Innovating and Inventing for Sustainable Cities:

a Tale of Three Incongruities

Paper Presented at the 34th International Conference of the System Dynamics Society, Delft, Netherlands

20th of July 2016

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Abstract

Global population growth and urbanization continue apace, making cities ever more important to humanity. But most cities are not environmentally, economically, socially, or fiscally sustainable and are unable to secure the investment financing needed for multi-dimensional sustainability. At their root these problems proceed from the misapplication of Cartesian reductionist approaches to complex dynamic city-systems. A new framework is needed for integrated, collaborative, systemically effective investment essential to city sustainability; this paper introduces an initiative to provide that framework, now under way in partnership with the cities of London and Boston. This is a unique opportunity for the System Dynamics field, one that requires large-scale socio-economic innovation as well as a host of new technological inventions that will reshape and automate the practice.

Key words

Sustainability, Cities, Urban Dynamics, Innovation, Invention, System Dynamics

Acknowledgements

The authors would like to thank Christiana Amacker, Adem Delibas, Norbert Englert, Arash Golnam, Christoph Kirch, Maya Marti, Manuel Niederberger, Philipp Thimm, Alexander Voigt, Thomas Scheiwiller and Karin Thümmel-Eberle for contributing to the work underlying this paper.

1 Unsustainable Cities and Sidelined Resources

1.1 Introduction: A Tale of Three Incongruities

Cities are crucially important to the welfare of humanity and the world. Globally, mankind is steadily urbanizing and this trend is expected to continue. Today cities are the engines of three-fourths of global economic growth, most energy consumption occurs in cities and they produce the majority of emissions. It is quite literally true that we cannot get the planet right without making cities sustainable.

Yet most cities are failing to cope with most of the many challenges they currently face, and are even less capable of dealing with the emergent consequences of present unsustainability. Put bluntly, we can say that the *modus operandi* of today's cities is not sustainable despite the abundance of resources available – both financial and intellectual – to establish and maintain cities on trajectories toward sustainability.

This is incongruous, that is, something inconsistent, out of place, inharmonious. Making cities sustainable is a story of three specific and intertwined incongruities and their resolution.

- Incongruity #1: Cities are the main engines of global economic growth, but not sustainable and can't obtain the investment funding needed to become sustainable.
- Incongruity #2: Capital markets (institutional investors, fiduciaries to the middle classes) desperately need solid new investments, but there's no framework for investing in cities on the scale needed.
- Incongruity #3: System Dynamics is a unique enabling technology for sustainable cities, but (despite multiple attempts) has had no significant or lasting influence on them.

Drucker identifies such incongruities as particularly promising sources of innovative opportunity: *"An incongruity is a discrepancy, a dissonance, between what is and what 'ought' to be. We may not understand the reason for it; indeed, we often cannot figure it out. Still, an incongruity is a symptom of an opportunity to innovate."* (Drucker 1985:57).

Here it is important to distinguish between innovation and invention:

- Invention means creating new things or ideas;
- Innovating, as Drucker uses the term, means creating new value, demand, customers, markets.

Inventing, then, is about creating new things; a simulation language or model is an invention, as is System Dynamics itself. Drucker (1985:35) argues that innovation is a "diagnostic discipline", and comes from a "systematic examination of the areas of change

that typically offer entrepreneurial opportunities". Innovating is therefore about creating new value, demand, customers, and markets. Invention without innovation is usually insufficient to accomplish these things. As will be shown, this distinction between inventing and innovating will prove critical to resolving the three incongruities at the heart of city unsustainability.

1.2 Sustainable Cities

It is beyond the scope of this paper to explore alternative definitions of city sustainability. In line with the widely accepted Brundtland definition of a sustainable development (WCED 1987), a sustainable city must enable current inhabitants to meet their needs without compromising the ability of future inhabitants to meet their own needs. While city sustainability has a strong local flavor (particular in regards to social, spatial, and economic dimensions), serving the needs of current and future inhabitants is not sufficient. A sustainable city must operate in a manner that is consistent with global sustainability.

