It Takes a Village:
A Scientific Design Process for Generating Sustainable Cities in China

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ABSTRACT: The recently completed European Commission sponsored SUCCESS project studied rural villages in six Chinese provinces from a sustainability perspective. With as yet few inroads from the larger unsustainable Chinese economy, the villages are excellent living exemplars of an almost complete proto-sustainable economy, albeit at no longer acceptable levels of development and opportunity. The form of the villages, their households, and their agricultural allotments create a visual record of their material economy. Systems dynamics models of these village economies were created to experiment with many "what if" scenarios for future development. At first, inherently unsustainable aspects of village life (fossil fuels, agricultural chemicals, etc.) were replaced in the models with comparable sustainability oriented means. Through a civil society, sustainable scenario-building process the farmers were able to understand both the consequences of their current activities as well as a range of their future prospects. The researchers were then able to extend this multiple scenario building process to sequentially enlarge these sustainable village models to the scale of towns and eventually cities. Through this Scientific Design Process, it thus becomes possible to project new, modern, sustainable city models rooted in Chinese circumstance and tradition.

Keywords: sustainability, systems dynamics modeling, Chinese villages

INTRODUCTION

Within the next five to ten years at least 200 million Chinese farmers will migrate from their villages to hundreds of new industrialized cities. There are strong indicators that these new Chinese cities will be massively unsustainable from economic, environmental, social, and cultural perspectives. China's extensive industrialization and urbanization program will have dire consequences not only for China but the rest of the planet as well. A sustainable alternative to this detrimental development must be created and implemented.

The goal of the European Commission sponsored research program "SUCCESS" has been to forge a sustainable future for the Chinese village [1]. Working with seven villages in six Chinese provinces, SUCCESS has initiated sustainable civil society processes which have the potential of increasing the life quality and economic potential of the villages through Sustainability Oriented Means (SOM).

The great majority of China's developing cities will be extensions of existing villages which have historically maintained a balanced relationship with their landscapes and resources. Recently, this balance has been interrupted by China's rapid and uncontrolled modernization. However, in spite of a few unsustainable practices that have crept their way into these village-systems, the villagers still produce their own food, provide most of their own labor and material resources, and balance the effects of their way of life on the natural environment. For this reason, the SUCCESS project has identified the traditional village as an appropriate place to begin to implement sustainability processes and to provide a starting point for the modeling of the future sustainable city.

The SUCCESS project team of 40 researchers worked collaboratively using the operational definition of sustainability as "a local, informed, participatory balance-seeking process, operating within a Sustainable Area Budget, exporting no harmful imbalances beyond its territory or into the future, thus opening the spaces of opportunity and possibility [2]." Through synthesizing scientific tools with design and participatory methods, this process seeks to avoid the narrow determinism of specialized scientific disciplines and, in so doing, demonstrate a rich and complex means of accommodating diverse and conflicting interests to create a Sustainable Civil Society (SCS) form of governance. Much of this definition has been adopted for inclusion in the European Charter of Cities and Towns Towards Sustainability (1994), which has become the major vehicle for the realization of Local Agenda 21 in Europe.

2. NATURAL AND URBAN ECOSYSTEMS

There is a growing consensus regarding many of the principles and attributes of the future sustainable city. However, few researchers have come to grips with designing operational methods and models for getting from here to there. Drawing upon the examples of cultural and environmental "proto-sustainability" found in historic and traditional settlements, the Center for Sustainable Cities has appropriated the insights and perspectives of the Greek polis, the medieval Italian hilltown, and, most recently, the traditional Chinese village as proto-sustainability models. Urban, architectural, economic, and ecological imbalances were dynamically rebalanced in these settlements through the self-adjusting process of just trying to get by—although the social and political dimensions of the times often left much to be desired.

Michael Redclift has shown that natural ecosystems initially pass through a phase where growth and production is favored, to a mature and sustainable level where diversity, regeneration and stability are favored, even as the level of productivity may be reduced [3]. Historic cities and villages that flourished over a long period of time naturally developed similar balance seeking processes. Once mature economic, ecological, and urban systems developed, their complexity, and thus their resilience and responsiveness, was perpetuated through a continual process of dynamic rebalancing. As a result, an understanding of the interrelation of many small decisions to the health of the whole city-system evolved. In ancient China, this understanding was institutionalized in the practice of Feng Shui which ensured a balance between the built environment and its natural surroundings.

