Smart Cities: Strategic Focus on Real-time Infrastructure Control Systems

by Tim Sowell and Johanne Greenwood

Executive summary

Complex legacy city infrastructures present an obstacle for cities struggling to provide better service to their citizens. Government spending patterns demonstrate a tendency to focus on IT while operational technology is overlooked. This paper examines the importance of a strategic approach to real-time platforms and flexible operational teams. This helps reduce costs, optimize investments, mitigate emerging staffing crises, and enables a more resilient, efficient city.

998-2095-11-13-15AR0

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Introduction

For most growing cities, service continuity and citizen safety are two ongoing challenges. Although city managers may passionately want to improve the quality of life of their citizens, a city is only as good as its underlying physical infrastructure (i.e. power and water systems, safety systems, traffic management, etc).

Citizen expectations are satisfied when responsive and highly available city services are accessible to them in an easily consumable format. Achieving such a level of responsiveness requires operational real-time control over the city and its systems. Crafting this type of solution would incorporate the city's physical assets, the service workforce, the changing landscape of the environment, and the movement and behavior of citizens. To achieve real time actionable decisions, visibility of the city situation in the NOW is required. This visibility must be coupled with the ability to enable the workforce to act upon systems in order to control fluid situations.

The value of the physical infrastructure relies on real-time control in order to maximize payback from the initial capital investments. A real-time control system is a computer system combined with instrumentation (sensors) that operators rely on to keep services running. Real-time control systems feed data to dashboards and to enterprise resource planning, asset management, and reporting systems in order to enable better and faster operational decisions.

Traditional city government spending patterns demonstrate that attention is often paid to IT-centric actions while operational technology (OT, the core physical infrastructure technology) is overlooked. In fact, both IT and OT need to integrate in order for city-wide strategies to spread benefit across multiple departments. Most cities already own many control systems that are dedicated to specific tasks (like power monitoring, traffic control, and water purification). For example, a city may have multiple water treatment plants performing similar function. However those separate plants often deploy systems from different vendors that do not communicate to each other. A city may also own a portfolio of buildings each with its own proprietary building management system. These on-premise systems often lack sufficient networking capabilities, making it impossible to access them remotely, and to consolidate important data.

Thanks to advancements in technology, these legacy systems now represent a potential source of advantage for cities capable of analyzing and relating data from these individual "silos" of systems. A real-time platform is what enables the systems operators within city infrastructure departments to gather that important data and convert it into information that helps to avoid crisis situations that disrupt services.

As cities work towards achieving a higher degree of operational excellence, there is no "one size fits all" formula. The transition must be managed as a journey, not a project. A real-time control platform serves as a framework for enabling advanced operations.

Examining the challenges

A number of issues have been identified that need to be addressed in order to facilitate improvement of city services.

Issue: Manual collection of data

Cause: Infrastructure lacking instrumentation, automation and control. Existing automation and control systems may be geographically distributed and require significant travel time for operators to manually access them. Examples may include water wells, treatment plants, municipal buildings, traffic control cabinets, and power sub-station equipment. Investments in these areas can become obsolete quickly. As a result, a trend is emerging to outsource the data reporting infrastructure to service providers.

Issue: Overall situational awareness

Cause: Standalone procurement mindset. Many cities lack a common operational platform purchasing strategy. Over time each department or utility run purchasing operations independently of all the others. Individual projects are often managed as standalone procurements, even within the same department. Buying policies are often designed to minimize initial purchase price and avoid vendor lock-in. The result can be that a single department has multiple diverse systems controlling similar infrastructure. Cities find themselves unable to obtain an overall view from many providers and legacy systems. Where infrastructure has been outsourced or procured via Build-Operate-Transfer (BOT) type business models, there can be issues of continuity once the initial service contract has expired. This leads to sub-optimal prioritization of actions, increased training costs, and extended ramp-up times for new operational staff.

Big data

"Big data" is a vague term for a massive phenomenon that has rapidly become an obsession with entrepreneurs, scientists, governments and the media *(Tim Hartford – Financial Times Magazine 2014).* The hype surrounding big data, cloud, wireless and mobile technologies risks obscuring the full extent of the transformation on offer. **In short, cities should not start with technology but instead start from their citizens and workforce** and work back to produce a plan to satisfy the future desired state with a **service-oriented technological solutions deployment**. A range of technologies and platforms are needed, and the most effective solutions will combine big data, cloud and IoT with on-premise systems, distributed platforms, and technically sustainable and proven products.

