplaces with large transactions volumes that cover the gamut of business experiences. The variety of successful structures includes 3rd party commodity exchanges, auction providers, bulletin-boards, back-end fulfilment services and market information sources. The products also cover a huge spectrum from chemicals, feed stocks, polymers, to fuel oil and personal consumer items. One enterprise such as ChemConnect, services more than 9000 companies from over 150 countries worldwide. Functions are broad and specialized in some instances. cc-hubwoo delivers source-to-pay electronic solutions and supplier network management by managing a e-procurement community with more than 60 buying corporations and over 12,000 connected suppliers in 44 countries worldwide. It processes 2 million purchase orders with €5 billion in annual spending. The Quadrem marketplace links 47,000 suppliers and 700 buyers and accounts for US $13 billion annually. [6]

2. The Smart City Data Trust Problem

Smart cities are urban environments with complex problems, and partial or possible visions of solutions to those problems. Within the context of this paper, smart cities are viewed as intelligent and rational decision making environments, and not products or processes limited by trademarking or market defining attempts to associate the concept along particular product, resource or product lines (e.g.: IBM trademarks such as Smart Oil®, Smart Traffic®, Smarter Banking®, Smarter Cities®, Smarter Commerce™, Smarter Energy®, Smarter Healthcare®, Smarter Oil®, Smarter Planet®, Smarter Public Safety®, Smarter Traffic®, Smarter Water®, Smartmodels®, SmartSuite®) that would differentiate a company or service from other competing concepts and products addressing the intelligence needed in a smart city to successfully function and deliver services to a cities stakeholders. Although there is no uniformly agreed to definition of a smart city, many of the offered definitions are generally in agreement regarding the overarching mission of a smart city - seen as a city that can functionally deal with the complexity of providing services to large numbers of people, business, and entities. As Chourabi, et. al. [7] have pointed out, the cities have an almost limitless litany of problems varying from "... waste management, scarcity of resources, air pollution, human health concerns, traffic congestion, and inadequate, deteriorating and aging infrastructures." Other problems may appear in these environments in social, coordination, communication and decision making areas that are seemingly intractable since they are more organizational in nature and not addressable as technical, physical or material requirements. As the evolving research and literature on cities shows problems of these types are complex since they are associated with multiple and diverse stakeholders, high levels of interdependence, competing objectives and values, and social and political complexity. [7]

The scope of the smart city problem is not only huge, but is global and not specific to any country or area of the world. As URBAC has stated, the European cities are "... not sustainable, inclusive or productive enough for the modern age." [8] There is recognition that innovative solutions to problems are needed everywhere or the problems will be overwhelming. The key focus is problem prevention, with cities required to organize their innovative efforts, prioritize, and then seek new solutions. Solutions cannot simply be left to chance or to government initiatives, but must be designed into daily services and support both legacy and new systems, with their associated data, and processing. Once designed as daily services with clear objectives and performance capabilities, they must be made readily available to the citizen through the marketplace.

Data from solutions must also be made appropriately available to the public, based on clear policy, or at a minimum accessible for the public good. The collective population of the city, citizens and city employees, must overcome historical resistance to data sharing and hesitation to reduce time to accomplish the ever changing fluid goals of the city. In the pursuit of this end, the introduction and use of a foundational services platform must limit any disturbance of existing boundaries of control, ownership, responsibility, and funding. Last, all of the legacy and capabilities must strive to provide and leverage bi-directional engagement of the citizens and city employees.

Historically, these have been difficult if not impossible objectives to reach when framed by traditional technology systems development and implementation approaches with traditionally long development cycles as well as large, expensive, and politically charged management decision structures which leave little room for change and less room for accepting any external dependencies for implementation. By establishing a marketplace of a trusted set of foundational services based upon policies that ensure trust and participation, each of the objectives can be achieved and sustained to deliver a marketplace driven system that enables service discovery and effective combination.

3. Definitional Inclusion of IT

It is our belief that IT is an integral component and possibly one of the most important foundations of a smart city.

In their summarizing paper Chourabi, et. al. [7:2289] identify both important trends and suggest research agendas about cities that may become "smart." A recurring theme recognized as both one of the greatest challenges and as a potential success factor and a core component of smart city is information. It is seen as one of the core components in 4 of the definitions of a smart city. A city that monitors and integrates conditions of all of its critical infrastructures with IT [9]; connecting the IT infrastructure that leverages intelligence [10]; combining ICT and Web 2.0 technology with other organizational, design and planning efforts..." [11]; and one using computing technologies to make the critical infrastructure components and services of a city... more intelligent, interconnected, and efficient" [12].