Today the word "sustainability" is so frequently and casually applied as to have become almost meaningless. We have therefore developed a systems-based definition of city sustainability in the course of dynamic simulation experiments using the city of Chicago as the subject. A sustainable city has:

1) Rising incomes and municipal revenues (to cope with increasing demands on local government)
2) Positive fiscal balance and a strong balance sheet (so needed investments can be financed)
3) Well-maintained infrastructure
4) New investment funding and development projects bringing new infrastructure and services without big schedule and cost overruns (and resulting under-delivery of needed functionality)
5) Balanced use of municipal space
6) High (or at least rising) quality of the city's operational performance and services
7) Energy consumption and emissions flat at much lower levels than today
8) Per-capita city debt and taxation flat at what stakeholders regard as reasonable levels
9) High (or at least rising) Quality of Life (as measured by a variety of stakeholders) and strong social balance (upward mobility, cultural diversity, income differentials, affordability, etc.)

While this is obviously a summary-level definition, it has proved both practical and revealing in tests of real-city performance under a range of infrastructure investments and policy changes. A sustainable city is performing well on the dimensions listed above. A city being a system of systems, the above-listed dimensions of city sustainability are tightly coupled by

those dynamics. Consequently city sustainability and unsustainability are systemic phenomena and sustainability is an all-or-nothing proposition: because of their dynamic interconnectedness a city that performs well on only some of these dimensions is not sustainable.

Based on these dimensions one is hard-pressed to identify any cities that are sustainable. Most cities have performance problems on multiple dimensions. London, for example, faces a housing crisis and deteriorating transportation adequacy. Though highly successful by comparison with most cities, London also suffers from chronic under-funding of infrastructure and other investments needed to cope with its own success and resulting growth. Prior to the recent Brexit vote, that growth was expected to expand greater London's population from its present level of 8.6 million to 11 million or more in 2050.

First published by the Mayor's office in 2014, the London Infrastructure 2050 plan identifies nine essential infrastructure investment areas: public transport, health care, digital connectivity, energy supply, housing, education, water supply and distribution, recycling/reuse/waste management, and green space. In the 35 years to 2050 London needs £1.3 trillion of infrastructure investment – an annual average of about £37 billion in funding. Although these numbers do not include additional and much-needed investment in social services and reduced energy consumption and emissions, they substantially exceed both the magnitude and pace of public investment in London in recent decades and the volume of investment funding available from public-sector sources as they are currently structured.

The global need for city infrastructure investment funding is quite large. Today the world's top 600 cities total 1.5 billion in population and generate half of global GDP. By 2050 the population of these cities is expected to grow by 73% to 2.6 billion; the infrastructure investment to cope with growth in these 600 cities amounts to approximately £280 trillion.

Incongruity #1. Cities are the economic engines for ¾ of global growth; they also consume about 70% of all energy and generate 75% of all emissions. As one of the world's most successful cities London exemplifies a global conundrum, a massive systemic incongruity with pervasive consequences for all of humanity: **Investment is essential for social, economic, environmental, and fiscal sustainability in cities, but cities cannot currently obtain the substantial funding required.**

This is the first of the three intertwined incongruities that must be resolved to make cities sustainable.

1.3 Institutional Investors on the Sidelines

The chronic shortage of investment funding in cities is not due to a lack of financial resources. To the contrary, capital markets are characterized by an abundance of funds and a shortage of quality investment opportunities. As fiduciaries for middle-class wealth, institutional investors (such as insurers and pension funds) are responsible for huge

amounts of capital; but they struggle (in an era of central-bank repression) to find safe investments that will produce long-term risk-adjusted returns consistent with promises to and the needs of their clients.

Incongruity #2. Here we face the second incongruity: **Cities need huge amounts of investment funding and institutional investors need large-scale long-term investments, but traditional frameworks allow financing only on a limited scale** that does not satisfy cities' current needs and falls far short of the investment required for sustainability.