Issue: Inability to unify and coordinate teams with shared data

Cause: Siloed systems without a shareable data model. To meet expectations for resilience and energy efficiency, teams increasingly need to share long-term planning data and short-term forecast data to make effective strategies and execute response plans.

Issue: Stakeholders lack information or distrust it

Cause: Systems designed without relevant reporting and with inadequate focus on trustworthiness. It is well accepted that "one cannot manage what one does not measure" but too much data can rapidly overwhelm city decision maker and interested citizens. If data points are suspected of inaccuracy, are in conflict, or appear to tell an ambiguous story, they will be distrusted and ignored.

Issue: Lack of synergy with citizens' and visitors' behavior

Cause: Lack of real-time data optimized for different classes of user. The population of the city is an integral part of how the city functions, and culture and behavior directly impact the performance of the city systems and the results achieved. A new, growing class of citizens is beginning to take manners into their own hands, and they rely on connectivity to accomplish their goals. For example, more and more citizens are active participants using mobile applications to update the city on issues such as public services (failed street lights, overflowing rubbish bins etc.). Also a new class of energy consumer called "prosumer" is beginning to emerge. A prosumer is someone who blurs the distinction between a "consumer" and a "producer". In the context of a city, prosumers are consumers of city services who can (if appropriately supported) adapt their consumption patterns to achieve a better balance of outcomes (like taking a train instead of a car to get to work if the roads are overloaded).

Issue: Lack of operational innovation

Cause: Inability to simulate, model and anticipate the effects of change. City operational teams tend to be risk averse as they usually lack a safe area for experimenting with new ideas without the risk of citizen complaints. This leads to a "if it's not broken, don't fix it" mentality that preserves the status quo and does not drive continuous improvement.

Issue: Transitioning workforce

Cause: Baby boomer retirement, incoming "digital natives". The number of highly experienced operations, maintenance, process workers who will retire in the next 5 to 10 years is significant. Some managers estimate that 80% of their current team will be retired in 5 years. This challenge is particularly acute in some economies where there is a significant lack of qualified people to replace the existing "baby boomer" generation.

The “time to experience” has to be shorter than ever for the new workers coming on board to replace retirees. Increased geographic mobility and changing employment prospects mean that new hires move on to their next jobs within relatively short periods – sometimes less than a year. The implication is that cities can’t afford to spend months on training and coaching before new employees become effective. The new generation of “digital natives” expects instant access to the required knowledge; they expect “touch experience”; they expect collaboration from anywhere; and they expect to learn on the fly. Traditional operational interfaces used for city systems will not satisfy the expectations of this new workforce.

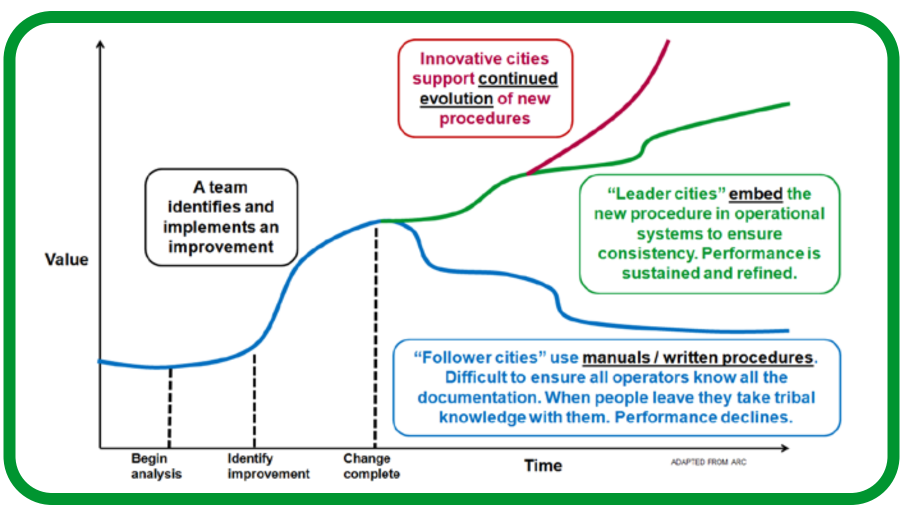
Solution: Enabling flexible operational teams