Definitional work continues to include IT with Harrison et al's study [10], who describe it as being interconnected, with an ability to capture and integrate live real-world data. Their practical description applies "... sensors, kiosks, meters, personal devices, appliances, cameras, smart phones, implanted medical devices, the web, and other similar data-acquisition systems, including social networks as networks of human sensors." Chourabi, et. al. [7:2290] noted "Interconnection means the integration of those data into an enterprise computing platform and the communication of such information among the various city services. Intelligence refers to the inclusion of complex analytics, modeling, optimization, and visualization in the operational business processes to make better operational decisions. In contrast, the Natural Resources Defense Council [7] defines smarter in the urban context as more efficient, sustainable, equitable, and livable. Toppeta [11] emphasizes the improvement in sustainability and livability. Washburn et al. [12] view a smart city as a collection of smart computing technologies applied to critical infrastructure components and services. Smart computing refers to a new generation of integrated hardware, software, and network technologies that provide IT systems and real- time awareness of the real-world and advanced analytics and actions that optimize business processes [12]." Chourabi, et. al. [7:2290]

The key point of these definitional statements is that many directly involve or depend upon information systems, interconnection, and data integration. The smart city necessitates operational success based upon highly effective digital communication, embedded intelligence, sensors, tags, and software.

The many definitions of a smart city caused Chourabi, to offer eight factors that could impact "... the design, implementation, and use of smart cities initiatives." Five of the eight success strategies proposed by Chourabi, et. al. [7] involve descriptions of information systems and applications of technology. Chourabi et. al.'s review of the literature supports this, noting that smart city IT initiatives and projects have highlighted these issues as important success factors or major challenges [13].

They point out that Gil-Garcia and Pardo [13] found e-government initiatives and smart city initiatives with commonalities in that smart city initiatives were governmental and used IT in their projects. They also link similar observations in other research noting that the smart city projects are supported by computing technologies applied to critical infrastructure components and services. Smart computing refers to a "new generation of integrated hardware, software, and network technologies that provide IT systems with real-time awareness of the real world and advanced analytics to help people make more intelligent decisions about alternatives and actions that will optimize business processes and business balance sheet results" [12]; Information and Communication Technology (ICT's) are key drivers of smart city initiatives [14]. A key point made by Ebrahim and Irani [15] is that using IT in smart cities is not a guarantee of the success of an initiatives and that training, integration and project objectives are important to success in smart cities.

The second success factor in this observational approach identified governance activity supported by emerging IT (smart governance) as defined by Forrester as core to smart cities projects [16].

The third success factor Chourabi et.al.'s posited as important was the ICT infrastructure [16]. The discussion addressed object networks, wireless infrastructure (fiber optic channels, Wi-Fi networks, wireless hotspots, kiosks) [17,18,19], service-oriented information systems [20,21]. They observed that IT infrastructure availability and performance is essential to a smart city's development, but literature addressing ICT infrastructure barriers of smart cities initiatives is not readily available.

E-government technological barriers are used as surrogates for blocking factors since smart cities' initiatives are similar to e-government initiatives in their use of ICT. Ebrahim and Irani [15] offer IT challenges grouped into IT infrastructure, security and privacy, and operational cost dimensions.

Chourabi et.al.'s [7:2294] conclude where we begin, "Technology may be considered as a meta-factor in smart city initiatives, since it could heavily influence each of the other seven factors. Due to the fact that many smart city initiatives are intensively using technology, it could be seen as a factor that in some way influences all other success factors in this framework."

4. Evidence of Smart City Projects

There is strong evidence that smart city projects require effective IT. The table 1 illustrates how deeply and frequently IT projects address or are key parts of smart city objectives.

5. Policy

We propose that policy is essential for technological success and employing IT as an essential technology that can truly enable smart cities. Further, we affirm that this policy focus can be effectively communicated due to the open characteristics of a marketplace that makes service and data available, and can aid consumers as they protect themselves against unwise acquisitions, fraud, deception, or sales practices that may not meet their specific requirements.

