

Early variability in the conceptualisation of “sustainable development and human factors”

Andrew Thatcher

Psychology Department, School of Human & Community Development, University of the Witwatersrand, Johannesburg, WITS, 2050, South Africa

Abstract. The sub-discipline of “sustainable development and human factors” is relatively new, first being used in 2006 with a Technical Committee of the IEA being established only in 2009 and a similar special interest group on “green ergonomics” at the Institute of Ergonomics and Human Factors being established in 2010. In general though, the definitions and practice of “sustainable development” is highly contentious and ambiguous across a range of disciplines. This paper examines the diversity of definitions and approaches to sustainable development and human factors in the early papers in this sub-discipline. An examination of 45 chapters and papers (from 2008 to 2011) reveals a surprising consistency in the definitions used for sustainable development but also a large proportion of the papers where no definitions are given at all. The majority of papers were, however, biased towards an economic capital and social capital emphasis, which is to be expected of work traditionally in the ergonomics paradigm. Further, most papers were theoretical in nature demonstrating a great opportunity for empirical work. The variability in definitions is discussed in relation to the future challenges facing the growth of this emergent sub-discipline and opportunities for further theoretical and empirical work.

Keywords: triple bottom line; work systems sustainability; sustainable development; green ergonomics

1. Introduction

1.1. Defining sustainable development

The most commonly cited definition of sustainable development is Brundlant’s (1987) World Commission on Environment and Development (WCED) definition: “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [5]. The important components of this definition are the notion of implied social development and the notion of an inter-generational time dimension. Sustainable development, according to the WCED definition, involves balancing the needs of the world’s poor against the needs of the world’s rich in such a way that both groups can have an equal opportunity to reap the benefits of continued economic growth. This definition is very much human-centred (i.e. human development, largely along economic lines, and human inter-generational sustenance). The link to the envi-

ronment is based on the assumption that poverty often exacerbates the negative effect on the environment through the over-exploitation of scarce resources (e.g. the overgrazing of limited land, deforestation for agricultural land and fuelwood, the degradation of limited arable land through poor agricultural methods; the use of outdated industrial machinery that is environmentally inefficient, and the over-exploitation of limited water supplies because no other supplies exist). The goal of sustainable development then, is social and economic upliftment to reduce these environmental impacts [5]. This argument assumes that through social and economic upliftment, communities will be able to adopt modern facilities and methods that reduce the negative impact on the environment and allow more globally equitable living standards and trade arrangements.

The second widely recognized scientifically conceptualisation of sustainability is known as the “Triple Bottom Line” [14]. This conceptualisation encourages a balanced focus on people, nature, and

economics. Writing from an organisational perspective, Dyllick and Hockerts [13] referred to sustainability triple bottom line as a balance between economic capital, natural capital, and social capital (see Figure 1). Taking a strictly economic sustainability perspective would mean that a community (or organisation) is sustainable based on the extent to which financial gain can continue to sustain the activities of the community (and in the case of public companies, can continue to grow value for its shareholders). Taking a strictly environmental sustainability perspective means that a community does not use natural resources at a rate faster than can be replenished or absorbed by the natural environment. Taking a strictly social sustainability perspective means that the wellbeing needs of the community (and individuals within the community) are met without compromising the wellbeing of related communities or other individuals within the community. Of course, the “triple bottom line” approach is not about addressing only one of these perspectives, but a balanced recognition that each type of capital must be addressed to attain true sustainability.

Gupta [18] noted more than a decade ago that while sustainable development, as a concept, has become increasingly accepted, “its objectives [have] become more and more diffused and less attainable” (p. 99). Johnston et al [22] estimated that there are approximately three hundred “alternative and variously-modified definitions of sustainable development” (p. 60) currently in use. This proliferation in definitions ultimately means that despite its obvious importance, “sustainable development” is ambiguously and vaguely defined. They advocate The Natural Step (TNS) framework as a set of ethical principles (based on the scientific laws of thermodynamics – i.e. seeking to decrease systemic disorder, understanding carrying capacities, and understanding the “creation” of energy) on which to base a definition of sustainability. Similarly to the “triple bottom line” approach, the TNS framework argues that a focus on the needs multiple stakeholders (albeit at an ethical level) is necessary to achieve sustainability.

