Ergonomics in sustainable development endeavours in IDCs

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Abstract:

Given the complexity of problems and diverse reality of industrially developing countries (IDCs), the goals for ergonomic action vary greatly according to the particular case and scenario at hand. This paper proposes a multi-dimensional approach to reflect on the complexity of ergonomic needs in developing countries, focusing on development programmes. These can be a means of promoting consideration of ergonomics contributions, at both the planning and deployment stages of this kind of programmes. The paper reports on macroergonomic considerations applied to development programmes, adopting a systemic design approach. It is argued that macroergonomics can give important contributions towards achieving sustainable development, and, albeit indirectly, in mitigating the consequences of natural disasters. Recognizing the urgency in achieving sustainable development, a set of examples illustrating transitioning between goals for ergonomics intervention, as development progresses, is discussed from a practical perspective.

1. Introduction

Ergonomics enabled design and development endeavours are a means of proposing a better future, supporting progress for humanity. At the current global crossroads of socio-economic development, supporting bio-diversity while improving quality of life for all people requires shifting courses of action. Ergonomics represents an opportunity to materialise ethics in technology and in design, as the pursuit for efficiency and sustainability becomes rampant (Coelho, 2012). Technology, devised by human ingenuity, can create quality of life and support human well-being, but sustainability needs to be both a limiting factor and a triggering factor for innovation. By explicitly verifying feasibility, supporting, directing and proposing emergent forms of creating worthwhile, meaningful and purposeful relationships between people, technology and activity in context, the discipline of ergonomics is ever more relevant and necessary.

Natural disasters are succeeding at an ever increasing rate with growing costs and human death tolls (UNISDR, 2011). Ergonomics can have a role both in achieving sustainability, and hence contributing to prevent the consequences of disasters as well as in mitigation and disaster relief. Development aid can be a means of introducing ergonomics and human factors considerations, knowledge and techniques into the front line of action and transformation at the same time as development endeavours unfold.

2. Approaches to ergonomics in IDCs

Ergonomics can be placed at the service of work design and work

improvement, and hence play a role as a support discipline to design endeavours, with unique contributions to designing the human interface with technology. In industrially developing countries, ergonomists have directed great efforts towards developing ergonomics awareness among managers and workers in organizations. There is, however, little research on the degree of their success. Furthermore, access of organizations to ergonomics knowledge is usually very difficult, especially in industrially developing countries. Thus, building ergonomics awareness is certainly the first phase of the process (Helali et al., 2008). A rich set of actors can become vectors for the widespread promotion of the consideration of ergonomics (Figure 2).

A literature review on ergonomics in IDCs showed a track record of over 20 years of publications within this theme. Introducing the concept of industrially developing countries (IDC) within the ergonomics literature, Wisner (1985) pointed out that many factories transferred from industrialized countries to IDCs provided poor results both from health and production viewpoints due to disregard for ergonomical analysis and recommendations. To obtain good results in these circumstances, Wisner (1985) recommended that the work organization should not only to be transferred with the machines but also adapted.

Reporting on ergonomics in IDCs in the year 2000, O'Neill noticed that the majority of IDC populations were engaged in subsistence agriculture (the 'informal' sector). This author emphasized the importance of the cultural dimension for the successful delivery of ergonomics benefits, considering that the application of ergonomics differed between IDCs and IACs (industrially advanced countries) particularly through the limited infrastructure in IDCs to support ergonomics activity and interventions. Five years later, O'Neill (2005) reported on how ignorance of the comprehensive nature of ergonomics, and the benefits it can deliver, had adversely affected the progress and outputs of projects aimed at improving human health and (work) performance in IDCs. This author concluded that ergonomics had more to offer IDCs than was being taken up at the time. O'Neill (2005) also considered that the contributions that ergonomics could make to the Development Aid sector, particularly in the areas of sustainable livelihoods and technology transfer were not being realised at that time.