Chourabi et.al.'s review of the literature addressed policy as one of the critical factors. It was included as being "critical to the understanding of the use of information systems in appropriate ways." Chourabi et.al.'s [7:2292] review of the smart city literature noted changes in policies are necessary for innovation. They observe "that innovation in technology for a smart city can be relatively easily observed and broadly agreed upon", and we disagree with this implied ease of IT innovation. Technology's effective application must be supported by agreed to or imposed rule sets associated with either data or process (collectively called services). From a technical perspective, these conditions are codified into machine to machine agents. City managers, city employees, and citizens then use policies present to determine if and how they consume the available services. In the context of this paper, these rule sets which can collectively be viewed as or called are referred to as "Policies" that deliver the guidance and instruction for the control and operations of many things, including meta-markings such as release and retention, proper use, limits of liability, and source accreditation requirements.

The technical requirements of today's systems and services foster this need for policy. Modern, fluid architecture creates a dynamic virtual environment where nearly everything is negotiated: process execution, view, read, write, and all forms of modification. Negotiations happen early, during service or user initial introduction into the system, continuously, between systems agents representing provider and consumers of services, and late, providing feedback, enforcing temporal and distribution rules. Similarly each of these conversations exploit their related policies. Some will have been created as default policies when a service is first released in to the marketplace. Others will be dynamically created and applied based on various attributes defining the context of execution. Some might re-engage the user agent after initial operation on a schedule, duration, or event driven cycle to reevaluate its continued use, request or retrieve feedback, or validated the appropriateness of the services continued support.

The primary goal of these policies is to foster, enable, and support an environment of trust. Smart city systems respect the control choices of service providers. Service providers can expose all, some, a partial set based on consumer, none but an index of available by request, or no external exposure of their service. By providing a more diverse set of sharing options as part of the agent based negotiations the service owner has the opportunity to consider who is requesting the service, are they well known and do they have a history of interacting with the system? Conversely the consumer of services has the ability to evaluate the service prior to request from the marketplace by reading reviews or monitoring the services' rating, and perhaps even the ability to reject the service if the results appear to be outside of policy defined conditions. They could filter the list of available services based on the trustworthiness of the supplier, or the value assigned by prior consumers of the service. Once the consumer chooses a service they can base their scope of use (as a sole source or part of an aggregation or services) knowing the providence of the information they are consuming. The result is a service economy based upon the issuance and the acceptance of trust. Services in the marketplace that are deemed high risk become marginalized while those deemed reliable prosper. Trust flows outward to citizens, city employees and managers as the services use results in increasingly high quality outcomes.

Table 1. *Evidence that Smart city projects require effective IT*

Domain	IT Requirement/Initiative	Predicted change or trial demonstration	Reference
Urban design	Smart cities and big data - how the city is wired, generating new data planning impacts	Digital design ideas using digital representations and data that are also digital	Batty, [22]
Crowd-sourcing	Users combine data collection, selection, and assessment activities to achieve goals within a predefined context	Experimental evaluations of quality, participation, accuracy and urgency (crisis situation)	Benouaret, Valliyur-Ramalingam, Charoy, [23]
Governance across: traffic, infrastructure, energy	Processing, data transfer and analysis, and distributed computing; Internet of Things; Web technologies	Summarizes articles for a broad spectrum of smart city projects; focuses on deployment and evaluation.	CEFRIEL, Kotoulas, [24]
Security framework, aging infrastructure, Internet of Things (IoT) – big data	Cybersecurity policies, campus developments, infrastructure monitoring and integration of big data	Observes that innovative designs are tested as a proof of concept; e.g. Berlin TXL, Royal Seaport in Stockholm	Velosa, Nakano, Tratz-Ryan, Steenstrup, Perkins, [25]
Public infrastructure for mobility and electrical with IT	Apply IT to utilize energy and other resources efficiently by fusing information and control	Packaging all infrastructure construction from planning to operations; collaborate with public and private sectors for services; energy, charging and vehicle management	Yoshikawa, Sata, Hirasawa, Takahashi, Yamamoto, [26]
Real Time Monitoring with automated control processes for operators and service providers	Optimize operations for a shift of from heavy infrastructure to operators and service providers - ICT exploits data content of the sensor and crowd gathered data rather than just data pipes	Changing technology landscape in business models, architecture, traffic via M2M, backbone offload, management of heterogeneous, crowd-sourced data and big data mining	Dohler, Ratti, Paraszczak, Falconer, [27]
User involvement in Smart cities and Living labs	Involvement of users and stimulating bottom up innovation is very complex and must incorporate how to stimulate this kind of innovation	Entrepreneurs in a Living Lab smart city pilot in Amsterdam, the Climate street analyzed how involved entrepreneurs were engaged in bottom up innovation as a socio-technical network.	Sauer, [28]
Internet of Things to aid city BUs to improve or cost-effectively deliver services, and meet infrastructure requirements	City department business units (BUs) are updating their embedded electronic systems to IoT systems	Smart city projects in the U.S., Japan, and China incorporate IoT elements as Smart campus projects transportation solutions in Europe or Australia.	Velosa, Alfonso , and Lily Mok, [29]