Addressing these issues requires a multifaceted approach. Technology, process and people have to converge in a way that allows operational teams to perform in a more flexible manner. In fast moving cities**,** decisions must be made quickly, and cannot wait to be passed up the management hierarchy. Workers need to be empowered to make more decisions, and this is enabled through access to more information, more knowledge and access to experience. Thus “workers” need to be transformed into “knowledge workers.”

Urbanization is driving the rapid growth of technology within city operational systems. The new operational agility requires collaborative operational teams. Increasingly cities need to leverage their operational staff across a broader range of competencies and functions than in the past. Especially in smaller cities, operational staff members will have responsibilities that span a variety of sites and domains, and will require regular collaboration with planners and subject matter experts. The challenge of these operational teams is to allow consistent information access across the total team, so that work items can be shared and managed across the team.

Within the context of flexible operational teams, success today is largely dependent upon this type of situational management. Teams require enabling systems and processes to make and implement decisions –without those enablers they cannot be sufficiently responsive to the real-time situation. Flexible operational teams proactively receive and review trends and succeed in moving to a predictive rather than reactive model. They migrate beyond monitoring the present state (which implies notification via an alarm, which only indicates that the trouble has already occurred). Predictive models allow flexible operational teams to look ahead and to influence a potentially problematic situation before it begins to disrupt citizens.

Figure 1
Effect of embedded knowledge management



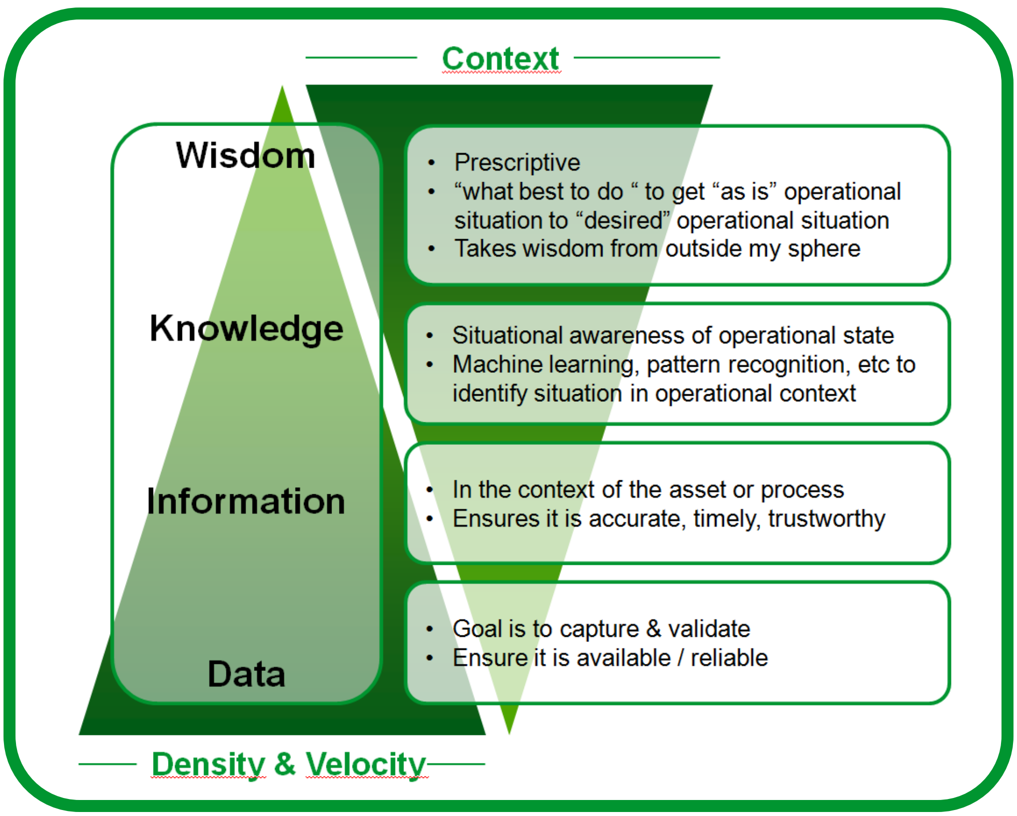
To achieve these outcomes the knowledge of “best practices” must move from the workers’ heads into the systems, so the dynamic work force can act in a consistent manner no matter their experience or location. This requires operations innovation and systems that enable operational practices to be embedded. **Figure 1** shows a situation where a city has gone through a performance improvement program. It shows the advantage retained when the practices are embedded in operational systems, and a culture and environment is fostered to empower continuous evolution of these operational processes.