Scott (2008) argued that ergonomics is more sorely needed, easier to implement, and potentially far more effective in industrially developing countries (IDCs) than where its efforts have been most concentrated - in the less densely populated, more affluent, technologically advanced world. According to this author, a two-pronged symbiosis of micro- and macro-ergonomics intervention has the potential to achieve both effective and sustainable development. Accordingly, Flemming et al. (2008) considered that counter-acting the over-harvesting of the earth's resources by the developed and developing world may not be achieved solely by technological solutions. Ergonomics specialists have an opportunity to contribute their expertise to help address deficiencies in achieving reductions in environmental impacts through behavioural interventions and therefore aid in shifting toward sustainable resource consumption.

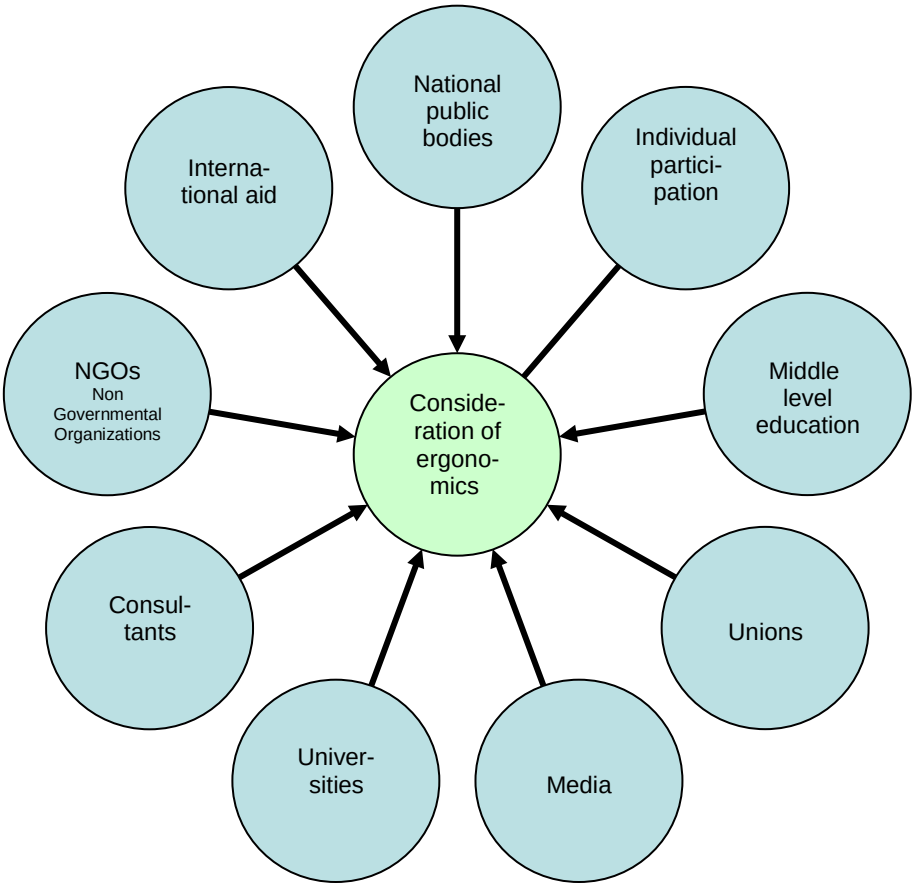

Figure 2. Potential actors wo may act as vectors for building awareness of Ergonomics in IDCs.

3. Urgency in achieving sustainability

While developing countries, particularly Small Island Developing States and Least Developed Countries, are disproportionately affected by natural disasters, the Great East Japan earthquake and tsunami of 2011 sent a clear message that developed countries are also vulnerable to such severe disasters. Unsustainable development practices, ecosystem degradation, poverty, as well as climate variability and extremes, have led to an increase in both natural and man-made disaster risk at a rate that poses a threat to lives and to development efforts (UNISDR, 2011). Disasters triggered by natural hazards destroy lives and livelihoods. They affect millions of people every year, rich or poor. By understanding the risks and applying the best methods of prevention and mitigation, human, physical and financial costs of disasters can be reduced. Each kind of natural disaster poses particular challenges and may be dealt with in each phase of the cycle with more or less ease, with better or worse mitigation and preparedness, and response and recovery. A flood may represent a devastating event, but it might be easier to mitigate its consequences, than those of a radioactive spill. When