6. Trust

In the context of policy acceptance, this paper utilizes trust defined as the willingness to rely on a business partner based on its past trustworthy behavior [30]. While trust is at the heart of relationships of all kinds, [31, 32] trust is considered generally crucial in many of the economic activities that can involve undesirable opportunistic behavior [16]. It is exactly that, opportunistic behavior that currently plagues a city's information solutions. Vendors, developers, support staff, user managers, acquisitions support and purchasing agents, executive decision makers, and users all have, intentionally or otherwise, created mythic fortresses of statistically flexible metrics and time delayed data in an effort to protect themselves from liability. One of the most important objectives of these assurance mechanisms is to create an illusion of success for anyone looking to question decisions or intent. Reporting, transparency, and communication are at an all-time high but somehow, trust that solutions adequately address problems remain elusive, and demonstrable successes based on time, budget, capability/performance are, at best, scarce.

Systems used in cities of today are often a complex mix of old batch and new transactional processing providing, by today's standards, simplistic reports; largely ignoring much of what can be achieved using modern sensor driven specialized services, and evolving mobile and social systems with complex correlation services finding value in a diverse collection of otherwise disconnected and unstructured data. The first wave of decision makers (decision making utility managers) were satisfied to receive data from systems that generally operated as control, billing and reporting systems. Obviously, they were not meant to meet the current or future goals of smart cities and are not coordinated or integrated. Although compared to the last decade's growing social networks whose data habits are far worse with regard to trust, coordination, and integration, cities are a shining light of clear data ownership, centralized control and responsibility, and clear data markings when necessary.

The authors contend that we have entered a unique generation of smart city solution development, support, and operation with new and more complete sets of trust establishing policies that do not necessarily fix responsibility on either the providing service or the consumer. The smart city can employ a mix of procurement and development practices that allows both the formal systems and social networking solutions to not only share risks and responsibility within a fluid power structure but also provides control to be passed around and shared as needed.

Over the last 20 years everyone has become more sophisticated in their expectations of what should be provided by city services. They have grown from grateful to have automation applied, to accustom to an industrial sense of large scale and highly repeatable quality support service to their current state; today, and for the foreseeable future everyone is demanding individualized, personalized services at the same speed and quality of the commoditized same size for everyone solutions of the recent past. Solutions deployed to aid in city management, economic development and citizen services are not only orders of magnitude larger, more complex, and result-driven, but are also required to integrate with in-place legacy systems. They must be dynamically composed accounting for up-to-date information, consumer preferences, and provider policies.

The resulting solutions are by definition architecturally complex, supporting multiple scenarios, mixing on premise, hybrid, and cloud hosted components, and all while providing simple decomposition and redeployment for unknown future use. Their services are dynamically scalable, dynamically compiled, and capable of complex multi-tenant support. Risk and responsibility are allocated with the same just in time dynamic underpinnings as determining runtime location or which source or sources should be included in the process. In practice, there are non-technical positive side effects well beyond service providing and service consumption. Policy acceptance and reliance based on trust can also provide declarations of responsibility bound to legally enforceable contracts in smart cities. Resulting actions taken can, and arguably should be judged in the context of the moment. Issues identified must be rapidly fed back to all involved parties effectively changing the context of a decision, and potentially making a different action (and previous decision) more justifiable or correct.

To support these dynamic and continuously evolving solutions, there is a need for high levels of trust among all participants, human and machine and among all of the assets involved in smart city development, provisioning, and delivery of services.