1.2. Defining “sustainable development and human factors”

In defining sustainable development and human factors, Steimle and Zink [31] drew specifically on the WCED definition and the “triple bottom line” approach. The focus in this early definition of sustainable development and human factors was on un-

derstanding how human factors/ergonomics could play a role in meeting the challenges of an increasingly resource-depleted planet. Steimle and Zink [31] encouraged ergonomists to make contributions through: understanding employment practices (e.g. relevant work schedules), complementing the design process of sustainability-oriented products (e.g. producing “ergonomically and ecologically optimized products” (p. 2358)), designing more efficient work systems, ensuring the safe operation of complex systems that may result in ecological and economic disasters (e.g. nuclear power plants), and through community ergonomics. Zink, Steimle and Fischer [39] extend on the triadic model to demonstrate the ways that existing human factors interventions have contributed to sustainable development (see Figure 1). The Economic-Social “arm” of the triad is where ergonomics has traditionally focused much of its attention (e.g. ensuring that ergonomics facilitates human wellbeing while also meeting organisational productivity targets). Ergonomics interventions typically include health and safety promotion, usability, and work-system design. There are a small number of ergonomics interventions that might be considered as representative of the Economic-Nature “arm” of the triad. These interventions have typically been eco-efficiencies (e.g. energy efficiency and work resources efficiency). Assisting organisations to manage change towards a more environmental sustainability might be an example of an ergonomics intervention on the Social-Nature “arm” of the triad. Limited studies have been reported that take an ergonomic approach in this regard.

The definition of sustainable development and human factors has been slightly complicated by a minor proliferation of similar terms. Hanson [19] and Hedge [20], for example use the term “green ergonomics”. The term “eco-ergonomics” has also been used, appearing as early as 1998 [8], to take into account the needs of the natural environment with which humans interact. Thatcher and Groves [34] used the related term, “ecological ergonomics”. A close reading of these works would suggest that the terms “green ergonomics” and “eco-ergonomics” have been used either as a subset of the larger domain of (i.e. an implied focus specifically on the contributions that ergonomics can make towards ensuring adequate natural capital) or as a synonym for “sustainable development and human factors”.

Since Steimle and Zink’s [31] definition there has been one symposium (culminating in a book), the formation of an IEA Technical Committee called “Sustainable development and human factors” (in

2009) which facilitated three presentation sessions at an IEA Congress that have focused on the issue of sustainable development and human factors, and the establishment in 2010 of a special interest group of the Institute for Ergonomics and Human Factors (in

the UK) called “green ergonomics”. In this paper, the ways in which sustainable development and human factors has been operationalised in its early stages of conceptualisation will be examined.