Advanced operational systems provide operators with the ability to capture data, validate its reliability, and make it available to the system for processing into information.
As data is developed into **information** it is placed into its relevant context, and it is determined which assets or processes are affected. Further contextual processing based on machine learning and pattern recognition transforms items of information into **knowledge**. The operator is provided with **overall situational awareness (**see **Figure 2)**. Examples of how this knowledge management would work include information about an emerging traffic incident and how it will affect multiple districts of the city; or a developing condition in the comfort systems of a building and the effect it is having on "x" amount of people.

An operator also requires the **wisdom** to decide what to do and the judgment to make the best decision based on the circumstances. Today, most operators have to rely on their personal operational experience to inform them of the best course of action. Operators have to wait for direction from senior staff. This impedes agile actions. This problem gets worse in environments with worker retention challenges. An advanced operational platform that incorporates workflow and knowledge management alleviates this issue. It provides every operator with instant access to the combined experience of the city's staff, offers them a set of scenarios that can be enacted along with the pros and cons of each, and enables them to act in a prompt and effective manner.

Individual data points provide little or no context, while a knowledge management system makes maximum use of the context to provide guidance and support.

Figure 2
The transformation of data through knowledge management.



Flexible team characteristics

Flexible operational team environments incorporate the following three characteristics:

1. **Roaming teams –** These are teams that work in a transient fashion across multiple assets / sites. In a traditional setting, sites and buildings were manned on a permanent basis. Now, it is more common for the support staff to be transient. This allows for more flexibility in work assignments and better utilization of the city workforce. All the functions relative to the zone of responsibility are still available.

2. **Central operational centers** - These centers have an operational lead controller who is directing the overall activity, and who is supported by a transient team of different skill sets. The operational centers are supported by a virtual team of experts who can be internal or external to the city. This approach recognizes that some specialists may not be city employees and increases the scope for collaboration to sister cities, academic institutions, and specialist advisors regardless of where in the world they are located.

3. **Virtual expert teams –** These teams are enabled through appropriate decision support systems, harnessing the community of expertise across the city and its ecosystem of public and private partners. The tools utilized by these teams supply decision support and connect expertise in a timely manner based on trusted, consistent information. Both roaming teams and the operational center participate as collaborators.

These integrated teams may be collaborating on one plant or several plant locations, one area of the city or several, with the whole team executing activities (work items) relative to the role and location in the most efficient manner. This collaboration can be performed in a timely manner and help to dissolve traditional boundaries such as departments, locations, and access barriers.

Teams equipped with overall situational awareness capabilities can co-ordinate both planned and emergency responses in a more effective manner. An example of planned response is repair and maintenance staging – if streets are dug up to address a water issue and then have to be dug up again three months later for a gas-line repair this is disruptive and costly. Teams can also prioritize fixing costly problems ahead of fixing ones that have lower impacts, and the system can provide estimates of the “cost of not fixing” each problem on the list. In an emergency situation sharing camera images, traffic status, co-ordinating utility repairs, along with first responders and security staff helps the city get back to a normal operational state far more quickly. Sharing information with citizens over social media, website, hotline or digital signage allows them to adapt their behaviour to be part of the solution and not worsen the problem.

The integration of a real-time control platform provides an anchor for contributing reliable summary data to reports and dashboards used by the mayor, city council and city department heads.

The flexible operational team is dependent on a connected and technologically-enabled ecosystem of equipment and people that allows for flexible human interaction. Simple control systems fall short of addressing the agililty needs of city operations.