Evidence indicates that institutional mechanisms can build trust in online B2B marketplaces. Pavlou [40] examined the ability of institution-based trust to build a trustworthy trading environment in the digital economy, and how specific institutional mechanisms contribute to the development of marketplace trust. Three trust outcomes —satisfaction, perceived risk, and continuity were examined with respect to their ability to influence of the proposed two dimensions of inter-organizational trust—credibility and benevolence. The research on 102 organizational buyers in an online B2B marketplace identified a relationship between institution-based trust and inter-organizational trust.

6.1 Basis of Trust

Drawing from three competing theoretical streams (specific beliefs dealing with integrity, benevolence, and ability; a general belief that another can be trusted; and actions reflected in a feeling of confidence and security in the caring of another) research on trust antecedents (social dispositions or tendencies to believe or not believe in others) have been identified. [35] These antecedents (presented in the Table 2) aid in developing a robust understanding of trust building.

6.2 Fast and Slow Antecedents of Trust

When we refer to trust earned we are generally referring to knowledge based trust. That is when we recall past performance with the focus of our intended trust and how well those who held our trust fulfilled their commitments despite our dependence and vulnerability [34]. Knowledge based trust plays a significant role in the operations and support of citizen engagement and system to system services. Knowledge based trust takes time to establish and as such requires more time than other trust antecedents to adjust / change / reverse. Institution based trust is similarly slow to form and change. Institution-based trust is the result of patterns formed across multiple instances involving analogous targets of trust. For example, if the last

Table 2. *Antecedents of trust in a city context*

Antecedent	Short description	In a city context
Knowledge-based	allows prediction of future behavior	Service has been a consistent trusted source of data and/or process
Institution based	situational normalcy and safe guards	Service marketplace has reliable reviews and ratings provided without additional cost
Calculative-based	cost benefit of cheating or cooperating	Use of foundational services consistently reduces time to delivery and complexity
Cognition-based	first impressions (like me and visual clues)	Service interfaces are available in consumers language and are consistent in style, semantics, and documentation
Personality-based	are you well meaning	Foundational services are created and operated in a transparent and inclusive way.

several successful services consumed provided significant value as consumption based services that prevented additional cost commitments when consumption ceased they would likely consider such a choice normal and customary, therefore, they might be more open, receptive, and trusting to using that as a model for service use going forward.

Unlike knowledge and institution based trust, calculative, cognitive, and personality based trusts are quick to form and quick to change. Calculative based trust represents our internal statistical analysis of a situation. As a city manager you may or may not trust an optimistic report from an external service if, in your opinion, the service stands to gain if you do trust their report or lose if you don't. Calculative trust influences both the subject and object of trust. This is similar to the effects described by Smith et al. [36] who demonstrated that project reporters would be reluctant to report problems if they are risk-averse and anticipate negative consequences for doing so. Iacovou, Thompson, and Smith proposed that project managers are more likely to engage in optimistic biasing when dealing with untrustworthy executives [37]. Unlike the logical calculative based trust, cognition and personality are based on emotion and intuition. These are snap decisions. Given a set of inputs do you feel good about things? Are you sure the numbers add up or is it a side-effect of an excellent hunch?

6.3 Improving Customer Decisions by Incorporating Appropriate Trust Building Practices

This conceptualization of the importance of trust is supported by Alaa [38] in the identification of factors that aid in the emergence properties of complex adaptive systems (CAS) and system that replace their own components (autopoiesis). Alaa argues that communication, collaboration, interaction, and trust are crucial drivers of human self-organization. This work also posits that mechanistic adaptive dynamics provide the short term flexibility in responsiveness to enable fast responses and adaptation to occur in problem situations. However, it further argues that control mechanisms, feedback, reflection and learning are also need to assure that anarchy does not result from the emergent situations. [38]

To gain and remain trusted smart cities must employ all of the antecedents of trust. In action these can be mapped to Available, Inclusive, Reliable, Valuable, and Usable (A.I.R.V.U).

Smart city foundational services provided to the benefit of all constituencies become dependencies in their supported workloads. At runtime the foundation may not know the level of criticality it is supporting. As such a foundational service must provide a clear service level agreement (SLA) as part of each interface. Once published the SLA needs to be rigorously monitored and the city becomes responsible for ensuring the availability published is always met or exceeded. Should the service begin to degrade the infrastructure hosting the service must detect and respond with additional system resources to be trusted as always available.