This incongruous condition exists for several compelling reasons.

- Cities generally produce much more government revenue (in various forms) than higher levels of government allow them to keep.
- Few city governments are reliably cash-flow positive; most are cash-neutral or in deficit; many have also reached traditional limits on financing.
- The multiplicity of vertical "silos" in a city's "system of systems" makes it hard to anticipate and track by traditional means (i) the performance of diverse city investments, (ii) resulting environmental/social/economic benefits, and (iii) the influence of such benefits on the city's fiscal performance and balance sheet.
- Public-sector investment projects have a well-known tendency to overrun schedules and budgets, which threatens expected functionality and performance benefits for the city (examples abound).
- Shifts in politics and political leaders may alter commitment to particular investments.
- As a result institutional investors cannot currently be confident that cities will earn a positive return on city investments after financing costs.

This last point is the most important; as fiduciaries, institutional investors cannot risk client assets without strong assurance that there will be a return on and (ultimately) return of the invested capital. Such assurance comes with knowledge that the city itself will consistently earn a positive return on investments made in it, after financing costs.

It appears, then, that the main barrier to large-scale new investment in making cities sustainable is – that cities aren't currently sustainable! What may sound like a paradox is in fact a logical consequence of the operational rules of institutional investors. In other words, the insufficiency of investment in cities is a systemic phenomenon.

Assurance of positive returns on investments for the city (after financing costs), and of a strong balance sheet and positive fiscal balance, are requisite for investment financing on a much-enlarged scale. New financial instruments are also requisite, accompanied by regulatory approvals and new modes of investor assurance.

But how to bring about such changes in cities and city financing?

1.4 System Dynamics on the Sideline

"Urban Dynamics" (Forrester 1969) is a founding work in System Dynamics and was a core vehicle for the invention of the field. It should be noted, however, that the original Urban Dynamics model focused on a general understanding of generic forces that shape the growth and decline of cities. It was not a model of a specific city, nor did it include the full set of feedback mechanisms (particularly economic and financial) that drive city performance. It and other early city simulators were outstanding technical inventions that produced considerable understanding among a small group of practitioners.

Subsequent research (Mass 1974; Schroeder, Sweeney & Alfeld 1975, Graham & Alfeld 1977) expanded the scope of the Urban Dynamics analysis, dealt with criticisms and misunderstandings emerging from other fields, and attempted a small number of real-world applications. In a review of the "first fifty years" of Urban Dynamics, Alfeld (1995) recounts the histories of five early applications of Urban Dynamics.

In spite of the analytical superiority of Urban Dynamics-style models relative to conventional methodologies, real-world applications have led to mixed results at best. Unsuccessful applications suffered from failure to understand and balance short- and longer-term city interests, or from a misguided focus on modeling and models rather than solutions that improved city performance and sustainability. Useful insights resulted when core principles of Urban Dynamics (relative attractiveness, ageing of buildings and limitations in land availability) were understood and internalized by city stakeholders. Implementation failures seem to have resulted from inadequate approaches rather than flaws in the methodology or technology. But nowhere did this work take root and have a pronounced or lasting influence on cities. One might conclude that the technical inventions (city simulators) worked noticeably better than did practitioners' attempts at socio-economic innovation; no lasting demand, no customers and market, emerged for dynamically assisted management of cities.

For the future, Alfeld (1995: 221) suggests two guiding principles: First, he suggests to "emphasize answers, not models" – for example, (i) demonstrating how to maximize the leverage of existing programs, (ii) quantifying tradeoffs between competing programs, and (iii) using the logic of the model to foster consensus within and across interest groups by developing and proving systemically synergistic solutions. Second, he emphasizes the importance of focusing on the user interfaces with these simulators rather than on the model and data. Interfaces need to enable administrators, planners, and other city stakeholders to run, evaluate, and understand their own scenarios largely without intervening experts. Used that way, city simulators can become platforms for stakeholders to organize and access systemically relevant information and knowledge and to understanding and intelligently influence the causality of forces at work in the city (Alfeld 1995: 222).