Unlike the modern city which is able, however briefly, to externalize its imbalances largely by dumping them into the global economic system (into the environment or into the future), the historic city or village either brought its local processes into balance within the limits of its supporting landscape or it deteriorated and was eventually abandoned. This balance-seeking image of mature ecological and urban systems may be taken as an essential point of departure for a sophisticated understanding of sustainability [4]. However, both natural and historic urban ecosystems are difficult to directly emulate in the transformation of the modern unsustainable city.

Both natural ecosystems and urban environments evolve slowly in real time. The historic proto-sustainable city or village developed as a balance seeking urban ecosystem through a lengthy trial and error process over many generations. However, modern unsustainable development in China is rapidly approaching ecological limits, spurred on by programs of massive industrialization and urbanization. If our urban environments are simply left to evolve in real time through a globalization driven, trial and error process, then systemic ecological and, as a result, economic collapse is likely to occur for the first time on a global scale. To avoid this unpleasant future, it becomes necessary to develop a synthetic process that is able to rapidly simulate the trial and error balance seeking process found in the natural evolution of historic cities and villages.

3. THE TRADITIONAL DESIGN PROCESS

The tradition of design as it has been transmitted through the profession of Architecture has long used a synthetic process which in modern times has been largely marginalized due to the primacy of analytical methods. Analytical methods either start with wholes and proceed to break them down into smaller and smaller parts or start with small parts and add them together with the expectation of ending up with a whole. These methods have a tendency to focus in on problems and isolate them from their larger social, cultural, and environmental contexts. In contrast, the synthetic methods of design always work at least conceptually with the whole.

In solving an equation each step is procedural and must be correct. But in developing a design, no one path can be known to be correct until the design is complete. From an analytical point of view, a design is wrong through each step in its development until the very moment when it has been completed. Only then does it have the possibility of being right, and even then it may be judged by any number of different, often conflicting criteria so that the success of the design must always be a matter of opinion.

In a world dominated by equations, this does not seem like a very promising approach, yet because it is an approach which is based on a regenerative, cyclical process, it may be the only sort of approach capable of becoming the basis for a transformation to sustainability. During a design process, any criteria, concept, information, material, organization or process may be experimented with in any number of alternative design trials. Trial and error is the process of design and though it may be time consuming it is substantially more efficient than making and correcting mistakes in bricks and mortar. It is the difference between spending hours and days at the drawing board or on the computer rather than, as in the historic process, spending decades and generations making corrections and adjustments to towns and buildings. During this synthetic progression an enormous number of attempts are made and discarded at every scale, from detail to overall concept, before the process is completed. Most of the attempts are rejected, not because there is anything wrong with the components, but because there is some lack of fit in the way in which the different aspects of the design relate to one another. Thus, a design can have its many aspects working well in relation to one another only to finally fail through a single, unworkable relationship. This is normal in the design process and it just means that the balance seeking process must continue until an acceptable closure has been accomplished.

4. THE NEW SCIENTIFIC DESIGN PROCESS

The traditional design process lacks two components necessary for generating sustainability: first is the capacity to quantitatively and qualitatively track the numerous interrelationships of different design attempts, not just with design issues, but with economic, ecological and social issues as well; second is the capacity to incorporate the ongoing participation of citizen stakeholders [5].

Tracking the interrelations of different design components and their effects on the whole can be accomplished through the use of systems dynamics modeling. This tool can be utilized to analyze several alternative "what if" scenarios in terms of their reverberated impacts on the whole system.

Once this tool is incorporated into a new Scientific Design Process (SDP) whereby creativity is generated through the conflict between and among both scientific experts and local stakeholders, then the potential for informing citizens and engaging them in a Sustainable Civil Society process will be possible. Citizen participation is not just a question of democracy or equality; instead, it is a necessity for the operation of a city on a sustainable basis. Under the right circumstances, citizen participation is the very source of complexity, diversity and creativity in the ongoing development of the sustainable city. The feedback from the systems dynamics modeling process needs to be enriched, or even contradicted, by the collective genius of the local culture and the traditions and know-how of the local inhabitants. Thus, the new Scientific Design Process circumvents the narrow technocratic determinism of individual scientific disciplines by incorporating conflicting multidisciplinary expertise into a larger balance seeking context of culture and place.