Strategic planning for real-time platforms

Cities should specify a real-time platform strategy that incorporates predictive models and knowledge management. The platform should also readily interface to other systems such as asset management and geographical information systems. The platform should enable roaming operators to access the systems from mobile devices.

Cities should seek opportunities to consolidate classes of similar infrastucture onto a common platform. In many cases, it will not be necessary to replace existing control systems such as building management systems. Legacy systems can be progressively incorporated into a new platform while still leveraging the new automation and control systems that are installed.

Many cities already focus on procurement practices that evaluate **total cost of ownership** rather than purely the initial cost of purchase. However, total cost of ownership is often evaluated for the single system under procurement, and is not evaluated strategically across the multitude of systems owned by the city.

Below are some recommendations for cost justifying a move to real-time controls.

- Control system price is typically composed of a base cost and incremental cost that depends on complexity and size of the system. Buying multiple systems incurs the base cost for each one. Buying a scalable platform and building multiple systems on top of it avoids incurring a significant number of multiple base costs. Investments are optimized and short term costs are balanced with total lifetime cost.

- Modern control platforms contain various templates and data models of real-world objects. When a system is extended, that work may be reusable to reduce the cost of the extension. If a system is purchased from a different vendor then work may have to be duplicated.

- It may be possible take advantage of cloud hosting or software-as-a-service[1] type business models. This can avoid costly upfront capex investments in IT hardware, since the control system is hosted in the cloud and the utilisation is paid from the opex budget.

Technical sustainability

“Systems which rely on custom programming or scripting tend to become costly, then unmanageable, then obsolete.”

Most cities that are purchasing systems want to avoid being locked in to a proprietary solution from a single vendor. However, buying multiple systems from different vendors may not be the most cost-effective approach and may also introduce additional layers of operator complexity. The risk of locking-in to one vendor can be avoided by choosing a proven platform solution that embraces open standards and that is widely used by different independent system integrators. Such an open platform will interface to other systems and devices as required. If, at some future point, the decision is made to adopt another control platform as the master, the existing open system platform can integrate into the new solution without too much effort. Under such a scenario, the cost of core platform maintenance is therefore spread among the entire customer base for the platform, and no particular city department has to pay this cost alone. Scaling the system to incorporate more devices or new areas should be possible through a configuration interface, similar to the settings menu on your smartphone, which avoids the need for maintenance of scripts or code.

Another tactic that cities adopt is to build their systems largely from open-source software, supported by custom programming to integrate the components. Open-source denotes software for which the source code is freely available. It can be modified or enhanced by anyone. This can be appealing as new features may be added for free by programmers from a community of enthusiasts. In contrast, proprietary software is owned by an individual or company. There are restrictions on its use, particularly licence fees, and its source code is usually kept secret.

[1] Software-as-a-service (SaaS) business models license software to users through subscriptions. The software is typically centrally hosted and accessed through the user’s web browser. This can relieve the city of various maintenance responsibilities related to the software and shift the costs of purchasing the system from up-front costs to a monthly subscription fee.

Internet of Things

The “Internet of Things” (IOT) enables smart devices, connected city assets and the humans who are accessing those devices, to gain real-time visibility to situations. Devices may have embedded automated practices which, in turn, allow for coordinated actions between operators and machines to resolve a problem - in some cases, before the problem occurs. IOT is not only about the devices: it is also about the alignment and orchestration of these disparate elements in order to produce value.

Clear standards and a configuration platform are required to properly manage these tens of thousands of devices and their embedded programming. Otherwise the system will become out of control rapidly.

The flexibility of open-source software can tempt buyers to specify a solution based on very idiosyncratic requirements. In theory, the access to the source code means that cities will always be able to hire programmers to modify the system - and to avoid the situation where a proprietary system "moulds like putty" around the initial needs but then "sets like concrete" and can't be changed later on.

In practice, the city will end up with a system which is unique and which becomes more complex with each modification. Eventually the costs of keeping a support team in place becomes prohibitive, as do the risks of changing a system that has grown too complex.

Scalability

Each component of the architecture should be capable of expansion as the city adds new or extends existing operational systems, and adds decision support information and business process automation to the architecture.