More recently IBM employed System Dynamics in modeling the city of Portland (Hennessy et al. 2011, IBM 2011). In that project, representatives from IBM, the city of Portland and other stakeholders created a model to inform the development of the Portland Plan. From early in the process publicly available sources were enthusiastic about the application of System Dynamics to city planning, but the project ended with little or no influence on strategic city planning and no apparent follow-on applications.

What went wrong? The IBM/Portland project combined a classic Urban Dynamics approach with participative group model-building. Despite public availability of a high-quality user interface for running city simulations, the simulator itself remained a black box to those not closely involved with its creation. The project did not create solutions or products accessible to non-experts. Discussions with insiders indicate that the project failed to obtain buy-in from important stakeholders both inside and outside city government. To whatever extent the simulator was a technical success, one might conclude that this project failed on the innovation side.

Incongruity #3. Despite the unique and proven analytical power of System Dynamics applied to city-systems, multiple application attempts have produced no lasting influence, benefits, or usage.

2 Needed: Socio-Economic Innovation Enabled by Investment and Invention

2.1 The Chicago experiment: What must one do to make a city sustainable?

As far as we know this important question went unaddressed until 2014, when Greenwood began investing in an effort to answer it.

The city of Chicago was our first experimental subject, a city which faces problems of under-investment, urban decline, and looming financial inviability. Using publicly available data we set up and calibrated a dynamic simulator of the city to support a series of experiments involving various forms of infrastructure investment along with land-use and taxation policies. The simulator structure is shown in the summary-level diagram below (see figure 1). This simulator is substantially more complete and capable than that of Urban Dynamics. It includes, for example, a full set of financial statements linked to other elements of the city-system.

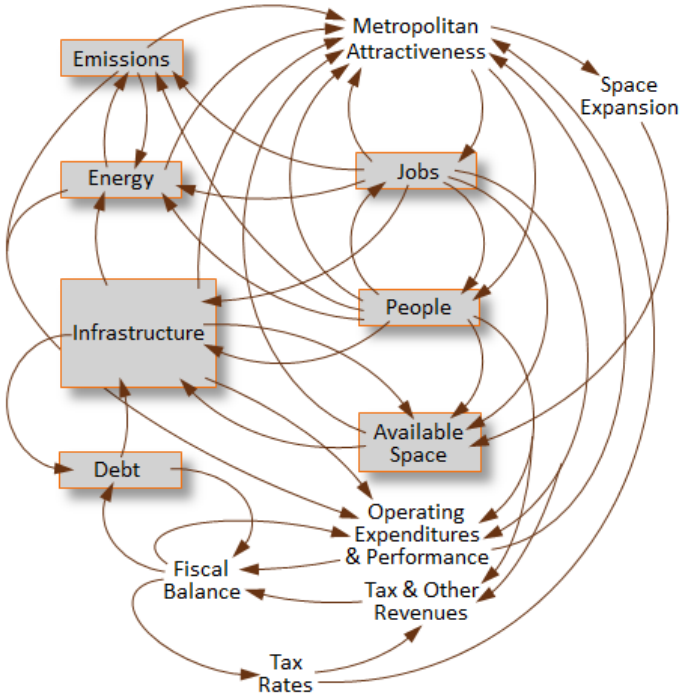

Figure 1: A summary-level diagram of the city simulator structure.

Having developed the simulator through several rounds, we also invested in a simple user interface and embarked on the experiment.

Chicago data and "business as usual" simulations show the city to be unsustainable on multiple dimensions (declining jobs and employment, deficit spending, insufficient investment in infrastructure, rising per-capita levels of debt and/or taxation, etc.). Our experiment aimed at answering this question: How far could Chicago progress towards multi-dimensional sustainability during a 12-year test period, based on combinations of five types of infrastructure investment and two policy changes? As experimental conditions we

assumed that funding for infrastructure investment could be much more available than in the past and that political opposition would not prevent investments and policy changes.