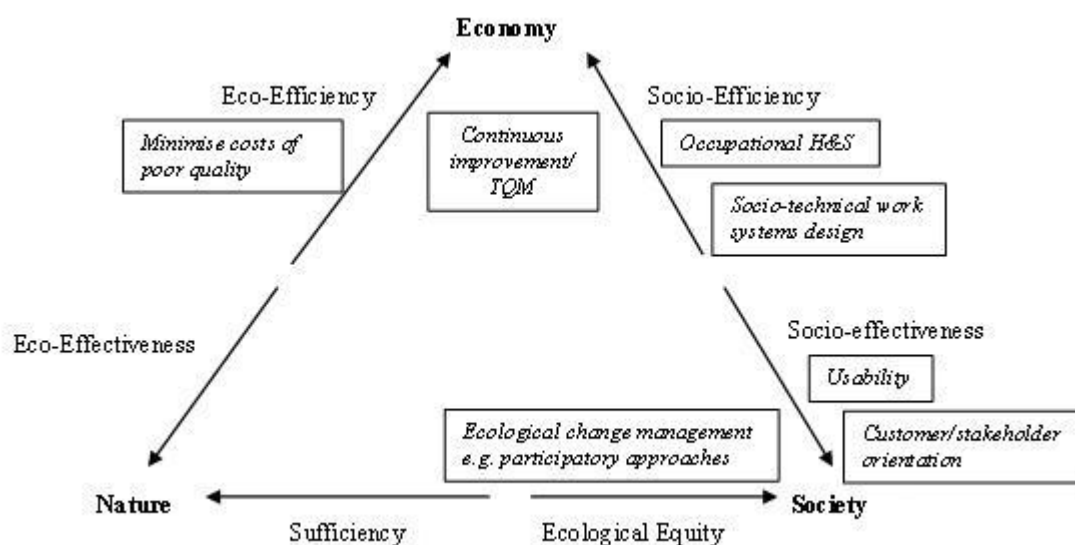


Fig. 1

Triadic model of sustainable development and ergonomics interventions (adapted from Zink et al (2008))

2. Method

2.1. Sample

This study is a literature review investigation. In order to focus the consideration of relevant literature the following texts were considered: (1) the 15 chapters of the book “Corporate sustainability as a challenge for comprehensive management” [38] arising from the symposium “Human factors and comprehensive management concepts as a precondition for corporate sustainability” held in Kaiserslautern, Germany in 2007; (2) the 12 papers of the 3 “HF & Sustainable Development” sessions at the IEA2009 Congress in Beijing, China that appeared in the proceedings (please note that three of the scheduled papers did not appear in the proceedings); (3) a further 13 papers at the IEA2009 Congress that addressed sustainable development or sustainability issues, identified through a keyword search of the proceedings; and (4) conference proceedings from the conferences of the two largest ergonomics societies for the

last three years: the Human Factors and Ergonomics Society (3 papers from the annual meeting in 2010) and the Institute of Ergonomics and Human Factors (the Broadbent lecture from 2010 [19] and one paper from 2011 [26]). Where appropriate, the references for these papers and chapters are given in the results. For a full list of the papers and chapters, please contact the author.

2.2. Analysis

Identifying relevant texts in the conferences was performed by searching for the following keywords in the titles and abstracts of conference proceedings: “sustainable”, “sustainability”, “green”, “ecological”, and “environmental”. Unfortunately, these search terms might also uncover a range of papers that would not be relevant for inclusion in this investigation. For the terms “sustainable” and “sustainability” papers to be relevant the author/s would have also to have written about development (i.e. sustained attention or vigilance studies were specifically excluded). Similarly, studies with the term “green” would also have to refer to sustainability, sustainable develop-

ment, or pro-environmental concerns (i.e. papers including the colour 'green' or a person's surname were specifically excluded). Papers with the term "ecological" were excluded if they only referred to ecological interface design or ecological validity. Papers with the term "environmental" were excluded if they only referred to work conditions (e.g. lighting, thermal comfort, etc.) without considering broader ecological, social, or cultural implications. The content analysis looked at three facets: (a) the definition/s of sustainability (if any); (b) the relative emphasis on economic capital, social capital, and natural capital aspects; and (c) theoretical vs. empirical work. For the second facet, since many of the papers addressed the three aspects of sustainability to varying degrees a weighted score was assigned to each paper. A weighting of 1 was given for each primary focus area and a weighting of 0.5 was given for each secondary focus area (thus, a score of between 3 and 1 was possible for each paper: 3 where all three aspects were the primary focus and 1 where there was only one area of primary focus). A paper would therefore have to have at least one primary focus area (i.e. economic, social, or natural) to be included in this analysis.

3. Results

There were 45 papers or chapters available for review; 15 book chapters, 25 conference papers from the IEA 2009 Congress, 3 conference papers from the HFES 2010 Annual Meeting, and 2 papers from the IEHF Conferences (1 in 2010 and 1 in 2011). The results are presented for each of the facets investigated.