Trustworthiness

Trustworthiness is a composite of system availability and event accuracy. It is achieved through a combination of methods for handling hardware and operating system availability, application availability, information availability and accuracy. Experience has proven that users will quickly abandon an operational or decision support solution which can’t be highly trusted. Service levels in a city are paramount – the city cannot stop running!

Efficiency

An appropriate system architecture ensures network traffic is minimized, and functions are processed only where they are needed.

Enabling effective leadership for change

Appointment of a CTO/CIO

City managers or mayors will likely benefit from appointing a chief technology officer to coordinate operational technology strategy across multiple departments. This could also be part of the role of a chief information officer (CIO) as long as that responsibility extends to operational technology as well as traditional IT. The CTO/CIO should work across city departments, functions and utilities to identify short and long term opportunities and to design an overall strategy. Projects should be identified to provide a starting point for the journey to operational excellence. One or two projects can be identified to start the journey that extends the system and brings departments together across their functional boundaries. Once operational teams begin to experience the advantages, then they will be more likely to support further integration. Until those positive experiences emerge, managers and operators may tend to resist integration and city-wide platform approaches, because the change will represent more negative risk and loss of control than positive opportunity and increased capacity.

Funding models

Existing funding models may be an impediment to investment in shared platforms. For example if one department is funded by ratepayers (e.g. collected as part of a water or energy tariff) and another is funded by taxpayers (e.g. collected as part of a property tax) there may be challenges to manage if one department owns the system and extends use of it to the other. Cost sharing may not be well identified and return on investment may be confusing. It may be necessary to create a shared services model, with a clear cost contribution from each user department.

A real-time platform strategy can work with both capex and opex-centered approaches. Some public organizations such as municipal departments, hospitals and schools have been seeking to shift expeditures from overstretched capex budgets to opex budgets. This gives stakeholders the flexibility of providing access to products or services via monthly payments. In other cases the low rate of borrowing extended to government-related bodies can make capex investments a better option. The primary benefit of a shift to opex from capex is to free up cash. The money that would have been invested in a capex purchase is available to spread across multiple opex purchases, enabling an organisation to access multiple services / benefits over a shorter period of time.

Conclusion

Real-time platforms have been understated as a core component of the smart infrastructure that underpins the smart city.

Flexible operational teams provide a set of capabilities that enable cities to achieve urban efficiency. This requires a fundamental shift away from traditional, inflexible operational processes to new operational experiences that provide agility and flexibility of execution. Workers are enabled to become knowledge workers. They become empowered to perform multiple tasks, in flexible roles and from multiple locations.

A strategic approach to real-time platforms eliminates the wasted effort and increased cost of siloed control systems. Such an approach enables unification across assets, applications and systems. Each of the existing systems continues to run, but now they become aligned with information and visualization models. Predictive analysis and communication are supported in order to facilitate rapid decision-making. Investments are optimized for the long term. This can bring reduction in total cost of ownership, cost savings from energy efficiency, reduction in staff costs, and improvements in resilience and sustainability.

Such a system, since it is based on an open, standardized platform has longevity to evolve. New and disruptive technologies will continue to emerge. However a system based on open standards and with a flexible architecture design will allow cities to quickly adapt to changes.

About the authors

Tim Sowell has 30+ years of international experience in industrial software applications and software development, living in Australia, Europe, Middle East, Africa, and North America. Tim’s passion is to drive operational effectiveness through step changes in how technology is applied and address the agile operational strategies in the industrial/manufacturing sector. Tim's current role is leading Software Strategy and Architecture at Schneider Electric for Industry Solutions. In this role Tim works across product lines to define and execute software strategy to increase the value of multi-product solutions, lower total cost of ownership, and create an agile system for today’s living and dynamic industrial environment.

Johanne Greenwood has 20+ years of international experience as a software developer, educator, advisor and change agent. She led creation of Energy University, a free online e-learning resource which took first prize in Learning Category in the European Commission Sustainable Energy Europe Award. She drove energy efficiency solutions into a worldwide portfolio of manufacturing sites and commercial buildings, and contributed to ranking Schneider Electric at #9 in the Global 100 Most Sustainable Corporations in the World. Today, Johanne focuses on Smart Cities and supports cross-functional teams around the world to collaborate with cities and partners to build and achieve their vision of cities that are efficient, livable and sustainable.