A SYSTEMS APPROACH TO DESIGN SUSTAINABLE MEGACITIES' INFRASTRUCTURE AND MAINTAIN FOUNDATIONS OF HUMAN WELL-BEING: SOCIAL, ENVIRONMENTAL, ECONOMIC

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INTRODUCTION

This paper presents a systems approach to place the UN 17 Sustainable Development Goals in a systems context to develop infrastructure for megacities. It should be noted, however, that the suggested approach is applicable to planning not just for megacities but for communities in general. The movement of populations to urban concentrations is a fact; it is estimated that 66% of the world's population will live in cities by 2050. TABLE 1. shows population growth and demand growth. The UN 17 SDGs are intended to address the growing world population and improve the status of humanity.

UN SDGs

The UN 17 SDGs , seen in TABLE 2 , offer a marshalling of global groups to develop many alternatives to each SDG. The UN SDG process will continue through 2030 and provides a basis for discussion of human well-being as well as environmental stewardship. Each alternative to an SDG is predicated on local considerations and requirements. The terms "sustainability" and "foundations of human well-being" will be used as criteria in the paradigm with the 17 SDGs. These criteria in addition to appropriate SDGs guide tradeoffs within the systems-approach paradigm presented herein. The use of these criteria emphasize that the approach must be a "human well-being-oriented paradigm" for cities.

WHY A SYTEMS APPROACH FOR THE SDGs?

The rationale for the systems approach employing the UN 17 SDGs is there is a need for a paradigm that integrates the 17 SDGs as well as other considerations. The systems paradigm is use-proven: it has been used to design initial concepts for the NASA space station, for a Jupiter orbiting spacecraft, and for other NASA projects by the author. Before presenting the paradigm, the sustainability criterion is explored, as is the "foundations of human well-being" criterion. Finally, it is recommended that the paradigm be applied to small communities to develop the use of the paradigm for smart megacities.

WHAT IS SUSTAINABILITY?

There is no universally-accepted definition of sustainability. Despite the lack of such a definition, maintaining and fortifying the foundations of human well-being is an ongoing challenge as well as an opportunity for the engineer to offer service. Sustainability is, as will be seen, a useful criterion for the tradeoff process of the systems paradigm.

“Sustainability,” simply defined, is the capacity to endure. For human society, “sustainability” implies the long-term maintenance of responsibility for as well as stewardship of the world and the responsible management of its resources, all of which have environmental, economic, and social dimensions. In ecology, sustainability describes how biological systems remain diverse and productive over time, a necessary precondition for the well-being of humans and many other organisms. Long-lived and healthy wetlands and forests are examples of sustainable biological systems.

Healthy ecosystems and environments provide vital resources and processes (known as "ecosystem services"). There are two major ways of managing human impact on ecosystem services. One approach is environmental management; this approach is based largely on information gained from educated professionals in earth science, environmental science, and conservation biology. Another approach is management of consumption of resources, which is based largely on information gained from educated professionals in economics.

Human sustainability interfaces with economics through the voluntary trade consequences of economic activity. Moving towards sustainability is also a social challenge with implications for, among other areas, international and national law, urban planning and transport, local and individual lifestyles, and ethical consumerism. Human efforts toward more sustainable styles of living take many forms, from controlling living conditions (e.g., ecovillages, eco-municipalities and sustainable cities), to reappraising work practices (e.g., using permaculture, green building, sustainable agriculture), or developing new technologies that reduce the consumption of resources.

The term “foundations of human well-being” is used in terms of sustainability of the environment and human spirit as related to the UN 17 SDGs.

WHAT ARE THE FOUNDATIONS OF HUMAN WELL-BEING FOR MEGACITIES AND SMALLER COMMUNITIES?