3.1. Definitions of sustainability

The largest single proportion of papers (N=20 papers; 44%) provided no explicit definition of sustainability or sustainable development. For some of these papers, while a definition of sustainability was not explicitly given, there were implied elements of either the "triple bottom line" (N=8; 18%), or some aspect of longevity within the system (N=6; 13%), in a large number of these papers suggesting that there was some understanding of the underlying dynamics of sustainability. However, there were still 6 papers without any deeper understanding of sustainability. In these papers sustainability was generally inferred as an entirely economic activity (i.e. will the organisation continue to make profits?) or in socio-

economic terms (i.e. will this business continue making profits so that it can continue employing people?).

Where a definition was provided the most common definition was the WCED definition (i.e. "meeting the needs of the present generation without compromising the ability of future generations to meet their own needs" – N=13 papers; 29%), followed by definitions that explicitly defined some aspect of corporate longevity or longevity of specific programmes (9 papers, 20%). The WCED definition was usually accompanied by some understanding of the triple bottom line (i.e. some indication of social, economic, and environmental needs even if the important principle of balance was not always emphasized). In one instance (Moore et al, 2011) a quadruple bottom line was introduced; the fourth dimension being "cultural diversity". A summary of the representation of definition categories can be found in Table 1.

Table 1
Summary statistics for definitions

	N	%
WCED or Triple Bottom Line	13	29
Longevity/continuedness	9	19
Other	3	8
None	20	44

The organisational definitions included "sustainable competitive advantage [11] (p. 42); the "long term success of any organisation" [36] (p. 57), "sustainable organisational excellence" [10] (p. 80) or a corporatization of the WCED definition: "meeting the needs of the firm's direct and indirect stakeholders ... without compromising its ability to meet the needs of future stakeholders as well" [7] (p. 96). Other definitions included the "sustainability of socio-technical change" [6] (p. 139), the "promotion of wellbeing and quality of life of current and future generations" [28]; and "equity between people currently living on earth and equity between this and future generations" [15]. Some of these definitions obviously reflect variants of the WCED definition.

3.2. Emphasis on nature, social or economic factors

The papers were skewed towards economic capital (all 45 papers had economic factors as an area of secondary or primary focus, with 25 papers as a primary focus, 20 papers as a secondary focus, and a weighted score of 35) and social capital (41 papers had social factors, with 23 papers as a primary focus,

18 papers as a secondary focus, and weighted score of 32). In contrast, natural capital papers were either a primary (N=8) or a secondary (N=9) focus in only 17 of the 45 papers (and a weighted score of 12.5). If the triadic relationship of the triple bottom line were represented based on the representivity of these emphases, the triad would appear misshapen (see Figure 2).

Quite a large number of the papers, particularly the book chapters from Zink [38], focused on corporate sustainability with human elements (13 of the 15 chapters were almost exclusively corporate focused). The book chapters covered a range of important issues from the sustainability of social responsibility interventions [21] to the sustainability of organisational change interventions [6][36]. Scott [30] and Drury [12], however, encouraged ergonomics to think beyond the organisational context. Scott [30] tackled the important issue of the sustainability of ergonomics interventions in marginalized communities, particularly those with poor social and economic resources. Drury [12] suggested that ergonomists possess important skills in representing information in order to help leaders and decision-makers in understanding the current crises and providing solutions for the future. The papers at the IEA 2009 Congress also showed a similar bias towards corporate sustainability (indeed, 3 of the papers were shortened versions of chapters in the Zink [38] book). Flemming and Jamieson [16] and Thatcher [33] made suggestions for how ergonomics can contribute to the design of products and interfaces to ensure environmental sustainability. One paper [1] looked at the sustainability of agricultural systems, one at fishing systems [35], and one at tourism systems [25] at the industry level. It was also interesting that two papers [27][32] introduced the Life Cycle Assessment method (LCA). LCA encourages us to think about a product or organisation not as an end-product but as a system with inputs and outputs (a concept that should be quite familiar to open-systems ergonomics approaches). An LCA approach means taking all stages of the life cycle of a product or system into account

from the procurement of the raw materials to the decommissioning, re-commissioning, or disposal of the product at the end of the product's life. A few papers also addressed sustainability as a consideration of "place" [2] [28] and how we, as humans, respond in a way that ensures continued physical and psychological wellbeing (i.e. a continued existence in a place such as an organisation or a job).