Although the full range of tests and results is beyond the scope of this paper, our experiment produced the following results and insights.

- Even a large investment in any single infrastructure type does little to improve city performance and nothing to make it sustainable. Most such investments fail to produce city fiscal gains that exceed financing costs, which causes per-capita debt and taxation to increase.
- Substantial simultaneous funding for all five investment types sharply improves Chicago's performance on several dimensions of sustainability (economic, environmental, and Quality of Life) but sharply worsens performance on other sustainability dimensions (unemployment increases and per-capita debt and taxation are much higher).
- Combining all five investment types with complementary policy changes in land use and taxation produces performance consistent with sustainability on all nine dimensions listed above. The most notable improvements:
    - The city becomes consistently cash-flow-positive and per-capita debt is capped at a modest level;
    - Investment increases ten-fold and much of that is self-financed;
    - Energy consumption and emissions decline sharply and stabilize at much lower levels despite healthy economic growth;
    - The quality of city services and overall quality of life improve sharply;
    - The city's performance trajectory diverges dramatically from the "business as usual" scenario, with significant and measurable performance improvements accumulating quickly (within the normal span of political office).

The most important outcome (from a financial standpoint): investments in the city earn positive long-term returns (for the city) after financing costs; that is an essential condition for sustaining increased private-sector financing.

Some important insights from this Chicago experiment:

- City returns on investment depend as much on overall conditions in and performance of the city-system as they do on the nature of the investments themselves;
- The same is true of policy changes – changes that would make the city less sustainable in the absence of investment funding have the opposite effect when such funding is increased and performance improves;

- This means that improving the city's systemic performance tends to increase returns from city investments and policy changes, which tends to increase and sustain private-sector willingness and ability to provide investment funding;
- A city that attracts increased investment and begins to move towards sustainability on multiple dimensions will experience self-reinforcing performance and funding gains that should accelerate movement towards sustainability.

Sustainability therefore seems to be self-financing, both through the city's surplus cash flows and by attracting and justifying increased private-sector funding. In other words, increasing city sustainability tends to make itself sustainable. A corollary also seems to be true: deteriorating city sustainability tends to make itself sustainable. To put it another way, a city in a state of unsustainability will tend to remain in that state unless acted on by forces (investments and policy changes) that put it on a different trajectory towards sustainability.

Pondering why a city's movement towards sustainability should tend to be self-perpetuating, and why an unsustainable city tends to remain unsustainable, the answer to both questions seems to be the same. Unsustainable cities tend to be trapped in that state by the power of self-reinforcing feedback; when effectively energized by new investment and policy changes, the same feedback begins lifting the city out of unsustainability.

The context for these feedback effects is decades (at least) of a- or even anti-systemic approaches to running cities like Chicago. Cartesian reductionist thinking attempts to decompose complex dynamic systems (such as cities) to their constituent elements so those elements may be understood and managed. The consequences of reductionism can be seen in the many vertical "silos" to be found in a city, each being defined and managed as if it were largely independent of the others; they can also be seen in layers of government above the city level and in the gradual arrogation of authority and control over the city to higher government levels.

Cartesian reductionism has taught humanity a great deal about system components. It is in systems that limitations inherent in the Cartesian approach come to the fore and do great damage. By definition the behavior of a system is other than the behavior of its component elements. The system is that which cannot be understood from its decomposed elements; decomposition prevents systemic understanding. To the extent that it survives, a city-system "managed" along reductionist lines is at least pronouncedly sub-optimal and sometimes dysfunctional. The unpleasant consequences of sub-optimal and dysfunctional city performance accumulate, gradually diminishing options, resources, freedom of movement, and sustainability. The city's own mismanaged dynamics hold it pinned in a problem-ridden and unpleasant corner of its performance envelope.