The foundations of human well-being constitute a criterion for the paradigm process. What are the foundations for human well-being? We would argue that the foundations of human well-being include freedom, self-determination, intimacy with another, community, shelter, food, water, health, entertainment, property, knowledge and opportunity to prosper and opportunity to use one´s particular gifts and talents. All of these are linked to the culture of communities, tribes or governments. These foundations are reflected in everything from archeological record of early humans to the life-styles of every human community, from desert nomads to tribal communities to villages, small towns and large cities around the world. You may add to this list, and I hope you will.

ARE LARGE CITIES AT A TIPPING POINT?

All these foundations depend on the sustainability of resources; food, water, materials, and energy sources, all of which are dependent on the environment and form part of infrastructure. Humanity’s footprint in the natural environment is growing as more people move to the world’s cities and demand for infrastructure grows in the rural and peri-urban environments which serve those cities. This movement to urban areas directly affects human wellbeing in all areas, not just the urban. FIGURE 1 depicts the interactions of rural, peri-urban and urban environments. Any action taken in one region impacts life in the other two regions, as shown in FIGURE 1.

The footprint of human society and infrastructure on the natural environment cannot be erased in every case. The utilization of natural resources necessarily depletes those resources. The creation of roads, buildings,

pipelines, waste treatment plants, power generation and delivery systems, and other structures built from cement, steel and other resources, necessarily has downstream effects on human well-being.

A paramount question of today is: have we already reached, or will we soon reach a tipping point, a moment when cities have become so large that human well-being is no longer achievable? Asssuming for the moment that such a tipping point has not yet been reached, how should we proceed? Our proposed response is the systems approach that incorporates the UN 17 SDGs discussed here below.

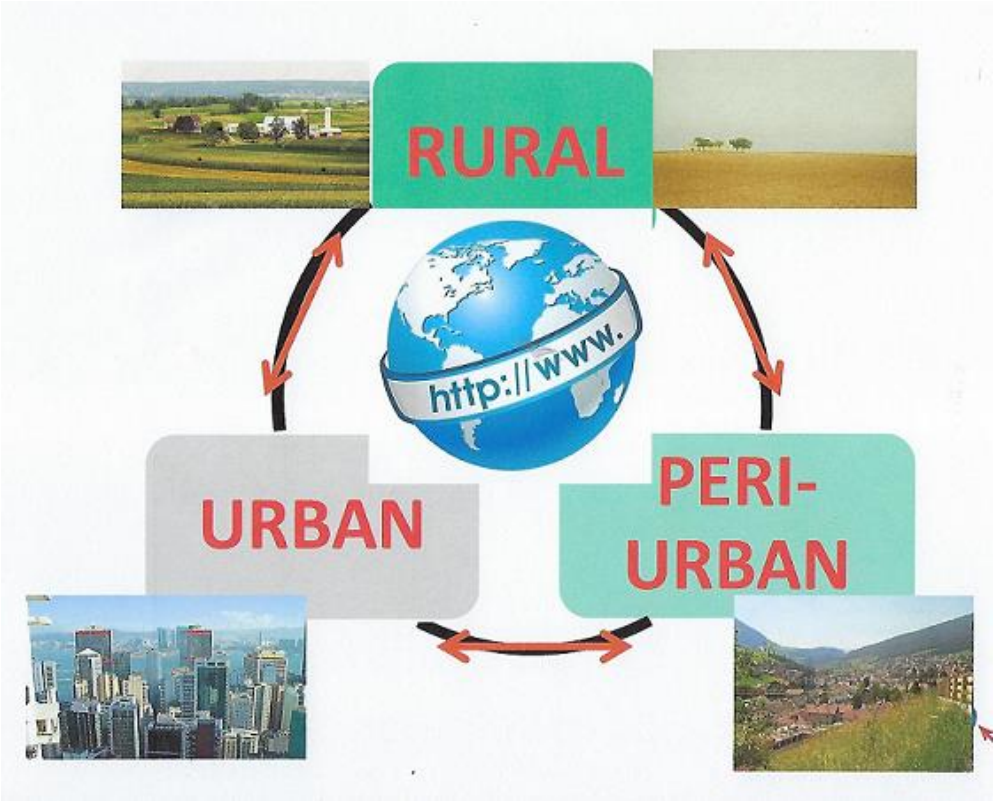

FIGURE 1 . URBAN PRI-URBAN AND RURAL ENVIRONMENTS ARE INTERDEPENDENT

WHAT IS THE SYSTEMS APPROACH PROPOSED AND HOW DO WE INCORPORATE THE SDGs?