A good example of empirical work balancing the economic, social, and natural capital components is Torres et al [35] into mussel production. While the emphasis in their paper was on ensuring safe and healthy working conditions (social capital primarily), this was a consideration together with environmental (if the natural environment is not nurtured then mussel population may collapse) and economic (if the mussel population collapses then there will be no more jobs for the mussel farmers) considerations. The role of ergonomics in this context is to understand (and help the major role-players understand) the interplay of these factors and to find solutions that meet the triple bottom line requirements. The Torres et al [35] example is interesting because a "traditional" ergonomics approach might have been to mechanise part of the process in order to reduce the health and safety risks. However, mechanization would have (a) increased the rate of harvesting (thereby accelerating the rate of mussel population decline) and (b) reduced the number of labourers required to work the mussel beds thereby disrupting the flow of financial capital in the community.

More recently, the papers by Hanson [19], Sankvist et al [29], and Moore et al [26] propose a much wider range of possibilities for sustainable development and human factors. These include helping designers understand how we use energy, how we (as humans) might behave more efficiently, how do we design for "green" economies, how we deal with a globalised economy, and how we might cope with the necessary behaviour change to a sustainable global system.

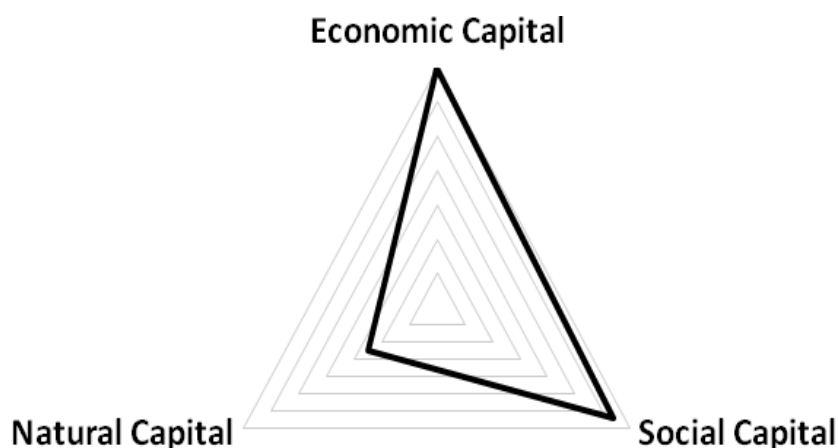


Fig. 2

Proportional representivity of papers on sustainable development and human factors along triple bottom line components

3.3. Theoretical vs. empirical investigation

The majority (87%) of the 45 papers considered were theoretical in content (6 of the papers, i.e. 13%, contained empirical results). This should not be surprising for a fairly new sub-discipline that requires a great deal of cross-disciplinary understanding and the building of strong theoretical foundations. What was surprising in the empirical work was the diversity of the contexts and the type of sustainability initiatives. The empirical work included a chapter based on archival data looking at the sustainability of a technological intervention [6], the design of an interface to reduce the amount of energy used [16], the design of a patient aid using natural fibres [9], the sustainability of a mussel-farming operation [35], the sustainability of dental practitioners work [23], and of ethnic handicraft workers [17]. However, only one [35] of these six empirical papers defined sustainability (using the WCED definition). It will be necessary in future empirical work to underpin the practical application with theoretical underpinnings.