The Chicago experiment leads us to this conclusion: clawing back even a modest portion of the substantial and unpleasant consequences of sub-optimal city performance produces large gains which tend to self-perpetuation. Clawing them back is possible because the same powerful feedbacks now holding the city pinned in its unsustainable state will, if re-

energized in another direction, lift it out of that state. This is systemic transformation powered to a large degree by the system itself, consequently such transformation requires neither genius nor total political control.

2.2 What is required of System Dynamics to make cities sustainable?

Having demonstrated through System Dynamics experimentation the possibility of establishing cities on trajectories towards multi-dimensional sustainability, we cannot imagine accomplishing such transformative change without the practice and discipline of System Dynamics. But early applications are already altering this practice and discipline to such an extent that they will soon cease to bear much resemblance to their current forms. The substance of the field will remain but its forms are radically changing and new inventions are transforming existing processes and empowering new actors.

Making cities sustainable requires several big, new things of System Dynamics and system dynamicists.

1) First, recognize that making cities sustainable constitutes socio-economic innovation. Second, recognize that System Dynamics practice is and will continue to be about inventing things rather than innovating. The innovation is utterly dependent on these inventions but they are not and cannot be the innovation – they just make it possible.

2) Next, be aware that socio-economic innovation succeeds or fails according to the values of stakeholders in the systems that are the locus of that innovation. Also be aware that few of those stakeholders are inventors of any kind and that their values consequently have little in common with those of System Dynamics practitioners/ inventors. Socioeconomic innovation will continue to fail in cities if it is pursued based on the values of system dynamicists – a primary reason why there has been no lasting influence from city-simulation initiatives to date.

3) In our small field deep experts build small numbers of models based mostly on their own values and interests. That works to an extent in academia and consulting but it's inconsistent with socio-economic innovation. To innovate in cities we have to reverse the whole process and develop simulators and software and tools working from the outside in, that is, working in from the great diversity of city stakeholders based on what represents value to them. We have to design the technology, the inventions, to conform to the city-system innovation on which we're focusing and to the values of those who will determine whether that innovation succeeds or fails. The inventions must serve and enable and conform to that innovation and those for whom we are innovating – it rarely works the other way around.

4) System Dynamics will cease to be a craft-based practice, developing skills through long apprenticeship at the feet of master practitioners and dependent on slow,

laborious, mostly-manual work by those experts. The fact that the work is done on computers doesn't save it from being manual. The processes of System Dynamics must be industrialized (i) so that very small numbers of deep experts are no longer a bottle-neck on quality applications and (ii) to accelerate the acquisition of expertise and the creation of new experts. Establishing a single city on its trajectory towards sustainability involves such a large effort as to be impossible unless the practice of System Dynamics is extensively automated. Automation is a form of invention, which we're pretty good at. Other fields have automated, so can we; and as an added benefit automation should greatly improve quality.

5) We must transform high-quality System Dynamics applications practice so that it can be safely carried out by professionals who know little or nothing of System Dynamics itself. It is impossible to scale up the practice as it currently exists, and it is impossible to make more than a tiny handful of cities sustainable through practices that are inherently unscaleable. Making System Dynamic practice scaleable requires redeveloping our technology, tools, processes, and practices for transfer to and safe operation by other professionals; it also requires expanding our practice to include the training of the trainers of these other professionals. Remember that these professionals will have values that differ from ours; their values and ours must be congruent and compatible, but they will not be the same. The new forms of our technology, tools, processes, and practices must conform to their values as well as ours.

6) We must invent new software that liberates System Dynamics experts from their traditional role as indispensable intermediaries between "users" and simulation models. This involves much more than just wrapping a good user interface around a city simulator. It means inventing city-stakeholder software that integrates and automates all of the access and exploratory and diagnostic capabilities currently provided by expert system dynamicists.

2.3 The initiative in London and Boston: a space for collaborative innovating

To establish a city on a trajectory towards multi-dimensional sustainability requires a great diversity of knowledges, skills, resources, and capabilities. A subject city and a team of system dynamicists are necessary but very far from sufficient.