Table 3. *Antecedents of trust mnemonic*

Antecedent	
Knowledge-based	Available
Personality-based	Inclusive
Institution based	Reliable
Calculative-based	Valuable
Cognition-based	Usable

Smart city systems should use 30 years or more as a target lifespan. This provides a level of stability consistent with the extreme longevity of major infrastructure in a city. While it would be extremely unlikely the foundational services would go unchanged for the entire 30 year period any change needs to be widely communicated in advance. A well-managed change control and matching communication process establishes the personality of the system in the eyes of the service consumers.

Strategic roadmaps lay out intention, consistent before action and T-minus notifications provide opportunity for feedback and impact to the operational process of the service and engaged consumers. A dynamic feedback process before, during, and after change occurs also strengthens the personality based trust of the service as participants see their voice impacting the services.

For the majority of solutions in a city consuming foundational services will be done through an online marketplace. Overtime the city can, and should, provide more than one service for any workload. The marketplace should be open to services provided by multiple city organizations, vendors, and interested third parties such as other city agencies. This creates an environment that fosters continuous improvement, diversification, and of course competition. Providers of services to the marketplace and the consumers of services spread out through the marketplace need to trust the city to not only broker the connection between the two but to ensure that the potentially unique controls (policies) of a service are reliably advertised and enforced. For the service consumer the marketplaces' ability to provide tools for service discovery such as relevance, popularity, or ratings based searching reliably return the correct results.

Engendering calculative trust is challenging for a new service. New implies risk and the consumer, frequently beginning with a negative sense of value may choose to simply avoid the risk of an unknown. Initially this can be addressed by providing clear and measurable information about the service, its intended outcomes, and how it performed under test conditions. Once the service is operating within a workload emitting useful measures that can be compared to the anticipated baseline will also improve calculative trust not only for the consumer but for those who maybe considering the service for future use. Of course providing a means to rate and review the service leaves a historical record to help reduce perceived risk and increased the perception of value for others.

Testing the usability of the foundational service is different from the traditional end user usability testing. End-use testing is directly primarily at functionality and the ability to perform a necessary action or service. While ease of operation does translate into a development context (specifically the ease with which a consuming workload can find and consume a service) the diversity among service consumers makes direct comparison difficult because there may be many ways to successfully complete an action or perform a service.. In place of usability foundational services look to usable as a measure. Once a service is discovered its usability is determined by the level of effort required to implement the service as part of a workload. Was it described in such a way that expectations were properly set? Does the documentation provide clear guidance and examples? Is it in the 'native language' of the individual using the service? All of these, done well, create a strong sense of cognitive trust.

7. Developing a Sound Architecture

Implementing a trusted foundational service for a smart city is complex. It requires a mix of centralized and federated services with consistently executed low level resource management and operational instrumentation. At the highest level it can be described as being composed of a marketplace, services (workload components, data, and analytics), and data analytics. All supported by a set of management controls, integration services, and classic infrastructure (Network, storage, and compute).

A trusted foundational service needs to combine two usually mutually exclusive architectural meta-models; Centralization and Federation. This is the result of supporting services from the marketplace to be run on the provided infrastructure as well as or optionally on the consuming workloads dedicated infrastructure.

The architecture provides a single surface exposing all non-foundational services development interfaces. This is illustrated above as 'Accessible Service facades". The façade pattern provides both a simplified interface and a means to partition features for composability as well as creating a means for an initial security boundary should any provided service choose to do so. Each service available in the marketplace would provide a default façade and document its extensibility, access restrictions, and related facades such as a management façade created for administrative activities. Following this pattern consuming workloads can trust the service has properly expressed its capabilities and is enforcing the necessary parameters internally relieving the burden of integration and transformation from the consuming workload as long as they meet the documented needs of the service façade.

Behind the safety of the service facades are the means to support integration, insight, discovery, and management. All four elements are required for a foundational service provider to be more than just another service host. The Integration components are responsible for service request/response, transport, and sequencing based on the service route maps passed after successful agent based negotiation between the calling workload and the providing service. It also stands as the primary surface accessing resources managed at either the physical or the virtualized elastic infrastructure pools. These shared pools of resources are automatically balanced based upon demand to provide optimized resource usage, and to ensure an organization can obtain maximum resource utilization and high availability as required by the varying systems and service load demands.