4. Discussion

A surprisingly large proportion of the papers did not define sustainability at all and where it was defined most used the WCED definition which is widely acknowledged as vague [22]. The lack of consistency in defining sustainability might be seen as a

threat to the identity of this new sub-discipline of ergonomics. However, what is important to draw from this variability is that “sustainable development and human factors” is not yet bound by the constraints of restrictive definitions. This is evident in the large variability of projects and themes attempted by researchers and theorists working in this emergent area. There are a number of potential paths that could be followed at this point: (1) the IEA Technical Committee could be prescriptive and insist that a particular definition is adopted and adhered to; (2) a new definition (and/or terms of reference) that encompasses the emergent themes could be developed – one contender for a new definition might be the TNS framework (since it is based on a scientific definition that might have more leverage in ergonomics/human factors as a scientific discipline); or (3) allow the continued proliferation of terms and definitions and risk the term becoming vague, ambiguous, or misused. The path to follow would depend on the commitment and direction provided by the IEA Technical Committee on sustainable development and human factors.

Despite contentions that conceptualisations of sustainable development are biased towards Nature/Ecological issues [22], it would appear that in the early stages of this sub-discipline of ‘sustainable development and human factors’ the conceptualisations are perhaps biased towards Economic and Society issues. This is unsurprising given the emphasis in ergonomics on the human (social) influences and their relationship to organisational (and work) effec-

tiveness and performance. Where efficiency is considered this is usually in the context of energy efficiency for the human worker rather than the energy efficiency of the system as a whole (although there were three papers on eco-efficiency). In this paper it is argued that ergonomics needs more theoretical and empirical work examining the social-nature connections and on the economics-nature connections. Examples of the social-nature connections could be to look at how we might help conservation groups, parastatals, and non-government organisations with a focus on natural environments to facilitate people connecting with their natural environments. This could be achieved through macroergonomic interventions such as assisting with change management initiatives or through what Kellert et al [24] refer to as biophilic design, design that connects people with natural systems. Biophilic design is based on Wilson's [37] concept of biophilia; that human wellbeing is achieved through our acknowledgement that we are part of nature. Interventions on the nature-economic "arm" of the triad include eco-efficiency (there were three papers reviewed that looked at eco-efficiencies – two theoretical and one empirical) and eco-effectiveness. Ergonomics arguably has a lot to offer the emergent practices of biomimicry [3] and cradle-to-cradle design [4]. For example, ergonomics can offer particular input on how biomimetic and cradle-to-cradle designs might be usable and universally adopted.

In addition, the papers that focus on social issues tended to focus on social issues from an individual perspective or from the perspective of the organisation. Despite using the general WCED definition, very few of the papers embraced the notion of working with poorer communities in order to facilitate developmental upliftment (as is implied in the WCED definition). The notable exceptions were Scott [30] and Moore et al [26] who specifically highlighted the plight of the poor in industrially developing countries. Scott [30] mentions several low-cost interventions that seek to address development through ergonomics in poorer communities. Moore et al [26] specifically mention the role of Social-LCA and Ergonomists Without Borders as opportunities where ergonomics might play a role in social upliftment.

Ideally though, the focus should be on triple bottom line approaches that look for win-win-win ergonomic solutions. Approaches that focus exclusively on stewardship of the natural environment do not guarantee that people will have sufficiently financial security to feed (and protect) themselves and their

families, just as financial wealth does not guarantee that people will look after their natural environment. Approaches that look at linking economic, social, and natural capital should be actively promoted. Such interventions include finding ways to connect business with the communities they serve, especially if those communities are connected with their natural environment. Torres et al [35] is one such example of a triple bottom line approach with potential win-win solutions.

Finally, most of the work reviewed here (nearly 90%) was theoretical rather than empirical. Given the relatively infancy of this sub-discipline, this should not be very surprising. It is encouraging that a great deal of theoretical work has preceded the rush to practical application. At the same time it emphasizes that there are enormous opportunities for more empirical work that seeks to test the theoretical work.