Such transformational change can emerge only through collaborative work by cities, institutional investors and their fiduciaries (asset managers), enabling middle-men (banks, audit/advisory firms, regulators, and rating agencies), charitable foundations, and System Dynamics practitioners and their affiliates (software developers, etc.).

- Cities are half of the new city-finance market that must emerge for cities to move towards sustainability. Cities provide the need, occasion, and justification for large new volumes of urban investment financing.

- Institutional investors (insurers and pension funds) are the other half of that market, providing investment funding which they, as fiduciaries, need to place on behalf of their clients (the middle classes).
- Asset managers are fiduciaries to the institutional-investor fiduciaries. They advise such investors, packaging new investment products for them and distribute such products to them.
- Investment banks create financing and sell it on to institutional investors, often via asset managers.
- Rating agencies evaluate and rate the risk of newly created and existing financing based on the credit-worthiness of the institutions being financed.
- Audit/advisory firms provide assurance and consultancy-type services to cities, institutional investors, and asset managers.
- Insurers and pension funds (institutional investors) are closely supervised by regulators, who determine the acceptable range and terms of products in which institutional investors may invest.
- Charitable foundations offer experience in and focused funding for city sustainability initiatives.
- System dynamicists provide and apply analytical technology that is a critical enabler of the new city-finance market that must emerge for cities to move towards sustainability. More importantly, System Dynamics practitioners provide the knowledge of city-systems and process of determining how they may safely be transformed and financed in trajectories towards sustainability.

There is little precedent for such a co-creation partnership. The incentive for such disparate organizations to collaborate lies in the transformative potential inherent in the prospect of making cities sustainable. That potential exists in different forms for each type of organization: cities see their transformation in new investment funding for sustainability; institutional investors see transformation in new long-term fixed-income investments in large volumes and with attractive returns. Asset managers see transformation in large volumes of new investment products that synergistically integrate infrastructure, social-impact, and green investments – for which there is rapidly growing and unsatisfied demand from their institutional-investor clients. Investment banks see transformation in providing their services in a large and fast-growing new finance market, one that could become the largest such market in the history of finance. Audit/advisory firms see transformative potential in new advisory-service services and markets (the largest such markets since ERP). Charitable foundations see transformation in larger vehicles for more concentrated and leveraged contributions to city sustainability. System Dynamics practitioners see transformative potent for their entire practice and field.

The requisite work can only be accomplished collaboratively and in integrated fashion. From the city end of this multi-party partnership, that work is to devise, test, and demonstrate tailored combinations of investments and policy changes that will establish each city on a trajectory towards multi-dimensional sustainability including positive returns on city investments after financing costs. From the capital-market end of the partnership (the institutional investors) the requisite work is to design and develop financing instruments, processes, measurements, and standards suitable to the new city-finance market, acceptable to and approved by institutional investors, regulators, and rating agencies. In the middle of the partnership the work of investment banks and audit/advisory firms enables and facilitates this co-creation process. At the center of the partnership the work of System Dynamics practitioners and their affiliates provides the platform for collaboration between cities and capital markets and the tools and processes for monitoring and ensuring the feasibility of the entire process and its planned outcomes.

Greenwood launched this initiative in late 2014. The Greater London Authority joined in early 2015, followed by the city of Boston early in 2016; a third city is expected to join in the second quarter of this year. Discussions with other organizations began in mid-2015 and are ongoing.

For more than a year Greenwood and London have been collaborating on the Greater London Simulator Prototype. The Prototype simulates the 32 boroughs comprising Greater London and the over-arching Greater London Authority. It is almost certainly the most potent and capable dynamic simulator of a metropolitan area developed to date. We have developed new software that automates and greatly speeds the process of simulator set-up and validation; this is proving vital as the size and tight dynamic coupling of city simulators is testing the boundaries of what can be done via unautomated processes. Beginning around mid-year we will begin applying these tools and adapting the Prototype simulator structure to the city of Boston and the rest of the towns comprising greater Boston. The Greater London Simulator Prototype will reach maturity in the second half of this year; analytical use has begun and will accelerate as the Prototype nears maturity.