two or more disasters combine (e.g. extreme heat and forest fire) resources will come under stress and these are considered complex emergencies. There is growing evidence (Guha-Sapir and Santos, 2012) that it is the poorest of the poor who will take the highest toll when a disaster strikes, and those which are most vulnerable and will often be permanently submersed in poverty as a result of a drought, earthquake or hurricane. When several kinds of emergencies or natural disasters combine and interact, this may require new approaches to mitigation, in order to work together in a synergetic approach. Forest fires lead to the loss of biodiversity and to soil erosion on the medium term, which increases proneness to droughts due to the lack of vegetation, and to flooding during rare rainfall events, since vegetation also contributes to increased water absorption of the soil when rains are heavy. Hence, preventing forest fires can contribute to mitigate other risks in the medium term. Tools that emphasize these kinds of interactions and enable their understanding may become helpful in assisting decision makers in assessing alternative mitigation strategies or recovery plans. Development programmes should be planned and monitored with respect to a myriad of weaknesses and threats (risks) (Coelho et al., 2012), including natural disasters and their consequences, as well as strengths and opportunities. A systemic approach is beneficial in analysing existing systems when planning and proposing interventions aiming at development efforts. Moreover, these efforts benefit from the analysis and monitoring using a macro-ergonomics perspective; keeping complex relationships at organizational, community and social levels under observation, as these, even if often disregarded, play a decisive role in the success of development endeavours.

4. The systemic design approach

The methodology of Systemic Design (SD) looks at making better use of material and energy flows in order to model our production and energy systems according to Nature (Bistagnino, 2009). Living systems are "open" in the sense that they continually draw upon external sources of energy and maintain a stable state of low entropy that is far from thermodynamic equilibrium (Schrödinger, 1943). Many industrial ecosystems have come about ad hoc for better business, while others have been facilitated through external actors. However, as these theories and ventures may be innovative for the industries, they are still no more than solving problems that have arisen from environmental pressure and economical revisions. Systemic theory is the study of how complex entities interact openly with their environments and evolve continually by acquiring new, "emergent" properties (Heylighen et al., 2000). Rather than reducing an entity to the properties of its parts or elements, systems theory focuses on the relationships between the parts that connect them into a whole. This approach is patterned after the self-organizing behaviour of living systems. This type of reasoning leads to the "Gaia hypothesis", which claims that the world is a single giant organism (Lovelock, 1988). SD proceeds with constant awareness of related systems, boundary conditions, external effects and potential feedback. SD plans entities with inherent "resilience" by taking advantage of fundamental properties such as diversity (existence of multiple forms and behaviours), efficiency (performance with modest resources consumption), adaptability (flexibility to change in response to new pressures) and cohesion (existence of unifying forces or linkages) (Fiksel, 2003).

To encourage systems design that explicitly incorporates sustainability thinking, it is useful to have clear principles. The theory of SD offers a scientific method that derives from the generative science and evolves from industrial ecology, symbiosis, ecosystem and cluster theory. It can be summed up by its five basic principles (Bistagnino, 2009):

1) Man at the centre of the project: the product has become the fulcrum of a paradigm of values and actions, as economical wellness, the quantity of monetary resources, the wish of belonging to a social status, negatively shape consumption choices. The systemic approach, instead, questions the present industrial setting and proposes a new paradigm where at the centre of each productive process there are social, cultural, ethical and biological values that every man shares.

2) Output>Input: as in nature, what is not used by a system becomes a raw material for the development and survival of someone/something else; in the production process the waste (output) of a system become an opportunity (input) for another one, creating new economic opportunities and new jobs.

