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Liveability and Sustainability Based Framework and Process Models for Engineering System Design

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Abstract

Engineering system designers appreciates the importance of incorporating liveability and sustainability as part design parameters. The biggest hurdle is still on translating them into meaningful practical parametric values as readily input representing them as design variables. Understanding the design framework model and the design process model used by engineering designers will allow effective introduction of liveability and sustainability factors into their design process. The paper presents the reconstructed design framework and process models based on observation performed by an experienced designers. The results indicate that the points of contact for liveability and sustainability on the design framework model is multiple rather that singular. The entry points for the two criteria into the design process model are on all stages from the identification of owner's requirement through to approval and rectification. The finding could leads to the rewriting of engineering designs manuals as well as the format of presenting engineering technical specifications.

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Keywords: Liveability, Sustainability, System Design, Process Design, Framework

1. Introduction

Majority of engineering designers still stick to traditional design approach and has not effectively adopted the liveability and sustainability oriented approach. Awareness is at a sufficiently high level and scepticism is not an issue. The biggest hurdle is possibly in translating sustainability into design inputs. Engineers are mostly mechanistic when handling design projects. What matters most is the performance specifications of the final system to be delivered and always measured quantitatively, number-based, engineering measurement. The tradition seems to stay even though technology has changed the ways designs are drawn, presented and used during manufacturing process. Designers' manuals have not been rewritten to capture the yes and no in producing sustainability-based engineering designs. References used by designers such as engineering and technical specifications, benchmark values and rules and regulations have not been reformatted so as to be designer-friendly. Translating sustainability into meaningful numbers is a task currently not within the everyday vocabulary of mechanistic engineering designers.

Engineering system designers always approach their design tasks using two distinct models. The first is the design framework model representing sub-systems to the design that must not be missed. It will take the form of a tree-diagram or a mind-map diagram showing elements and sub-elements to the scope and level necessary for the intended functions specified for the engineering system. It is normally prepared via brainstorming sessions facilitated by subject-matter experts. The model will reflect the deliverables for the design work such as equipment list, layout drawings and equipment's engineering and technical specifications. The second is the design process model representing workflow of the whole engineering system design project from first exchange of information on owner's statement of needs through to final testing and minor modification task if

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designers are retained until that stage to supervise the task. The model may take the form with dates attached and hence it reflects the process of delivering each deliverables of the design works.

Finding the best way to change the way engineering system designers think could be done by looking at where liveability and sustainability come in into the two models. Changes introduced into the design framework model and the design process model will be more effective and easily recognized and accepted by the designers..

2. Literature Review

Leby and Hashim[1] describe factors that represent the quality of living and comfort around neigborhoods as liveability. Liveability dimensions that are crucial for neighborhoods include social, physical, functional and safety. Factors that influence liveability dimension are community life and social contact, environment quality, accessibility, feeling of safety, numbers of crime and accident, and maintenance of built environments .Lee and Chai[2] evaluate conditions that provide environmental liveability and benefit to the community by preventing disasters and sustainable subsistence. To evaluate liveability in the community, issues that must be considered are health, convenience, comfortable, secure and socioeconomic. Other criteria of environment liveability can be availability of water, density of public facility, growth and development of the population, and agriculture resources.

MHRC[3]conducted a quality of living study, which examined the potential living standard of community environment location in over 380 cities worldwide. It looks into some aspects which could be classified with the factor of living qualities through location assessment, such as, social environment, economic environment, public service infrastructure, safety and security, health issue, transportation infrastructure, availability of consumer good adequate housing, availability of schooling and recreation opportunities. Example of public service and transport factor are availability of water and electricity, telephone, mail, airport, and traffic congestion. Wei and Jiali[4]pointed out six indices of liveability to build strategy for developing Tie Xi district in Shenyang into a city of "easy living, comfortable living, healthy living and peaceful living". These six indexes of livable environment are social civilization degree, economic wealth degree, environment beautification degree, resources bearing degree, life facility degree and public safety degree. Example of liveable environment criteria that elaborate within six indices are integrated management of water resources, energy resources, education facilities, communication coverage, safety from crime and rate of pollution.