Data analytics, ingest, processing, and analytical outcomes are first class components of the architecture in parity with services and the marketplace. While the future of smart cities lie in their ability to provides services the road from today to tomorrow begins with the data. The foundational services architecture allows cities to rapidly deliver on data transparency, open data access, and basic data aggregation. The analytical services create new insights from current data, and over time, trend analysis from the amassed data lake created when data providers allow the city to retain copies of the data they flow through the foundation.

There are a fairly large array of options for implementing the marketplace component of the foundational services. An argument can be made that it should be fully isolated from the services and analytics components due to the anonymous access

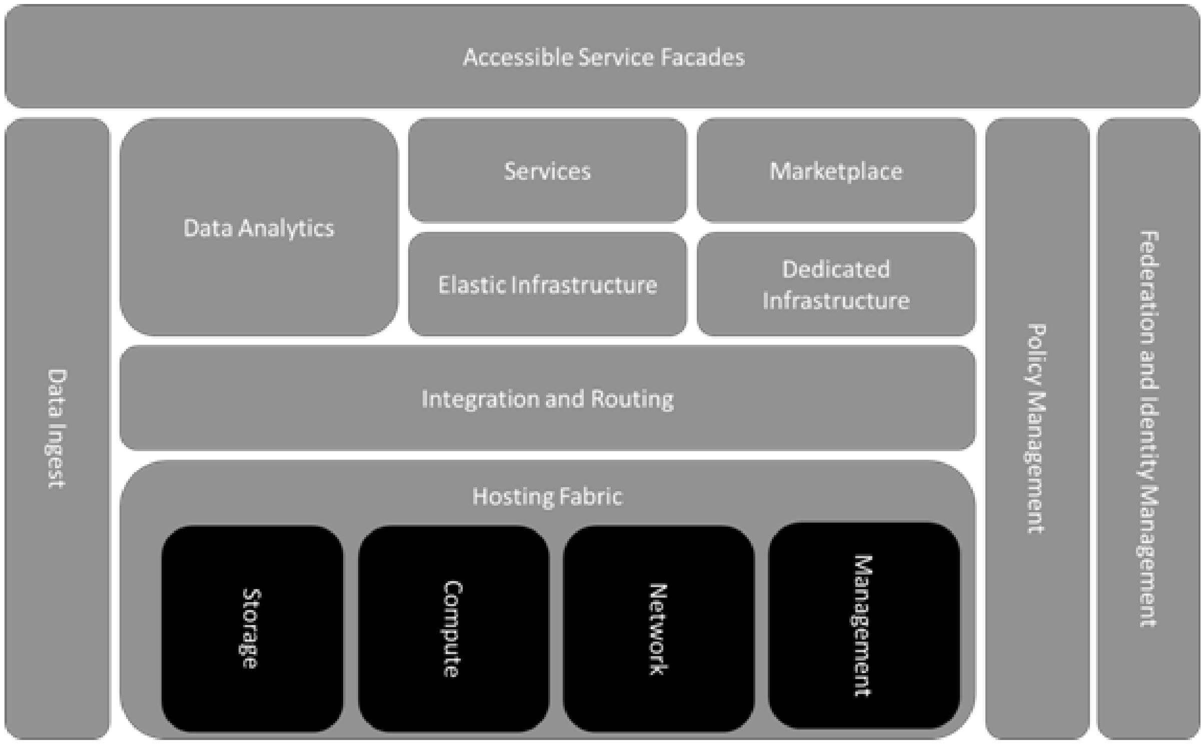

Figure 1. *High level foundational services.*

that allows potential users to browse for services. A similarly motivational argument leads to tight integration to services and analytics. While tight integration creates low latency as the three components change, security needs are a real and increasingly motivation part of all city systems. Access controls added to service policies must be rapidly reflected in the marketplace to ensure suppliers release controls remain aligned with their intent. Clearly the specifics of any individual marketplace implementation needs to be considered in the context of the implementing organization in such a way that it remains internally and externally consistent with local governance and law while removing barriers to use, increasing overall city transparency, and providing a reliable trusted experience for citizens, city management, and city employees.