5. SYSTEMIC FEEDBACK WITH THE SUSTAINBILITY ENGINE™

5.1 Beginning the New Scientific Design Process

In the "SUCCESS" project a systems dynamics model was developed for a village named Dujia located in China's southwestern Yunnan province. The relationships among the different parts of the village system were constructed from systems diagrams comprised of "Intelligent" icons that linked together to form an interconnected web of cause and effect relationships. These mathematically-based systems icons represent the metabolism, that is, the energy, time and material flows of a village. It is possible to add or subtract functions from the village model or to change their relative quantities to enable "what if" questions to be asked by citizen stakeholders.

Dujia's main source of income is from the growing of commodity crops for export. Part of the agricultural economy of Dujia was modeled, along with other aspects of their day-to-day life, and modeling experiments were conducted by changing the agricultural allotment for different crops.

In conducting this simple "what if" experiment, the model showed that sugar cane, considered to be one of the major cash crops of the village, was associated with a negative net cash-flow. With further analysis it was discovered that the villagers would actually be able to eliminate almost half of their annual labor yet still increase their net earnings if they simply stopped growing and tending to sugar cane. The large amount of income generated bi-annually from the sale of sugar cane had seemed to be a profitable venture, however the expenses associated with its production would gradually accumulate throughout the year to slowly eliminate any net profit.

The causes and effects of this slow aggregation of expenses becomes evident through the systems dynamics modeling process, and from this point the villagers become aware of the kinds of "what if" questions to ask and have entered into the systems dynamics model. A positive feedback loop of information is constructed from this participatory process and eventually, more and more complex determinations are made through the numerous "what if" questions to permit villagers to synthesize new scenarios making possible an enhanced sustainable quality of life [6].

5.2 Current Technological Practices

Recently, architects and designers have gravitated toward the delivery of the contract documents in digital formats that have the capability of extracting useful information about nearly any part of the virtual building. Material takeoffs of practically every nut and bolt, together with their locations and specifications, are easily charted. Also, maintenance and replacement schedules can be developed and recorded. Changes made in material, size, energy performance, and cost can be automatically projected through the building model and its database, so the reverberations of those changes can be displayed almost instantly. It is a small conceptual step from the design and management of conventional buildings to the design and management of sustainable cities. However, in the case of sustainable cities, much more information is attached to the components, systems, and building blocks that make up the city.

5.3 The Sustainability Engine™

Still under development, the Sustainability Engine™ is a powerful software tool that integrates the capabilities of intelligent CAD, facilities management, and GIS software with the systems dynamics modeling software utilized in the SUCCESS project. The Engine will serve as the principal design, feedback, and management tool in the negotiation of sustainable cities. It will be able to reproduce stakeholder proposed scenarios as both physical designs and energy and material flow models. Within the Engine will be compiling module libraries of building blocks that contain universally applicable scientific data as well as data obtained from local conditions. These attributes may include embodied energy, distance from source, cost, availability within the region, labor requirements, recyclability, insulation value, land use implications, energy and material flow connections to other regenerative systems, and the various inputs and outputs involved in the functioning of the module within the city-system. These modules will function as plug-in, "free body" objects that provide inputs and outputs when attached to a larger sustainable city scenario model [7]. When it is fully developed the Engine will be an essential technical means and public policy tool for facilitating a democratic participatory stakeholder process.

5.4 The Sustainable Area Budget

Carefully defining the boundaries of a system is a crucial step in the building of any systems model. There are two types of boundaries in the sustainability modeling process: the boundary defined by the local conditions of the town-region, and the boundary of the Sustainable Area Budget (SAB). The boundary set by the local town-region is defined by Geographic, economic, climactic and natural resource limits, as well as cultural and administrative limits. The SAB is an equitable land budget within which the citizens of a city can negotiate their way of life. This metric of sustainability means that in principle, each individual is entitled to one six billionth of the earth's regenerative capacity interpreted as land area. A city's working budget is thus the aggregated Sustainable Area Budget of its citizens. The SAB becomes a quantitative yardstick that provides the datum for the new scientific design process [8].