Li and Meng[5]evaluate a liveablity index system for renovation process from old community location of a livable city. Liveability index systems that highlighted in renovation process are a civilization of community, living security, comfortable with the natural environment, convenient life, health of living environment and renovation of buildings. The example of living security aspect and health of living environment are rate of industrial sewage treatment, estate management, traffic safety and management of preventing disaster. EIU [6, 7] rank the best of city through the liveability survey assessment across five broad categories including stability, healthcare, culture and environment, education and infrastructure. The subcategories of stability assessment evaluated are prevalent of pretty crime, prevalence of violent crime, the threat of terror, threat of military conflict and the threat of civil unrest. The sub categories for infrastructure are quality of facilities (road network, public transport, international links, energy provision, water provision, and telecommunications) and availability of good quality housing.

Merad et al.[8] states that sustainability of city sometime is being synonymous with having a public mission such as education, health , security and safety to work done by government. Arundela and Australian[9] asses innovation activities within national government through public administration, public service provider and publicly- owned commercial corporations. The example of public administration are fire protection, police, waste management, environment and health. Zugravua and Sava[10]also evaluate the performance indicator derived from the role of the government in providing opportunities to give benefits of public activities and public sector efficiency throughout public administration, education, health –care and public infrastructure.

Ashley et al.[11]describes government agencies responsibility to serve the public good to ensure lasting sustainability such as department of park and recreation, department of youth and community development and food department. Bernard et al.[12]classification five cases of basic attributes by governance are education, healthcare, transportation, defense and justice. Ida and Gabriella[13]state that welfare service and water supply need to be recognized as a particular type of public service to the complexity of governmentally in considering the increase of development of the citizen.

Kamani et al.[14] highlighted that within the context of design aspect of space and its importance in creating a desirable sustainable system and environment of the future has not been directly addressed. This claim is true when looking at the work by Ismail et al. [15] 0n sustainable green environment framework for megafloats. Liveability within the context of human expectation of its system and surrounding environment has been highlighted by Kamani et al. [16]and in conjunction with the work by Ralph[17]. Kamani et al. [16] also highlighted claim by Steel[18]that 'place have great capacity for influencing on people's characteristics and shape their behavior towards the system and its environment in the long and short period'. Liveability within the context of space layout and geometry and the use of vegetations during planning and conceptual designing has also been highlighted by Ahmed et al. [19]and so as the case on the importance of spaces layout and orientation[20].

3. Observation on Current Design Framework and Process Models

Fig. 1. shows the simplified model of a standard engineering system's design framework. The two compulsory elements are the sub-systems and functions. Sub-system and functions splits into two; primary and secondary/optional and consists of a long list of material, items, equipment and machineries, hardware or otherwise, required by each sub-system system. These are the infrastructure required so that the sub- system can perform the intended functions. Functions could be basic and standard or advanced type. All functions are linked to and traceable to the engineering system's missions and objectives. It is possible to have optional sub-system and facilities to cater for missions which are extension and supplementary to the basic and compulsory missions. The second compulsory design component is the sub-system configuration. This is the general representation of the relationship connecting one sub-system to the other sub-systems. In most cases the connections are physical. Sometimes though they are virtual and indicating that the sub-system is indirectly connected to the other. Configuration of an engineering system therefore concerns with synchronization of outputs from the many sub-system and their equipment and facilities such that the resultant output matches the system's objective. When perfectly synchronized all sub-system and their equipment work harmoniously. Operationally, a perfectly configured engineering system is very efficient and user friendly. Putting the equation governing the design of engineering system within the perspective of standards, rules and regulations all sub-systems, equipment, facilities, shapes, sizes and configurations must comply with safety and engineering reliability requirement. Compliance is to local as well as local industrial and engineering standards and all analysis performed are to prove full compliance. Not uncommon too for selection of sub-system and their equipment and configuration to take input the nature of which is custom and tradition that have been accepted as local norms. A common argument on this is the suitability of a system to specific practices of dominant ethnic group.