3) Relationship: it is important to consider, more broadly, all the networks of components that make the food system, including materials (resources) and energy, which are used, captured and stored through different stages of the product life cycle. Understanding the pattern of materials and energy flow and investigating where it can be improved can allow us to find entry-points for designing more sustainable food system.

4) Towards *autopoiesis*: in nature self-maintaining systems sustain themselves by reproducing automatically, thus allowing them to define their own paths of action. In this way the system is naturally led to balance and to preserve its independence. If in the food system we would also start in terms of *autopoiesis*, it could be possible to allocate efficiently and distribute the material and energy flow equally.

5) Act locally: as an eco-system is deeply influenced and shaped by its habitat, the same happens for any other type of system. Based on the opportunities provided by the local context, new opportunities can be created by reducing the problems of adaptability due to "general" solutions and increasing people's participation.

Currently, rejects generated by manufacturing processes, are only viewed as a cost. In order to go through a project with the systemic design approach, it is essential to start from the current state and to make a peculiar observation of all the aspects which are part of the system (input), what occurs inside it and what comes out of it (output) (Figure 1).

The analysis of these inputs and outputs will have to be done in two different ways (Couvinhas et al., 2011):

1) Quantitatively, so as to know the quantities that we move around and we avail of;

2) Qualitatively, to know exactly what we have at our disposal.

These simple steps provide a clear idea of: the resources needed their features and origins; rejects or processing waste, their specific qualities and their final destination; what occurs throughout the processes, comparing the specific differences between inputs and outputs. The vision holistically embraces the whole process and enables one to perceive the relationships interwoven within the analysed system. For an overall vision, it is necessary to arrange a graphic scheme, allowing retracing, both with eyes and mind, of the flows of matter and energy of the system under examination and analysis. From the analysis of the problems and the configuration of the starting scheme, the quality of the outputs are highlighted, so that they can be turned into inputs for other production processes or systems, looking for possible links with other territorial realities which, despite their great differences, may be integrated within the analysed production process. The outcome of this analytical chain usually promotes the exponential growth of the productive capacity of a territory, as a result of which, it is able to produce new material goods, to offer new services to citizens and to ultimately increase the number of jobs. Yet, contextual surveys show that in many cases a demand actually exists but it is met by imports or external resources. By exploiting the resources of the territory, development has a local dimension and new self-sustained realities are spawned, both in terms of energy, of production and of supply (Couvinhas et al., 2011).

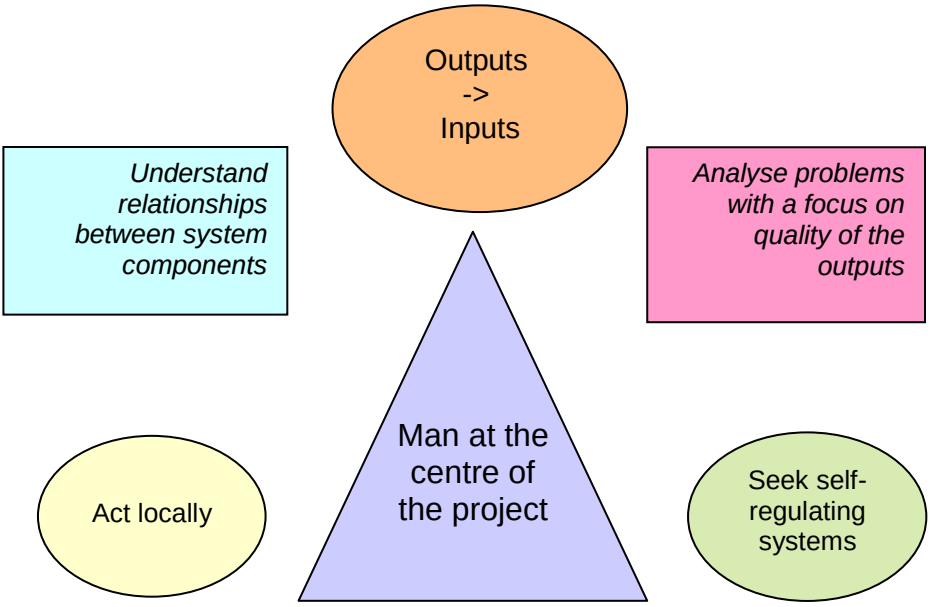

Figure 1. Systemic design approach to deal with development problems.