The UN 17 SDGs are presently being pursued on a piecemeal basis. Despite the interconnectedness and interdependence of the UN 17 SDGs themselves, there is no generally accepted plan for a unified approach to their achievement in the world's cities. The world needs such a plan. To answer this need and provide such a plan, a systems approach previously employed by the author in the design of unique and complex NASA systems is offered and described. The suggested systems approach provides a means for planners to place the UN 17 SDGs in perspective and allows them to develop alternative outcomes for public consideration.

FIGURE 2 is the diagrammatic presentation of the suggested systems approach. The Objective can be seen on the left, followed by the Requirements to meet the Objective. Next, Alternatives to each Objective are

developed. The selection of competing alternative solutions takes place in the shown Tradeoff process. The Tradeoff process is governed by the particular constraints and criteria of each situation. Sometimes a requirement becomes an objective, and the systems approach can be used to develop Alternatives. Similarly, an Alternative may in turn become the subject of the system's study. This progress is referred to as Nesting. The Alternatives can then be subjected to the Trade-off process. Note that iterations are used to reach a conclusion or conclusions, which can then be presented for public review and decision.

A universally understandable example of the suggested systems approach in action might be the planning of a family vacation (see FIGURE 3). Any one requirement may itself be subjected to a systems-approach study of its own.