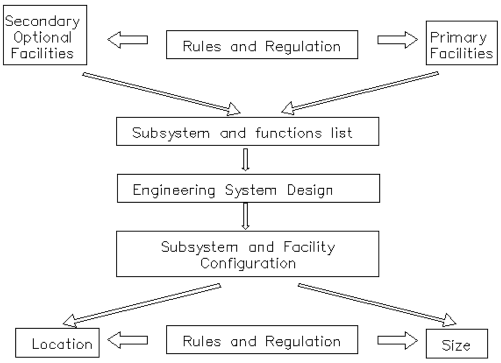

Fig. 1. Conventional design framework for engineering system design

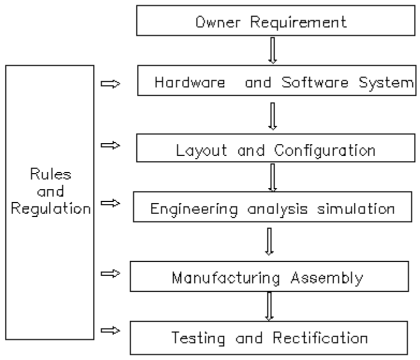

Fig. 2. Conventional design process for engineering system design

Fig. 2. shows a simplified conventional process of designing an engineering system. Take note of the fact that the whole process is repeated few cycles before reaching the final design. Overall, the process can be divided into two stages; first the conceptual and preliminary and second, the detailed and advanced. Conceptual designing is at the stage where owner's requirement is compiled and inputs are from their mission statements as well as project objectives. An expert analysis of the compilation will lead to the primary functions and operations the engineering system needs to perform. Secondary or optional functions are also identified and the final list will help designers in identifying the required physical and non-physical infrastructures for the engineering system. Hardware and software are selected based on specifications of individual item as well as its compatibility as an integrated system. Judgement on compatibility and the final decision on sub-system and their equipment integration, respectively, are the process and the results for the final part of conceptual and preliminary design stage. The second design stage, detail designing and construction design, starts with scientific analyses to check the engineering integrity of the system. The most common is via numerical analysis either manual or computer-based such as finite element method (FE) and computational fluid dynamic method (CFD). FE and CFD are advanced in nature normally employed when simulation of the engineering system's dynamics is required. Confirmation on the system's design within its environment will bring the design process to the final stage; preparation of the construction drawing for the purpose of manufacturing and assembly. Rules and regulation on safety and technical integrity is always referred throughout the process except during compilation of information for the building up of the owner's requirement.

4. Proposed Models and Discussion

Presently, engineering system designer always adopt a system approach and aware of the need to incorporate the elements of liveability and sustainability in all their designs. The practical and underlying question asked is where and in what form do liveability and sustainability come in into the design process. Another question is are they considered as primary design variables that affect the final shapes and characteristics of the design or are they just secondary variables indirectly influencing the design but not to the extent of affecting the system's functionality. Meanwhile take note of the fact that when the definitions for liveability and sustainability are mapped together it is clear that sustainability is a subset to liveability. Theoretically therefore their points of contact and entry into the design framework model and the design process model respectively should overlap. Identifying the point of contact for sustainability should reflect the point of contact for liveability. Meanwhile, it is worth noting that, based on general definition, the other elements of liveability, apart from sustainability, are economy, amenity, health, equity, education and safety.

Fig. 3. shows the proposed points of contact for sustainability on the framework for engineering system design while Figure 4 indicates its point of entry into the design process. By definition system's sustainability is its ability to continue with the defined system's characteristics and on a

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much wider perspective, may they be physical characteristics or operational performance characteristics of the system and environment within which the system exist. As such the definite first point of contact for sustainability on design framework model in Figure 3 is on the element identified as sub-systems and functions. However, sustainability is also referred to when dealing with sub-systems' shape and sizes and locations with respect to each other. Therefore it is safe to say that the point of contact is not singular but multiple and encompassing. In conformity with system approach to engineering system design it is therefore fair to claim that sustainability guidelines shares the same hierarchy as the present engineering rules and guidelines and engulfing the whole framework.