5. Macroergonomic considerations in development endeavours

Three reports on ergonomic aspects of development initiatives taking place in Industrially Developing Countries (IDCs) were scrutinized by Coelho et al. (2012). These included a macro-ergonomics intervention in a habitation

community in Cape Verde (aimed at designing solutions contributing to sustainable development) (Couvinhas et al., 2011), the evolution of poultry growers' control strategies as an integrative broiler operation was introduced in Mozambique (Ferrara and Lee, 2010), and a set of macro-ergonomic considerations related to the Agro Forestry Village Project in Mozambique (Walter et al., 2011). The scrutinizing study sought to set the reviewed development endeavours against the backdrop of the goals of ergonomic interventions. This reflection was meant to inform development agents in future processes of design and implementation of integrated community and work systems transformation. The set of studies reviewed suggested that development projects' aims are necessarily tied to the satisfaction of human needs, and as such, the latter translate directly into the projects' aims, adapted to the context of the development intervention or initiative. As human needs are varied and multidimensional (Maslow, 1943), so are development projects' goals interconnected and multi-layered, sharing a common aim, improving the quality of life and the well-being of the people involved in the transformations. These aims translate into the satisfaction of safety, comfort, self-actualization and added self-esteem needs as a result of the implementation of new activities or transformation of existing ones, in stark alignment, implicitly or explicitly, depending on the case, with goals for ergonomic interventions. Moreover, development programs are inherently socio-technical system development activities and, as such, a systems approach is a prerequisite for their successful design and implementation (Coelho et al., 2012).

One of the salient themes springing from the analyses about the relationships between the three studies revisited by Coelho et al. (2012), is the uncertainty associated with the materialization of both the resources and the benefits envisaged by development initiatives. For instance, in the case reported by Couvinhas et al. (2011), low-technology solutions were deployed as a means of increasing the potential for reproducibility of the solution proposed in the project to deal with drinking water scarcity and its widespread adoption. Uncertainty implies that thorough understanding of the environment, especially the consequences of lacking infra-structure and institutions, must be obtained in the planning of these kinds of projects, with the expectation that there are a myriad of dimensions and levels where potential benefits might accrue as well (Coelho et al., 2012). Potential benefits and failures hence need to be viewed in perspective with strengths, weaknesses, opportunities and threats underlying the development problems in their context. The study by Ferrara and Lee (2010) suggested that mechanisms for self-evaluation throughout the life cycle of the project provide a meta-cognitive capability to address issues at various levels according to the effectiveness of activity at those levels. This self-regulation is necessary because without the adoption of appropriate technologies and increased knowledge that is created through experience and education, human development does not take place (Coelho et al., 2012). Human factors engineering provides macro-ergonomic resources as well as micro-ergonomic resources and these can be used jointly at all levels of the needs satisfaction hierarchy.

6. A goal-hierarchy perspective of development ergonomics

Ergonomics, as an applied science that supports and enables the viability and feasibility of design endeavours, offers data, knowledge and

methods pertaining to the physical, cognitive, environmental and organizational domains of human activity. Through an intervention in existing systems, ergonomics may elaborate on an existing basis of work system and equipment in the shape of a corrective intervention. However, when new design endeavours are to unfold the ergonomics approach is broadly informed by other perspectives (social, motivational and cultural).

An important development goal in rural areas is enabling people to have several options, independent of gender, whether it involves creating their own business in response to new demand for goods and services, or working in labour-intensive processing, or harvesting (Paul, 2008). The fundamental aim of development endeavours in these settings is that the consequences of work system change brought about by the growth of industry reverberate positively on family and community life alike, while controlling for environmental impacts.