Prototype work will be succeeded by a three-year Pilot during which partners in the Initiative will carry out their collaborative work. The Prototype simulators will be succeeded by even more powerful and detailed versions that individually simulate each borough, city, and town in the greater metropolitan areas. By the end of the Pilot the partners will have developed, tested, reviewed, and received approvals for a first major round of new investment funding in each partner city. An Implementation and Expansion stage will follow the Pilot, during which the partners implement first-wave financing, investments, and projects in the original partner cities and extend the partnership to include a new group of cities.

The response of current and prospective partners to this initiative has been most interesting. They see the uniqueness of its large scope and objective in a world where most new efforts aim at incremental improvements. They also see the unique partnership and co-

creation effort as consistent with and requisite for the accomplishment of that large objective. They are motivated by the transformative potential of this initiative for their organizations, and by the prospect of playing a formative role at its inception.

4 Conclusions

We launched this initiative as a radically different approach to systemic societal challenges. We outlined ways in which the field of System Dynamics will be changed in the course of this Initiative. We are confident that the enabling technologies (the inventions) are available or can be developed, that confidence being based on real achievements in these areas. If successful, this approach to the application of System Dynamics will open up a new and very large space for effective management of complex dynamic systems, and will make System Dynamics itself scaleable to meet that need. We are confident that our field will benefit from the practice of innovation as a methodical, purposeful search for ways to create new value, and that the experience gained during this Initiative will inform innovative efforts in other areas where System Dynamics ought to have had an impact.

The real challenges, in our opinion, lie in the inter-organizational, political, cultural, communicative and co-creation aspects of this Initiative. In these respects the initiative is already breaking new ground. How do we ensure that the initiative remains strongly focused on the collaborative creation of societal wealth rather than falling victim to profit-maximization behavior of individual organization? For the Initiative to succeed, partners and a wide array of city stakeholders must benefit from it. We believe that the Initiative's unique content and approach provide an unusual opportunity to benefit all such interests in integrated fashion, bringing clarity, rationality and moderation as better alternatives to political extremes and gridlock.

References

Alfeld LE (1995): Urban Dynamics, the First Fifty Years. System Dynamics Review 11(3), 199-217.

Drucker PF (1985): Innovation and Entrepreneurship. Harper: New York.

Forrester JW (1969): Urban Dynamics. Pegasus Communications: Waltham, Mass.

Graham AK, Alfeld LE (1977): Introduction to Urban Dynamics. Wright-Allen Press: Cambridge, Mass.

Graham AK (2011): Varieties of System Dynamics Practice. Proceedings of the 29th International Conference of the System Dynamics Society, July 24-28, Washington DC. Available online: http://www.systemdynamics.org/conferences/2011/proceed/papers/P1272.pdf (2016-03-08).

Hennessy G, Cook J, Bean M, Dykes K (2011): Economic Dynamics for Smarter Cities Proceedings of the 29th International Conference of the System Dynamics Society, July 24-28, Washington DC. Available online: http://www.systemdynamics.org/conferences/2011/proceed/papers/P1124.pdf 2016-03-08).

IBM (2011): IBM and City of Portland Collaborate to Build a Smarter City. News release on the Website of IBM, August 9th. Available online: http://www-03.ibm.com/press/us/en/pressrelease/35206.wss (2016-03-08).

Mass NJ (1974): Readings in Urban Dynamics: Volume 1. Wright-Allen Press: Cambridge, Mass.

Schroeder WWIII, Sweeney RE, Alfeld LE (1975): Readings in Urban Dynamics: Volume 2. Wright-Allen Press: Cambridge, Mass.

WCED (1987): Our Common Future. World Commission on Environment and Development. Oxford University Press: Oxford.