It means therefore and as shown in Figure 4 the first point of entry into the design process for sustainability as a design input should be when compiling the owner's requirement. At that stage of the design process conventional designers will select equipment and facilities based on pure technical merit. For sustainability-based designs steps must be in place for first, updating mission statements and project objectives so that sustainability becomes part and parcel of the project itself. Second step is to map all sub-systems and equipment against the required sustainability criteria such as energy conservation, pollution prevention, waste reduction and material management. Third step is prioritizing and ranking of sub-systems and equipment selection made will be techno-economically balanced. Therefore present engineering system designers should be ready to put extra effort on identifying the correct and most relevant sustainability criteria for the different systems and equipment, detecting sustainability-related items in the list of technical specifications of the equipment and finally ranking and selecting the best. Some sustainability criteria are more subjective than others and therefore extra resources are required for group decision making using, say, computer-based fuzzy decision making tool.

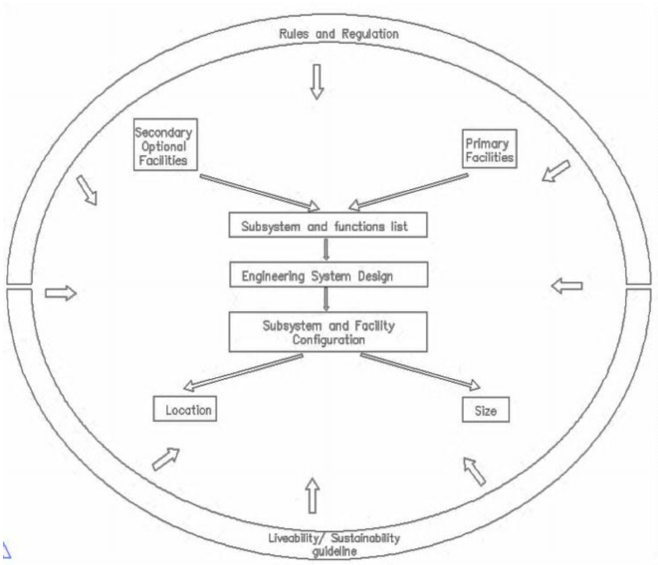

Fig. 3. Sustainability-based design framework for engineering system design

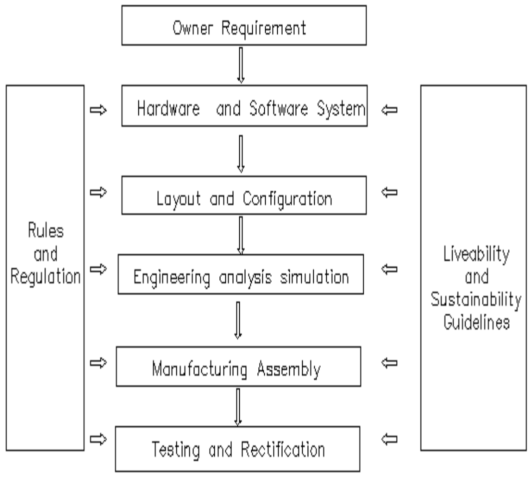

Fig. 4. Sustainability-based design process for engineering system design

5. Conclusion and Recommendation

Engineering system designers are slowpracticing liveability and sustainability approached design methodology. Awareness of the importance of liveability and sustainability criteria as design parameters is high but problems on translating them into meaningful design input values have block them from adopting the approach in an effective manner. Current engineering design practices should be revised and format for the presentation of design's reference documents such as standards, rules and guidelines, engineering and technical specifications must be improved such that sustainability criteria are well defined using meaningful expression, formulas and values. Extra effort and resources required to execute the additional task of identifying relevant liveability and sustainability criteria affecting their design, scanning liveability and sustainability oriented engineering and technical specifications, selecting the most appropriate sustainability-friendly equipment and facilities and putting emphasis on conservation of energy, pollution prevention, waste reduction and material management throughout the project's lifecycle must be rewarded. The equations used for techno-economic viability should also be accordingly revised so as to appreciate the benefits of liveability and sustainability to an engineering project

The argument presented and models developed have been based upon pure observation. In depth research could be undertaken to revise and enrich the models

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