INTERNET OF THINGS AND THE FUTURE OF LIFE-CYCLE ASSESSMENT IN SMART WORLD

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INTRODUCTION

Robust Life-Cycle Assessment (LCA) requires current and accurate data—that is, inappropriately limited at present, due to the lack of all-inclusive observations and measurements—particularly in developing countries. Moreover, despite advances in (open-source/free) databases and software platforms, procedure of doing a careful and transparent LCA is still remarkably time-taking (viz. it is very difficult to perform rapidly in early stage of design of multipart objects like large buildings or urban districts). Technological breakthroughs namely in Information and Communication Technology (ICT) promise an emergence of the so-called Smart World in which the Internet of Things (IoT) makes it possible to uniquely identify and track everything, anywhere, anytime[11]. It also enables collecting real-time data (e.g. energy and carbon input/outputs) associated with objects via network of sensors, that makes LCA much more precise and automated compared with today's conventional methods[10]. Nevertheless, while about 4 billion people across the world still don't even have internet access[12], how likely is the real Smart World to emerge?

MATERIALS AND METHODS

The so-called Smart Factory is characterized by optimum production management, utilizing advanced ICTs in context-sensitive environment[7]—within its limited system boundary. However, resources, industries, products, users, wastes and emissions are all interconnected and correlated in a complex broad system whose boundary is (at least) as large as the whole Earth. Regarding detailed bills of materials, a factory in one country may use resources, machinery and services from other countries. Thus, real Smart Factories, as aggregation, may arise only when all their up-stream and down-stream effects associated with others also become smart. This will be realized in Smart World. In other words, development of smart environments in local scale highly depends on the improvement of smartness in other environments world-wide, and vice versa.

As Smart City is more complex than Smart Factory, the complexity of Smart World is definitely not less than Smart City. According to the complex innovation dynamics demonstrated in the Triple-Helix model (as a shift from *Mode 2* thesis with trans-disciplinary approach to a bottom-up cultural reconstruction[5]), it is conceivable, that to create a knowledge society in global scale, should improve the interactions between "intellectual capital of *Universities*, *Industry* of wealth creation and their participation in the democratic *Government* of civil society"[5](U-I-G)—all over the world. On the one hand, knowledge, market and learning are in-between-areas (U-I, I-G, and G-U) which express output generated by the three main spheres in *an advanced Triple-Helix network model for Smart Cities performance*[6]. On the other hand, analysis on data about global living conditions shows significant global enhancement in all areas of poverty, literacy, political freedom and education, not only during the last two centuries but also in recent decades[9]. Thus, future development of smart environments in pervasive global scale seems plausible. However, it shouldn't be neglected that extremely-technology-oriented-development of (Smart-) Cities can result in economic polarization, social/spatial fragmentation[4], suburbs and unsustainable urban sprawl[8]. It may also intensify the *brain drain* impact on some developing countries[2]. It's also

worth mentioning that currently many factors that increase emissions and reduce efficiency (at various stages from design to end-of-life) of products, themselves are caused by economic/political problematic decisions, and unsolved social/cultural issues either within countries or between them.

RESULTS AND DISCUSSION

Strengthening the relations between the three spheres of the Triple-Helix model in global scale can gradually generate smart environments around the world and—by paying attention to learning *between* and *across* projects[3]—eventually, Smart World may emerge. In such a situation, taking advantages of pervasive IoT, LCA becomes case-specific, accurate and automated—which could upgrade City Information Model (CIM)[1] to a global version; and when coupled with Augmented Reality (AR), every object will clearly monitor out its desirable/undesirable impacts on natural resources, and consequently, green-washing will be prevented. This leads the world towards the ultimate aim that any LCA is supposed to serve: optimal designs and informed decisions.

CONCLUSION

LCA will reach to its ultimate goals and accuracy only within the context of Smart World. Furthermore, development of ICT/IoT won't lead to emergence of Smart World unless the interrelations of the actors of the Triple-Helix also improve worldwide. Further research on, and development of IoT together with interdisciplinary studies—viz. to integrate it with various fields of engineering, architectonics, urban planning and design—is necessary but not sufficient; in fact international and inter-institutional collaboration between social, cultural, political and economic bodies is also indispensable for identifying and solving problems concerning main agencies of knowledge-based innovation systems in various parts of the world.

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