6. PARTICIPATION IN THE SUSTAINABLE CITY GAME

6.1 Playing the Game

Once the Sustainable Area Budget has been formulated and fully operationalized as a means of defining the sustainability datum of a city-region, a kind of game—the Sustainable City Game—can come into play. Unlike most current decision-making processes which, because of competing interests, become highly charged power struggles that focus on single issues without taking into account the sustainability of the whole system, the Sustainable City Game is a non-threatening concept through which a sustainable decision making process can be initiated. With the assistance of the Sustainability Engine™, the citizen stakeholders of a given city-region could negotiate amongst themselves how they could afford to live within the limits of their land budget through their own creativity and ingenuity.

The Sustainable City Game begins by encouraging players to place any legitimate needs and ideas on the table. Then, varied teams of stakeholders – together with designers, social scientists, natural scientists, and other professionals – attempt to assemble a number of different design scenarios that represent these competing interests. These design scenarios would all be negotiated within the Sustainable Area Budget of the city. Thus, the design and development of the city becomes an empowerment process, engaging citizen stakeholders in the shaping of their common, sustainable future.

In the playing of the Sustainable City Game, stakeholders together with architects and scientists attempt to assemble a sustainable city, initially drawing on existing building blocks from the Sustainability Engine™ that most closely meet their needs and desires. If no building blocks are suitable, existing blocks are modified or the architects develop completely new ones that respond to the local architectural vernacular, particular site conditions, material availability, the local technical know-how, and the desires of the stakeholders. Because any urban design that represents the needs or interests of only one stakeholder or group of stakeholders will not contain the diversity or complexity of a real city, such a limited model when analyzed through the Sustainability Engine™ will appear in its first trial run as a city-system that is grossly out of balance.

The feedback of this imbalance becomes an important moment for the stakeholder-players. It indicates to them that in spite of the fact that their immediate needs may have been well satisfied by their preferred urban proposal, because their interests represent only a portion of the city-system, many other needs must be met in order for the city-system to be approaching equilibrium. This feedback then supports a significant operational principal of the sustainability endeavor: any proposition may be put on the table, but in order to be carried forward in subsequent iterations of the Game, the overall city-system scenario in which the proposition is embedded must be near to or approaching equilibrium. Very quickly it is seen that no matter how beneficial a given proposition may appear (or however politically powerful its proponent), it must still attach itself to a more extensive network of mutually supportive propositions to form a larger, well-balanced, synergistic scenario in order to remain viable as the Game progresses.

Unlike a typical urban design process in which one best case proposal is either accepted or rejected, the Sustainable City Game sets up a matrix of decision-making information embedded in flexible urban design systems. Through utilizing the Sustainability Engine™ the Game demonstrates how on the one hand, seemingly beneficial detail proposals can cause large dislocations and imbalances as their effects reverberate through the city-system, and on the other hand, how some seemingly counter-intuitive early decisions can lead to a rich, synergistic end result in which most or all of the stakeholders' initial desires are either met or exceeded [9].

When comparing The Scientific Design Process of the Sustainable City Game to other approaches to sustainability it can be seen how it presents a comprehensive, scientific, integrated, democratic, governance method well suited to achieving urban sustainability. The Sustainability Indicator method, currently the most popular approach among policy-makers both here and abroad, creates checklists of indicators, intended to measure and incrementally reduce the levels of unsustainability. By disaggregating the problem of unsustainability into many sub-problems, it makes it easier to deal with them in isolation. However, it has the tendency to do the easy things first, "picking the low-lying fruit" and at no point on any of the separate indicator scales or on the aggregated scale is there a place where sustainability can actually be said to exist. The Ecological Footprint method is a highly quantitative approach which is extremely effective as an analytical tool for assessing the environmental load of a city by calculating the aggregated territory appropriated, or consumed, by current human activities. While metaphorically and visually, the approach is a powerful and compelling educational tool, it isn't useful in shaping a solution once the magnitude of the problem is recognized because it urges stakeholders to embark upon a succession of separate, incremental movements to reduce their town's ecological footprint, rather than dealing with the town as a whole system. Thus, it fails to understand and grapple with the synergistic consequences of the many causes of unsustainability. In contrast, the Sustainable City Game, working within a Sustainable Area Budget, begins from the premise that sustainability is an ongoing, balance-seeking process, not a collection of incremental steps. Through seeking a quantitative yard stick from which to launch a policymaking process of democratic deliberations, it produces a paradigm shift from trying to reduce our environmental loads, to collectively restructuring our places, our processes, and our lifestyles within an equitable budget of the earth's ecological resources.