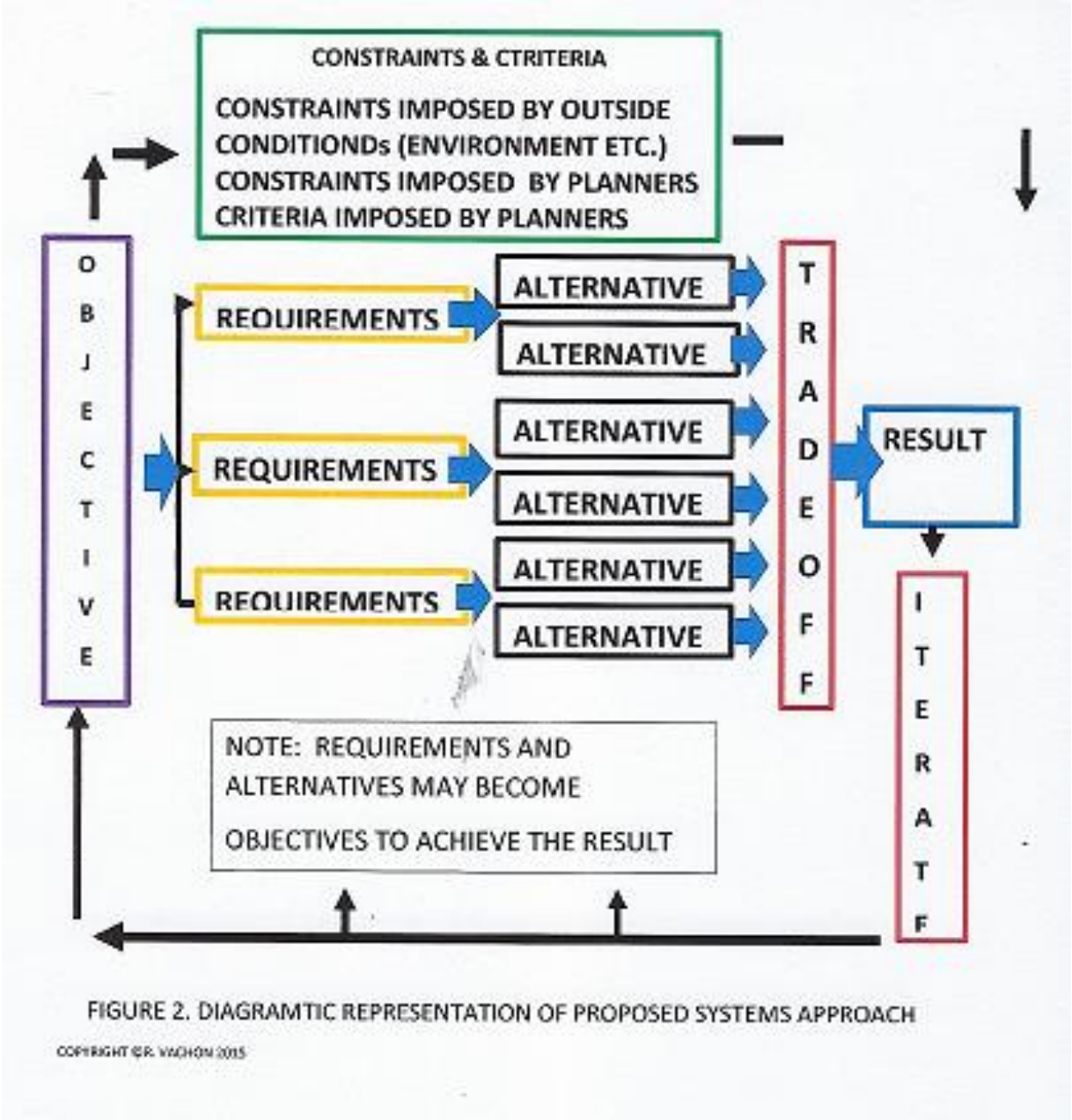

FIGURE 2. DIAGRAMTIC REPRESENTATION OF PROPOSED SYSTEMS APPROACH

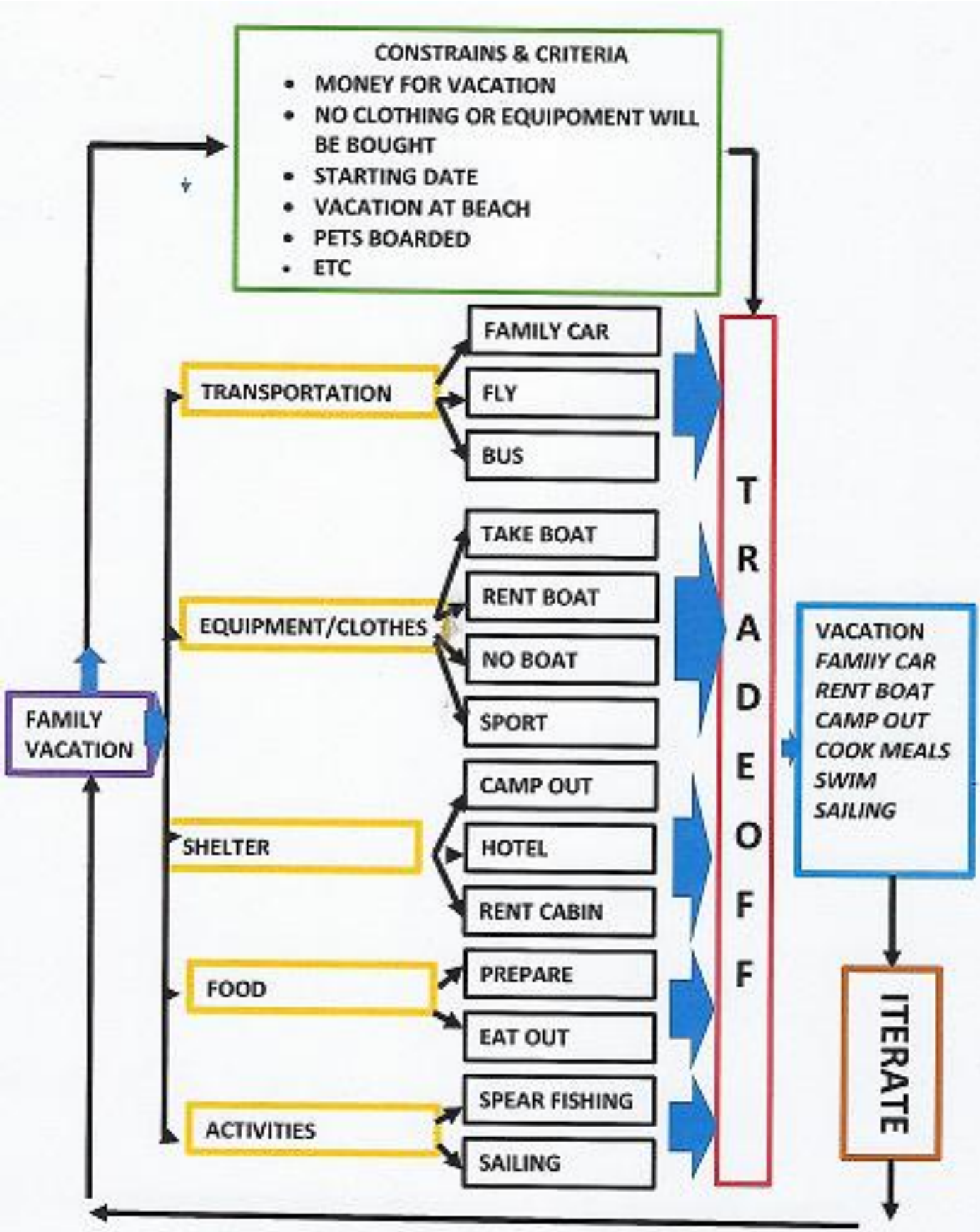

FIGURE 3. SYSTEMS APPROCH TO PLAN FAMILY VACCATION

HOW TO APPLY THE SYSTEMS APPROACH TO DESIGN A SMART MEGACITY UTILIZING THE 17 SDGs

FIGURE 4 depicts the suggested systems approach employed for the sustainable design of a SMART MEGACITY. The UN 17 SDGs are placed in the context of the system approach paradigm with the sustainablity, foundations-of-human-well-being and COP criteria applied . The list of 17 SDGs is shown in TABLE 2, and the UN's color code-coded pictographic repesentation of the 17 Goals is FIGURE 5. Some goals may be assigned within the systems approach paradigm as constraints or criteria, as approporiate; that is, as constraints and criteria governing the selection of alternatives to requirements in the Trade-off phase. In fact, the assignment of SDGs may be changed during the iteration process. In FIGURE 4, the assignment is for any size community – from small to mega city. It is interesting and important to note that while all requirements are important, water and energy are two essentials. Water scarcity is predicted as seen in FIGURE 6, and there is great debate at present over sources of energy. Questions about about the best ways to provide for communities' water and energy needs are not yet settled. Thus, the application of the paradigm using the SDGs suffers from uncertainties concerning water availablity and energy mixes, in addition to the fact that the SDGs remain under development through 2030. Nonetheless, the time will come when this paradigm will be able to provide reliable answers for community development at every scale from small communities to megacities.

To prepare for that moment, it is recommended that the paradigm be applied to a community of approximately 100,000-200,000 residents, in a developed country, as as sample study. This effort would provide needed opportunities to learn how best to use the paradigm and would document those best practices. It is recommended that WFEO prepare a proposal to an appropriate funding source such as (e.g.) the Bloomberg Foundation. Bloomberg recently made a USD$1M grant to Georgetown, TX (population 70,000) to enable that community to achieve 100% reliance on renewable electricity sources. Georgetown relies on the Texas electrical grid and pays a set price for backup power when wind and solar sources do not provide sufficient supply. The contract price for electricity from the Texas grid was fixed. Later, Hydraulic fracturing technologies were developed that then reduced the price of gas-generated electricity from the grid below the price that had been set for Gerogetown. That and other factors have led to electricity costing more for Georgetown residents than for the average Texan grid customer. Lessons learned from the Georgetown experiment would be helpful in learning how to apply the systems approach for optimal results.