It should be noted that the papers reviewed here must be considered as a subset of the total papers extant in the literature. This review focuses on a specific set of papers and it is acknowledged that there may be papers that were not included in this review. This includes possible articles published in the ergonomics journals and papers published in the proceedings of the smaller ergonomics and human factors conferences. The papers reviewed here were chosen specifically because they were either presented at the most prominent ergonomics/human factors conferences (i.e. IEA Congresses, HFES Annual Meetings, and IEHF Conferences) or in the first book on "sustainable development and human factors". The results of the analysis may have been different if the papers found in the broader literature were also included in this review. On a final critical note it is important to emphasise that the analysis was conducted by a single person with no independent validation of the categories. It is possible that a different reader with a different set of biases might provide a slightly different set of interpretations.

References

- [1] I.N. Adiputra, The Systemic, Holistic, Interdisciplinary and Participatory (SHIP) approach for sustainable agriculture in Bali, in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [2] A.A. Almeida, Architectural conception and evaluation of the environment: relations between human factors, and environmental factors, in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [3] J. Benyus, Biomimicry: innovation inspired by nature, in New York: Quill William Morrow, 1997.
- [4] M. Braungart & W. McDonough, Cradle-to-cradle: re-making the way we make things, in London: Vintage Books, 2009.

- [5] G.H. Brundlandt, Our Common Future. Report of the World Commission on Environment and Development, in. Oxford: Oxford University Press, 1987.
- [6] P. Carayon, T.B. Wetterneck, A.S. Hundt, S. Rough & M. Schroeder, Continuous technology implementation and sustainability of sociotechnical change: a case study of advanced intravenous infusion pump technology implementation in a hospital, in K.J. Zink (Ed.), Corporate sustainability as a challenge for comprehensive management, Heidelberg: Physica Verlag, pp. 139-151, 2008.
- [7] V. Cesarotti & C. Spada, The impact of cultural issues and interpersonal behavior on sustainable excellence and competitiveness: an analysis of the Italian context, in K.J. Zink (Ed.), Corporate sustainability as a challenge for comprehensive management, Heidelberg: Physica Verlag, pp. 95-113, 2008.
- [8] J. Charytonowicz, Ergonomics in architecture, in P. Vink, E.A.P. Koningsveld & S. Dhondt (Eds.), Human Factors in organizational Design & Management VI, Oxford: Elsevier, 1998.
- [9] J.R.H. Claumann, M.R. Lupion, R.M. Pereira & G.M. Scabello, Natural fiber as sustainable technology and ecologic and economically right alternative in making supporting device of ramble: an experimental research, in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [10] S.M. Dahlgaard-Park & J.J. Dahlgaard, A strategy for building sustainable innovation excellence – a Danish study, in K.J. Zink (Ed.), Corporate sustainability as a challenge for comprehensive management, Heidelberg: Physica Verlag, pp. 77-94, 2008.
- [11] K.N. Dervitsiotis, Developing sustainable competitive advantage through operational excellence and adaptation excellence with value-innovations, in K.J. Zink (Ed.), Corporate sustainability as a challenge for comprehensive management, Heidelberg: Physica Verlag, pp. 37-55, 2008.
- [12] C.G. Drury, The future of work in a sustainable society, in K.J. Zink (Ed.), Corporate sustainability as a challenge for comprehensive management, Heidelberg: Physica Verlag, pp. 199-214, 2008.
- [13] T. Dyllick & K. Hockerts, Beyond the business case for corporate sustainability. *Bus. Strat. Environ.*, 11, 2002, pp. 130-141.
- [14] J. Elkington, Cannibals with forks: the Triple Bottom Line of 21st Century business, in Oxford: Captone, 1998.