At the turn of the millennium, a trend towards change was acknowledged within the discipline of ergonomics. As a discipline, ergonomics had been mostly focused on eliminating human pain and discomfort, both of a physical and cognitive nature, and in so doing, minimizing loss. An alternative approach to ergonomic design in the context of consumer products was brought forward by Jordan and Macdonald (1998), concerning the creation of products that bring positive benefits to users in terms of pleasure. Such an approach, when extended to the discipline of Ergonomics and Human Factors, could be coined as the maximization of gain and pleasure, as opposed to the minimization of pain and loss with a focus on safety and human-system compatibility (Noy, 2000). Besides pleasure, this approach promotes satisfaction, creativity, personal growth, meaningful activity and human-system symbiosis. Springing from this expanded perspective, ergonomic goals for both development interventions and for design endeavours were presented by Coelho (2011). These goals encompass minimizing loss, attaining health and safety and comfort, and maximizing gains.

Minimizing loss approaches typically are concerned with preventing the loss of life, amputation, fostering the respect for human rights, for working time regulations, the availability of toilets, the provision of rest periods, of drinking water, guaranteeing that workers have enough to eat, safeguarding against major health and safety threats and against loss of property. In this domain, ergonomic action may be triggered by the deployment of more or less straightforward checklists derived from international regulations and recommendations (e.g. ILO – International Labour Office, a United Nations institution), albeit the action that is necessary may not necessarily be easily carried out. This involves working towards preventing accidents and occupational diseases, improving workstation design, work organization and work tool adequacy to the workers, furthermore, involving workers and management alike in those efforts. This may necessitate an increased effort in raising awareness of the need to think about ergonomics for all the actors involved (management, workers, clients, unions).

In terms of the practical application of this hierarchy, consider the example of factories that have gone beyond minimizing loss to attend to worker safety and comfort, in an effort to achieve higher efficiency and quality, and hence improve competitiveness. Automation of processes will also pose new challenges, and promote an added need to focus on cognitive

issues, rather than merely on physical, organizational, and preventive aspects of workplace ergonomics. Workers need to be trained and receive performance feedback information in order to perform their jobs safely and with added efficiency. Individual responsibility is determinant to improving quality and productivity. Empowered workers, responsible for their own work, are more able to meet quality and productivity standards. The introduction of new technology should be an enabler of this transformation process leading to greater worker (collaborator) empowerment.

Ergonomic approaches geared to implement an acceptable level of health and safety and comfort typically involve abiding to guidelines and standards, or following mathematical rules, assuring risks are assessed and that preventative approach to occupational disease and accidents is taken, focusing on efficiency, productivity and training, using anthropometric and other data. Achieving this goal of ergonomics application involves the application of rules, considering empirical information from the workplace and the worker and work environment as well as data from the ergonomic knowledge base and body of theory. This represents an important effort in terms of analysis and implementation and is bound to necessitate an ongoing effort to maintain the levels of health and safety and comfort envisaged.

Achieving the ergonomic goal that involves maximizing gains involves the deployment of complex analytical tools (such as cognitive task analysis or activity theory) and the analyst doing this must be armed with knowledge and skills of a higher order to be able to use these tools effectively. This kind of complex high level approach is not only deemed suitable to deal with the latest technology that tends to pose cognitive challenges and deeply changing the nature of work, but also with organizational complexity, or work complexity, and cognition. Its deployment in organizations signals a major effort and is a sign of uncompromised commitment to achieving high levels of productivity, job satisfaction and the capacity to innovate and maintain agility.

On the positive side, and considering an example from sustainable forestry development in Mozambique, Juma (2010) reported that automation and job enlargement were bound to break the love-hate duality associated to the chainsaw in this sector in northern Mozambique, and bring higher motivation to job seekers and employees alike in this sector. Hence, while the chainsaw had been placed at the core of the ergonomic focus of the forestry industry, other issues are important, such as the use of personal protective equipment, including hearing protectors, gloves, protective clothes, safety devices installed in chainsaws, and so on. Forestry is not only about cutting wood (especially not sustainable forestry), nor is the sector static, as Mozambique is expected to develop quickly in this area. In fact, sustainable products forestry is anticipated to spark broad clusters of agro industry. Hence, a complete range of ergonomic problems, encompassing physical, cognitive, complexity, technology, health and safety, comfort and organizational and motivational issues is recognized in the development of agro forestry villages in Mozambique (Walter et al., 2011).