For one of a number of detailed descriptions of the Georgetown Project described aboved, please see: https://www.forbes.com/sites/chuckdevore/2018/12/17/texas-taxpayers-pay-for-political-virtue-signaling-with-costly-renewable-energy/#370c054446a6. An exploration of the Georgetown Project demonstrates the need for the sort of

systems approach paradigm offered in this article.

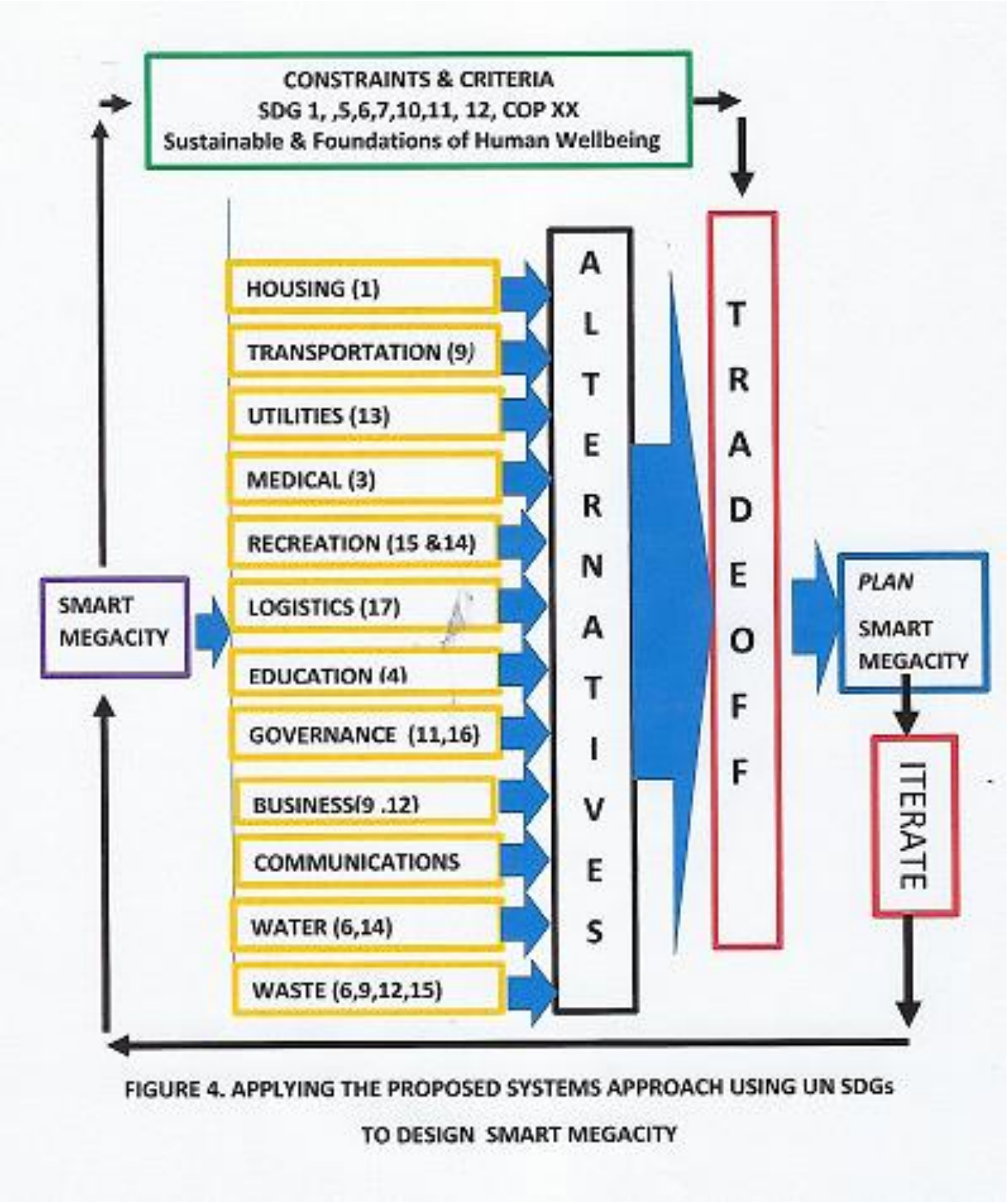

FIGURE 4. APPLYING THE PROPOSED SYSTEMS APPROACH USING UN SDGs TO DESIGN SMART MEGACITY