6.2 Initiating the Sustainable City Game in China

The SUCCESS project researchers asked villagers what aspects of their lives they wanted to maintain and what they wanted to change. The researchers focused on the local ecology, economy, sociology, and built environment. By getting the villagers to place their concerns and suggestions on the table with the researchers' concerns and suggestions, the SUCCESS project made the first step of the sustainable city gaming process in the villages.

A specific example of this gaming process is the participatory design and construction of a bathhouse in Xia Futou in Henan Province. Without a fully developed Sustainability Engine™, or even a computer, the design negotiation process was acted out in the streets and byways of the village. Numerous site plan proposals were "drawn" at full scale with rocks placed in the shape of the proposed building on the future site of the bathhouse. Through this process, a conversation between the architects of the SUCCESS project and the villagers emerged and eventually led to an agreed upon plan.

While the SUCCESS project initiated, in seven villages, the empowerment process necessary for the playing of the Sustainable City Game, it will be necessary to look past the scope of SUCCESS in order to generate a sustainable future for China.

7. VILLAGES TO SUSTAINABLE CITIES

7.1 From Seeking Bureaucracy to Seeking Balance

Under the SUCCESS project the current metabolism of Dujia was studied and modeled as an example of a typical traditional Chinese village. Unsustainable practices, such as the use of fossil fuels, agricultural chemicals, and other unsound agricultural techniques were replaced in the systems dynamics model with sustainability-oriented equivalents. This systems model can be used as a template for future models that could project traditional Chinese villages into modern sustainable cities.

If the future Chinese city is to evolve from the village with sustainability as its intention, then merely regurgitating western patterns of "green" projects will not be sufficient. A city that tries to achieve sustainability through a checklist of "best practices" or though accumulating incremental improvements in efficiency through bureaucratic regulations will continuously hit increasingly insurmountable barriers that could inadvertently hurl it further into the chasm of unsustainability. This is because, as previously stated, sustainability is an ongoing balance-seeking urban design process that can only function when developed as a whole system. As standards change, the "best environmental practices" of the present, that merely seek to create a less unsustainable city, will become the unacceptable practices of the future. On the other hand, any city-region that has negotiated its urban balances within its Sustainable Area Budget cannot become obsolete in the future.

For example, establishing criteria for maximum CO_2 emissions standards for a given industry is indicative of today's bureaucratically oriented approach, which is, in and of itself, too specific and narrowly focused to make any real steps toward sustainability. In contrast, following the principles outlined here, a sustainable city-region must balance out its total CO_2 emissions from all sources according to its Sustainable Area Budget at the scale of its region. If it chose to allocate a particular factory with a large part of that budget, due to its great importance in the town-system, this would be perfectly acceptable as long as the total budget of the city-region-system was not exceeded and CO_2 on a net basis was not exported beyond the city's territory. The specific path to balance that each city takes should not be governed by isolated decisions that do not consider the possibilities of seeking equilibrium at the scale of the whole city-region-system [10].

7.2 Sustainability Oriented Architecture

The concept of "sustainable architecture" is another example of a well-intended attempt to make cities less unsustainable. However, because individual buildings require various inputs and produce various outputs that must be rebalanced at the scale of the city, the term "sustainable architecture" becomes an oxymoron. In fact, the term "green architecture" is a term better suited to describe ecologically sensitive design, but the new term Sustainability Oriented Architecture (SOA) is a holistic and far more accurate description of the place of architecture within a comprehensive sustainability process.