While discussing complexity in chicken growing operations (poultry) in Mozambique, Ferrara (2010) emphasized how profitability and competitiveness in this sector lead to scaling up operations, with a view on tighter margins, with thousands of birds needed to meet profitability at slim

margins. Hence, providers of care were faced with a growing number of birds under their care, getting into the thousands (up to 12 thousand birds), creating the need for strategic thinking (triggered by reflection and meta-cognition). Ferrara (2010) introduced a complex but encompassing depiction of poultry grower's control strategies and their evolution, considering three time frames (immediate – the next few minutes, medium term – the next weeks, and long term - a matter of the coming months). For each of these time frames, Ferrara (2010) described the tasks (and goals) inherent to the seven dimensions of poultry growing care: feeding, water, heat, light, air circulation, sanitation and health. This author shed light into the similarities of monitoring and resource supply among similar tasks in agronomic and nursing care, as this approach to work analysis can serve a broad range of care industries. The control aspects of poultry growing integrate sensory-motor actions with responses. The identification of such closed loop systems uncovered the use of a multiplicity of strategies available to the grower to achieve an objective. Although constraints and resource availability limit strategy options in practice, the possibility to act at different time horizons, demonstrated how ergonomics problems in IDCs can be as encompassing and far reaching as ergonomics in IACs. A full set of ergonomic concerns can be present in one single industry. Urgency, however, dictates a condensed process in time, one that aims to gradually, but steadily, implement and achieve the three afore-mentioned goals of ergonomic interventions in work systems quickly.

The third level of the goal-hierarchy presented in this section and discussed in relation to development endeavours, may be expanded, establishing a parallel with the work of Thatcher (2012), proposing a framework for affect in designing for sustainability. The three elements of Thatcher's framework (design for functional balance, design for early engagement, and design for aspirational ideology) depict the three points at which affective design tools might be leveraged to encourage the choice for sustainable products and behaviours. Ultimately, the process of promoting sustainable development may benefit from an understanding of what motivates people to adopt and want to continue to use sustainable tools, artefacts, and systems. Hence, future studies might consider, by means of the deployment of an ethnographic approach, and resorting to a combined cultural-historical and motivational perspective, the affective resonance of proposed system development alternatives. This may lead to increasing the likelihood of success in achieving the sustainable development aimed.

7. Conclusion

Ergonomics can have an important role in achieving sustainability and hence contributing to prevent the consequences of disasters as well as in mitigation and disaster relief. Development aid can be a means of introducing ergonomics and human factors experts into the field at the same time as development endeavours unfold. Ergonomics specialists have an opportunity to contribute their expertise to help address deficiencies in achieving reductions in environmental impacts through behavioural interventions and therefore aid in shifting toward sustainable resource consumption. Tools that emphasize complex systemic interactions may become helpful in assisting decision makers in assessing alternative paths for action. A systemic approach is nonetheless needed to analyse existing systems and propose interventions aiming at development efforts. Moreover, these efforts benefit

from the analysis and monitoring using a macroergonomics perspective; keeping complex relationships at organizational, community and social levels under observation, as these, even if often disregarded, play a decisive role in the success of development endeavours. The analysis of the development programmes revisited in the paper suggests that mechanisms for self-evaluation throughout the life cycle of the programmes provide a meta-cognitive capability to address issues at various levels according to the effectiveness of activity at those levels. This self-regulation is necessary because without the adoption of appropriate technologies and increased knowledge that is created through experience and education, human development does not take place. Continuing to raise awareness of ergonomics potential benefits is still very much needed, despite the successes attained by the consideration of ergonomics in development programmes.

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