TABLE 1. GROWTH IN POPOULATION AND CONCOMITANT GROWTH IN DEMANDS with 66% of POPULATION IN CITIES

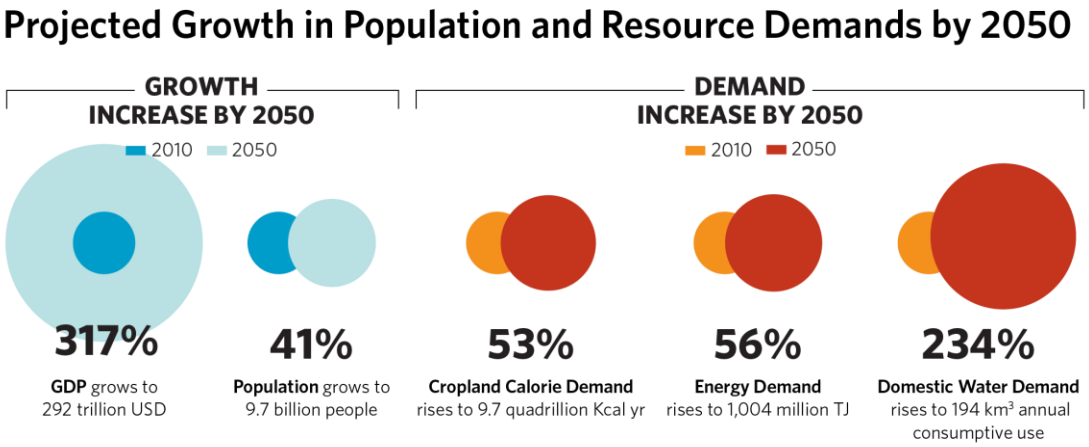

TABLE 2. UN 17 SDGs

1. No Poverty
2. Zero Hunger
3. Good Health and Well-being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation, and Infrastructure
10. Reducing Inequality
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life On Land
16. Peace, Justice, and Strong Institutions
17. Partnerships for the Goals.