- [15] K. Fischer, C. Hobelsberger & K.J. Zink, Human factors and sustainable development in global value creation, in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [16] S.A.C. Flemming & G.A. Jamieson, Display design and energy conservation performance: a microworld study, in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [17] P. Gharehbaglou, H.S. Naeini, A. Vazirdaftari & Y. Roknifard, Ergonomic assessment of handicraft tasks among the university students by NMQ and RULA methods, in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [18] A. Gupta, Ecology and development in the third world. London: Routledge, 1998.
- [19] M. Hanson, Green ergonomics: embracing the challenges of climate change, in *The Ergonomist*, 480, 2010, pp. 12-13.
- [20] A. Hedge, The sprouting of “green” ergonomics, in *HFES Bull.*, 51, 2008, pp. 1-3.
- [21] P. Hermel, Social responsibility, strategic management and comprehensive corporate development: old roots, new issues? in K.J. Zink (Ed.), Corporate sustainability as a challenge for comprehensive management, Heidelberg: Physica Verlag, pp. 217-229, 2008.
- [22] P. Johnston, M. Everard, D. Santillo & K.-Henrik Robèrt, Reclaiming the definition of sustainability, in *Env. Sci. Pollut. Res.*, 14, 2007, pp. 60-66.
- [23] D. Jonker, B. Rolander, I. Balogh, L. Sandsjo, K. Ekberg & J. Winkel, Mechanical exposure among general practice dentists in Sweden and possible implications of rationalization, in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [24] S.R. Kellert, J.H. Heerwagen & M.L. Mador, Biophilic design: the theory, science, and practice of bringing buildings to life, Hoboken: John Wiley & Sons, 2008.
- [25] A. Manuaba, Emphasizing role of ergonomics in sustainable development of Bali, in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [26] D. Moore, C. Drury & K.J. Zink, HF/E in sustainable development, in: M. Anderson (Ed.), *Contemporary Ergonomics and Human Factors*, Boca Raton: CRC Press, pp. 347-354, 2011.
- [27] J.L. Palomera, Human factors as eco-efficiency value, in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [28] M. Pitkänen & V. Louhevaara, Mediating links between sustainable development and occupational wellbeing in the Finnish context, in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [29] T. Sanquist, M. Moezzi, E. Vine, A. Meier, R. Diamond & T. Sheridan, Transforming the energy economy – the role of behavioral and social science, Proc. HFES 54th Ann. Meet., 2010, pp. 763-765.
- [30] P.A. Scott, The role of ergonomics in securing sustainability in developing countries, in K.J. Zink (Ed.), Corporate sustainability as a challenge for comprehensive management, Heidelberg: Physica Verlag, pp. 171-181, 2008.
- [31] U. Steimle & K.J. Zink, Sustainable development and human factors, in W. Karwowski (Ed.), *International encyclopedia of ergonomics and human factors* (2nd ed.), London: Taylor & Francis, pp. 2258-2263, 2006.
- [32] P. Talvenmaa, M. Uotila, V. Louhevaara, P. Ryttilahti, M. Pitkänen, Sustainable innovative materials in high tech applications to promote health and wellbeing, in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [33] A. Thatcher, Ergonomics for sustainable development and hedonomics: incompatible or mutually compatible? in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [34] A. Thatcher & A. Groves, Ecological ergonomics: designing products to encourage pro-environmental behaviour, in *CybErg 2008: The Fifth International Cyberspace Conference on Ergonomics*, Kuching, Sarawak, Malaysia, 15 Sept.-15 Oct., 2008.
- [35] M.K.L. Torres, C.S. Teixeira & E.A.D. Merino, Ergonomics and sustainable development in mussel cultivation, ? in Proc. 2009 IEA, Beijing, China, Aug. 9-14, 2009.
- [36] X. Tort-Martorell, P. Grima & L. Marco, Sustainable improvement: six sigma – lessons learned after five years of training and consulting, in K.J. Zink (Ed.), Corporate sustainability as a challenge for comprehensive management, Heidelberg: Physica Verlag, pp. 57-76, 2008.
- [37] E.O. Wilson, *Biophilia*, in Cambridge, MA: Harvard University Press, 1984.
- [38] K.J. Zink (Ed.), Corporate sustainability as a challenge for comprehensive management. Heidelberg: Physica Verlag, 2008.
- [39] K.J. Zink, U. Steimle & K. Fischer, Human factors, business excellence and corporate sustainability: differing perspectives, joint objectives, in K.J. Zink (Ed.), Corporate sustainability as a challenge for comprehensive management, Heidelberg: Physica Verlag, pp. 3-18, 2008.