8. Role of the Marketplace

Smart cities require a service marketplace in which decisions can be construed as "votes" for that service or product. City consumers will play key contributing roles in determining what services are successful, and offered at what price in the marketplace. Awareness of the potential for fraudulent and deceptive practices, protection techniques, problems resolution, etc. will also be crucial. In a SMART city environment, everyone can be viewed as a consumer, and almost everyone can be considered a producer providing services (in many cases information and knowledge for others to consume). The marketplace envisioned is mixed in that both planned and open with government controlling some factors affecting services and offers and users deciding what to be offered and used. Theory, research, and data support this likely success of this marketplace and show why, regardless of uncertainty that arises when unknown parties (possibly remote and separated buyers and sellers in both time and in space) using online marketplaces are proliferating.

Bakos' work provides strong support for the hypothesis of the benefits derivable from this type of marketplace. His work illustrates how information systems become intermediaries between the buyers and the sellers in a market, creating an electronic marketplace. The "...electronic marketplaces reduce the inefficiencies caused by buyer search costs, in the process reducing the ability of sellers to extract monopolistic profits..." by lowering the cost to acquire information. Further, they increase "...the ability of markets to optimally allocate productive resources." The impact of lower buyer search costs in markets with differentiated product offerings further improves the users' experience because efficiencies in the market are then formalized. An additional benefit is that the consumer may be able to separate price information from product attribute information. This engenders additional competition along each of these dimensions. [39]

The Smart city marketplace will be trust based. The Smart city stakeholders' will perceive that " institutional mechanisms are in place to facilitate transaction success." Research by Pavlou and Gefen shows that "...IT-enabled institutional mechanisms — specifically feedback mechanisms, third-party escrow services, and credit card guarantees — engender buyer trust in the community of online auction sellers." [40] Similarly, a marketplace intermediary providing an institutional context engenders buyer's trust in the community, facilitating online transactions through lowered perceptions of risks. Their research on buyers in Amazon's online auction marketplace supports this proposed structural model, found from longitudinal data that transaction intentions were correlated with behavior. The authors attributed the effectiveness to both institutional mechanisms encompasses both "weak" (market-driven) and "strong" (legally binding) mechanisms that develop trust in the community of sellers, contributing the effective online marketplace. [40]

9. Benefits

Smart cities put people at the core of every investment, not systems. Smart cities use analysis to predict and adjust while remaining responsive to the events of the day. They adapt to constantly changing demands because they consistently engage citizens, technical and business decision makers, and city workers and managers. Teamwork and leadership are enabled by a foundation of consistent, interoperable, services. Foundational services, not just solving the problem at hand but positioning to solve the unknowns of tomorrow that span various verticals in a cityscape represent the proactive nature of smart city leadership and the best of what technology can do for real people.

Smart systems increase citizen engagement by simplifying the experience allowing everyone to participate. Long gone are the days when anyone waited to meet during office hours to report a problem. Using policy based, trusted foundational services barriers of time and place are essentially removed. Citizens acting on the moment to report or request and social media tools to put those reports into context keep city leaders and managers informed and involved.

Trusted tools for city workers, managers, and leaders remove technical barriers between otherwise siloed organizations to improve continuous collaboration. As a bonus, trusted systems still achieve traditional automation of otherwise manual and labor-intensive tasks, improve operations, and provide real-time (frequently single pane of glass) views on health and safety of the city.

Separate from the foundational services but still core to smart city ongoing operation is an asset library of high quality, vetted, reusable software components. Trusted components increased reuse and sharing, reduced complexity for partners and providers, and increases system quality. All while reducing the time it takes to get solutions into the hands of real people.

10. Conclusion

Trust is highly important as a success ingredient in both the development stage, and in operations and maintenance for all systems. It is critical that city wide systems implement policies that improve and sustain trust that in turn help smart cities manage systems that are in both developmental and operational stages simultaneously, and will be so for many decades to come. While practices and methodologies traditionally focus on the initial development of a single solution or integrating legacy solutions and improved /new systems to provide incremental service improvements as a replacement systems, this paper and the growing literature on smart cities requires far more technological development because the reality of the problems faced by cities are far more complex and intransigent. It is necessary to recast the systems and operational activities of cities into smart iterative, adaptive, and self-managed systems that must constantly delivers services through technologies that are being combined to work more effectively as a whole. There is no simple build and integrate, or replace operation for the smart city of today. Instead it's collaboration and facilitation that allows all involved to rely on and be highly trustful of the evolving system, its operations, and outcomes.

This paper provides a more detailed view of the linkages among the trust relationship, and the critical need to implement agent based, machine to machine policy that guides automated system interactions and assures every one of reliable and valid data, and ensure greater operational success.

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