FIGURE 5. PICTOGRAPH OF 17 SDGs

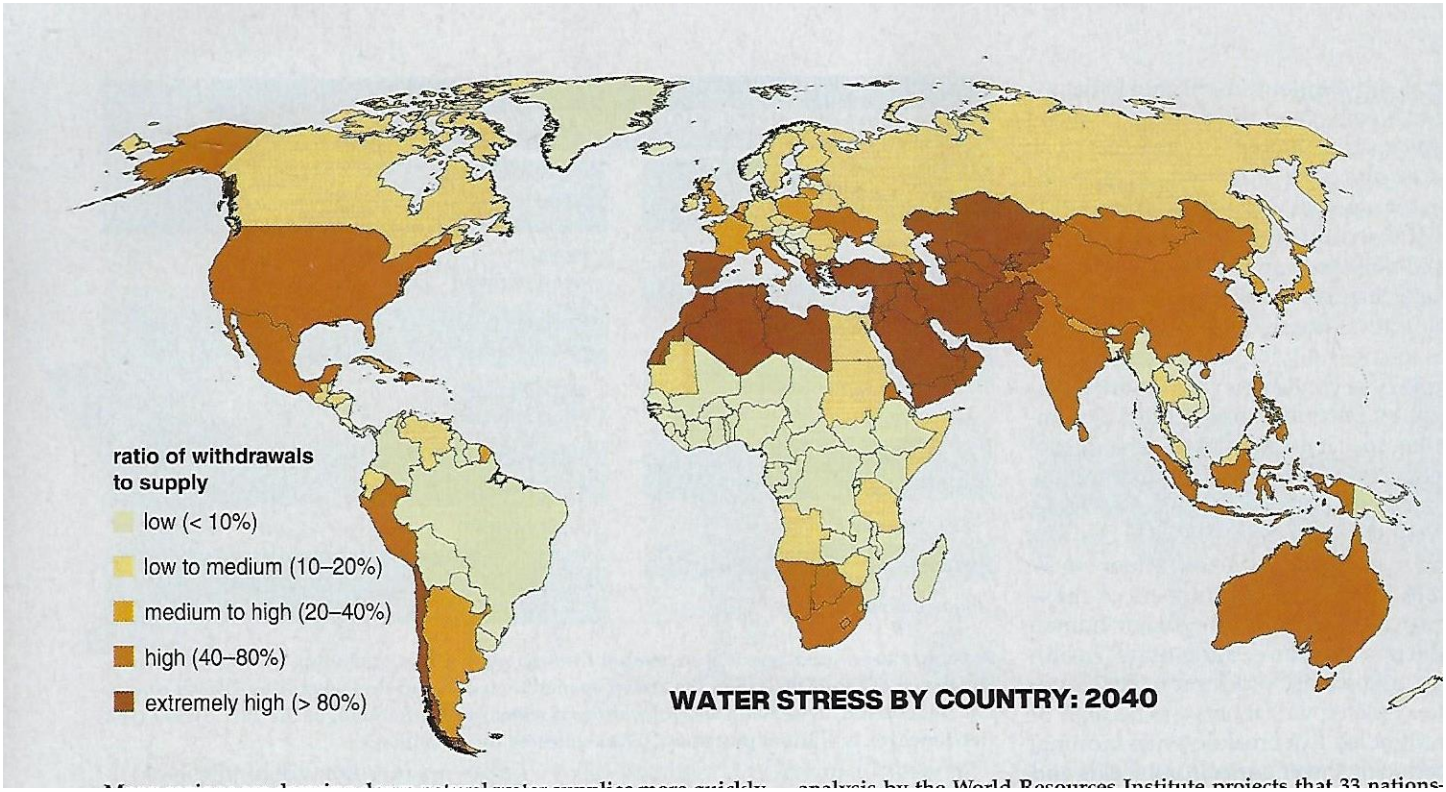

FIGURE 6 WATER STRESS BY COUNTRY :2040 (AMERICAN SCIENTIST SEPTEMBER – OCTOBER 2019)

CONCLUSION:

The systems approach described in this article has been successful in achieving alternative results for complex systems and evaluating alternatives for optimal outcomes. The UN 17 SDGs are laudable, and SGD development will continue through 2030. The results of their pursuit will be country- and region-specific, with some results applicable extra-region. People are migrating increasingly to urban areas, creating true megacities. For these massive communities to be sustainable, the systems that support them must be sustainable and must be intentionally planned to promote the foundations of human well-being. Planning a megacity must include planning of its peri-urban and rural surroundings. Planners must be open-minded and free from personal agendae. Their planning systems must consider the possibility, indeed the likelihood of unanticipated innovations and for their inclusion in those systems. Innovation is continual: just as electric lights replaced kerosene lamps, which had replaced whale oil – our technologies will surely develop and will naturally need to be integrated into our evolving systems. The definition of sustainablity cited above concludes with "developing new technologies (innovation) that reduce the consumption of resources." The rapid pace of innovation makes planning and applying the SDGs a challenge. The systems approach paradigm allows planners to "plug and play," so that society at large can consider a variety of outcomes and take part in the decision process. This naturally democratic process will serve to protect societies from the artificial imposition of partial solutions with unanticipated negative consequences and provide a path for inclusion of innovative technologies.