Typical design aspects of "green architecture" such as green roofs, solar panels, recycled materials, or passive solar design cannot create a "sustainable building", nor can an aggregation of "green buildings" alone, create a sustainable city. "Green architecture" tends to focus on creating autonomous buildings, however, specific building techniques, and the buildings themselves, can only ever serve as tools for the implementation of sustainability at the scale of the city. The role of the architect in a sustainable city is to be more than just a "green designer." In an attempt to create autonomy at the scale of a city-system, Sustainability Oriented Architecture uses "green" tools, and itself, becomes a tool, in a balance-seeking negotiation process. Sustainability Oriented Architecture can only be a component in a larger city model developed using the new Scientific Design Process of the Sustainable City Game.

7.2 The City-as-a-Hill Urban Model

The City-as-a-Hill is a concept developed by the Center for Sustainable Cities and Oikodrom, the Vienna Institute for Urban Sustainability, as an urban implantation to be built over the Westbahnhof railroad yard in Vienna [11]. This is the sort of new urban model that is particularly well suited for Chinese development conditions. The City-as-a-Hill is urban design model that fits well with the existing dense built environment tradition of the villages while allowing for all of the economic activities, occupations, services, and industries that would be both necessary and desirable in the sustainable Chinese city of the future. The Sustainable City-as-a-Hill would be surrounded by a large agricultural hinterland corresponding to its population-based Sustainable Area Budget that would supply all of the land-based resources necessary to support its industry and way of life.

Originally inspired by the dense human-scaled urban fabric of medieval Italian hilltowns, the new model provides for a walkable pedestrian scale, which requires few vehicles, and allows for necessary public spaces such as markets and squares. Whereas its medieval counterpart was a city built on a hill, the new urban model becomes a city built as a hill, with the inner "hill" being comprised of the many large scale industrial buildings, mass transportation and other necessary infrastructure that is needed for the operation of a modern city. The construction of the hill is made possible by a flexible structural system, the Coupled Pan Space Frame, a post-tensioned concrete structure developed by Richard S. Levine at the University of Kentucky. This space frame spans large distances and at the same time allows for systems infrastructure to be interwoven within the depth of the structure. The space frame system also easily accommodates future expansion and modification of the city, allowing the surface to evolve and increase in complexity.

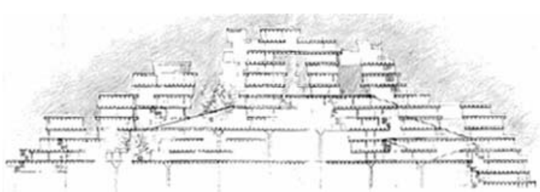

Figure 1: Sectional View of the Westbahnhof City-as-a-Hill Urban Model

7.3 The Future Sustainable Chinese City

The City-as-a-Hill urban model is small enough to be affordable to build in a short period of time and would be much more amenable to mirroring traditional Chinese urban and residential patterns than are the many foreign-influenced unsustainable urban patterns that are now emerging all over China [12]. After the Chinese village is modeled and projected into the future on a sustainable basis, this "proto-sustainable" Chinese village is used as the starting point for the participatory evolution of larger towns and cities whose growth and development proceeds through this same sustainable scenario building, aimed at developing diverse, vibrant new towns for China's future. As the first sustainable city emerges, its success would provide the momentum and enthusiasm for the building of additional sustainable cities, each with different activities and industries and therefore, different urban and architectural design. A network of such cities would be linked together to form a regional network of synergistic sustainable settlements. In this way, sustainability could be exported to the hundreds of new cities forming across China.

CONCLUSION

The massive urban industrialization of China is an extraordinary experiment that will affect the entire world. The traditional Chinese village has operated for thousands of years according to balance seeking proto-sustainability processes. However, this way of life is largely dying because the recent "open door" governmental policies have promoted virtually unchecked industrial growth at a scale and speed never before seen in Earth's history. China is presently the most experimental society on the planet. While most of the experimentation has involved adopting a great variety of western unsustainable practices, the SUCCESS project represents the beginning of an alternative course that can bring China toward future city models that are rooted in Chinese culture, but also function as modern industrial cities that operate on a sustainable basis. The research initiated in China through the SUCCESS project demonstrates the resources, technology, and, more importantly, an operational process necessary for generating the first modern sustainable city.

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